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THE EFFECTIVENESS AND SUSTAINABILITY OF FOREIGN EXCHANGE MARKET INTERVENTIONS AND STERILISATION POLICIES

By

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ABSTRACT

The main motivation for this thesis comes from the lack of comprehensive studies on issues related to increases in central bank debt certificates − monetary stabilisation (or sterilisation) bonds (MSBs). The MSBs have been, in particular, issued in emerging economies (e.g. Korea, China, Indonesia, Taiwan, Chile, etc.) to offset the impacts of sterilised FX market interventions on domestic money and thereby to reduce imminent inflationary pressure. The objectives of this thesis are to examine the impacts of and motivation for sterilised FX interventions comprehensively and to explore methodologies to assess the sustainability of MSB-dependent sterilisation policy.

Following Chapter 2 where we overview the main theoretical issues and statistical facts related to sterilisations, Chapter 3 and 4 investigate the impacts, profits and motives of sterilised FX interventions in selected countries (e.g., Korea, Australia, Japan, etc.). We examine the impacts of interventions on the level and volatility of the exchange rate and the determinants of central banks' sterilised interventions. In particular, these chapters provide investigations on whether central banks exhibit asymmetric intervention preference for inducing or resisting domestic-currency depreciation. We apply a variety of recent econometric techniques with daily intervention and monthly foreign reserve data for cross-country analyses. The methodologies include Asymmetric Component Generalised Autoregressive Conditional Heteroskedasticity (ACT GARCH), bounds test and friction model.

Chapter 5 compares the degree of sterilisation and *de facto* capital mobility – particularly focusing on emerging countries under inflation targeting – by estimating

sterilisation and offset coefficient with panel data for 30 countries. We also use a simple model explaining interest rate determination to investigate whether sterilisations have significant effects on local interest rates. Both panel and time series instrument variable analyses are applied.

Chapter 6 proposes several methodologies for assessing the sustainability of MSB-dependent sterilisation policy. Owing to the lack of concrete theories on the central bank debt policy, we modify theories of fiscal sustainability and then derive central bank's intertemporal budget constraint, which is separated from the central governments. Several sustainability conditions are obtained, based on cointegration relation between total revenues and expenditures or on central bank's monetary reaction function. Then, the sustainability tests are applied to empirical studies on the Bank of Korea's sterilisation policy. The assessment of central bank's MSB-dependent sterilisation in this chapter is a novel area and the main contribution of this thesis.

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ABBREVIATIONS

ACT GARCH	Asymmetric Component Threshold GARCH
AIC	Akaike information criteria
ADF	Augmented Dickey-Fuller
ARCH	Autoregressive conditional heteroskedasticity
ARDL	Autoregressive Distribution Lag
AUD (or A$)	Australian Dollar
BIS	Bank for International Settlements
BOE	Bank of England
BOJ	Bank of Japan
BOK	Bank of Korea
BOP	Balance of Payment
B/S	Balance Sheet
CB	Central Bank
CDS	Credit Default Swap
CI (a,b)	Cointegrated with cointegrating vector (a,b)
CIC	Currency in Circulation
DWH test	Durbin Wu Hausman test
ECB	European Central Bank
ECM	Error Correction Model
EGARCH	Exponential GARCH
FDI	Foreign Direct Investments
FE	Fixed Effect panel model
FSC	Financial Supervisory Committee(in Korea)
FR	Foreign Reserves
FRB	Federal Reserve Bank (of the US)
FX	Foreign Exchange
FX rate	Foreign Exchange rate (domestic per foreign)
FXI	Foreign Exchange Market Interventions
GARCH	Generalised Autoregressive Conditional Heteroskedasticity
GLS	Generalised Least Square
GMM	Generalised Method of Moment
GUM	General Unrestricted Model
HAC	Heteroskedasticity and Autocorrelation Consistent
HP filter	Hodrick-Prescott filter
HQ	Hannan-Quinn information criterion
IBC	Inter-temporal Budget Constraint
IFS	International Financial Statistics

IIS	Impulse Indicator Saturation
IMF	International Monetary Fund
IT	Inflation Targeting
IV	Instrument Variables
I(n)	Integrated order of n
i.i.d	identically independently distributed
JPY (or J¥)	Japanese Yen
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
KOSPI	Korean Stock Price Index
KTB	Korean Treasury Bond
KRW (or K₩):	Korean Won
MB	Monetary Base (or base money, high-powered money)
MOSF	Ministry of Strategy and Finance
MPC	Monetary Policy Committee (of the Bank of Korea)
MSB	Monetary Stabilisation (Sterilisation) Bonds
NDA	Net Domestic Assets
NFA	Net Foreign Assets
NPC	No Ponzi Condition
OLS	Ordinary Least Square
OMO	Open Market Operations
O/N	Overnight
P/L	Profit and Loss statement
PP	Phillips-Perron unit root test
PS	Primary surplus
PV	Present Value
PBOC	People's Bank of China
RBA	Reserve Bank of Australia
RE	Random Effect penal model
REER	Real Effective Exchange Rate
se	Standard Error
SIC	Schwarz's information criteria
SVAR	Structured vector autoregressive
S&P ASX 200	Standard and Poor's Australian Securities Exchange index 200
UIP	Uncovered Interest rate Parity
USD or US$	US dollar
VAR	Vector Autoregressive
VECM	Vector error correction model
3SLS	Three Stage Least Square
2SLS	Two Stage Least Square
Δ	Changes or first differences

CHAPTER 1 INTRODUCTION

Since the collapse of the Bretton Woods system in 1971, most countries have used foreign exchange market intervention (hereafter FXI) to both slow rapid FX rate movements and signal their views that their exchange rates do not reflect fundamental economic conditions (Edison 1993). Despite their sustained and frequent FXIs, authorities seem to have been able to retain their monetary policy independence to some extent by sterilisation operations (IMF 2011). Sterilisation of FXIs means that any change in the monetary base is neutralised by open market operations (hereafter OMOs), using domestic bonds in the opposite direction so that the monetary base remains unchanged.[1]In other words, sterilisation enables CBs to determine the money supply and thereby to set and control their policy interest rates without interference from external shocks.

During the 1970s and 1980s, when capital mobility was limited, sterilised FXIs provided the monetary authorities with an additional policy tool to pursue exchange rate objectives independently of their monetary policies. However, as capital mobility has accelerated since the early 1990s, many advanced countries have reduced (or abandoned) their FXIs and allowed more flexible movement of FX rates. This trend has been due mainly to the consensus based on the trilemma hypothesis (Mundell 1963; Summers 1999; Fischer 2001) that, given perfect capital mobility, a central bank (hereafter CB) cannot accomplish the simultaneous control of interest rates and exchange rates. In other words, a perfectly independent monetary policy could be guaranteed with the CB allowing exchange rates to

[1]The sterilisations include FXIs and subsequent OMOs to offset any changes in the monetary base caused by the FXIs, and thus aim to simultaneously control both FX rates and targeted interest rates (or monetary base). Sterilisation broadly indicates any form of activity like changes in reserve requirements or mandatory deposits in the CB's account in an attempt to leave the domestic money supply unchanged in the face of external shocks. In this paper, FXIs indicate sterilised interventions to influence FX rates, and sterilisations denote OMOs for the purpose of leaving the monetary base (or local interest rate) unchanged.

change without limit.[2] This leads to the natural reasoning that given perfect (or high) capital mobility, a *de facto* free float may be consistent with an independent monetary policy regime like inflation targeting (hereafter IT).Since the mid-1990s, confronted with substantial and persistent capital inflows, Korea and many small open emerging economies have faced a trilemma similar to that the advanced countries did a decade ago. With capital account liberalisations, these countries have been concerned about how to maintain monetary independence while stabilising FX rate fluctuations at the same time. Overall, there seems to have been a greater tendency to abandon intermediate FX rate regimes and to adopt inflation targeting (Eichengreen 2008).

According to theory, it is expected that FXI should decrease under an IT regime, other things being equal, because sustained interventions may not be compatible with IT, which is inherently a rule-based regime, emphasizes policy transparency and theoretically assumes a free float regime (Svensson 1999, 2010).Sterilisations (for maintaining monetary independence) will become less effective or less feasible as domestic markets are more integrated with international markets (Mundell 1963). However, most emerging IT countries appear to still actively conduct sterilised FXIs after introducing IT with more flexible FX regimes. For emerging countries facing massive capital inflows, sterilisations have been used as a main tool to lessen the undesirable effects of these flows. East Asian countries are frequently cited as an example of successful sterilisation in the sense that they have retained monetary independence without abandoning the control of FX rates (see Reisen 1993). In this context, sterilisation may be regarded as an imperfect substitute for capital controls under which the CBs can control both FX and interest rates.

[2] The trilemma tells that it is impossible for a country to achieve three contradicting but desirable goals simultaneously: (i) freeing capital completely, (ii) fixing FX rates, and (iii) setting domestic interest rates indifferently of foreign shocks – but that it can only attain a combination of two of these objectives. Thus, in order to stabilise both interest rates and FX rates, the authorities must control capital flows.

Sterilisations in emerging countries are mostly characterized by fast-growing accumulations of foreign reserves and considerable issuance of monetary sterilisation bonds (hereafter MSBs). MSBs indicate bonds or bills issued by CBs in order to drain surplus liquidity (i.e., excess money supply), which may lead to inflation. MSBs have an effect on putting off imminent inflation caused by increases in money, but must be paid back in the future. According to the BIS, about 31 economies have MSBs as of end of 2002 (Hawkins 2003). MSBs are mainly denominated in the local currency and pay nominal interest rates to their holders. Sterilisation accordingly involves an exchange of foreign reserves and MSBs.

The build-up of foreign reserves has been most prominent in emerging countries, mainly because these countries tend to fear the appreciation of the domestic currency more than its depreciation (Levy-Yeyati and Sturzenegger 2007) and because policy makers believe that large foreign reserve holdings will be helpful in preventing or addressing possible sudden stops and capital flow reversals in the future. MSBs have been used particularly in emerging countries whose Treasury bond markets are relatively less developed. When issued by competitive tender, MSBs are regarded as more market-friendly instruments than reserve requirements.

Despite all of these aforementioned benefits, however, sterilisation has limitations in being continuously used as a policy tool to address capital inflows. First, complete sterilisation (in the context of completely offsetting the effect of capital inflows) may be impossible with high capital mobility. For example, given a situation in which domestic interest rates are higher than foreign ones, the sterilisation of capital inflows is an actual monetary tightening. Successful sterilisations may hence leave the existing domestic-foreign interest rate differential unchanged, and thus attract further capital inflows. The effect of initial sterilisation is offset by consequential international capital flows, so that domestic interest rates significantly different from the internationally prevailing level cannot persist in the long-run (Herring and Marston 1977).

Second, there are considerable quasi-fiscal costs associated with sterilisation particularly in emerging countries, because most CBs exchange high-yielding domestic assets for low-yielding foreign reserves. Persistent sterilisations and resultant large issuances of MSBs cause CBs to suffer financial losses. When the CB cannot afford to continue sterilisation due to its accumulated financial losses, the public will come to doubt the CB's will to control inflation, because unsterilised capital inflows may lead to inflation and because financially-unsound CBs are likely to make up for their losses by taxation or monetisation in the long run. Recapitalizing the CB (by taxation) may weaken its monetary policy independence from the central government or politicians.

Third, there is a sterilisation peril, in that sterilisation itself could lead the CB's monetary policy into credibility problems (Calvo 1991). For example, if the CB issues nominal MSBs to sterilise capital inflows induced by an increase in domestic money demand, the sterilisation could push nominal interest rates unnecessarily high and thereby perpetuate the domestic-foreign interest rate differential, which will exacerbate the CB's balance sheet problem. This may be particularly true for emerging countries (confronted with capital inflows) where the CBs are in severe *"debtor"* positions. Given domestic interest rates higher than foreign rates, debtor CBs are frequently forced to issue either MSBs with higher interest rates than market rates, in order to encourage market participants to purchase them, or long-term MSBs in order to reduce their rollover risk.[3]

Fourth, if FXIs are asymmetric in the sense that dominant interventions are to resist appreciation, the sterilisation costs will be much higher. From the practical perspective,

[3]Generally, long-term interest rates are higher than short-term ones. Most CBs issue short-term bonds with maturities of less than one year (e.g. Japan and Switzerland). But some CBs issue bonds with maturities of up to three years (in Korea, China and Taiwan) or even 20 years (in Chile).

sterilised interventions to resist domestic-currency appreciation are more feasible than those for fighting against depreciation, because the CB can easily print money. Particularly, CBs in emerging countries have more incentives to prefer asymmetric intervention, because the foreign reserves are regularly revalued in terms of the domestic currency. However, the sterilisations may not be sustainable in the long run given the possible inflation costs incurred by printing money and the sterilisation cost from domestic-foreign interest rate differential.

Despite considerable discussion, studies on the effects and sustainability of sterilisation policies of the 2000s have been rare. Particularly, there has been little investigation of the sustainability of MSB-dependent sterilisation, which has already become a critical issue in several emerging economies like Korea, Taiwan, Chile and China. In this regard, Korea and several countries provide good examples, because they are still engaging in active sterilised interventions and have issued massive amounts of MSBs and because several of their CBs have experienced considerable financial losses from sterilisation activities. This thesis investigates the sterilisation policies in selected countries from the specific viewpoint of CB financial soundness and sterilisation costs.

The ECB (2006) briefly points out the possible side effects of sterilisation and sustained reserve accumulation, which are discussed in this thesis:

"Continued reserve accumulation may over time entail some risks and costs, such as inflationary pressure, over-investment, asset bubbles, complications in the management of monetary policy, potentially sizeable capital losses on monetary authorities' balance sheets, sterilisation costs, segmentation of the public debt market and misallocation of domestic banks' lending"

With regard to the issues of sterilisation risks and costs, the effects and motives of sterilised FX interventions, interlinks between sterilised interventions and monetary operations, sterilisation costs are the main interests of this thesis.

CHAPTER 2 THEORETICAL/STATISTICAL BACKGROUNDS AND THESIS STRUCTURE

2.1 Theoretical background

In this section, we review the main theoretical issues concerning sterilisations. At first, based on Frankel(1997)'s simple IS-LM analysis with an open economy, we explain how sterilisation operations affect the financial variables – especially interest rates – in different situations in terms of exchange rate regime and capital mobility. Our interest is sterilisation undertaken to offset the effects of capital inflows on the monetary base. The point here is to understand that, given a certain degree of capital mobility, the appropriate policy responses to capital inflows depend upon the causes of these flows and the exchange regime; and that there exists a sterilisation peril that persistent sterilisation may threaten price stability. Afterwards, we briefly explain the channels through which FXIs influence the level and the volatility of exchange rates. More detailed explanations are presented in each relevant chapter.

2.1.1 Sterilisation and trilemma

2.1.1.1 Sterilisation under perfect capital mobility

In this section, sterilisation is narrowly defined as OMOs by which the CB ensures that the money supply returns to its level prior to the FXIs. If sterilisation is impossible, the CB can neither determine the money supply nor set domestic interest rates independently of foreign disturbances like capital flows. Accordingly, the CB's inability to sterilise implies the loss of its monetary policy independence (Frankel 1997, p 268).

According to Mundell (1963) and Obstfeld (1982), given completely perfect capital mobility the feasibility of sterilisation depends upon the exchange rate regime. Under a fixed exchange regime, sterilisation operation is impossible because of offsetting capital flows. For example, open market sales of domestic bonds cause an incipient appreciation of the domestic currency. To maintain the official parity the CB must intervene by selling the monetary base for foreign reserves. As a result, the initial open market sales are offset by an increase in the foreign component of the monetary base. In this case, the CB cannot sterilise the foreign reserves through offsetting the domestic monetary base, even temporarily, and the monetary base is thus determined independently of the CB intentions (Obstfeld 1982, p45).

Any open market purchase (to offset the effect of foreign-currency selling interventions) may bring about infinite capital outflows and deplete the foreign reserves until they are all exhausted and the fixed regime collapses (Mundell 1963, pp.484-485). Accordingly, sterilisations just change the foreign reserve level without affecting the levels of output and employment. Open market sales (purchases) of domestic bonds result in an equal increase (decrease) in the foreign reserves. Theoretically, complete sterilisation may be unsustainable within perfect capital mobility, because the size of the OMOs in domestic bonds becomes indefinitely large (Boyer 1979).

In contrast, under a completely flexible exchange regime (where FXIs are not carried out), unsterilised capital flows do not affect inflation and sterilisation is thus not necessary. In this case, the appreciation of the domestic currency leads to a fall in relative prices of imported goods and consumption shifts from the nontradable to the tradable goods sector, which contributes to a lessening of the inflation pressure (Frankel 1997). Consequently, a flexible FX regime automatically adjusts the possible inflation pressures.

To sum up, given perfect capital mobility the CB is totally subject to the "trilemma," so that it is impossible to maintain exchange rate parity and control the domestic money supply simultaneously, through sterilised intervention. Sterilisation may be regarded as a more feasible and necessary option under imperfect capital mobility, because perfect capital mobility makes sterilisation activities impossible (in the case of a fixed regime) or unnecessary (under a flexible regime).

2.1.1.2 Sterilisation under imperfect capital mobility

When capital mobility is limited, sterilised interventions, irrespective of the exchange-rate regime, may be viewed as an attempt to simultaneously target both exchange and interest rates in the short-run (Obstfeld 1982). Under a fixed exchange rate regime, sterilisation is possible in the short-run and even encouraged in order to reduce the inflation pressures caused by capital inflows (Frankel 1997, p 265). Sterilisations are less needed under a flexible than a fixed exchange regime, because the appreciation of the domestic currency reduces the inflation pressures. The more flexible the exchange rate, the less likely it is that capital inflows will lead to inflation and sterilisation be necessary (Haque et al. 1997).

However, limited capital mobility does not always guarantee the feasibility of sterilisation and resultant monetary autonomy. In a world in which Ricardian equivalence holds, any sterilisation is powerless. In this case, the public rationally expects the future inflation and the future tax liabilities implied by the MSBs and the foreign reserves and thus internalise the budget constraint of the CB. Hence, sterilisations financed by increasing MSBs will not alter the 'outside asset' supply. In this case, the sterilisations will not affect the domestic interest rate or monetary base even with imperfect substitutability between foreign and domestic assets (Obstfeld 1982, pp. 45-46).

2.1.2 Causes of capital inflows and sterilisation

As will be seen in the section 2.2, despite flowing temporarily out during crisis periods, international capital has flowed steadily into emerging countries over the last two decades. Most CBs in emerging countries appear to sell the monetary base for foreign reserves due to fears of appreciation and then sterilise the increases in money by selling domestic bonds. With regard to the feasibility of sterilisation, there exist two opposite arguments. Calvo (1991) shows that, even in conditions of limited capital mobility, sterilisation of capital inflows is more difficult than the conventional trilemma indicates, because the sterilisation itself tends to perpetuate the domestic-foreign interest rate differential, attracting capital inflows and causing excessively large fiscal costs. Sterilisation could thus run into serious credibility problems and thereby not be sustained in the long run, as shown in Latin America (see Calvo et al. 1993).

Reisen (1993) argues on the contrary that sterilisation is easier than the conventional trilemma proposes, as exemplified by East Asian countries. They have retained some degrees of monetary autonomy while stabilising their exchange rates through sterilisation. Some studies have attempted to bridge the gap between these two views by pointing out that the feasibility of sterilisation differs depending upon the causes of the capital inflows (see Frankel 1997, Haque et al. 1997). Sterilisation is more feasible when the capital inflows stem from a fall in foreign interest rates while being more difficult when they are caused by an increase in domestic money demand.

We illustrate the effects of sterilizing capital inflows coming from different driving forces by using a simple IS-LM analysis (Frankel 1997). The factors driving capital inflows are (i) an increase in domestic money demand, (ii) a fall in foreign interest rates, and (iii) an increase in the current account surplus. At first, we consider the simplified balance of payments (*BP*) consisting of the current account (*CA*) and the capital account (*KA*):

(2.1) $BP = CA + KA$

(2.2) $CA = CA\{Y_d, Y_f, E(\Delta S)\} = EX\{Y_f, E(\Delta S)\} - IM\{Y_d, E(\Delta S)\}$

(2.3) $KA = KA\{i_d - i_f, E(\Delta S), \ \Omega\}$

where i_d=domestic interest rate, i_f=foreign interest rate (assumed to be exogenous), Y_d=domestic disposable real income, Y_f=foreign disposable real income, EX = export, IM = import, E=expectation, $S = FX \times (P^* / P)$ where *S* is the real exchange rate measured by the spot FX rate(domestic per foreign) times the relative price ratio(= foreign price/domestic price) and Ω=other factors influencing the capital account such as exchange rate risk and default risk. It is assumed that prices are fixed in the short run, and changes in real exchange rates thus depend only upon nominal exchange rates: $E(\Delta S) = E(\Delta FX)$.

The infinite responses of *KA* to $(i_d - i_f)$ indicate perfect capital mobility. Since i_f is assumed to be exogenous, *KA* infinitely and instantly responds to changes in domestic monetary operations. Under a fixed regime ($E(\Delta S) = 0$), the *BP* curve does not shift. Under a flexible regime, the slope of the *BP* curve depends upon the degree of capital mobility. Under perfect capital mobility, *BP* does not shift because ΔKA overwhelms ΔCA. Under imperfect capital mobility, *BP* is upward-sloping. Imperfect capital mobility indicates the case where the *BP* curve is flatter than *LM*: capital is very but not perfectly mobile (Frankel 1997).

Aggregate demand (Y_d) for domestic output depends upon the domestic demand ($A = C + I + G$) and net foreign demand for domestic goods (CA):

(2.4) $Y_d = C(Y_d, W) + I(i_d) + G + CA\{Y_d, Y_f, E(\Delta S)\} = A(Y_d, i_d, G, W) + CA\{Y_d, Y_f, E(\Delta S)\}$: IS curve

where *C*=consumption, *I*=investment and *W*=wealth. The standard form of real money demand is assumed:

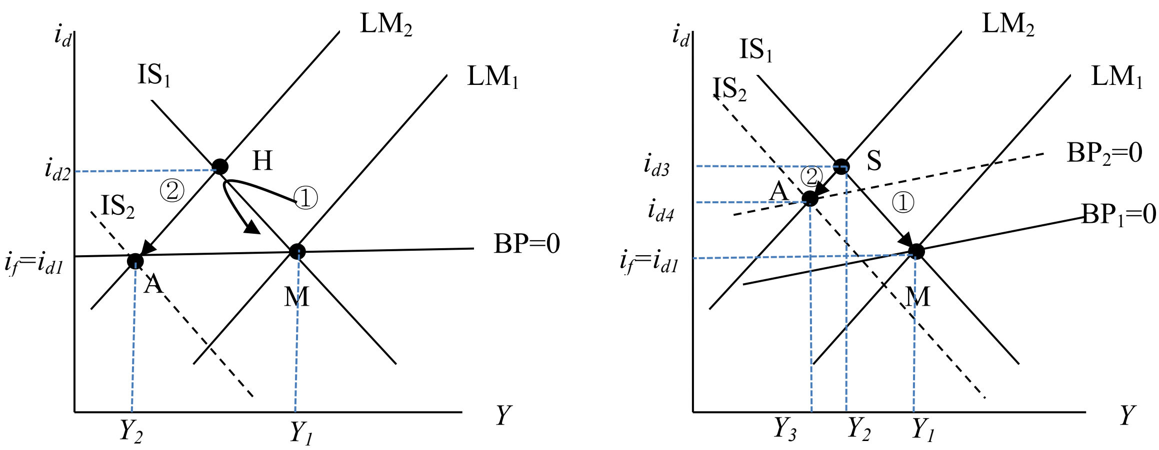
(2.5) $M_d / P = L(i_d, Y_d, \Phi)$: LM curve

where Φ indicates other variables affecting money demand (e.g. stock of bonds, expected exchange rate, inflation, etc.). If M_s denotes the money supply, then the condition for money market equilibrium is $M_s = L(i_d, Y_d, \Phi)P$. Here, unless the CB can influence interest rates, it cannot control the money supply. In this case, sterilisation is impossible, and the money stock is endogenously determined by money demand (Frankel 1997, pp. 267-268). Note that, under imperfect capital mobility, ΔS affects *CA* and thus shifts both *IS* and *BP* in the same direction - see equations (2.2) and (2.4). On the graph, if the internal equilibrium (i.e., the intersection of the *IS* and the *LM* curves) is above the BP curve, higher domestic interest rates induce capital inflows.

2.1.2.1 Increase in domestic money demand

Figure 2.1 describes the case where initial capital inflows are caused by an increase in domestic money demand. This situation may occur when the expectation of high domestic inflation is dampened. *Under perfect capital mobility*, as the *LM* curve shifts leftward ($LM_1 \rightarrow LM_2$), the economy moves temporarily from *M* (initial equilibrium) to *H* (the hypothetical point where high domestic interest rates induce infinite capital inflows), and the domestic interest rate thus rises from i_{d1} to i_{d2}. Since $i_{d2} > i_f$ at *H*, foreign capitals flow infinitely in, and the domestic currency appreciates irrespective of the exchange rate regime.

Figure 2.1 Increase in domestic money demand ($LM_1 \rightarrow LM_2$)



(a) Perfect capital mobility **(b) Imperfect capital mobility**

Notes: 1. Y_d = domestic income; i_d= domestic interest rate; i_f= foreign interest rate
2. M: initial equilibrium; H: hypothetical point to which economy instantly moves (Under perfect capital mobility, the economy cannot remain here even in the short-term, because the high i_d induces infinite capital inflows); S: point which could be maintained in the short-run by sterilisation; A: appreciation
3. The BP curve is horizontal under perfect capital mobility and upward-sloping under imperfect capital mobility.
4. A rightward movement on the horizontal axis indicates an increase in inflationary pressure.
5. For simplicity, it is assumed that $i_d = i_f$ at initial equilibrium and i_f is exogenous.

Source: Author's modification of Frankel (1997)

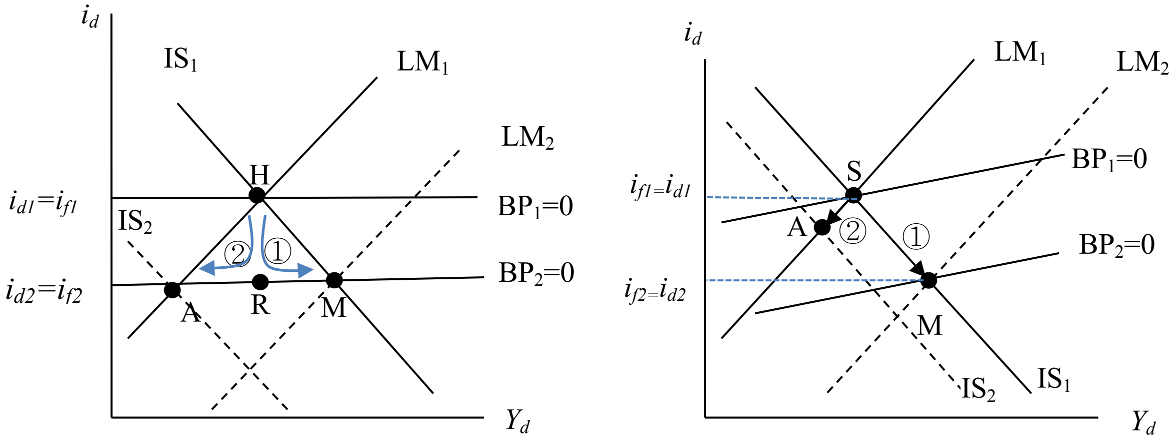
① Under a credible fixed FX regime, the CB should immediately intervene in the FX market (by purchasing foreign reserves with base money) in order to maintain the official parity. In this case, foreign and domestic assets are perfect substitutes because $E(\Delta S) = 0$. *KA* reacts *infinitely* to interest rate changes and arbitrage transactions insure that $i_d = i_f$, so that the point *H* (where $i_d > i_f$) cannot be sustained – i.e., any sterilisation is impossible in this case. As a result, the increase in base money created by FXIs causes the LM curve return instantly to where it was ($LM_2 \rightarrow LM_1$). Accordingly, the economy returns to its initial equilibrium M where $i_d = i_f$. There is no change in *Y*, i_d or inflation. ②Under a completely flexible regime, the appreciation of the domestic currency leads to a reduction in exports ($IS_1 \rightarrow IS_2$) and the economy thereby moves to *A*, where inflationary pressure is weakened (auto-stabilisation of flexible regime). As a result, the sterilisation for controlling inflation is not necessary.

Under imperfect capital mobility, ①if CB sterilises the capital inflows by issuing MSBs at point S, the sterilisation generally entails needlessly high interest rate(i_{d3}) and contracts economy($Y_1 \rightarrow Y_2$). In this case, there is a possibility that sterilisation may rather cause to destabilise economy due to the increasing sterilisation cost that comes from domestic-foreign interest rate differential (Calvo1991). If CB expands money supply ($LM_2 \rightarrow LM_1$) to meet the increased money demand rather than sterilise it, the economy gradually return to M. ② If CB allows the appreciation of domestic currency, both *IS* and *BP* curve shift to the left and then economy goes to A. Note that if CB allows more flexible exchange rate, domestic-foreign interest rate differential decreases from $(i_{d3} - i_f)$ to $(i_{d4} - i_f)$ and the necessity of further sterilisation decreases.

2.1.2.2 Exogenous fall in foreign interest rates

Figure 2.2 illustrates the case where capital inflows increase due to an exogenous fall in foreign interest rates $(i_{f1} - i_{f2})$ which results in a downward shift of the BP curve ($BP_1 \rightarrow BP_2$). *Under perfect capital mobility*, the CB has no choice but to accept the fall in i_d $(i_{d1} - i_{d2})$ so that the economy temporarily moves to *R*. ①Under a fixed regime, capital inflows lead to increasing appreciation pressures that force the CB to conduct domestic-currency selling interventions ($LM_1 \rightarrow LM_2$), and the economy attains its equilibrium at *M*. In addition, the investment stimulated by the fall in i_d lets the economy move to M. ②If instead the authorities give up fixed parity, the domestic currency appreciates, the *CA* worsens ($IS_1 \rightarrow IS_2$), and the economy is in equilibrium at *A*.

Figure 2.2 A Fall in foreign interest rates($BP_1 \rightarrow BP_2$)



(a) Perfect capital mobility **(b) Imperfect capital mobility**

Notes: 1. At initial equilibrium (H and S), it is assumed that $i_d = i_f$.
2. An exogenous fall in foreign interest rates leads the BP curve to move downward ($BP_1 \rightarrow BP_2$).
3. Other notations are the same as those in Figures 2.1 and 2.3.

Under imperfect capital mobility, the CB sterilises capital inflows by selling domestic bonds at point *S*. During this sterilisation process, i_{d1} is kept higher than i_{f2} in the short-run. ①When the CB eventually lets the money supply increase ($LM_1 \rightarrow LM_2$), the domestic interest rate goes down to i_{d2} and the economy moves to *M*. That is, domestic interest rates may converge with foreign interest rates in the medium or long run. ② If the CB allows appreciation of the domestic currency ($IS_1 \rightarrow IS_2$), the economy moves to point *A*.

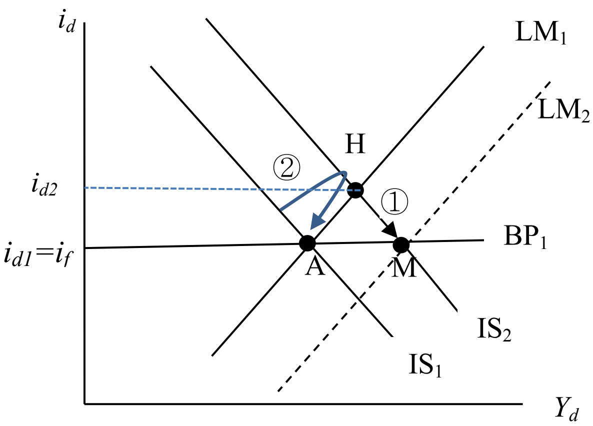
2.1.2.3 Improvement in current account

Figure 2.3 illustrates the case where the current account improves due to an exogenous export increase. In abbreviation notation, this would be $CA\uparrow \rightarrow$ IS right: IS_1 to

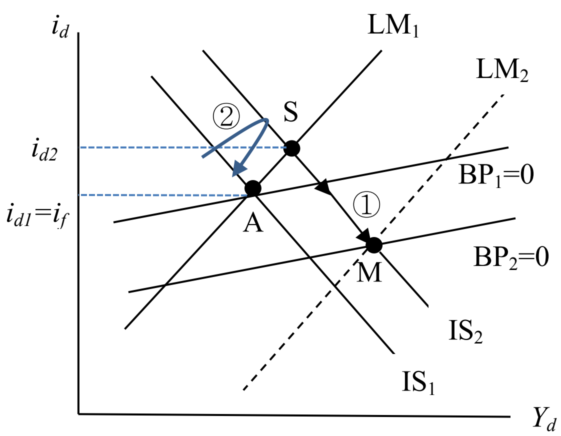
$IS_2 \rightarrow$ $i_d\uparrow$: i_{d1} to i_{d2} $\rightarrow KA\uparrow$ due to $i_{d2}>i_f \rightarrow$ economy temporarily moves from *A* to *H*. ①*Under perfect capital mobility* and a fixed exchange rate regime, capital automatically flows in through the BOP, allowing full accommodation of the increase in domestic output($LM_1 \rightarrow LM_2$). The economy thus moves to *M*. ②If the CB gives up the fixed exchange rate and instead fix the monetary supply, the domestic currency appreciates and the *CA* deteriorates, which causes the IS curve to move leftward ($IS_2 \rightarrow IS_1$). The economy then returns to the initial points at *A*.

Under imperfect capital mobility, an improvement in the *CA* causes both the IS and the BP curves to move rightward. The CB may keep i_{d2} higher than i_f by sterilizing capital inflows at point *S* in the short-run. ① But the CB eventually gives up the sterilisation for fixing the interest rate, and the capital inflows move the economy to the equilibrium point *M*. ②If the CB abandons the fixed exchange rate regime, the appreciation of the domestic currency leads the economy to move toward A.

Figure 2.3 Improvement in current account ($IS_1 \rightarrow IS_2$)



(a) Perfect capital mobility



(b) Imperfect capital mobility

Notes: 1. A is an initial equilibrium where $i_d=i_f$.
2. Other notations are the same as those in Figures 2.1 and 2.2.

2.1.3 Feasibility of sterilisation, and sterilisation peril

The CB's ability to sterilise capital inflows depends upon the exchange rate regime, the degree of capital mobility, the cause of the capital inflows, the policy objectives of the country, its monetary policy stance, and the degree of development of its financial markets (Haque et al. 1997). First of all, as seen in the previous section, sterilisation is feasible (in the short-run) and meaningful under limited capital mobility. As the trilemma suggests, given perfect capital mobility, the sterilisation of capital inflows is impossible under a perfectly fixed exchange regime and unnecessary under a completely flexible one. We can accordingly expect sterilised interventions to be frequent in cases of intermediate FX regimes and imperfect capital mobility. Second, sterilisations are less feasible and more costly when the domestic bond markets are thin. For example, CBs in less developed financial markets are sometimes forced to sell MSBs by providing interest rates higher than market rates.

Third, under a managed float or a fixed regime, the necessity of sterilisation depends upon the causes of the capital inflows, because whether they lead to inflation or not is affected by the forces driving them (Haque et al. 1997). As seen in the previous section, when capital inflows are pulled in, for instance by a sustained increase in domestic money demand, domestic interest rates go up. In this case, the capital inflows are unlikely to be inflationary. Continuing sterilisations, therefore, which are by their nature monetary tightening, may lead to unnecessarily high domestic interest rates ($i_{d3} > i_{d4}$ in Figure 2.1(b)) and perpetuation of the interest rate differential. In this case, monetary expansion may be a more desirable policy than sterilisation. If the capital inflows are pushed in by a decline in foreign interest rates, however, the level of domestic interest rates will not be any higher than it was before the capital flows in ($i_{d2} < i_{d1}$ in Figure 2.2(b)). Since the fall in foreign interest rates induces investors to prefer domestic assets vis-à-vis foreign ones, sterilisation will not in itself push domestic rates up. In this case, there might be a case for sterilizing the inflows by selling the MSBs.

Comparing the three different causes of capital inflows, we can clarify the links between domestic interest rates and sterilisation (Frankel 1997, p 278). First, sterilisation leads to a larger domestic-foreign interest rate differential, irrespective of the cause of capital inflows, than when there is no sterilisation. In all three cases, domestic interest rates are higher at point S (where the money supply is fixed by sterilisation) than at point M (where the money supply is allowed to increase) and at point A (where the domestic currency is allowed to appreciate).

Second, when capital inflows are induced by a fall in foreign interest rates, the level of domestic interest rates is not higher after capital inflows than it is before capital inflows. In this case, the increase in domestic interest rates caused by sterilisation may not be a significant problem. In contrast, when capital inflows are, for example, encouraged by an increase in domestic money demand, domestic interest rates are higher with capital inflows than without them. In this case recourse to sterilisation may be more costly, and monetary expansion instead may be proper.

Calvo(1991) points out a possible risk of sterilizing capital inflows induced by an increase in domestic money demand which could be a response to an exchange-rate oriented stabilisation programme. When the CB issues *nominal* MSBs to purchase foreign reserves in order to sterilise capital inflows, there may be a peril of destabilising rather than stabilising the economy. In this case, as seen in the previous section, the CB should keep nominal domestic interest rates high in order to prevent the monetary base from increasing, and thus leave the domestic-foreign interest rate differential unnecessarily large. This situation induces further capital inflows, which will require additional sterilisation, and thereby perpetuates the interest rate differential. This "*vicious cycle of sterilisation*" results in a persistent accumulation of MSBs and foreign reserves. A large stock of MSB outstanding may jeopardize the sustainability of the CB's anti-inflation policies and eventually weaken central bank independence from the government. (See section 5.2.1.3 for details on sterilisation peril).

2.1.4 Effects of sterilised interventions on exchange rate

In the previous section, we focused mainly on the issue of whether monetary operations for sterilisation are able to offset the changes in the monetary base caused by FXIs. In this section, our concern is how sterilised FXIs affect exchange rates. Under hard pegs, FXIs are often rule-based in that the timings and amounts of interventions are predetermined in most cases, because their objective is to maintain fixed parity. Under flexible regimes, in contrast, FXIs are likely to be optional and discretionary (Duttagupta et al. 2005 p 8). The intervention objectives under a flexible regime are not easily differentiated. In general, CBs are known to intervene in the FX markets to address misalignments, to calm disorderly markets, and to provide or accumulate foreign reserves.

According to standard asset-pricing models of exchange rate determination, non-sterilised FXIs may influence the FX rate by affecting the monetary base, just as other monetary operations do. However, the monetary base will not change in the case of sterilised interventions. As to the effect of OMOs, there seems to be a consensus that the CB can set and maintain short-term interest rates at a desirable level by controlling the supply of the monetary base in the short run. Theoretically, the effects of OMOs are explained by the "liquidity effect" (Friedman 1969, Thornton 2010) or the "announcement effect" (Guthrie and

Wright 2000). However, as to the effects of FXIs on FX rates, there exist more ambiguous and rather doubtful views (see Edison 1993, Sarno and Taylor 2001, Menkhoff 2008).

To explain the effects of sterilised intervention, previous literature presents mainly four channels: (i) the portfolio balance channel (Dominguez and Frankel 1993a), (ii) the signalling channel (Mussa 1981, Kaminsky and Lewis 1996), (iii) the microstructure or order flow channel (Hung 1997, Evans and Lyons 2002), and (iv) the coordination channel(Sarno and Taylor 2001). The portfolio channel suggests that FX intervention can affect FX rates by changing the net supply of foreign assets and eventually shifting the relative compositions of private investors' portfolios. Sterilised interventions would hence be more effective when foreign and domestic assets are imperfect substitutes, and when the amount of intervention is considerably large relative to market turnover.

In the signalling channel theory, FX intervention can affect FX rate by providing information about future monetary policy or economic fundamentals and thus changing market expectations. According to the signalling approach, sterilised intervention can still affect exchange rates even under perfect asset substitutability and with a small intervention amount. For example, foreign-currency purchasing interventions cause agents to expect future monetary expansion and thereby cause the domestic currency to depreciate. However, the signalling channel appears to contradict the widespread practice of secret interventions in most countries.

The microstructure and coordination channels are proposed because empirical studies based on the portfolio and signalling channels have provided little evidence that macroeconomic variables have strong and consistent explanatory power except in extraordinary circumstances. The microstructure channel theory suggests that the CB's transactions influence exchange rates by altering order flows and thereby changing the expectations of noise traders. According to this theory, a single CB intervention transaction, regardless of the intervention amount or secrecy, can affect exchange rates by triggering a multitude of subsequent trades in the markets. The coordination channel theory meanwhile emphasizes that publicly-announced interventions can play a significant role in coordinating trades in the direction of equilibrium when exchange rates deviate far from economic fundamentals because of herd behaviour or self-fulfilling expectations.

The effects of sterilised intervention through the aforementioned channels rely on certain assumptions: (i) (for all channels) that Ricardian equivalence should not hold[4]; (ii) (for the portfolio balance channel) that domestic and foreign assets should be imperfect substitutes; and (iii) (for the signalling channel) that there exists asymmetric information in the FX markets. The feasibility of each theory appears to have changed in line with the continuing development of financial markets. As financial markets become integrated, the portfolio channel appears to weaken. The signalling effect is instead then put consistently forward as the main channel. Particularly, the microstructure and coordination channels both of which focus on the role of information and the use of high frequency data (like daily and intra-daily trade amounts), appear likely to be more persuasive in explaining the impacts of FXIs in the future. However, the portfolio channel may still have valuable implications for developing countries whose capital markets are still not freely open to international investors, and the traditional signalling channel may have weak explanatory power in countries where monetary and FX intervention policy are conducted by separate entities.

Previous empirical studies suggest that the effects of sterilised intervention on the exchange rate level appear short-lived or very slight (Edison 1993). As for the effects on FX

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[4] When Ricardian equivalence holds, a sterilised intervention is simply a swap in the currency composition of "inside assets" (i.e., foreign reserves and MSBs), and thus does not create net wealth. Sterilised intervention should therefore have no effect on the foreign exchange market equilibrium (Dominguez 2009, p1036).

volatility, most studies seem to find a tendency for sterilised intervention to increase rather than reduce FX volatility (Sarno and Taylor 2001, Menkhoff 2008).

2.1.5 Inflation targeting and sterilisation

In typical IT models, exchange rates are assumed to change in line with uncovered interest rate parity (see Svensson 1997; 2010).A sterilised intervention is powerless unless it changes interest rates, because the interventions would be offset by capital flows in the opposite direction. In this situation, changes in interest rates rather than sterilisations should be more effective in influencing exchange rates. Thus, CBs with IT regimes use short-term interest rates as their main policy targets. Any change in the monetary base caused by FXIs is almost contemporaneously sterilised in an automatic way. Thus, under a typical IT regime most interventions are sterilised ones.

However, as seen in the previous section, even when UIP holds and the portfolio balance effect is excluded, sterilised FXIs can affect FX rates by signalling the future direction of the interest rate path (Mussa 1981). For example, current foreign currency-buying interventions signal current overvaluation of the domestic currency, and that the policy interest rate should be lowered in the near future. This signal accordingly changes the market expectation of future monetary policy and thereby influences the current exchange rate. Most empirical work seems to agree that the transmission channel between FXIs and FX rates is likely to be highly uncertain and unstable (Edison 1993, Sarno and Taylor 2001, Menkhoff 2008). As a result, under an IT regime it is more difficult to use FXI as an independent policy tool, and a short-term interest rate is considered most effective as a single policy tool. Given free capital movements, the CB under an IT regime is more likely subject to the trilemma constraint, because IT theory typically assumes a freely floating exchange rate(Eichengreen

2008).According to Eichengreen, the CB's attempt to control FX rates under an IT regime may transform the FX rate into a nominal anchor in place of target inflation. In this case, there is a risk of losing monetary independence. It is accordingly expected that a positive relationship exists between an IT regime and FX volatility.[5] According to the concept of *strict* IT, sustained sterilised interventions and intermediate exchange rate regimes are likely to be inconsistent with IT.

In practice, however, IT regimes are always flexible in the sense that all CBs under IT not only aim at stabilising inflation but also put weight on other economic objectives. Thus, some of the literature argues that sterilisation to manage floating exchange rates could be consistent with an IT regime (Bofinger and Wollmershaeuser 2001, Truman 2003). These views argue that a CB under an IT regime is able to target both FX and interest rates to some extent. In these views, the justifications for FXIs are in general based on the order flow or coordination channels. Hence, a sterilised intervention can be effective even if the intervention amount is small enough to be offset by international capital flows, because even one intervention transaction can create a "hot potato effect" triggering many subsequent trades (Holub 2004). As the international financial markets are rapidly integrated and many countries adopt IT, the implications of the portfolio balance channel seem to be diminishing.

Sterilisation has a particular implication in an emerging country in which the authorities over the monetary and foreign exchange policies are divided among the CB and the government, respectively. Most CBs set short-term interest rates as their operating targets, and then automatically offset the money changes (caused by government FX interventions), which destabilise the target interest rates. If there is no prior policy coordination between the

[5] However, introducing a more rule-based and credible regime like IT may help to reduce FX volatility in emerging markets in the medium to longer run, because FX rate-oriented policies are likely to be more fragile and less credible in these countries. Eichengreen (2008) concludes that IT regimes enable emerging countries to adopt the policy regimes of advanced countries (e.g. independent monetary policies with capital account liberalisation) without exposing themselves to high levels of FX rate volatility.

two authorities, the CB has no choice but to take ex-post actions to offset the impacts of FXIs. In the absence of sterilisation, the treasury would control the monetary policy instruments by changing spending and taxation or intervening in FX markets. Note that, in a monetary model, non-sterilised FXIs would have the same effects on interest rates as OMOs. As a result, sterilisations enable CBs to maintain independence from their governments.

2.1.6 MSB-dependent sterilisation and domestic interest rates

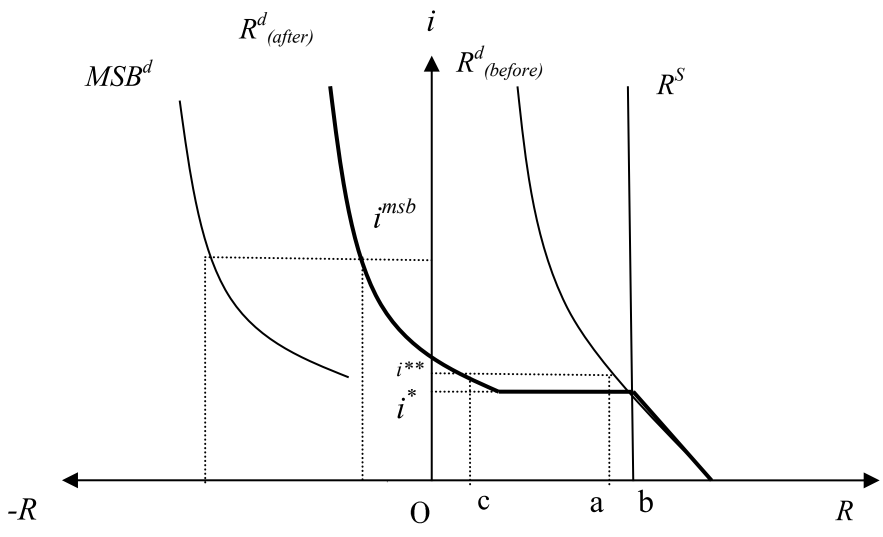
Sterilisations of capital inflows could cause domestic interest rates not to fall and thereby induce further capital inflows. This is the more plausible scenario for the case of MSB-dependent sterilisation, because MSBs are issued with long-term maturities relative to other sterilisation tools (such as reverse repo and term deposit). To examine this, let us consider the changes in demand for bank reserves before and after MSBs are issued.

Figure 2.4 displays the shift in reserve demand induced by the issuance of the MSBs. If reserves (R) consist of only required reserve, the reserve demand curve will be vertical. However, considering banks' need for excess reserves for interbank payments, a downward-sloping demand curve appears appropriate, like $R^{d}_{(before)}$. The supply of reserves (R^{s}) is assumed to be perfectly controlled by the CB to maintain its target interest rates (i*). Now, suppose that the CB issues MSBs to drain excess reserves: issuing MSBs can be depicted in the second coordination, since demand for MSBs is positively correlated with interest rate.

Note that the increases in MSB issuance lead to the same amount of bank reserve decreases, and that the CB must provide purchasers with an interest rate at least above i*

because banks would not buy MSBs below i^*.[6] Thus, combining the two demand curves for the MSBs (in bond markets) and bank reserves (in reserve markets), the reserve demand curve after the issuance of MSBs can be drawn as the thicker line, $R^d_{(after)}$. Because of the excessive issuance of the MSB, reserve market interest rates are likely to be frequently interrupted by long-term interest rates, which may not be controllable by the CB. This interruption, in turn, may hamper the efficacy of the OMO by causing the CB to lose controllability of the target interest rates. For example, the CB needs to withdraw more reserves (i.e., *b-c* rather than *b-a* in Figure 2.4) to raise the short-term interest rate ($i^* \rightarrow i^{**}$ in the figure) in this case.

Figure 2.4 Reserves demand curve before and after the issuance of MSBs



Source: Cha (2007)

Furthermore, under a liquidity surplus, banks can decline to surrender excess reserves, by reducing their purchases of MSBs. To avoid this, the CB would have to offer a

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[6] In Figure 2.4, i^{msb} is higher than the interest rate prevailing in the reserve markets, which is close to the operational target rate (i^*) since (i) the CB needs to provide higher interest rates than market rates to encourage banks to participate in the auction; (ii) the average maturity of the bonds is longer than that of money market instruments such as repos. For example, the average duration of outstanding MSBs is 11.2 months as of the end of 2006, while the maturities of typical market instruments are normally 3 months (e.g. commercial paper, certificate of deposit, and repo) in Korea. According to the liquidity preference hypothesis, longer-term bonds should provide higher interest rates than short-term bonds.

higher yield on the MSBs, above the CB's desired intervention rate. In this way, the stability of overnight interest rates may be obtained at the cost of destabilising other interest rates (Toporowski 2006). In this case, the rate of return of the MSB would be higher than that of treasury bonds with the same maturity, which might crowd out treasury bonds, and contribute to a long-term interest rate hike. Consequently, foreign currency buying interventions may have an intrinsic risk of impairing the efficacy of domestic monetary operations.

However, there are several arguments that FXIs and OMOs may be harmoniously implemented with specific prerequisite conditions satisfied. Bofinger et al. (2001, pp. 389-390) argues that it is, in principle, possible for CBs to limit the appreciation of domestic currencies and to target the money market rate simultaneously. Such a dual policy is limited by the sterilisation potential, which is the amount of intervention resources (that should be supplied to the banking system for draining excess liquidity) and sterilisation costs. If MSBs can be issued continuously with affordable interest rates and be rolled over without enormous demand for redemption, unlimited sterilisation is possible. If, however, the public doubt the redemption of MSBs, due to the enormous interest payments, MSB-dependent sterilisations may be no longer sustainable.

2.2 Statistical backgrounds: Capital flows and sterilisations

2.2.1 Volatility of exchange and interest rates, and inflation

In this section, some statistical facts are presented to provide overviews on the evolution of sterilisation, exchange rates, interest rates and capital flows in selected main countries categorized into five country groups: IT-advanced, IT-(emerging) Asia, IT-(emerging) Europe, IT-Latin and non-IT countries.[7] The sample periods are divided mainly into the 1990s, when many advanced IT countries introduced IT regimes, and the 2000s, when many emerging IT countries introduced them (see Chapter 5 Table 5-1).

The theories of IT and the trilemma expect that the introduction of IT in emerging countries generally leads to more volatile FX rates and more stable short-term interest rates around the target levels (Svensson 2010). This is because IT countries should adopt free floats to effectively implement IT regimes (Mishkin and Savastano 2001) and because short-term interest rates are more explicitly targeted under IT regimes. Other things being equal, it is expected that FX volatility would be higher, and interest rate volatility would be lower under IT regimes than under non-IT regimes such as monetary or exchange rate targeting regimes. Note also that if the authorities allow for more volatile FX or interest rates, the need for FXIs and subsequent sterilisations will decrease.

[7] Seven IT-advanced: countries: Australia, Canada, Norway, New Zealand, Sweden, Switzerland, UK
Four IT-Asian countries: Indonesia, Korea, Philippines, Thailand
Six IT-European countries: Czech Rep., Hungary, Israel, Poland, Turkey, South Africa
Five IT-Latin countries: Brazil, Chile, Colombia, Mexico, Peru
Eight Non-IT countries: China, Euro area, Hong Kong, India, Japan, Malaysia, Singapore, Argentina
Note that Israel and South Africa are classified as IT-Emerging Europe in consideration of their economic connection to European countries. Most of the non-IT group consist of countries under fixed exchange rate regimes (China, Hong Kong), a country where the FX rate is nominally anchored (Singapore) or countries where sterilised FXIs are known to frequently occur under *de jure* flexible exchange rate regimes (Japan, India).

Table 2.1 shows some statistics about exchange rate and interest rate volatilities while Table 2.2 demonstrates the level of foreign reserves and balance of payment in 5 country groups. Both tables suggest several implications about the development of sterilisation. First, in most emerging IT groups, both exchange and interest rates became less volatile after IT was introduced, from around 2000.[8] For example, FX volatility in the IT-Asia decreased from 1.9% to 1.4% and interest rate volatility from 1.2% to 0.3% (both volatilities measured as standard deviations of daily changes within one quarter). The less volatile FX rate during the post-IT period appears to contradict prior expectations.

Second, in the last decade, FX rates were less volatile in the emerging-IT (except the IT-Europe) and Non-IT group than in the IT-advanced group, while interest rates were less volatile in the advanced-IT group than in the emerging-IT and Non-IT groups. For example, quarterly FX rate volatility in advanced-IT countries averaged 1.8% in the 2000s, while ranging from 0.8 to 1.5% in the emerging-IT (except IT-Europe) and Non-IT groups. Interest rate volatility in the advanced-IT was 0.2%, the least volatile among all country groups. More stable short-term interest rates and more volatile FX rates in the advanced-IT country group may be ascribed to the longer history of their IT regimes, their deeper money markets and their less frequent FX interventions. The low FX rate volatility in emerging-IT groups (even after adoption of flexible regimes) may, on the other hand, be attributed to their frequent FXIs. Both FX and interest rate volatility are in the meantime generally low in non-

[8]According to the classification of *de facto* and *de jure* FX regimes published by the IMF(2002, 2006), the number of countries adopting managed or independent floating regimes increased between the 1990s and the 2000s. For example, among the countries included here, most IT-countries shifted their FX regimes from fixed to managed float or independent float regimes from the late 1990s. Examples of crisis-driven shift are Korea(1997), Thailand(1997), the Philippines(1997), Indonesia(1997), Colombia(1999), Brazil(1999), Mexico(1994) and Argentina(2001), while examples of voluntary changes are Chile(1999), Poland(2000), the Czech Republic (1997), Hungary(1994), India(1995), Peru(1999), the Philippines(2000), South Africa(1997) and Turkey(2001). See the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions*(2002, 2006) for the IMF's *de jure* and *de facto* classifications of FX regimes. The IMF's *de jure* classification stopped after it began compiling *de facto* regimes.

IT countries,[9] because most countries in this sample group (e.g. China and Hong-Kong) adopt fixed exchange rate regimes, because their CBs (e.g. in China) rely on nonmarket instruments to control short-term interest rates, or because their interest rates have been maintained at close to zero per cent (e.g. in Japan) for considerable periods of time.

Table 2.1 Volatilities of exchange and interest rates, and inflation rate

(Unit: %, 1990 Q1- 2010 Q4)

	Volatility (average standard deviation during the period)						Change (average Q on Q growth rate)			
	Δ FX rate[1)]		Δ Interest rate[1)]		Δ REER[2)]		REER[3)]		Inflation rate[4)]	
	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s
IT-advanced	**1.4**	**1.8**	**0.3**	**0.2**	**2.6**	**3.8**	**-0.09**	**0.08**	**0.56**	**0.64**
UK	1.5	1.4	0.2	0.2	3.0	2.9	0.19	-0.15	0.70	0.69
Australia	1.2	2.2	0.1	0.1	3.3	4.6	-0.18	0.37	0.53	0.70
IT-Asia	**1.9**	**1.4**	**1.2**	**0.3**	**4.9**	**6.5**	**-0.16**	**0.06**	**1.81**	**1.18**
Korea	1.5	1.6	0.9	0.1	3.5	7.5	-0.32	-0.07	1.20	0.79
Indonesia	3.1	1.9	2.0	0.6	-	-	-	-	3.11	2.05
IT-Europe	**5.5**[5)]	**2.2**[5)]	**2.1**	**0.9**	**5.0**	**4.6**	**0.25**	**0.24**	**5.47**	**1.40**
Czech Rep.	1.6	2.0	1.2	0.1	5.5	2.6	0.37	0.44	0.79	0.55
IT-Latin	**2.6**	**1.5**	**2.6**[6)]	**0.5**	**6.3**	**5.0**	**-0.06**	**0.17**	**4.02**[6)]	**1.11**
Chile	1.0	1.9	6.3	0.4	3.2	4.1	0.18	0.03	2.03	0.78
Non-IT	**1.1**	**0.8**	**0.5**	**0.3**	**4.0**	**2.4**	**0.15**	**-0.14**	**0.98**	**0.70**
China	1.4	0.2	0.2	0.1	7.1	0.9	-	-	-0.07	0.09
India	1.3	0.9	2.0	1.1	4.4	2.9	-	0.02	2.05	1.58
Japan	2.0	1.5	0.1	0.0	5.7	3.9	0.23	-0.20	0.16	-0.05
Hong Kong	0.0	0.1	0.0	0.0	0.1	0.2	0.46	-0.40	1.18	0.16
Singapore	0.1	0.1	0.0	0.0	2.6	2.2	0.12	0.05	0.41	0.42

Notes: 1) The volatilities of FX rates (interest rates) are measured as the standard deviations of the daily percentage changes in local currency units per USD (domestic money market rates) within a quarter.
2) The volatilities of REERs are measured as the standard deviations of the monthly percentage changes in REERs (measured by the IMF) within the sample period (i.e., a decade).
3) The changes in REER are calculated as the percentage changes (= log differences) of the quarterly REER during the sample periods (i.e. a decade). The REER is calculated based on unit labour costs. A decrease (-) in its value represents a real depreciation of the domestic currency.
4) Inflation rate is measured as (average) quarter-on-quarter percentage changes in the CPI. During the sample period, there were several episodes of hyper-inflation: in Peru (1990M7-1990M8; monthly inflation 48.4%), Brazil (1989M2-1990M3; 68.6%), Argentina (1989M5-1990M3; 66.0%), and Poland (1989M10-1990M1; 41.2%) (Siklos 2000b).
5) The high FX rate volatility in IT-Europe is attributable partly to currency re-denominations in several countries (e.g. Poland in 1995, Israel in 2003, and Turkey in 2005).
6) In calculating the volatility of interest rate and inflation in the IT-Latin group, we exclude Brazil whose interest rates were extremely high and volatile in the early 1990s.

Source: Author's calculation based on quarterly data on IMF *IFS* and daily data on DataStream

[9] The FX volatility in the non-IT group differs depending upon the FX regime. FX volatilities are very low in countries with fixed regimes or exchange rate targeting(e.g. China, Hong Kong and Singapore) and high in countries with flexible regimes (e.g. Japan).

Third, it seems that both FX and interest rates are more stable in countries holding larger amount of foreign reserves – see Table 2.1 and 2.2 together. It is thus likely that sterilisation with accumulation of foreign reserves has played a role as an imperfect substitute for capital controls (Steiner 2010). For example, in the 2000s the accumulation of foreign reserves was particularly prominent in emerging IT-Asia where FX rate volatility was maintained at the lowest level among all IT-groups and interest rate volatility was as low as that of the IT-advanced group. The reserves-to-GDP ratio in IT-Asia doubled over the last two decades – from 43.8% to 87.7% in Table 2.2 – the highest degree of increase among all IT groups: The ratio of Korea in the 2000s was 95.8%, remarkably high compared to those in the other IT-groups. In Table 2.2, only a few countries in the non-IT group with fixed FX regimes showed higher reserves-to-GDP ratios than Korea's: e.g. China (126.2%), Singapore (359.9%) and Hong Kong (307.2%). The reserves-to-GDP ratio in the IT-advanced was, on the other hand, only 31.9% during the last decade, the lowest among all groups. The non-IT group shows the highest reserves-to-GDP ratio, at 133.4%.

Combining the statistics on FX volatility Table 2.1 and foreign reserves in Table 2.2, more volatile FX rates in the IT-advanced in the 2000s may be partly explained by the relatively low increase in their foreign reserves, which may imply that the IT-advanced intervened less in the FX markets. The less volatile FX rates and higher FR/GDP ratio in the IT-Asia may in contrast suggest a high possibility of more active FXIs. Notwithstanding sterilisations, the volatility of REER appears to have not become stable in some countries over time. Rather, it seems to have grown more volatile in the IT-Asia and IT-advanced in the 2000s.

Fourth, inflation appears to decrease over time. Although inflation rates were higher in the IT-emerging groups than in the IT-advanced group over the past two decades, they fell considerably in the 2000s. However, we cannot attribute the low inflation in the IT-emerging groups to effective sterilisations, since inflation rates appeared to dampen globally in the 2000s.

2.2.2 Foreign reserves, balance of payments and capital inflows

Table 2.2 shows the foreign reserves, BOP and capital inflows. First of all, in the 2000s, IT-Asia experienced 'twin surpluses' in both its current and its capital accounts, while IT-Europe and IT-Latin made up for their current account deficits by running capital account surpluses. Note that the REER in the IT-Asia group depreciated most during the 1990s and appreciated least during the 2000s as seen in Table 2.1. In terms of nominal exchange rates, the currencies of IT-Asia appreciated most against the US dollar during the 2000s (see Table 2.3 in the next section). Considering that FXIs occurred mostly on a daily basis and that the CBs know only the nominal FX rate, we expect that the pressures for domestic currency appreciation and the consequent necessity of sterilisation may be stronger in the IT-Asia group, all other things being equal. Despite the twin surpluses in IT-Asia in the 2000s, the low volatilities of both FX and interest rates (in Table 2.1) may indicate that the sterilisations were effective in managing capital inflows in these countries.

Second, owing to their rapid build-ups of foreign reserves, most countries face liquidity surpluses in their domestic money markets. The degree of liquidity surplus is shown by the increase in net foreign assets (NFA) as a share of currency in circulation (CIC). Note that an NFA-to-CIC ratio above 1 indicates the existence of a liquidity surplus within a banking system where liquidity creation is driven predominantly by the accumulation of foreign reserves and there are no other substantial liquidity-absorbing operations (Loeffler et al. 2010). In the case of a liquidity surplus, the CB is the debtor in the money markets, which makes its sterilisations more complicated and costly than in the case of a liquidity shortage (Ganley 2000).[10] The extent of liquidity surplus is most prominent in the IT-Asia owing to sterilisations of massive capital inflows stemming from twin surpluses. For example, the NFA-to-CIC ratio more than quadrupled in Korea, from 200% to 900%, which is the highest ratio among all IT countries and contrasts with the low ratios of the UK(-4~19%) and Japan (5~15%).

Table 2.2 Foreign reserves and balance of payment[1)]

(Unit: %, quarterly average, 1990 Q1- 2010 Q4)

	FR[2)]/GDP		NFA/CIC		CA/GDP		KA[3)]/GDP		FDI/GDP		PF/GDP		OT/GDP	
	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s	1990s	2000s
IT-Advanced	**28.0**	**31.9**	**244.1**	**291.8**	**-0.92**	**2.61**	**1.60**	**0.60**	**0.33**	**-1.72**	**-0.51**	**-0.75**	**1.57**	**3.26**
UK	12.8	8.0	19.3	-4.2	-1.54	-2.22	1.12	2.50	-1.79	-1.05	-0.68	4.29	3.40	-0.49
Australia	15.0	17.9	125.4	149.4	-4.07	-4.48	4.28	4.69	0.85	0.95	2.73	3.55	0.40	0.14
IT-Asia	**43.8**	**87.7**	**203.3**	**466.3**	**-1.27**	**2.32**	**2.73**	**0.37**	**1.09**	**0.09**	**3.57**	**3.60**	**0.13**	**0.53**
Korea	27.8	95.8	200.3	899.5	0.40	1.88	1.36	0.79	-0.42	-6.04	9.82	9.60	-0.35	7.08
Indonesia	37.3	52.2	-	219.5	-1.10	2.31	1.21	-0.55	1.74	1.32	0.75	3.87	0.29	-4.06
IT-Europe	**40.0**	**60.1**	**-**	**279.0**	**-1.97**	**-2.64**	**3.49**	**4.07**	**3.05**	**7.69**	**1.29**	**1.29**	**2.54**	**5.36**
Czech Rep.	67.6	89.2	-	236.0	-2.84	-3.46	7.42	5.84	7.94	8.49	2.58	1.54	2.76	1.46
IT-Latin	**32.7**	**44.5**	**-**	**344.4**	**-2.84**	**-0.51**	**2.79**	**1.70**	**2.32**	**4.12**	**1.19**	**-0.49**	**-0.49**	**-0.01**
Chile	79.9	64.6	-	422.2	-3.30	0.82	4.66	0.14	5.65	6.36	-0.98	-7.63	0.20	0.43
Non-IT	**101.9**	**133.4**	**305.8**	**415.3**	**3.20**	**5.49**	**-1.89**	**-2.88**	**1.21**	**0.57**	**-1.18**	**-3.37**	**-2.11**	**-0.69**
China	39.8	126.2	74.6	282.5	1.96	3.75	-	-	-	-	-	-	-	-
India	27.4	63.8	43.7	151.1	-1.14	-0.50	2.46	3.40	0.71	0.86	0.37	1.01	1.35	1.52
Japan	3.5	16.1	15.2	4.6	0.59	0.83	-0.49	-0.48	-0.14	-0.24	-0.08	-0.34	-0.22	0.10
Hong Kong	174.7	307.2	598.6	742.1	6.17	9.26	-0.61	-4.82	3.41	-0.18	19.83	-15.61	-28.50	7.82
Singapore	303.3	359.9	938.7	1280.5	17.05	18.51	-11.47	-12.04	5.22	6.05	-11.60	-9.86	-4.89	-8.06

Notes: 1) FR: Foreign Reserves, NFA: Net Foreign Assets, CA: Current Account Surplus), KA: Capital Account Surplus, FDI: Foreign Direct Investment (net inflows), PF: Portfolio Investments (net inflows), OT: Other Investment (net inflows)
2) USD-denominated values of FR and BOP are converted into local-currency denominated values by using quarterly average exchange rates.
3) The capital account includes the financial account less foreign reserve assets.
Source: Author's calculations based on quarterly data on IMF *IFS*

Third, capital inflows to IT-Asia in the 2000s came mostly from volatile portfolio investments. Relatively long-term and less volatile FDI accounted for only a very small portion of total capital inflows. This was in contrast to the cases of IT-Latin and IT-Europe,

[10] Under a liquidity shortage in the banking system, sterilisation costs are not a crucial problem because the CB is the creditor, meaning that it has the initiative in monetary operations. For example, the debtors in the banking system, i.e. commercial banks, have no choice but to participate in the CB's operations; otherwise they are exposed to default risk due to lack of funds for payment and settlement.

where considerable capital inflows came via FDI. If the capital inflows are in the form of hot money such as portfolio investment or short-term loans, as opposed to equity or FDI, it is more likely to be temporary, causing a greater need for intervention to prevent appreciation in the first place (Reisen 1994). Thus, immediate sterilisations are expected to be more necessary in the IT-Asia group. Aforementioned, sterilisation peril indicates that given money demand, sustained sterilisation can lead to increased excess money demand. The CB hence needs to conduct sterilisation over a limited period, eventually choosing to either accommodate the capital inflows through money expansion or appreciation of the domestic currency (Kletzer and Spiegel 2004, p 912).

Previous studies provide several reasons explaining the capital inflows into emerging markets: external or push factors (e.g. declines in foreign interest rates) and internal or pull factors (e.g. capital account liberalisation, increases in domestic money demand, etc.) Although it is extremely difficult to differentiate the causes of capital inflows, previous studies suggest that the declines in US interest rates have played a more significant role in driving capital into developing countries than pull factors (Fernandez-Arias and Montiel 1996). It may thus be plausible that sterilisations have in general been the proper responses to capital inflows in most emerging countries over the last two decades. There may nevertheless be a sterilisation peril in emerging countries, since these capital inflows have been influenced by a combination of pull and push factors rather than by a single factor (IMF 2011), and because the rapid increases in foreign reserves in some countries may hint at the possibility of overly persistent sterilised interventions. One preliminary conclusion drawn from the aforementioned statistics is that, since the introduction of IT or more flexible FX regimes in the 2000s, many emerging countries appear to have succeeded in stabilising both interest rate and FX volatility by accumulating reserves.

2.2.3 Sterilisation costs

Table 2.3 shows a simple estimation of sterilisation costs (SC). SC are mainly defined as the difference between the local-currency denominated yield on the NFAs and the yield that the authorities could earn by reducing the volume of their reverse-repo operations (or MSB issuance) by the same amount. That is: $SC = [i_t^d - (i_t^f + \Delta S_t)]NFA_t$ where i^d= the domestic money market rate; i^f= the US fed funds rate; ΔS_t= the percentage change in spot FX rates (domestic currency per USD); and *NFA*= net foreign assets. This equation is based on the strong *ceteris paribas* assumption that the interest and exchange rates are not influenced by intervention decisions (see Holub 2004, pp. 29-30). Despite its oversimplification, the estimated SC provides a general view of the relationships between SC and the relevant variables over time. Note that SC is estimated in terms of domestic-currency denominated values and that it will be larger when (i) $i_t^d > i_t^f$; (ii) $\Delta S_t \downarrow$(appreciation of domestic currency) or (iii) NFA is larger.[11]

The estimated costs look consistent with prior expectations based on the statistics cited in the previous sections. First, sterilisation costs seem higher in emerging than in advanced countries. The SC-to-GDP ratio in the 2000s is lowest in the IT-advanced group at 0.45%, and highest in the IT-Asia group at 0.80%. The SC-to-GDP ratios in the rest of the groups range from 0.54% to 0.66%. Sterilisation costs appear to increase over time in most countries, but with several exceptions. For example, in Japan, Canada and the UK, SC seems to be negligible in most periods. The SC-to-GDP ratios in these countries are far less than

[11] If we assume that UIP holds, i.e. that $i_t^d = i_t^f + E_t(\Delta S_{t+1}) + \rho,$ where $\rho =$ risk premium, then $SC = [(E_t(S_{t+1}) - S_t) + \rho_t]\Delta FR_t$. This equation suggests two sources of sterilisation costs coming from the build-up of foreign reserves. First, unexpected appreciations/depreciations of the domestic currency lead to CB financial losses/profits. This unexpected risk will be averaged out over the long term and is thus unsystematic with rational expectations assumed. Second, there exists systematic risk originating rather from the risk premium on domestic assets, which is mainly reflected in the interest rate differential.

0.05%. The small costs in Japan may be due to the much lower domestic interest rate compared to foreign rates (i.e, $i_t^d < i_t^f$) while those in the UK may be due to the infrequency of interventions (i.e. small NFAs). In the case of Canada, the domestic money market rates follow the US fed funds rates at similar levels.

The SC-to-GDP ratios in China, India, Singapore and Czech Rep. are, in particular, high at from 1.26% to 1.69% in the 2000s.[12] Although China and Japan have built up massive amounts of foreign reserves over the last decades, there seems to be a significant difference between two countries in their estimated SC. This difference may come from the differences between their exchange rate regimes (free float vs. peg), their main sterilisation tools (short-term repos vs. MSBs) and the behaviours of their domestic interest rates (near zero rates vs. relatively high rate).

Second, in most emerging IT groups sterilisations seem to have not been so costly in the 1990s (when most currencies depreciated against the USD), whereas their SCs increased significantly in the 2000s (when most currencies appreciated). For example, IT-Asia currencies appreciated by 22.8% over the last decade, while advanced-IT currencies appreciated by only 1.1%. It is likely that the significant differences in SC between the IT-Asia and IT-advanced groups owe primarily to their different extents of currency appreciation in the 2000s.

Third, interest rate differentials (= local money market rate - US federal funds rate) have become narrower over time in most emerging countries, due mainly to the accelerating consolidation of the international financial markets and the globally low interest rates in the 2000s. Domestic interest rates have been higher than foreign rates except for in Japan,

[12]The simply-estimated sterilisation costs here are similar to those of previous studies (see Kletzer and Spiegel 2004). For example, sterilisation costs for Latin and Pacific Basin countries in those studies were estimated at 0.25 to 0.5% of GDP, which is very close to our estimation (0.54%) in Table 2.3. In some countries facing huge capital inflows (e.g. Singapore and Taiwan), the costs rose above 1% of GDP.

Switzerland, Hong Kong and Singapore. The domestic-foreign interest rate differentials appear positively correlated with sterilisation costs, should we exclude the changes in FX rates. For example, among the countries whose currencies changed by less than 5% during the last decade (e.g. most advanced IT countries, plus Hong Kong), those with small interest rate differentials (e.g. Canada, the UK, Hong Kong) had relatively negligible sterilisation costs compared to other countries. Note that SC increases significantly when the CB uses MSBs as its main sterilisation instrument rather than reverse-repos. In the case of Korea, the estimated SC-to-GDP ratio increases from 0.24% to 0.32% in the 1990s and from 0.31% to 0.55% in the 2000s when one-year yields on MSBs are used instead of overnight call rates.

Table 2.3 Simplified sterilisation costs, interest rate differentials and FX changes

(Unit: %)

	1981Q1- 1990Q4			1991Q1- 2000Q4			2001Q1- 2010Q4		
	Cost /GDP[1]	Rate gap[2]	FX rate change[3]	Cost /GDP[1]	Rate gap[2]	FX rate change[2]	Cost /GDP[1]	Rate gap[2]	FX rate change[3]
Australia	0.06	2.0	35.3	-0.14	1.4	36.3	0.43	2.8	-1.8
Canada	0.00	17.2	-2.4	0.00	0.5	26.6	0.00	0.3	-1.1
Norway	0.49	9.9	11.2	-0.49	2.2	41.8	0.81	1.8	-1.3
New Zealand	0.53	2.4	39.6	-0.14	2.2	36.9	0.72	3.4	-1.8
Switzerland	-0.73	2.1	-38.4	-0.86	-1.4	26.6	0.95	-1.4	-1.6
UK	-0.09	3.1	13.6	-0.03	1.9	26.2	0.02	1.4	-0.3
IT-Advanced	**0.04**	**4.2**	**36.2**	**-0.28**	**1.6**	**35.9**	**0.45**	**2.1**	**-1.1**
Indonesia	-	5.4	99.1	-	15.2	105.5	0.59	5.9	-11.4
Korea	0.11(0.48)	2.9(5.2)	3.4	0.24(0.32)	6.7(9.3)	36.6	0.31(0.55)	1.5(2.9)	-18.5
IT-Asia	**-**	**4.4**	**56.9**	**-**	**8.4**	**60.0**	**0.80**	**3.0**	**-22.8**
Czech Rep.	-	-	-	-	6.0	29.7	1.69	0.5	-86.1
Hungary	-	15.9	60.1	-	17.1	155.7	0.97	6.0	-48.3
IT-Europe	**-**	**38.3**	**246.8**	**-**	**21.9**	**171.7**	**0.59**	**8.5**	**-22.7**
Brazil	-	-	-	-	-	-	0.95	13.1	-27.4
Chile	-	-	5.7	-	3.9	54.6	0.48	1.6	-24.1
IT-Latin	**-**	**-**	**11.7**	**-**	**12.1**	**119.6**	**0.54**	**5.2**	**-14.9**
China	-	0.4	113.5	-0.21	2.5	43.6	1.26	0.8	-21.9
India	-	0.6	82.4	-0.06	7.2	90.1	1.30	8.2	-5.6
Japan	-	-3.2	-54.6	-	-2.9	-23.2	0.00	-2.2	-31.9
Hong Kong	-	3.8	41.1	0.02	0.3	0.1	-0.27	-0.4	-0.5
Singapore	-2.07	-6.1	-20.7	-2.81	-3.2	0.2	1.54	-1.0	-30.2
Non-IT	**-**	**-1.4**	**30.5**	**-0.68**	**1.6**	**27.2**	**0.66**	**2.0**	**-6.8**

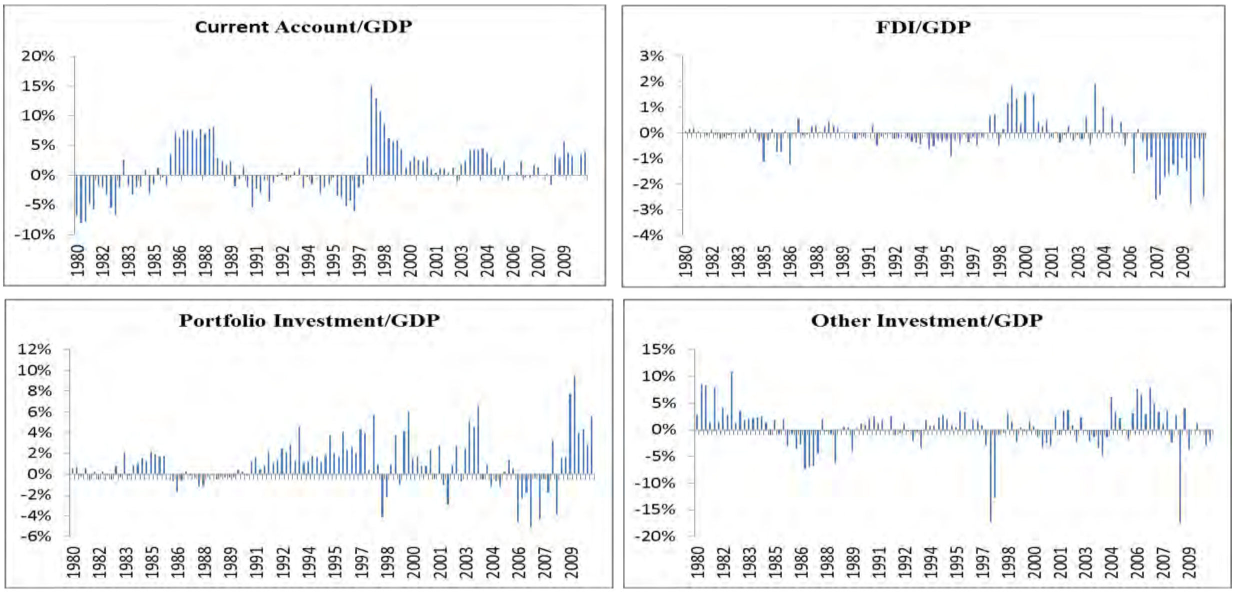
Notes: 1. Quarterly averages
2. Interest rate gap = local money market rate-US fed funds rate (quarterly averages).
3. The FX rate changes indicate accumulated percentage changes during the sample period. (-) indicates appreciation of the domestic currency against the USD (.
4. The figures in ( ) for Korea indicate the results when yields on 1-year MSBs are used instead of money market rates.

Sources: Author's calculation based on IMF *IFS*

2.2.4 Main statistics on sterilisations in Korea

As depicted in Figure 2.5, Korea has experienced a steady increase in capital inflows since the early 1990s when it began to push capital liberalisation. Since the late 1990s, Korea has run surpluses in both its current and capital accounts. The degree of capital inflows seems to have increased significantly right after the 1997-98 currency crises, when Korea completely opened its stock and bond markets. Despite short-term capital outflows owing to the two financial crises (1997-98 Asian currency crises, 2008 US mortgage crisis), capital inflows to Korea appear to have recovered at remarkably fast paces. These inflows have been characterized by a predominance of volatile and short-term portfolio and other investment. Equity investments occupy over 80% of total portfolio investments. Other investment is mostly short-term borrowings from non-residents. FDI shows net outflows since the mid-2000s, when capital movements appear to have grown more volatile. Because of the nation's twin surpluses, the BOK has had to deal with increased supplies of the foreign component of the monetary base and resultant liquidity surpluses.

Figure 2.5 Balance of payments in Korea

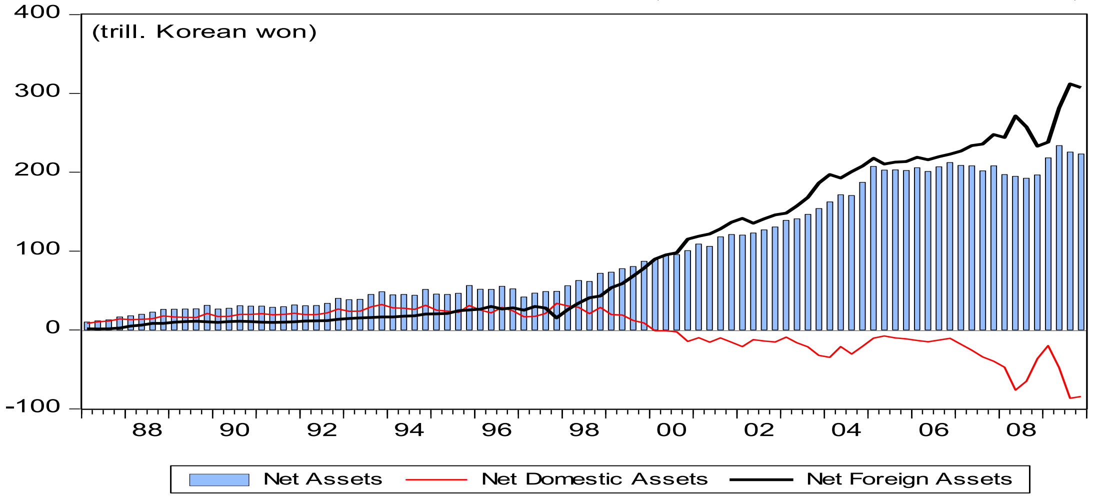


Data: IMF *IFS*

Figure 2.6 shows the quandary that the BOK confronts. During the 2000s, NDAs decreased continuously with negative values while NFAs increased with positive values. This implies that, as foreign reserves rushed in, domestic liquidity could have become too "loose" to stabilise inflation or too "tight" to resist the pressures for the domestic currency appreciation.

Figure 2.6 Evolutions of NFA and NDA in Korea

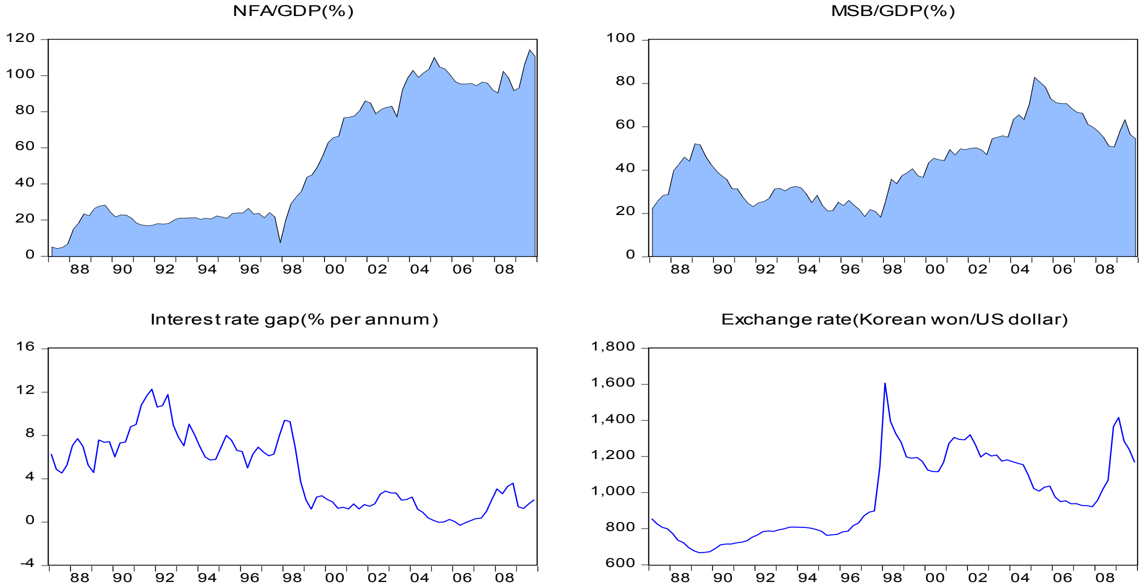
(Nominal, KRW trill. 1987Q1- 2009Q4)



Data: IMF *IFS*, BOK Economic Statistics System (http://ecos.bok.or.kr)

As shown in Figure 2.7, the increasing supply of foreign assets led to increases in MSBs except during the two crisis periods. During the crisis periods, NFAs and MSBs decreased because the BOK had to keep the local currency from depreciating rapidly and to inject ample liquidity into the money markets. However, the stock of MSBs shows a general trend of increase over time in line with foreign assets. The domestic-foreign interest rate gap is almost uniformly positive, although its level appears to be decreasing. Since its rapid depreciation in 1997, the nominal exchange rate has faced persistent appreciation pressures (except during the period of the 2008 US-subprime crisis). BOK frequently experienced financial losses from sterilisations during the 2000s owing to its huge volume of foreign reserve holdings and MSB outstanding, as domestic interest rates were higher than foreign rates and because the domestic currency appreciated against the US dollar.

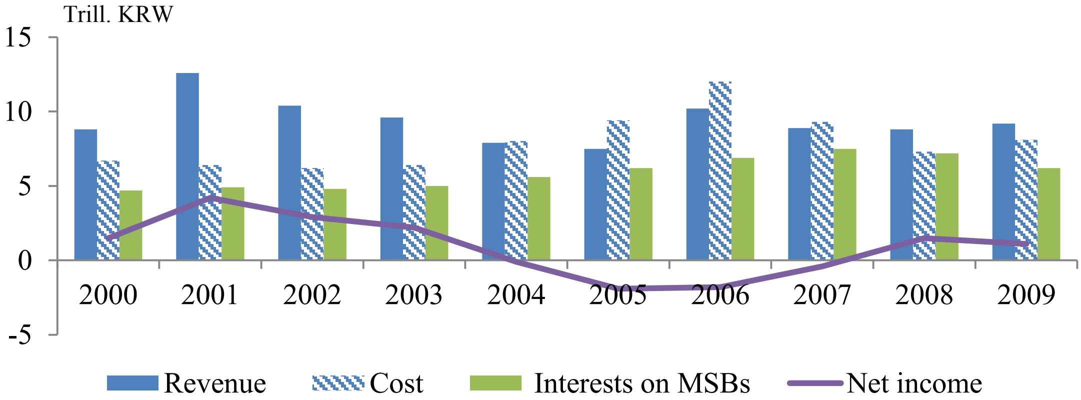
Figure 2.7 NFA, MSBs, interest rates and exchange rate in Korea



Note: interest rate gap = O/N unsecured call rate – US federal funds rate
Data: Author's calculation based on IMF *IFS*, BOK Economic Statistics System (http://ecos.bok.or.kr)

Figure 2.8 shows that the BOK experienced serious fiscal losses in 2004-2007, which stemmed mostly from the interest paid on MSBs. Note that the interest payments on MSBs occupy around 70-90% of the BOK's total costs in recent years. Accordingly, whether or not the current MSB-dependent sterilisation policy is sustainable in the future has been a controversial issue. However, there has been no comprehensive attempt to examine the issues involved.

Figure 2.8 Profit and loss of the BOK



Data: BOK annual report, each year

2.3 Thesis structure

This thesis consists of seven chapters, including the Chapter 1 introduction and this Chapter 2. The sequence of the chapters follows that of the sterilisation procedures pursued in most countries over time, as illustrated in Figure 2.9. The rest of this chapter presents an overview of the main research questions, and brief reviews of the concurrent literature and the methodologies used. The main estimation results are also briefly provided. More detailed reviews of the literature and stylised facts are provided in each subsequent chapter. The main research questions are addressed in Chapters 3 through 6, before Chapter 7concludes.

2.3.1 Impacts and profitability of sterilised FX interventions: Chapter 3

Suppose a CB confronted with a surge in capital inflows. The CB generally intervenes in the FX markets by selling domestic currency for foreign currency. This intervention, if unsterilised, leads to increases in both foreign reserves(FR) and the monetary base(MB), which may increase inflation expectations, as shown in Figure 2.9. Emerging countries are known to more prone to "*fear of floating*" (Calvo and Reinhart 2002) or "*fear of appreciation*" of the domestic currency than advanced countries (Levy-Yeyati and Sturzenegger 2007). CBs thus attempt to offset the impact of capital inflows (i.e., increases in the MB) mainly by selling of domestic assets – mostly treasury bonds –or by issuing MSBs. At this stage of sterilisation, several significant issues are raised with regard to the intervention effects and motives, which will be addressed in Chapters3 and 4, respectively.

Chapter 3 attempts to answer the following questions: (i) Through which channels do interventions influence FX rates? (ii) Do sterilised FXIs have effects on the exchange rate level and volatility? and (iii) Are FXIs profitable? The previous literature appears to weakly support the short-term effects of interventions on FX rate level (Edison 1993, Sarno and Taylor 2001). As for the impacts of FXIs on FX volatility in advanced economies, there has been little evidence that interventions systematically decrease FX volatility. Instead, many studies suggest that interventions are generally positively related with FX volatility or with no change in volatility, at least in the short-run (Rogers and Siklos 2003, Frenkel et al. 2005, Disyatat and Galati 2005, Dominguez 2006). On the other hand, some studies suggest that interventions may reduce FX volatility, particularly in emerging economies (Oura 2008, Domac and Mendoza 2002).

The contradictory results come partly from the simultaneity problems that always exist in studies on intervention effects – causality does not always run from interventions to FX volatility because CBs tend to intervene when FX rates are volatile. The secrecy of FXI conduct is known to contribute to the conflicting results as well. To deal with the simultaneity problem and to obtain more robust estimation results, we use dummies for persistent and large-scale interventions, making it possible to see whether the isolation of these unusual interventions can avoid the simultaneity bias (Kim and Sheen 2002, 2006, Newman et al. 2011). Particularly, we apply an asymmetric threshold component (ACT) GARCH model with daily data on Korea, Japan and Australia to estimate the intervention effects on FX level and volatility. This model differentiates the intervention effects on long-term and short-term exchange rate volatility and enables us to catch the transient leverage effect on conditional volatility. Our estimation results suggest that interventions have limited effects on changing FX rate level into the desired direction and stabilising FX volatility, despite small differences in the effects, in the three countries. Estimations of sterilisation profits show that only BOK experienced intervention losses due mainly to the interest rate differential and its asymmetric intervention preference.

2.3.2 Motives of sterilised FX interventions: Chapter 4

Three main research questions are raised with regard to intervention motives: (i) What are the determinants of the intervention decision? (ii) Do CBs (in small open emerging economies) have an asymmetric preference for domestic-currency depreciation over appreciation? and (iii) Are there any differences in the degrees of asymmetric preference among countries? Most studies suggest that deviation from the FX rate trend or volatility triggers the CB's intervention – to reverse the current trend or to reduce volatility. Particularly, previous studies refer to "*leaning against the wind*" or *"smoothing*" as the main intervention motives (Sarno and Taylor 2001). Several studies have recently focused on asymmetric intervention motives, i.e. that interventions in emerging countries generally appear lenient with regard to depreciation of the domestic currency but strict concerning its appreciation (Levy-Yeyati and Struzenegger 2007, Ramachandran and Srinivasan 2007).

To deal with the aforementioned questions, we first use the monthly foreign reserves of 11 countries as proxies for interventions, to compare their degrees of asymmetric intervention motive as many as possible. Based on the empirical specifications drawn from the buffer stock model for reserve demand (Frenkel and Jovanovic 1981, Ramachandran and Srinivasan 2007), we test cointegration between foreign reserves and exchange rate change by using Pesaran et al.'s bound test (2001). We have found a significant difference in CB preference for asymmetric interventions among sample countries.

This result has limitations, however, because the foreign reserves include non-intervention transactions and because monthly data does not reflect the fact that intervention decisions take place on a daily or even an intra-daily basis (Beine et al. 2009). Hence, we estimate both a probit model and a friction model (Rosett 1959; Neely 2005b), with daily data in Korea, Japan and Australia, to investigate their intervention motives. Notably, friction models have recently begun to be used for examining the degrees of asymmetric intervention motives. The results of probit and friction estimations suggest common determinants of FX interventions in the three countries: the degrees of current FX rate deviation from trend, the levels of FX rate volatility, etc. In particular, the friction estimation provides direct evidence of significant asymmetric intervention preference for inducing domestic-currency depreciation in Korea.

2.3.3 Degree of sterilisation and capital mobility: Chapter 5

Sterilisation has been used in most emerging countries as a main policy tool to avoid the trilemma constraints. The effects of sterilisation depend upon the degree of capital mobility, the institutional features of monetary and FX policy and the natures of the capital flows. Given the assumption of limited capital mobility, complete sterilisation may be possible in the short-run. In this case, sterilisation probably raises domestic interest rates, preventing them from converging toward the international level, and thereby induces further capital inflows. Sustained sterilisations are in conflict with purely free float regimes and are associated with fixed exchange rate regimes. In this regard, three questions arise: (i) How have the degrees of sterilisation and (*de facto)* capital mobility in major countries changed over time? (ii) Are there any significant differences in the degrees of sterilisation and capital mobility across countries? and (iii) Do sterilisations cause local interest rates to fall or to rise? If they raise local rates significantly, then it is likely that the capital inflows may stem from pull factors such as increases in local money demand. Otherwise, capital may be assumed to be flowing in due to push factors like declines in foreign interest rates.

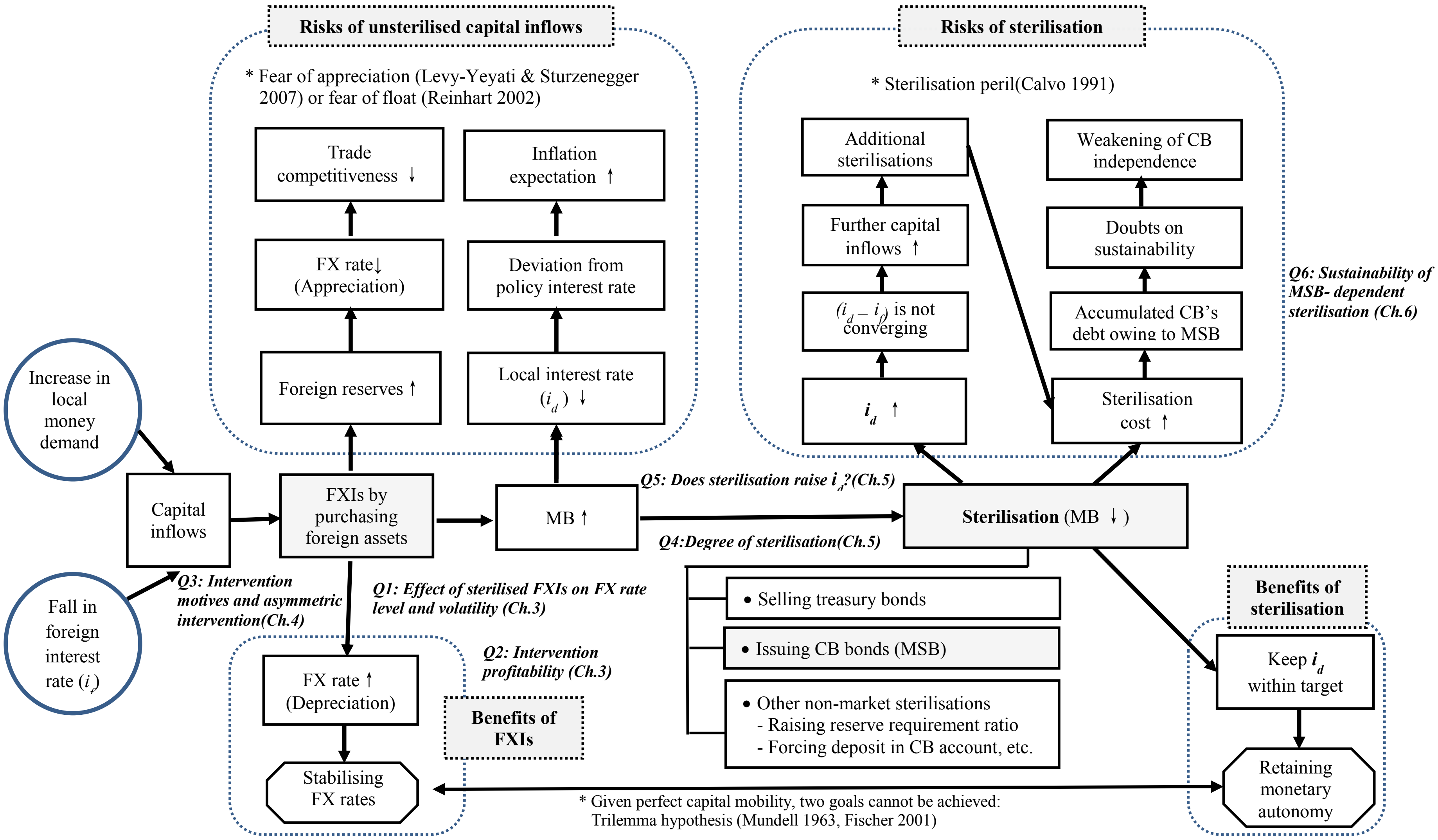
In Chapter 5, we compare the degree of sterilisation and *de facto* capital mobility by estimating sterilisation and offset coefficient with panel data on 30 countries (most of which IT countries and are grouped into five categories). For this, modifying previous studies (Brissimis et al. 2002, Ouyang et al. 2007), we derive a simple simultaneous equation and then estimate the two coefficients with fixed effects. The result of panel estimation show that most IT-emerging countries significantly increased their sterilisations from the late 1990s and were conducting almost complete or over-sterilisation in the 2000s. The sterilisations in most countries appear successful in retaining monetary policy independence by limiting *de facto* capital mobility. Estimation of sterilisation effects on domestic interest rates based on Edwards and Khan (1985) suggest the possible sterilisation peril in some emerging countries (e.g. IT-Asia countries). Time series analyses for selected individual countries are carried out for comparison purpose.

2.3.4 Sustainability of MSB-dependent sterilisation: Chapter 6

CBs have several options for sterilizing capital inflows. The most frequently used sterilisation tool is OMOs, which are market-friendly and also used most frequently in advanced countries. Specifically, CBs may sell treasury bonds (outright or by repurchase agreements) or issue MSBs in order to drain an excess liquidity in money markets. Otherwise they can use less market-friendly sterilisation tools such as raising the required reserve ratio or swapping government deposits held with commercial banks for government bonds. MSBs meanwhile differ from other sterilisation tools: (i) Unlike the unremunerated reserve requirement, MSBs are interest-bearing instruments; (ii) MSBs have longer maturities and pay higher interest rates than repo transactions; and (iii) Issuance of MSBs increases the CB's debts (liabilities), while the selling of treasury bonds reduces its assets. It is hence expected that MSB-dependent sterilisations may have larger sterilisation peril, through driving up domestic interest rates and causing high sterilisation costs, than other types of sterilisation.

In this regard, an interesting and novel issue arises: (I) How can we evaluate the sustainability of MSB-dependent sterilisation policy? (ii) What is the condition for MSB-dependent sterilisation to be sustainable permanently? (iii) Is a current MSB-dependent sterilisation policy in Korea sustainable? Although many previous studies have examined the profit/loss on sterilised FXIs or OMOs for sterilisation, none have attempted to assess MSB-dependent sterilisation policy sustainability. Chapter 6 aims to answer these questions. Since there is no specific theory on sustainability of the CB's debt policy, we need to apply the existing theories of fiscal sustainability. Based on such fiscal sustainability theories as Barro (1979) and Bohn (1995), we first derive the inter-temporal budget constraint of the CB that relies on the issuance of MSBs as its main sterilisation tool. We next set up empirical models and then suggest a sequential procedure for sustainability testing. We provide evidence that current BOK's sterilisation policy depending on MSBs may not be sustainable.

Figure 2.9 Sequence of sterilisation, relevant research questions to be addressed



CHAPTER 3 THE IMPACTS AND PROFITABILITY OF STERILISED FX MARKET INTERVENTIONS:

Are sterilised FX interventions effective in stabilising exchange rates?

3.1. Introduction

In the context of textbook definition of exchange rate regimes, no FX intervention (hereafter FXI) will be conducted under a purely free float exchange rate regime (Frankel 1997). CBs will stabilise an economy by adjusting short-term interest rates, which may influence exchange rates. Therefore, free float exchange regimes provide a higher degree of monetary independence to CBs. In reality, however, many countries are assumed to intervene in the FX markets: (i) to counter (reverse) current, disorderly market conditions – "leaning against the wind"; (ii) to accelerate a current trend – "leaning with the wind"; (iii) to reduce excessive FX volatility or to slow down current trend – "smoothing"; (iv) to correct severe FX rate deviation from a long-run equilibrium level; (v) to make intervention profits; and (vi) to participate in coordinated interventions with foreign authorities.

In particular, emerging countries under *de jure* free float regime are known to conduct FXIs and neutralise the impacts of the interventions by sterilisations, as evidenced by the sizable build-up of foreign reserves in most countries,[13] although many advanced countries recently seem reluctant to intervene. The policy makers of these countries tend to consider a sterilised intervention as an inevitable option to control exchange rates and interest rates simultaneously. In other words, sterilised interventions have been taken as an (imperfect) substitute for capital controls in order to avoid trilemma constraints (Steiner 2010 p5),

[13] The 10 largest holders of foreign reserves at the end of May 2012 are China (3,305 bill. USD), Japan (1,278), Russia (510), Taiwan (389), Switzerland(374), Brazil(372), Korea (311), Hong Kong (292), India (286) and Germany (239).

because both are similar in offsetting the effects of capital flows and thus ensuring monetary independence. However, although most market participants believe that sterilised interventions affect exchange rates,[14] many literatures suggest that the intervention effects on exchange rates are ambiguous (relative to the unsterilised interventions) both theoretically and empirically. The sterilised intervention may lose its ground as an independent policy tool to avoid the trilemma constraint unless they have significant effects on FX rates.

Despite numerous studies on the FXIs, there has been a considerable gap in previous literature. Firstly, most studies have been devoted to advanced countries like US, Japan and European countries, despite the fact that many small open emerging countries conduct active interventions (Beine 2010). Intervention motives and the channel of effects in emerging countries may be quite different from those in advanced countries. For example, because financial markets are thinner and economies are more export-driven in most emerging countries, FXIs are likely to be more asymmetric and influential in emerging countries than in advanced countries. In particular, asymmetric FXIs due to *fear of appreciation*, may cause CBs to make economic or fiscal losses and eventually hamper monetary policy independence from government or political parties (Nunes and Da Silva 2008).

Secondly, previous literature appears to have less focus on the institutional features of interventions associated with domestic market operations and sterilisation costs. For example, previous studies assume that CBs make intervention decisions. However, in most countries, governments decide interventions, although CBs undertake intervention transactions. Given that two authorities have somewhat different policy objectives and that the coordination between them may be weak particularly in the emerging countries, it is probable

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[14] Most survey studies suggest that both market participants and central bankers believe that the FXI can affect exchange rate movements into more aligned ways and thus help restore equilibrium (see Lecourt and Raymond 2006, Cheung and Wong 2000 and Neely 2000 for the surveys on traders, and Neely 2008 and Mihaijek 2005, for the surveys on policy makers).

that the FXIs could be conducted irrespective of future monetary policy stances.

If FXI can adjust the exchange rate level towards the desired direction or calm down severe fluctuations, the interventions are taken as "successful" (Ito 2003). The objective of stabilising FX rate would be achieved when FX interventions are profitable – that is, if a CB buys foreign currency when it is cheap and sell it when it is expensive, the interventions make profits (Friedman 1953). Thus, the assessment of intervention effects and profitability could provide overall views on the intervention performances.

This chapter empirically investigates the efficacy of sterilised FXIs in three countries: Korea, Japan and Australia. These countries are known for actively intervening in FX markets. Our objectives are to assess the intervention effects on FX rate level and volatility and to estimate the intervention profits. We attempt to answer following questions in particular: (i) Do FXIs affect the FX rate level as desired? (ii) Do FXIs reduce FX volatility? (iii) Do interventions differently influence long-term and short-term volatility? (iv)Through which channel do interventions influence FX rates? (v) Are FXIs profitable? When we can say "yes" to the question (i), (ii) and (v), we may conclude that the interventions are "successful".

The rest of this chapter is organised as follows. Section 2 describes stylised facts of FXIs in three countries. Section 3 reviews previous literature on the transmission channels of FXIs, and intervention effects on exchange rate level and volatility. In section 4, we firstly apply asymmetric component threshold (ACT) GARCH framework with daily data to three countries and estimate asymmetric intervention effects on exchange rate level and volatility. In particular, the decomposition of exchange rate volatility (into permanent and transitory components) is motivated by previous studies that suggest that the FX interventions appear to have different effects on short-term and long-term exchange rate volatility. In addition, we provide evidence on the profitability of FXIs. Section 5 draws conclusion.

3.2. Stylised facts of FX market interventions

It is worthwhile to compare the three countries due to the differences and similarities in their natures of economy and policy regimes as summarized in Table 3.1. The three countries are similar in that FX interventions have been relatively frequent in the 2000s compared to other countries such as the US and UK. The proportion of trades of Japan and Korea in the world economy is large, and main export goods of the two countries largely overlapped (e.g., electronics, automobile, shipbuilding, metal, chemical, etc.). Both Korea and Australia are adopting IT and considered as small open economy while Japan is a large economy with adopting monetary targeting. As a result, comparing the three countries would provide significant implications with regard to the relation between interventions and institutional, economic features.

Table 3.1 Main economic and market indicators of Korea, Japan and Australia

	Korea	Japan	Australia
Nature of economy	Small open emerging	Large open developed	Small open developed
Monetary policy regime	Inflation targeting	Monetary targeting	Inflation targeting
Policy rate	O/N unsecured call rate	O/N unsecured call rate (with quantitative control)	O/N cash rate
Exchange regime	Free float(1997)	Free float(1973)	Free float(1983)
Export (Bill.USD, 2010)	466 (7^{th})	770(4^{th})	213((21^{th})
Import (Bill.USD, 2010)	425 (10^{th})	694(4^{th})	202(19^{th})
Daily FX turnover (Bill. USD, 2009)	35	400	210

Notes: 1. Trade and FX market statistics are collected from International Trade Statistics (WTO, 2011) and BIS (2010), respectively.
2. Exchange regime classification follows IMF's "*Annual Report on Exchange Arrangements and Exchange Restrictions*" (2008)

Exchange rate regimes in three countries have been mostly classified as *de facto* independent float or free float (IMF 2008, Reinhart and Rogoff 2002, Shambaugh 2004, Rogoff et al. 2004).[15] Nevertheless, these countries are known to actively intervene in FX markets. As shown in Table 3.2, although a CB intervenes in FX markets as a legal agent for a government, a government, in general, has a priority on deciding interventions in most advanced countries. In some countries, FXIs are under the purview of CBs (e.g., Australia, Brazil, Czech Rep. Chile, Indonesia, etc.).

Table 3.2 Main features of FX interventions in major economies

	Authorities	Funds for interventions	Restrictions	Communications
Korea (1997M12)	Treasury and BOK	Government (Foreign Exchange Stabilisation Fund) and BOK	The treasury bond issued for FXIs should be approved by the Congress	Mostly keep secret practices; not disclose information
Japan (1973M3)	Treasury	Government (Foreign Exchange Fund Special Account)	BOJ follows the treasury's directives	Publicly announce beforehand in case of cooperative interventions with other CBs; publicly announced afterward and disclose information on the web
Australia (1993M12)	RBA	RBA	RBA needs to consult with government.	Publicly announce interventions beforehand and afterward in most cases; disclose information on the web
USA (1973M3)	Treasury and the FRB	Government (Foreign Exchange Stabilisation Fund) and FRB	Treasury has priority with regard to the decision.	Publicly announce beforehand in case of cooperative interventions with other CBs; quarterly report; report to the Congress; daily data with 1 year lag
Euro Area (1999M1)	ECB	ECB	FXI should be consistent with the general orientations formulated by members	Publicly announce beforehand in case of cooperative interventions with other CBs ; publicly announced afterward but limited(amount and timing are not included); monthly bulletin
UK (1992M10)	Treasury and BOE	Government (Foreign Exchange Operation Account) and BOE	Intervention by BOE is restricted for monetary policy objective	Publicly announce beforehand in case of cooperative interventions; disclose information on a monthly press release

Note: The times in (   ) indicate the introduction of free float regime.
Sources: Author's summary based on the information from each CB's homepage, Sarno and Taylor (2001) and Menkhoff (2008)

[15] Korea's exchange regime has changed from managed float to free float since 1997 financial crisis. In particular, Korea's exchange regime has changed from a multi-currency basket peg (before March 1990) to market average exchange rate system (managed float) (Mar 1990 – Nov 1997) to free float (Dec 1997 – present). Daily margin for exchange rate movement are completely abolished in December 1997.

Daily margin for exchange rate movement in Korea (% relative to closing price of previous day)

1990.3	1991.9	1992.7	1993.10	1994.11	1995.12	1997.11	1997.12
±0.4	±0.6	±0.8	±1.0	±1.5	±2.25	±10.0	none

RBA has an initiative to determine interventions. In contrast, the treasury makes principal decisions on the FXIs in Korea and Japan. However, there is a significant difference between Korea and Japan. Treasury holds a full power over the interventions in Japan because intervention funds are financed by issuing government's bonds. This is not the case in Korea. In Korea, cooperative discussions between the treasury and the BOK are forceful due to legal and practical reasons. In particular, the Act of BOK postulates that all interventions should be carried out with a consultation between the treasury and the BOK**.** The funds for the FXIs are shared equally by the treasury's Foreign Exchange Stabilisation Fund (FESF) (which consists of KRW and USD and is financed by issuing Korean Treasury Bonds) and the BOK. The limited amount of the FESF, which is totally controlled by Korean Parliament, enables consultations between the two authorities to be more substantially forceful.[16] In contrast, intervention funds are, in general, solely financed by the treasury (in Japan) or RBA (in Australia).

Korean authorities keep stronger secrecy in the procedure of interventions than most developed countries, because the authorities believe that keeping the secrecy is more helpful in preventing speculators from benefiting relevant information and in avoiding disputes over the validity of interventions (Rhee and Lee 2005, p 198). In particular, information on interventions is not announced either ex-ante or ex-post in Korea. BOK does not tend to notify its intervention intentions to its agent dealers. Japanese authorities also keep secrecy except for cooperative interventions with foreign authorities. The data on interventions are released ex-post in Japan and Australia. The authorities in Japan and Australia announce relevant information before interventions for enhancing intervention effects when they

[16]Korea's official foreign reserves amounted to 290 billion dollars as of the end of September 2010. The reserves consist of 252.0 billion dollars of securities (87.0%), 33.2 billion dollars of deposits (11.4%), 3.6 billion dollars of Special Drawing Rights (1.2%), 1.0 billion dollars of its IMF reserve position (0.3%), and 0.1 billion dollars of Gold (0.03%). Among the foreign reserves, over 80%of the foreign reserves are held by the BOK.

undertake cooperative interventions with other CBs. Particularly, RBA interventions are thought as publicly disclosed, because RBA announces the intervention publicly before entering the broker market directly (Edison et al. 2006).

In consideration of possible conflicts between a government and a CB – equivalently between FXIs and OMOs, it is plausible that the objectives of FXIs may not always be consistent with those of the current or future monetary policy stance. This is particularly true for the countries where FXIs and monetary policy are implemented by separate bodies (e.g. Korea, Japan, etc.), where the coordination between the two authorities is not strong and where CB independence is relatively weak. As interventions cause changes in monetary base, frequent FXIs are likely to be associated with weaker CB independence. For example, Nune and Da Silva (2008), using panel analysis for 13 Latin American countries, find a negative relationship between the FXI coefficient and the CB independence index in 1990-2003.

Under the managed floating regime (before December 1997), Korean authorities intervened in order to achieve current account equilibrium or to stabilise a REER by attempting to change exchange rates towards the desired direction. However, since the introduction of free float regime in 1998, the main objective has been to alleviate excessive FX volatility rather than to maintain a certain exchange rate target (Rhee and Lee 2005, pp. 196-197). Thus, leaning against unilateral movements of FX rates or smoothing severe volatility may be the main intervention motives in Korea. The intervention objectives in Japan and Australia are similar to Korea's: to smooth excessively rapid changes in FX rate and to adjust FX rate level into desired direction (Newman et al. 2011, Ito 2003).

Oral interventions are used to facilitate market stabilisation beforehand or to convey the authorities' concerns about FX rate movements in the three countries. In Korea, the BOK intervenes in both spot and forward FX markets. However, interventions in forward markets rarely occur except for the period of financial crisis or severe speculation attacks in offshore non-delivered forward (NDF) markets, because the effect of the interventions at maturity would then be the opposite of what the interventions initially aims for (Rhee and Lee 2005, p 197).

BOK mainly aims to adjust the movements of KRW/USD exchange rate. Recently, the movements of KRW/JPY rate, however, also appear to be amongst the main concerns for Korean authorities since the market participants expect KRW to track JPY due to the intense export competitions between Korea and Japan (Rhee and Lee 2005, p 201). Note that interventions for resisting the appreciation of KRW against JPY cannot be conducted in a way of selling JPY in Korea, since there are no FX markets for KRW/JPY transaction.[17] In contrast, BOJ and RBA undertake non-USD interventions that trade domestic currency with foreign currencies other than USD: e.g. Euro, Indonesian Rupiah, British pound, etc.

The BOK sterilises FX interventions fully and automatically on a daily basis by issuing MSBs (Rhee and Lee 2005). Japanese interventions were also almost completely sterilised before 2002 (Ito 2003). However, Japanese interventions in 2003 appear to be unsterilised because BOJ's current account balance money supply steadily increases with interventions (Spiegel 2003 pp. 1-2). This is because unsterilised interventions are little different from the sterilised ones under near-zero nominal interest rate. RBA sterilises the impact of interventions through foreign exchange swaps (Newman et al 2011).

[17] The interbank market for directly trading JPY and KRW opened in October in 1996 but closed in January 1997 due to a lack of liquidity. Thus KRW-JPY exchange rates are determined as cross rate via the comparison of KRW-USD rates in Seoul FX markets and JPY-USD rates in Tokyo FX markets.

3.3 Literature review[18]

Most recent studies investigate the effects of sterilised interventions because it has been theoretically and empirically supported that non-sterilised FXIs generally have significant effects on exchange rates by affecting the monetary base or interest rate[19] − which is labeled as "monetary channel." Under interest rate or monetary targeting, CBs have little to do non-sterilised interventions that occasionally conflict with monetary policy. Recently, non-sterilised FXIs have been extremely rare, because most developed countries implement monetary policy by targeting short-term interest rates with the allowance of more flexible movements of FX rates. CBs have to sterilise the impacts of the FXIs on the monetary base mainly by OMOs in order to manage the short-term interest rates close to their targets. Therefore, monetary channel may not be applicable any longer to most developed countries.

Most literatures on the sterilised FXIs examine the following issues (Edison 1993, Sarno and Taylor 2001, Neely 2005, Menkhoff 2008): (i) How does the intervention work? (ii) Whether the FXIs affect the level and volatility of exchange rates; (iii) To what conditions CBs intervene in the market; (iv) If interventions are effective, how the relevant factors (e.g. coordination, direction, secrecy and amount of interventions) influence the degree of the effects, and (v) Whether sterilised interventions are profitable.

3.3.1 Transmission channels of FX market interventions

To explain the effects of sterilised interventions, literature presents mainly four channels: (i) portfolio balance channel, (ii) signalling channel, (iii) microstructure channel or

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[18] The important literatures on the effects of FXIs in the 1980s- 990s are well documented in Edison(1993) and Sarno & Taylor (2001) respectively. As for later studies, see Neely(2005a), Ito(2007) and Menkhoff(2008) for developed economies, and also refer to Disyatat & Galati(2007) and Menkhoff(2012) for emerging economies.

[19] Non-sterilised interventions change base money, and thus, monetary aggregates and interest rates. Accordingly, OMOs and non-sterilised FXIs are alike in that they are expected to work through the monetary channel to influence exchange rates. To put differently, non-sterilised FXIs are the OMOs carried out by transaction of foreign currency rather than domestic securities (Schwartz 2000).

order flow channel and (iv) coordination channel. The latter two channels can be seen as a broader interpretation of the signalling channel. The feasibility of each theory appears to have changed in line with the developments of financial markets.

3.3.1.1 Portfolio balance channel

Portfolio balance channel is normally considered in terms of mean-variance optimisation: risk-averse investors are assumed to determine the optimal composition of their portfolio in consideration of expected return and risk, and thus investors require risk premium for foreign assets. Here, foreign assets are considered as more risky due to additional risks incurred by FX rate changes aside from interest rate risk. In this respect, FXIs can affect FX rates by changing net supply of foreign assets and eventually shifting relative composition of private investors' portfolio. Thus, interventions would be more effective when foreign and domestic assets are imperfect substitutes. The imbalance induced by the interventions necessitates the change in FX rates, interest rates or both, to restore equilibrium (Edison 1993, p18). Specifically, the risk premium can be expressed in the deviations from UIP condition:

(3.3.1) $rp_t = i_t - i_t^* - E_t S_{t+1} + S_t \quad \rightarrow \quad E_t \Delta S_{t+1} = rp_t - (i_t - i_t^*)$

where rp_t is a risk premium; i_t and i_t^* are domestic and foreign interest rate, respectively; S_t is the spot exchange rate (domestic per foreign currency); and E_t is the expectation operator. If CB sells domestic currency for foreign currency, the intervention increases the net supply of domestic currency. The sterilised intervention, with leaving domestic interest rate(i_t) unchanged, increases exchange rate ($S_t \uparrow$) mainly by raising risk premium for domestic currency ($rp_t \uparrow$). The existence of non-zero risk premium and its responses to the change in relative supply of domestic and foreign asset are considered as evidence of effective interventions. Since portfolio channel covers direct impacts of interventions volume on net supply of foreign currency, it is likely that the intervention impact would be stronger as the intervention is larger.

Edison (1993) reports that most studies conducted between mid-1980s and early 1990s appear to fail to find either statistically or quantitatively significant relation between interventions and risk premium. The two main reasons for the weak evidences on portfolio channel are that (i) intervention amount is rather small relative to the daily market turnover in FX markets and (ii) there seems to be a high level of substitution between the assets denominated in different currencies – particularly the major currencies. In addition, many conclusions of ineffective interventions may be largely based on the faith that FX rates are determined by fundamentals rather than by interventions (Williamson 1993 p193). However, the evidences against intervention effects in the 1980s have been challenged by later studies using official high frequency data[20] and more accurate econometric techniques (Sarno and Taylor 2001, Menkhoff 2008).

3.3.1.2 Signalling channel

Since early 1990s, a series of empirical studies have attempted to scrutinize signalling channel and re-examine portfolio channel. The literature largely support signalling hypothesis that interventions are informative of future monetary stance in the developed country (particularly in the US), thereby influence the market expectation. In particular,

[20] Major CBs such as Fed, ECB and BOE have begun to release their official FX market intervention data since mid-1990s. Although most central bankers let alone economists agree positive relationship between transparency and effectiveness in implementing monetary policy, the information on FX market interventions frequently exempt from public announcement. For instance, BOE is allowed to keep its market intervention information by Bank of England Act 15-2. The IMF also admits that it would not be always appropriate for CBs to provide detailed information on foreign exchange operations (IMF Code of Good Practices on Transparency in Monetary and Financial Policies 3.3.2).

signalling model assumes that CBs conduct sterilised interventions for conveying private information about exchange rate fundamentals or about future monetary stance (Mussa 1981, Dominguez and Frankel 1993(a), Watanabe 1994, Lewis 1995, Kaminsky and Lewis 1996, Fatum and Hutchinson 1999, Kim and Sheen 2006). For instance, purchases (sales) of foreign currency should signal a future monetary expansion (contraction) more effectively than a simple announcement. Although signalling channel would work without actual interventions, most CBs actually trade their money, because the CBs need to stake its own money in order to support the future monetary policy and thus to acquire credibility from markets. According to signalling approach, sterilised interventions can still affect exchange rates even under perfect asset substitutability where rp_t=0. Thus, equation (3.3.1) can be transformed into:

(3.3.2) $$(1+i_t) = (1+i_t^*)\frac{E_t S_{t+1}}{S_t}$$

The foreign-currency purchasing intervention causes the agents to expect the future monetary expansion and the depreciation of the domestic currency ($E_t S_{t+1} \uparrow$). In this case, given constant interest rates (i.e., i_t is fixed due to sterilisation and i_t^* is assumed exogenous), current exchange rates should be also depreciated for (3.3.2) to hold ($S_t \uparrow$).

In this approach, interventions are expected to be more effective if (i) financial markets are so efficient that information spreads out without any distortion; (ii) CBs have information unknown to the market participants; (iii) monetary policy should be conducted in a consistent way and thus considered as credible; and (iv) interventions are conducted with coordination with other CBs or other domestic institutions. The empirical evidences mostly confirm the prior expectation. Interventions are more effective when they are: (i) clearly informed or communicated (Dominguez 1998, Fatum 2000); (ii) consistent with the underlying stance of monetary or fiscal policy (Sarno and Taylor 2001, Menkhoff 2008); (iii) conducted in cooperation with other CBs (Humpage 1999, Fatum 2000, Lecourt and Raymond 2006, Menkhoff 2008, Fatum and Hutchison 2010).

Although several countries have recently begun to publish intervention information with a time lag, many countries, in reality, conceal most information (i.e., time and amount of interventions). Few publicly announce them beforehand. This practice of secrecy is called *'secret intervention puzzle'* because it appears contradictory to what signalling channel expects (Sarno and Taylor 2001).[21]

Intervention effects may be also asymmetric, depending on institutional features such as compatibility with monetary policy and depth of financial markets. Theoretically, IT is not consistent with regular and persistent interventions (Rogers and Siklos 2003 p 396). Mishkin and Savastano(2001)'s work on Latin American countries suggests that too heavy and frequent interventions would risk transforming exchange rates into a nominal anchor that has preceded over IT. Their argument indicates that IT is compatible with the interventions for smoothing short-term fluctuations but not with those aiming to prevent exchange rates from reaching market-determined level over longer periods (Mishkin and Savastano 2001, p 439). Kamil (2008) finds that, under IT regime, interventions for resisting the appreciation are effective only during the monetary easing period in Colombia. Generally, the sizable interventions for resisting the appreciation become ineffective, as the large-scale interventions are regarded as incompatible with meeting the IT.

[21] Ito(2007, pp 136-137) points out that the success of the clearly-announced intervention in accordance with Plaza Agreement, September 1985, encouraged many policymakers to hint or announce interventions. Nevertheless, there still exist rationales for supporting secret intervention (Cheung and Wong 2000, Hung 1997): (i) A secret intervention may be preferred when it is not consistent with monetary policy. (ii) Releasing intervention information may encourage speculations by revealing states of foreign reserves. (iii) A secret intervention is more effective when a CB tries to manipulate market by affecting technical traders especially in periods of thin trading day. In practice, survey results show that the main reasons for the secret interventions are either to minimize the effect on the market or to counter speculative attacks (BIS 2005).

3.3.1.3 Market microstructure channel

Empirical studies based on traditional asset market approach appear to provide little evidence that macroeconomic variables have strong and consistent explanatory power over FX rate except in case of extraordinary circumstance like hyperinflation (Park 2011 p875). Recent studies have increasingly turned to technical or institutional aspects of FX markets. Market microstructure channel (sometimes named differently as '*noise trader model*' or '*chartist-fundamentalist model'*[22]*)* focuses on the features related to trades and market participants. According to this approach, sterilised FXIs have significant effects on FX rates when a CB can alter order flows with their own orders, and thereby change noise traders' expectations (Hung 1997, Evans and Lyons 2004, Menkhoff 2008).[23]

Microstructure approach could be regarded as one of the efforts to loosen efficient market assumptions behind fundamentals-based models (like portfolio-balance or signalling model). This approach reflects technical or nonfundamental aspects (of FX markets) such as herd behaviour, technical trading and heterogeneous informed market (Frankel and Froot 1990, Popper and Montgomery 2001, Schmidt and Wollmershauser 2004). Consequently, this approach is appropriate to explain the movements of short-term exchange rates that are likely to be influence by nonfundamental forces (Cheung and Wong 2000). For example, if foreign-currency buying interventions influence the order flows, noise traders may take the interventions as changes in policy stance and expect domestic-currency depreciation. The

[22] Noise traders and chartists are market participants whose demand for currencies is affected by beliefs that are not fully consistent with economic fundamentals. Specifically, orders from noise traders are not perceived to be informative about exchange rate equilibrium. Thus, noise traders' investment strategies are considered as main sources of systematic forecasting errors. CBs can take advantage of this property of the traders in order to affect FX rate. Noise traders are often called differently both in academic circles and in real-world financial markets: they normally correspond to *uninformed traders*.

[23] Hung (1997) firstly argues that CBs can affect FX rates by manipulating order flows. In general, CBs intervene in FX markets through limited number of agents sworn not to reveal the existence of market interventions. If the orders by agents are observed by influential traders, market participants will assume the presence of some fundamental momentum – not the interventions – and initiate positions of their own which reinforce the direction of the order flow. (Archer 2005 p 47)

noise traders then follow the direction of the intervention (i.e. they also attempt to increase the purchase of foreign currency) and the intervention effect can be more intensified.

Note that the microstructure approach may be helpful to understand "*puzzle of secret interventions"* that could not be easily explained by the signalling approach. Bhattacharya and Weller (1997) and Vitale (1999) argue that an order flow itself is a signal even if CB intervenes anonymously, so that order flow channel may work even in secret interventions. Order flow approach expects that intervention impacts are stronger in a thinly traded market. If traders respond more strongly to the changes in order flows by influential private market participants rather than by CBs, secret interventions may be more effective. Allowing for information asymmetry, we can conjecture that even if the intervention amount is very small relative to market turnover, a single intervention may significantly affect exchange rates by triggering a multitude of subsequent trades. Through the study on order flows in FX interventions, Evans and Lyon (2001) divide asymmetric information associated with interventions, into two basic types: (i) asymmetric information existing between a CB and the public, which is the necessary condition for signalling channel and (ii) asymmetric information between market participants, which plays a role in determining intervention impacts irrespective of the channel through which intervention works.

3.3.1.4 Coordination channel

This approach focuses on the fact that publicly announced interventions can remedy a coordination failure in FX markets. FX markets can be disrupted by irrational speculations brought by noneconomic factors like trend-following trading strategies of chartists or technical analysts (Frankel and Froot 1990, Allen and Taylor 1992). Once exchange rate is deviated far away from fundamental equilibrium due to herd behaviours and self-fulfilling expectations, it is very hard for individual market participants to attempt to reverse the current trend even when they believe current FX rate to be severely distorted — this situation is called *'coordination failure'*. In this case, publicly announced interventions can play a significant role in coordinating trades in the direction of equilibrium by infusing '*smart money'* into the FX markets (Sarno and Taylor 2001). Publicly announced interventions could reverse current distorted trend into equilibriumby changing market sentiments. This is because credible announcements lead the weights of chartists and trend-followers to become lower than those of the fundamentalists in the FX markets. Hence, FXIs may play a crucial role in pricking the bubble before the bubble worsens (see Sarno and Taylor 2001). Communications or oral interventions may influence FX rates through the coordination channel. The coordination approach is closely related to the market microstructure approach, which concerns how information is incorporated into asset prices and emphasizes information heterogeneity in the FX markets (Fratzscher 2008a, p 1652).

Sarno and Taylor (2001) argues that more weight should be given to the studies of the 1990s, which suggest that FXIs can have greater impacts on FX rates than previously assumed, than those of the 1980s. They insist, because of the lack of the data on official interventions and exchange rate expectation, the empirical studies in the 1980s, most of which used foreign reserves as a proxy for interventions, may have limited implications. Neely (2005a) points out that using high frequency data and new methodologies like event study and friction model have enhanced understanding of interventions. Currently, despite its various lag in the transmission of intervention effect, it appears to be generally accepted that sterilised interventions affect exchange rates – particularly in the short run – for example, even within the intervention day or within a couple of days after interventions.

Considering the evidences of concurrent studies and the future evolution of financial environments, we expect that the importance of the portfolio balance effect will be diminishing particularly in the developed countries.[24] This presumption is supported by the recent surveys that the signalling effect is consistently put forward as the main intervention channel. In particular, the microstructure and coordination channel, both of which focus on the role of information, may be more helpful to understand the impacts of the FXIs in the futures. However, the portfolio balance model may still have implications for developing countries in which capital market is not yet freely open to international investors, and domestic currency is traded with an additional risk premium.

3.3.2 Impacts of interventions on exchange rate level and volatility

Most studies have used GARCH-type models consisting of mean equation (3.3.3) and variance equation (3.3.4) to see the impact of interventions on the FX rate, because FX rate movements typically show volatility clustering.

(3.3.3) $\Delta \ln S_t = \alpha + \beta \cdot INT_t + AX_{1t} + \varepsilon_t, \varepsilon_t \sim (0, \sigma^2{}_t)$: mean equation

where S_t is the exchange rate, the vector of regressors X_{it} is any other variables that might influence the exchange rate and ε_t is a disturbance term. While interventions explain contemporaneous exchange rate change in (3.3.3), many literatures use lagged intervention data in order to avoid simultaneity problems. If coefficient β is significantly different from zero, the intervention could be interpreted to affect FX rate level. Estimating the effects on FX

[24] Sarno and Taylor (2001) suggests two main reason for lesser importance of the portfolio balance channel: (i) The degree of substitutability between financial assets denominated in the major currencies increases as international capital markets become increasingly integrated; (ii) Typical size of interventions is very small fraction of total FX market turnover.

rate volatility heavily depends on the definition of volatility. The effects are estimated mainly by two methods. First, *ex-post* volatility is normally measured as conditional variance from GARCH (1, 1)-type specification:

(3.3.4) $h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 \varepsilon_t^2 + \beta_3 INT_t$ where $\varepsilon_t = \sqrt{h_t} v_t$, $v_t \sim N(0,1)$): variance equation

If β_3 is significant, the intervention influences FX volatility. Alternatively, if currency option markets are efficiently operated, then (*ex-ante*) implied volatility extracted from the option price provides an unbiased estimate of market forecast of volatility (Dominguez 1998). Aforementioned, intervention effects on FX rate level and volatility in the short-term perspective are evidenced positively since the mid-1990s, mainly by modified signalling approach such as microstructure and coordination channel. Nevertheless, most studies appear doubtful about the long-term effects of the interventions on exchange rates.

With regard to frequency, timing and amount of interventions, it is widely supported that large, infrequent and concerted interventions tend to have more significant effects on FX rates (Ito 2003, Lecourt and Raymond 2006). Fatum and Hutchison (2003, 2006) also agree that interventions are effective when used selectively and aiming for short-run stabilisation of FX rates. Dominguez (2003a) argue that CBs should intervene in FX market during heavy trading periods to maximise the intervention effects. However, some studies argue that the FXIs (involving a large amount and being repeatedly conducted in the same direction) may conflict with monetary policy. In this case, first intervention is likely to be effective but subsequent ones may not. IT particularly appears not to be consistent with the regular, frequent or unidirectional FXIs. Rogers and Siklos (2003) find that, since the introduction of IT, interventions have affected volatility and uncertainty of FX rates differently in Australia and Canada. Tapia and Tokman (2004)'s study of the Chilean case also suggests that the effect of interventions varied throughout the sample in line with monetary policy regime shift.

There has been little evidence supporting that interventions systematically reduce FX volatility. Instead, many studies suggest that interventions are generally positively related with FX volatility, or with no effect at least in the short-run. This holds for (i) ex-post volatility captured by GARCH models(Baillie and Osterberg 1997, Dominguez 1998, Aguilar and Nydahl 2000, Edison et al. 2006, Kim and Sheen 2006), (ii) ex-ante or expected volatility measured by implied volatilities extracted from currency option prices (Bonser-Neal and Tanner 1996, Rogers and Siklos 2003, Frenkel et al 2005) and (iii) realised volatility measured by squared returns or integrated daily moments of exchange rate (Dominguez 2006, Beine et al. 2006, 2009). In particular, many studies show that secret interventions tend to increase FX volatility (Bonser-Neal 1996, Dominguez 1998, Frenkel et al. 2005, Kim and Sheen 2006). Humpage (1999) is an exceptional work that the Fed's leaning against the wind in 1987-1990 was effective in reducing FX rate volatility.

Menkhoff (2008) documents that interventions increase FX rate volatility in the short run as they are regarded as information, although he admits that the interventions can reduce FX rate volatility in the longer period. These results may suggest that while many CBs are often assumed to conduct the FXIs for smoothing short-term exchange rate volatility, however, in practice, they have rarely succeeded — particularly with secret interventions. Thus, some economists often interpret increases in volatility as an evidence of perverse or destabilising intervention effects. However, in the markets characterized by the information asymmetry, the increase in FX volatility may be associated with the spread of new information rather than the lack of effects of FXIs (Beine et al. 2009, p 120). Accordingly, the rise of volatility may reflect the fact that traders react to the interventions. In the context of simultaneity problem, a comprehensive attention should be paid to examining the effects on the volatility, since CBs tend to intervene during the period of high volatility.

In summary, although the effects of sterilised interventions are not quantitatively large, recent evidences indicate that interventions may have very short-term effects on both FX rate level and volatility, particularly when the intervention is publicly informed, coordinated with other CBs and consistent with monetary or fiscal policy. Evidences are generally different depending on sample countries, sample periods and empirical specifications. While most studies prior to the 1990s, mostly based on portfolio balance channel, largely reject intervention effects, literature after the mid-1990s appears to support temporary or short-run intervention impacts. The evidences are not supportive of the long-term effects both in level and in volatility.

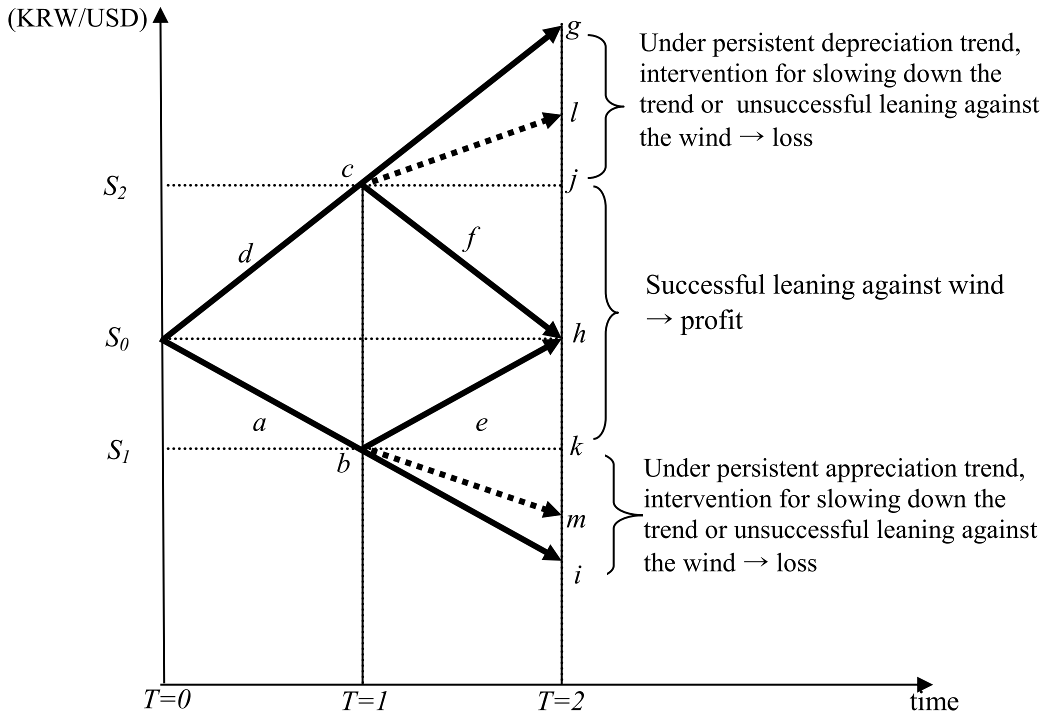
3.3.3 Profitability of sterilised FX interventions

3.3.3.1 Theoretical discussion

The profitability of FXIs provides one with an indirect way of assessing whether the intervention has been successful in stabilising exchange rates (Friedman 1953). According to Friedman, a CB should buy foreign currency when it is cheap and sell it when it is expensive in order to stabilise FX rate. Consequently, the interventions for exchange rate stabilisation should make a profit to be successful. Friedman's argument would be right when CB leans against wind and interest earnings are not considered. Simple example is well depicted in Figure 3.1, which is modified from Pilbeam (2001, p 525).

First, suppose that the BOK buys USD in the region ***ab*** where KRW appreciates and sells USD in the region ***eh*** where KRW depreciates. If FX rate follow the path ***dcfh***, the BOK's net purchase of USD assets will be zero and BOK will make a realised trading profit at T=2, because BOK buys USD at a low price and sell it at a high price. However, if KRW continues to appreciate (to follow the path ***abi*** or ***abm***), there will be a large cumulative net purchase of USD at T=2. In this case, the BOK experiences a (unrealised) loss by purchasing continuously depreciating USD. In contrast, when the BOK sells USD when KRW depreciates in the region ***dc*** but FX rate continues to depreciate (follow the path ***dcg***), the BOK will have large cumulative net sales of USD, which will also incur loss to the BOK.

Figure 3.1 Profitability of FX interventions and FX rate



Consequently, if a CB succeeds in leaning against wind, and thus reverses the current trend of FX rate movements, intervention profits would exist. In contrast, if the CB is unsuccessful in leaning against the wind, the intervention will incur a loss. In this context, *ex post* intervention profit may reflect the FX rate-stabilising effect of the interventions. Shortly, it is likely that the intervention of *"leaning against the wind"*, if successful, leads to a profit. However, profitability does not always guarantee the effectiveness of FXIs. When FX rates show an excessively persistent trend, the intervention resisting the trend can be considered effective in slowing down the trend, although it is not profitable. If the CB just aims for smoothing (or slowing down) current trend or fluctuations– not reversing it (as in the path ***dcl*** and ***abm***), the intervention will be effective though unprofitable.

Note that if the CB leans against the wind as Friedman presumed, any measurement of *ex-post* profitability will be inevitably biased by the cumulative amount of the interventions (Corrado and Taylor 1986). In the above figure, profits are more likely larger when net cumulative intervention is close to zero while intervention losses are likely to be bigger when net cumulative interventions are larger, i.e., when there is open long(or short) position on foreign currency. It naturally follows that profitability calculation heavily depends on how much cumulative intervention is arbitrarily allowed for – in practice, the choice of the start-and-end dates of the interventions (Pilbeam 2001 p 525). Therefore, profitability is not considered a single criterion for evaluating the effect of interventions (Edison 1993 p 42; Sarno and Taylor 2000 p861). Furthermore, if interventions do not affect FX rates, as many previous studies argue, intervention could be (non)profitable without (de)stabilising FX rates. Accordingly, the main issue tends to change from whether intervention loss indicates destabilisation to whether intervention incurs loss to CBs (Sweeny 1997 p 1668).

As for intervention profits, three arguments exist: (i) interventions are likely to be profitable, because CBs have more information; (ii) interventions are generally misguided and costly due to existence of intelligent and speculative market participants, so that the CBs are likely to suffer losses; and (iii) intervention losses (or profits) are expected to be zero, because current FX markets may be considered strong-form efficient relative to the interventions.

3.3.3.2 Evidence on intervention profitability

True profits can be obtained from actual transaction data that are not released by any country. Thus, recent studies use daily intervention data at best. Because researchers generally do not know the exact exchange rates applied to the transaction, they mostly use end-of-day or daily average FX rates. Since the volatility of intra-daily FX rates is smaller than that of weekly, monthly or quarterly FX rate, using daily data is considered most appropriate to get true intervention profit (Leahy 1995, Sweeny 1997). The typical equation for measuring intervention profit is as follows (Edison 1993 p 43):

$$(3.3.5)\ \Pi_t = \sum_{i=1}^{t} \{F_i(S_t - S_i) + S_i(r_i^* - r_i)\sum_{i=1}^{t} F_i\}$$

where Π_t is profits, F_i is dollar purchased at time *i*, S_t and S_i are end-of period nominal exchange rates(domestic price of foreign currency) at time *t* and *i* respectively, and r_i^* and r_i are the foreign and domestic interest rates respectively at time *i*. According to (3.3.5), intervention profits are mainly determined by two elements: (i) trading profit (or capital gain) − the difference between the end of period exchange rate at time *t* and the exchange rate at which the intervention (to buy foreign currency) is undertaken, (ii) interest earning from holding foreign currency rather than domestic currency. Trading profits are divided into two categories: realised profits and unrealised profits. If the CB adopts daily marking-to-market accounting, unrealised profits will change with daily FX rate changes. If the value of domestic currency continues to climb after USD-buying intervention, the CB makes a mark-to-market loss from the USDs accumulated. However, this loss would not actually matter for the CB, because there would be no immediate necessity to sell them in most cases. On the contrary, the value of domestic currency falls after USD-selling interventions, there would be mark-to-market loss from the domestic currency purchased. This loss matters for most CBs, because the loss occurs concurrently with reserves decrease.

Note that if CB sterilises the intervention, domestic interest rate does not change and then interest differential should be emphasized in calculating the profit. In this context, a sterilised FXI is a swap of interest-earning foreign assets (mostly USD-denominated) for interest-earning domestic assets or vice versa. Therefore, the choice of interest rates heavily affects the profitability calculation.

Since previous studies mostly suggested "leaning against the wind" and "smoothing" as two main intervention motives, evidences on profitability are mixed. Early studies before the 1990s appear not to support the profitability of interventions (e.g., Taylor 1982; see Sweeny 1997 for the survey on empirical literatures before the mid-1990s). When CBs are partially successful in leaning against the wind or merely smooth out (or delay) the FX rate swings, they makes a loss at least in the short run as the US authority experienced in the 1970s. However, these studies have limits in using foreign reserves as a proxy for interventions and in relying on too simplified calculations.

Literature after the mid-1990s (which uses intervention data) seems to more support the positive profit. For example, Neely (1998) shows that CBs generally make profits in the long run, although the profits may vary depending on sample periods. Ito(2003), and Becker and Sinclair(2004) find that the interventions in Japan and Australia are profitable in terms of realised capital gains, unrealised capital gains, and interest earnings. Particularly, low domestic interest rate in Japan enabled Japanese authorities to gain persistent positive interest earnings throughout 1991-2001. See Appendix 3.1(c) for the results of concurrent studies on intervention profitability.

3.3.4 Impacts of oral interventions

Recent studies have focused on the effect of communication or oral interventions used to convey the CB's intention of intervention, since major developed economies have virtually abandoned actual FXIs since the late 1990s. Oral interventions or communication may affect exchange rates and interest rates via a coordination channel in which the CB statements play a role as a coordination that induces market views to converge and move in a desired direction (Sarno and Taylor 2001, Fratzscher 2008).

The intervention communication appears to have somewhat stronger effect on FX volatility, but it still looks ambiguous in influencing exchange rate level. General conclusion is that the effect of the communication is more significantly asymmetric than actual interventions and oral interventions for supporting domestic currency are more likely to fail than those for inducing domestic currency depreciation. According to this view, intervention communications during the crises periods may not have significant effects. Fatum and Hutchison (2002), using both time series and event study of news generated by the ECB, suggest that markets respond differently to several types of news about interventions. They argue that only negative statement denying past interventions or ruling out future interventions appears to have persistent effects, but the market participants apparently ignore official statements supporting euro. Park and Song (2003), using the statements reported in newspapers, analyze the effects of oral interventions by Japanese government. Oral interventions are effective when carried out with actual intervention and during peace times. The effects of oral interventions are insignificant during the turmoil times like financial crisis. Beine and Lecourt (2004) conclude that CB's statements (during intervention periods) are effective, particularly in reducing FX volatility. Jansen and de Haan (2007) report that ECB statements do not influence the FX level but decrease FX volatility temporarily. Oral interventions, if coinciding with releases of macroeconomic data, are effective in reducing FX volatility. They also agree with Fatum and Hutchison (2002) that the statements of supporting euro have not, in general, been successful. However, Fratzscher (2005, 2008a) argues that oral interventions can affect both FX level and volatility. Conducting an event study for the ECB, the Fed and the BOJ, he suggests that oral interventions have significant effects on daily exchange rates in the desired direction. Communications reduce FX volatility on the days following the interventions while actual interventions mostly increase volatility.

3.3.5 Interventions in emerging economies

It seems that the CBs in emerging economies tend to intervene more frequently than their counterparts in developed economies do due to their higher exchange rate pass-through, greater openness or greater foreign currency liability. Calvo and Reinhart (2002) argue that despite the increasing number of countries allowing more flexible FX rates, stabilising FX rates still remain as a high priority among emerging economies in which policy credibility is lower, and exchange rate pass-through to inflation is higher – that is *'fear of floating*'. More volatile exchange rate movements may force the authorities in these countries to intervene more. For example, Cavoli and Rajan (2006b, 2007) find that as exchange rates have, in general, become more volatile, the post-crisis interventions are more frequent than pre-crisis (but less frequent than during the crisis), due to the prevailing fear of floating in most of the crisis-experiencing emerging countries. Hausmann et al.(2001a, 2001b) document that emerging countries (with a formally flexible regime) are more inclined to intervene to reduce FX rate volatility because of their inability to borrow in international capital markets in their domestic currency, the so-called "original sin". Aghion et al.(2000) theoretically show that emerging countries with greater foreign currency debt will optimally choose less exchange rate flexibility and thus tend to more involve in FX interventions under de jure floating regimes. CBs in dollarized economies need to build up foreign reserves to serve as a lender of last resort to commercial banks with high level of foreign currency liabilities. Kamil (2008) and Fiess and Shankar (2009) provide evidence that the countries with high external liabilities relative to assets tend to maintain a high level of interventions.

Some studies argue that the FXIs are likely to be more effective in emerging countries than in advanced countries due to (i) relatively less complete sterilisation, (ii) larger amount of intervention compared to market turnover, (iii) information advantage of CBs and (iv) moral persuasion (Canales-Kriljenko 2003).

However, it is evident that frequent interventions may lead to inconsistencies between interventions and contemporaneous monetary stance particularly under inflation targeting. A few studies have recently paid attention to whether interventions take place independently of contemporaneous monetary policy implementation in emerging economies (Gnabo et al. 2010). Evidences are ambiguous. For example, FXIs are conducted in cooperation with monetary setting in the Czech Republic but not in Brazil where both are carried out independently (Gnabo et al 2010). Overall, FXIs appear not effective as an independent policy tool under float regimes *cum* IT, because the interventions tend to be more effective when they are consistent with monetary stance, as signalling channel suggests.

Empirical studies on intervention effects in emerging countries are still scant due to the very limited official intervention data and the difficulties in modeling policy reaction function with high-frequency time series analysis (Guimaraes and Karacadag 2004, p 3). Although being highly sample-dependent, several studies help to understand the cases of emerging economies broadly. With regard to the intervention channels, portfolio balance model predicts that interventions are more effective in emerging countries than in advanced countries because of low asset substitutability. Moreover, portfolio channel may be supported by the facts that emerging countries have large foreign reserves relative to domestic FX market turnover or the stock of domestic bond outstanding. Microstructure channel, which expects that the amount of interventions relative to market turnover is crucial, also suggests that FXIs may be more effective in emerging economies (Archer 2005).

On the contrary, from a signalling perspective, it is not clear whether interventions have stronger effects on exchange rates in emerging economies than in developed economies. As CBs in emerging countries have a shorter history of institutional backgrounds and lower policy credibility than their counterparts in developed countries, signalling channel may be weaker in emerging countries. Consequently, monetary policy signal to the market is not likely to influence the level or volatility of exchange rate (Domac and Mendoza 2002). On the other hand, because financial markets in emerging countries are less developed and thinner than those in advanced countries, CB may have superior information stemming from reporting requirements (Canales and Kriljenko 2003). In this case, if the CB credibly and publicly announces the information to the market, signalling channel can work well in the emerging markets (Tapia and Tokman 2004, Guimaraes and Karacadag 2004). In practice, however, few emerging countries release the information.

FXIs, in general, appear effective for containing FX volatility in emerging economies (Oura 2008, Domac and Mendoza 2002, Abenoja 2003). For example, Abenoja(2003) suggests that Bangko Sentral ng Pilipinas(BSP) has intervened less, in terms of frequency and magnitude, and has been relatively symmetric in its intervention since 1997 financial crisis. He suggests that sizable and persistent interventions do affect the exchange rate in the desired direction, and help to reduce FX rate volatility. Nevertheless, the evidence of intervention effects on FX rate level in emerging economies are still relatively ambiguous just like those in developed countries (Disyatat and Galati 2005).

In summary, recent empirical studies suggest several significant aspects of the FXIs in emerging economies: (i) The interventions in these countries may have somewhat stronger impacts on exchange rate than those in developed countries; (ii) The interventions may affect exchange rates volatility particularly in the short run; (iii) The intervention under IT may have different effects in line with the evolution of inflation; (iv) There may be more room for the application of portfolio balance model.

3.3.6 Recent studies on FX interventions in Korea, Japan and Australia

This section briefly summarizes the recent evidences on the intervention effects in Korea, Japan and Australia. The studies on FXIs in Korea have focused on the intervention effects during the managed float regime from early 1990 until 1997 using OLS, VAR or GARCH. Most studies have analyzed relatively long-term effects of interventions using monthly or quarterly foreign reserve data as a proxy for intervention. As capital mobility has become rapid since the 1997 financial crisis, research interests have switched from portfolio balance to signalling model, because theories expect that FXIs work mainly through signalling effects under freer capital mobility. Most studies appear to suggest that (i) interventions affect the FX rate level only in the short run (e.g. at most within a month); (ii) main intervention motives are leaning-against-the-wind or smoothing; (iii) interventions are heavily influenced by the changes in trade competitiveness.

Using monthly data on foreign reserves and VAR model, Rhee (1997) suggests that the FXIs have only temporary effects on exchange rates and that intervention objective was mainly to lean against the wind. Park (1998) supports Rhee (1997) by using exchange market pressure and intervention index. Ryou and Kim (1998) examine the motives for FXIs using a VECM consisting of six variables (current account, capital account, FXIs, domestic credit, inflation rate and won/dollar exchange rate). They find that the BOK responds more to capital account shock than to current account shocks. Lee et al. (1998) provide evidence of significant signalling channel by examining changes in the BOK's daily foreign exchange position. They find that FXIs influence KRW/USD rate to the direction intended by the BOK. However, the effect does not last long.

Both Ryou and Kim (1998) and Lee et al.(1998) report strong tendency for resisting KRW appreciation by examining statistical properties rather than by adopting elaborated econometric methods. Ryoo (2003), Choi (2001), and Rhee and Song (1999) find that sterilised interventions had significant, short-term effects on the level and direction of FX rate in Korea. However, these studies have limited implications for understanding current interventions, partly because sample periods are confined to the pre-crisis period when managed float was prevailed, and partly because the proxies for interventions were not perfect. As capital markets nearly completely opened to foreigners and monetary regime shifted from monetary targeting to IT after 1997-98 crisis, FXIs are likely to be less effective in Korea, as Rhee and Song (1999) predicted.

The studies on the interventions of Australia and Japan have been based on longer historical time series and higher frequency data than those on Korea. The evidences on Australian interventions suggest that RBA interventions have fairly short-lived effects on FX rate level – interventions are mostly effective only on intervention day (Kearns and Rigobon 2005, Newman et al. 2011). Interventions are not successful in reducing FX rate volatility in the short-term perspective (McKenzie 2004, Edison et al. 2003, Rogers and Siklos 2003). Most studies find that RBA intervenes in FX market to smooth FX rate fluctuations rather than to change FX rate level (Kim and Sheen 2002, Kearns and Rigobon 2005). However, most studies appear not entirely free from simultaneity problem (Newman et al 2011).

The evidences on Japanese interventions provide somewhat different implications. Japanese interventions appear to have more significant effects on FX rate level and volatility than Australian ones do (Dominguez 2003a, Fatum and Hutchison 2006). In particular, interventions are effective irrespective of consistency with interest rate changes and secrecy (Fatum and Hutchison 2006). Japanese authority appears to target explicit or implicit FX rate level – e.g. 125JPY/USD in 1991M4-2001M3 (Ito 2003) and implicit target in 1993M9-1996M4(Galati et al 2005). However, in the 2000s, Japanese authorities appear to respond only to increasing uncertainty, i.e. severe fluctuation in FX rates, rather than targeting FX rate level (Galati et al 2005). In accordance with the changes in intervention objectives, intervention pattern appears to shift from small-scale and frequent to large-scale and infrequent interventions in the mid-1990s (Ito 2003, Ito and Yabu 2007). It is conceived that, in the short-run perspective, interventions are relatively successful in adjusting FX rate level as desired when interventions are infrequent and large (Ito 2003). Note that evidence on relatively successful intervention in Japan may be partly ascribed to non-sterilisation of FX intervention due to close-to-zero interest rate, which blurred the difference between sterilised and unsterilised interventions (Fatum and Hutchison 2006, Hillebrand and Schnabl 2003). That is, Japanese interventions were unsterilised sometimes – e.g. in 2003-2004(Fatum and Hutchison 2006), because unsterilised purchases of USD (sales of JPY) are expected to boost export and increase the monetary base. This contrasts to the other advanced economies where interventions are almost completely sterilised (Neely 2000). Many studies on Japanese intervention identify structural breaks in intervention policy in the mid-1990s (Ito 2003). See Appendix 3.1 for the main findings of recent studies on interventions in Japan and Australia.

3.4. Data and methodologies

3.4.1 FX interventions in Korea, Japan and Australia

We use daily data to delve into the impacts and profitability of sterilised interventions in Korea, Japan and Australia. Although there are several economies like the U.S and Euro area (in which daily intervention data are also available), we exclude these countries, because their last interventions were carried out a decade ago,[25] and they are thus not appropriate for comparison analyses. Sample period is 2001M1-2010M3 for Korea, 1991M4-2004M3 for Japan and 1989M1-2008M12 for Australia. Considering the institutional changes or the results of previous empirical studies (Taylor 2009, Ito and Yabu 2007, Ito 2003, Newman et al. 2011), we divide samples into two subsamples[26] and estimate parameter separately:

- Korea: pre-subprime (10/9/2001-31/7/2007), post-subprime (1/8/2007-23/3/2010)
- Japan: pre-Sakakibara (4/4/1990-30/6/1995), post-Sakakibara (1/7/1995-31/3/2004)
- Australia: pre-IT (5/1/1989-31/7/1992), post-IT (3/8/1992-31/12/2008)

Intervention data are domestic-currency values of interventions in US dollar. The daily intervention data on Japan and Australia are officially announced ones while the data on

[25] Since the late 1990s, FXIs have become much less frequent in many developed countries. For instance, FRB has intervened only twice since August 15, 1995. Similarly, both the Bundesbank and the Swiss National Bank ceased interventions entirely in 1995. The launch of the ECB in 1999 let member countries be free from the obligation of adjusting their exchange rates with a certain level under the ERM II. The ECB has not intervened since the late 2000. Even RBA and BOJ, traditionally frequent market interventors, have intervened less frequently last decade

[26] BOJ and RBA did not intervene in the market after March 2004 and December 2008 until the end of 2010. Thus, we exclude the periods from our sample. Most important institutional changes are the introduction of IT in Australia (Jan. 1993), inauguration of Dr. Sakakibara as a chief of Japanese interventions (Jun. 1995), and the advent of US-subprime mortgage crisis in Korea (Aug. 2007).Taylor (2009, p1) supposes that the subprime crisis flared up and began to shock most major countries in August 2007. Ito (2003) and Ito and Yabu (2007) suggest that there was a significant shift of Japanese FX intervention operations in June 1995.

Korea are not actual intervention data but estimated ones.[27] Nominal FX rates are closing spot rates in FX markets in Seoul, Tokyo and Sydney. Using end-of-day spot rate helps to address simultaneity problems. Money market rates are average overnight unsecured call rates in Japan and Korea, and average cash rate in Australia. The intervention amount (denominated as local currency) is measured as purchasing and selling amount of USD. For Japan, we include only JPY-USD interventions (345 observations during the sample period) and exclude 19 euro-JPY and 4 Indonesian rupiah-USD interventions. All interventions in Korea were conducted in KRW-USD FX markets. These high frequency data on Korea are collected from the Economic Statistics System (*http://ecos.bok.or.kr*) and the Korean Ministry of Strategy and Finance. The data on Japan and Australia are all obtained from the website of the Japanese Ministry of Finance (*www.mof.go.jp*) and Reserve Bank of Australia (*www.rba.gov.au*), respectively.

Table 3.3 shows that most interventions seem to have been conducted to resist domestic currency appreciation in Korea and Japan. In terms of the intervention amount (frequency), the ratios of USD-purchasing intervention (to total interventions) are 63.8 %(69.8%) and 92.8%(90.4%) in Korea and Japan, respectively. Most interventions are to purchase USD in Japan and Korea except for the crisis periods - e.g. 1997-1998 financial crises in Japan and 2008-2009 subprime crises in Korea. This indicates that BOK and BOJ appear to more care about domestic-currency appreciation rather than depreciation in peaceful times. In contrast, most interventions in Australia were to aim for selling USD after the introduction of IT in 1993 − USD-buying interventions have not been undertaken since then.

Note that Japanese intervention patterns significantly changed from frequent/small

[27] Korea's daily intervention data is obtained from estimation of the changes in daily foreign exchange positions of the BOK and the Foreign Exchange Stabilisation Fund, with consideration of the valuation effects of FX rate changes and return from the foreign reserves. Thus, the intervention data may include BOK FX trading whose aim is not FX intervention (e.g. portfolio rebalancing). There is hence a limit on interpreting the estimation results in the case of Korea, because the data do not completely sort out non-intervention transactions.

scale to infrequent/large scale in June 1995, when Dr. Sakakibara became Director General of the International Finance Bureau of Ministry of Finance (Ito and Yabu 2007 p197). Average amount of USD-purchasing (USD-selling) intervention increased from 50.1(29.2) billion JPY to 328.6 (684.4) billion JPY between two subsample periods. During the post-Sakakibara period, BOJ conducted the largest USD-selling intervention (19.9 billion USD) on 10, April 1998 and the largest USD-purchasing intervention (13.6 billion USD) on 3, April 2000.

Table 3.3 Statistics on the types of interventions in three countries

(Unit: 100 mill. KRW, 100 mill. JPY, mill AUD)

		Purchase of USD			Sales of USD			Total intervention	
		Amount (a)	Frequency (b)	Average (a/b)	Amount (c)	Frequency (d)	Average (c/d)	Amount (a+c)	Frequency (b+d)
Korea	Whole	1,687,500	497	3,395	955,700	215	4,445	2,643,200	712
		(63.8)	(69.8)		(36.2)	(30.2)		(100.0)	(100.0)
	Pre-subprime	1,337,500	393	3,403	65,900	35	1,883	1,403,400	428
		(95.3)	(91.8)		(4.7)	(8.2)		(100.0)	(100.0)
	Post-subprime	350,000	104	3,365	889,800	180	4,943	1,239,800	284
		(28.2)	(36.6)		(71.8)	(63.4)		(100.0)	(100.0)
Japan	Whole	635,402	312	2,037	48,933	33	1,483	684,335	345
		(92.8)	(90.4)		(7.2)	(9.6)		(100.0)	(100.0)
	Pre-Sakakibara	70,126	140	501	7,872	27	292	77,998	167
		(89.9)	(83.8)		(10.1)	(16.2)		(100.0)	(100.0)
	Post-Sakakibara	562,276	172	3,286	41,061	6	6,844	606,337	178
		(93.2)	(96.6)		(6.8)	(3.4)		(100.0)	(100.0)
Australia	Whole	16,016	293	55	28,699	180	159	44,715	473
		(35.8)	(61.9)		(64.2)	(38.1)		(100.0)	(100.0)
	Pre-IT	16,016	293	55	11,325	81	140	27,341	374
		(58.6)	(78.3)		(41.4)	(21.7)		(100.0)	(100.0)
	Post-IT	0	0	0	17,373	99	175	17,373	99
		(0.0)	(0.0)	(0.0)	(100.0)	(100.0)		(100.0)	(100.0)

Note: 1. The data of Japan and Australia are official ones while those of Korea are estimated ones.
2. The figures in ( ) indicate the proportions to total interventions.
Sources: Korean Ministry of Strategy and Finance, BOK, Japanese Ministry of Finance, BOJ, RBA

Table 3.4 displays the magnitudes of market turnover and FX interventions in major countries. In terms of the absolute amount of market turnover, the size of FX market is much bigger in Japan and Australia than in Korea. However, the intervention amount (as share of market turnover) is much bigger in Korea than in Japan and Australia. For example, BOK's average USD-purchasing intervention during the sample period occupies 1.47% of daily market turnover of 2004 while USD-purchasing intervention of BOJ and RBA takes up 0.88% and 0.04%, respectively.

Table 3.4 FX interventions as share of FX market turnover

(Unit: billion USD, %)

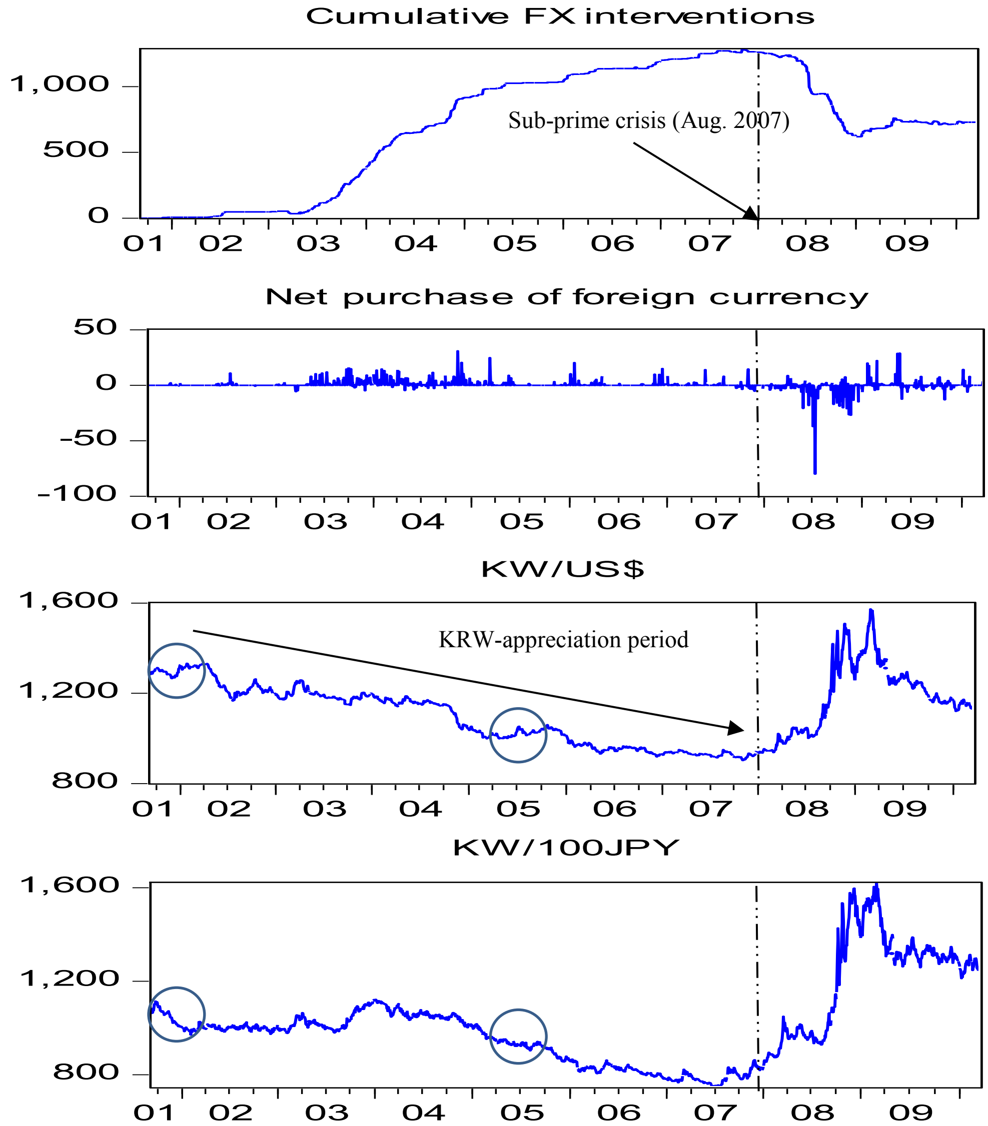
	FX market turnover[1]					FX intervention[2]	
	1998	2001	2004	2007	2010	USD-buying	USD-selling
Korea	3.56	9.81	20.53	35.24	48.32	0.3021	0.3956
	(0.17)	(0.58)	(0.99)	(0.82)	(0.96)	<1.47>	<1.93>
Australia	48.31	54.03	107.14	176.29	192.05	0.0385	0.1120
	(2.30)	(3.19)	(5.18)	(4.12)	(3.80)	<0.04>	<0.10>
Japan	146.27	152.7	207.41	250.22	312.33	1.8287	1.3314
	(6.97)	(9.03)	(10.03)	(5.84)	(6.18)	<0.88>	<0.64>
UK	685.16	541.7	835.28	1483.21	1,853.59		
	(32.64)	(32.02)	(40.38)	(34.65)	(36.66)		
US	383.36	272.58	498.64	745.20	904.36		
	(18.26)	(16.11)	(24.11)	(17.41)	(17.89)		
World total	2099.42	1691.73	2068.49	4281.1	5056.44		

Notes: 1. BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity, September, 2010.
2. Average intervention amount (denominated by domestic currency) ÷ average FX rate (domestic currency/USD) during sample periods.
3. ( ) indicates share to world total market turnover.
4. < > denotes share to FX market turnover in 2004.
Data: BIS(2010), Datastream

Figure 3.2 to 3.4 show FX rates and interventions in three countries. As expected, many observations have the value of zero during considerable periods and the interventions seem persistent. Overall, Korean and Japanese authorities seem to respond more sensitively to the domestic-currency appreciation than the depreciation while RBA appears more concerned about the domestic-currency depreciation. Figure 3.2 demonstrates nominal FX rates of KRW against USD and 100 JPY, and the amount of FXIs by Korean authorities.

KRW appreciated against both USD and JPY before the advent of sub-prime mortgage crisis in the late 2007. A large interest rate differential (especially during the early period of IT) and capital inflows (associated with rapid economic recovery and completion of capital account opening in the early 2000s) were key factors to the KRW appreciation. Except for the sub-prime crisis periods (2007M7-2010M3), most interventions were to buy USDs.

Figure 3.2 FX interventions and FX rates in Korea (2001M9-2010M3)

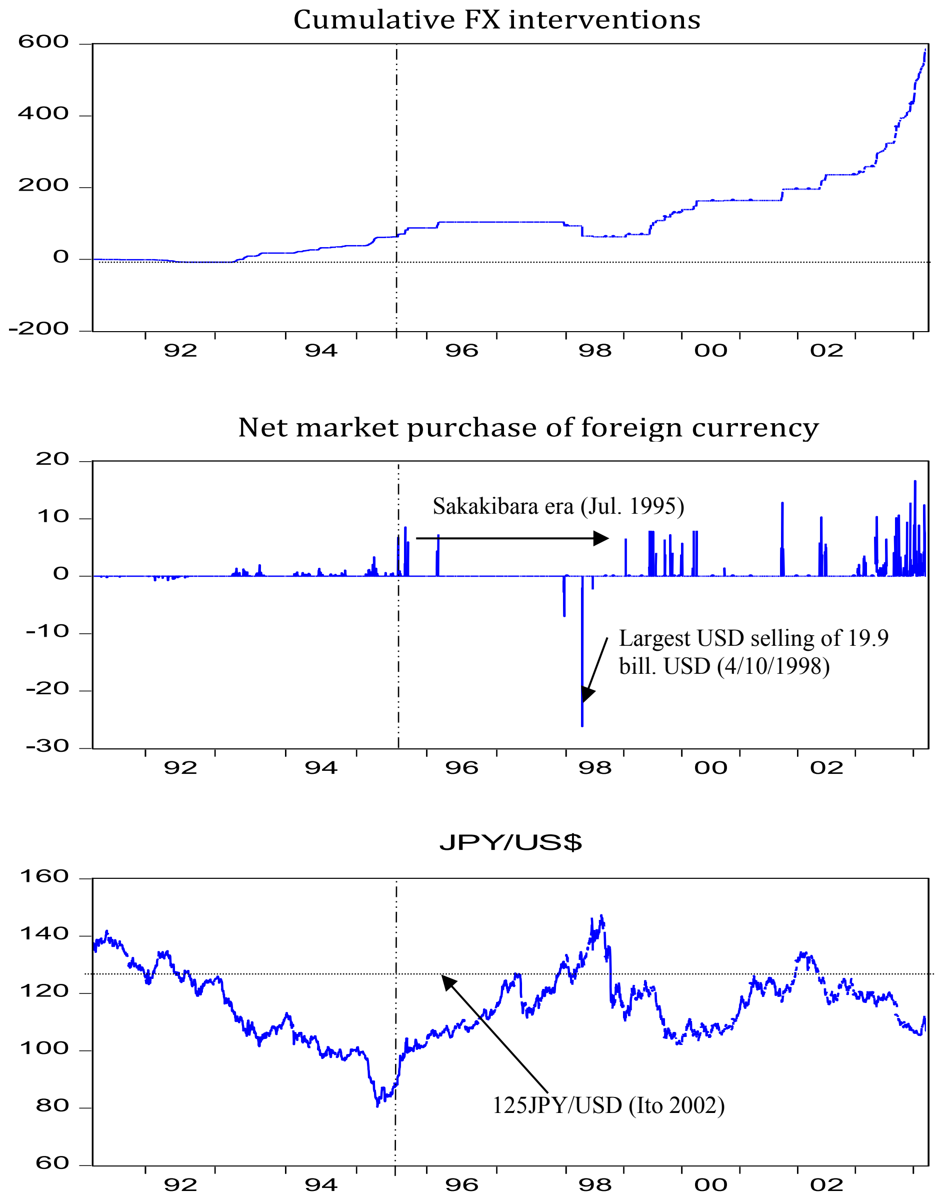


Notes: 1. Unlike Japan and Australia, Korean authorities do not officially release intervention data. The data used here are esimated from daily data on foreign exchange positions of the authorities.
2. A cumulative FXI is measured by accumulative sum of net USD purchases.
Source: BOK, and Ministry of Strategy and Finance (Unit of amount: 100 billion KRW)

Note that KRW/JPY and KRW/USD rates diverged at times. For example, KRW/JPY rates fell while KRW/USD rate rose in early 2001 and KRW/JPY rates went up while KRW/USD rates went down in 2005. Thus, it is probable that USD-purchasing interventions occur while KRW depreciated against USD but appreciated against JPY, if BOK is concerned with export competitiveness. Cumulative FXIs (measured as cumulative net purchase of USD) persistently increased before the sub-prime crisis period.

Figure 3.3 illustrates that JPY/USD fluctuated within the relatively narrow bounds of 135 and 105 for most sample period. JPY/USD rate reached its historical lows at 80.6 in April 1995 from its peak 159.7 in April 1990, and then rose up to 144JPY/USD in April 1998. Japanese intervention appears to be predominantly against the appreciation of JPY except for the period of financial turmoil in late 1997- early 1998 when BOJ intervened to support crumpling JPY.

Figure 3.3 FX interventions and FX rates in Japan (1991M4-2004M3)



Source: Japanese Ministry of Finance (unit of amount: 100 billion JPY)

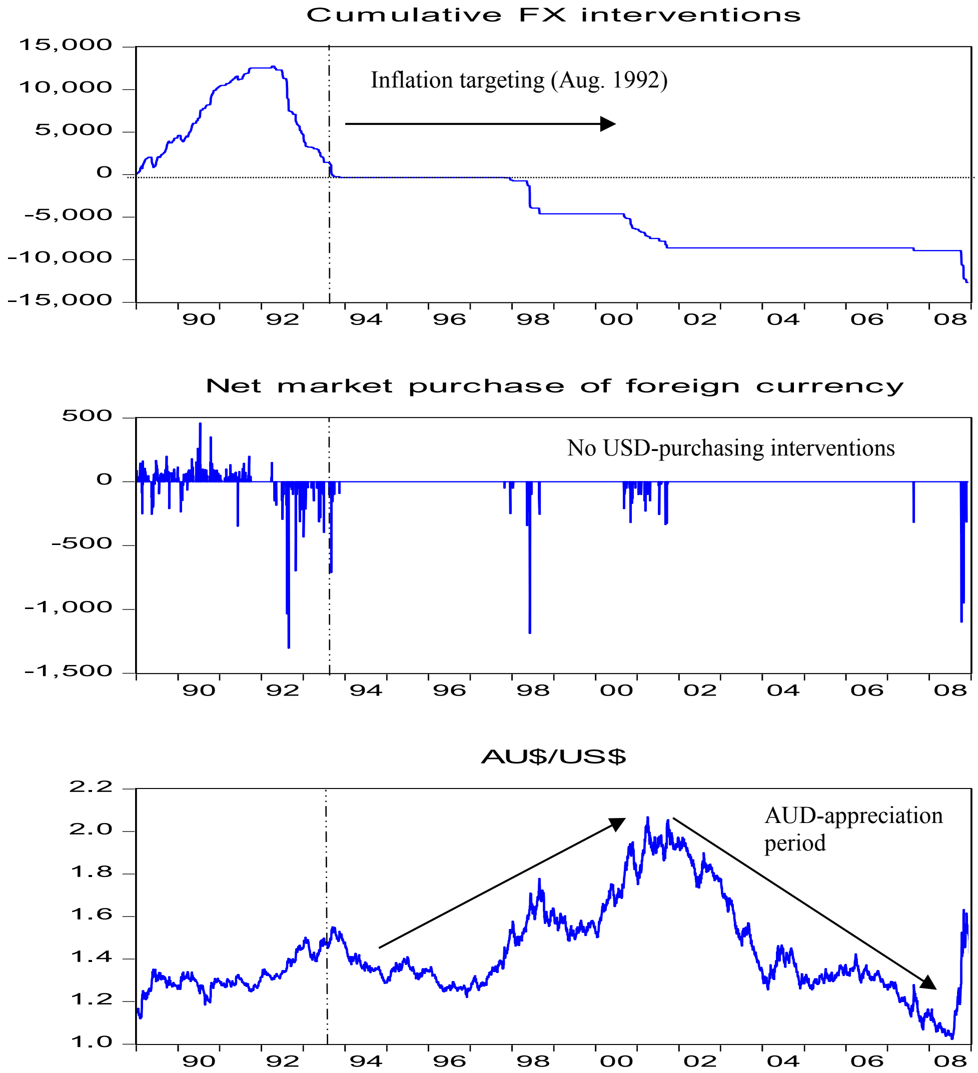
Ito (2003) and Ito and Yabu (2007) argue that BOJ sold USD (purchased JPY) when the JPY/USD rate were above 125 and purchased USD (sold JPY) when JPY/USD rates were below 125 during the 1990s. If this is the case, there will be large profit to BOJ. The plot of cumulative FXIs shows that BOJ have conducted persistent USD-buying interventions to induce the JPY-depreciation in the late-1990s and the early 2000s.

Figure 3.4 demonstrates that although AUD appreciated persistently as a KRW did in the 2000s, RBA's interventions seem significantly different from those of BOK. AUD depreciated against USD before 2001, and then continued to appreciate before sub-prime mortgage crisis in 2007-2008. However, RBA never conducted USD-purchasing interventions during the period of AUD appreciation in 2002-2007. Note that RBA's cumulative FXIs have been negative since the late 1993 as RBA increased USD-selling intervention. This may indicate that RBA seems less concern about the pressure of AUD appreciation in recent times.

Overall, RBA's interventions became less frequent after mid 1992 like those of other CBs in most advanced countries. In particular, RBA shifted intervention pattern from alteration of USD-selling and USD-purchasing to a series of less frequent USD-selling intervention − no USD-purchasing intervention after mid-1992 (Newman et al 2011, p70). This shift is ascribed to RBA's strong response to the consistent depreciation pressure in mid-1990s-early 2000s (mainly stemming from current account deficit) in line with the introduction of inflation targeting in 1993. This sharply contrasts with the Korean case where BOK mostly undertook USD-buying intervention to address the appreciation pressure.

The massive accumulations of foreign reserve in Korea and Japan are apparently ascribed to the predominance of USD-purchasing interventions while relatively slow increase in foreign reserves in Australia reflects the less frequency of USD purchasing interventions.

Figure 3.4 FX interventions and FX rates in Australia (1989M1-2008M12)



Source: RBA (unit of amount: million AUD)

3.4.2 Methodologies

Simultaneity is a typical problem we encounter when estimating intervention effects on FX level and volatility. That is, both exchange rate (dependent variable) and intervention (explanatory variable) may be endogenous, because they are determined simultaneously (Neely 2005). In this case, covariance between explanatory variables and residual is not zero, so that standard OLS may yield biased estimators. The degree of endogeneity is large particularly when we estimate intervention impacts on FX volatility, because interventions usually occur at volatile times.

To address the simultaneity problem, three methods have been suggested. Firstly, many studies consider only lagged effects of interventions and exclude the contemporaneous effects (Lewis 1995; Beine 2004). However, this approach is not satisfactory since interventions are conducted in real time during a day and the effect is very short-lived, as shown by many literatures using intra-daily data. Secondly, using dummies for persistent and large-scale interventions makes it possible to see whether the isolation of these unusual interventions can avoid the simultaneity bias (Kim and Sheen 2002, 2006, Newman et al. 2011). Third approach is to use an identification scheme that allows for estimating the model that includes contemporaneous intervention impacts (Kearns and Rigobon 2005). We mainly follow the first and the second approach to address simultaneity problems. In addition, we estimate traditional intervention profit to see whether FX interventions are profitable and thereby stabilise the FX rates. From the general conclusion drawn from the previous literature, we consider several hypotheses to be tested:

(i) FX interventions do not significantly affect FX rate level in three countries. If this is not the case, portfolio channel expects that intervention effects on FX rate level would be larger in Korea than in Japan and Australia because FX market in Korea is thinner and because Korea's interventions are based on more secrecy.

(ii) Interventions increase FX rate volatility rather than reduce it. This hypothesis is drawn from the general conclusion from the literature reviews as already seen in section 3.3.2 (see also Edison 1993, Sarno and Taylor 2001).

(iii) Interventions have more effects on short-term FX volatility rather than long-term one.

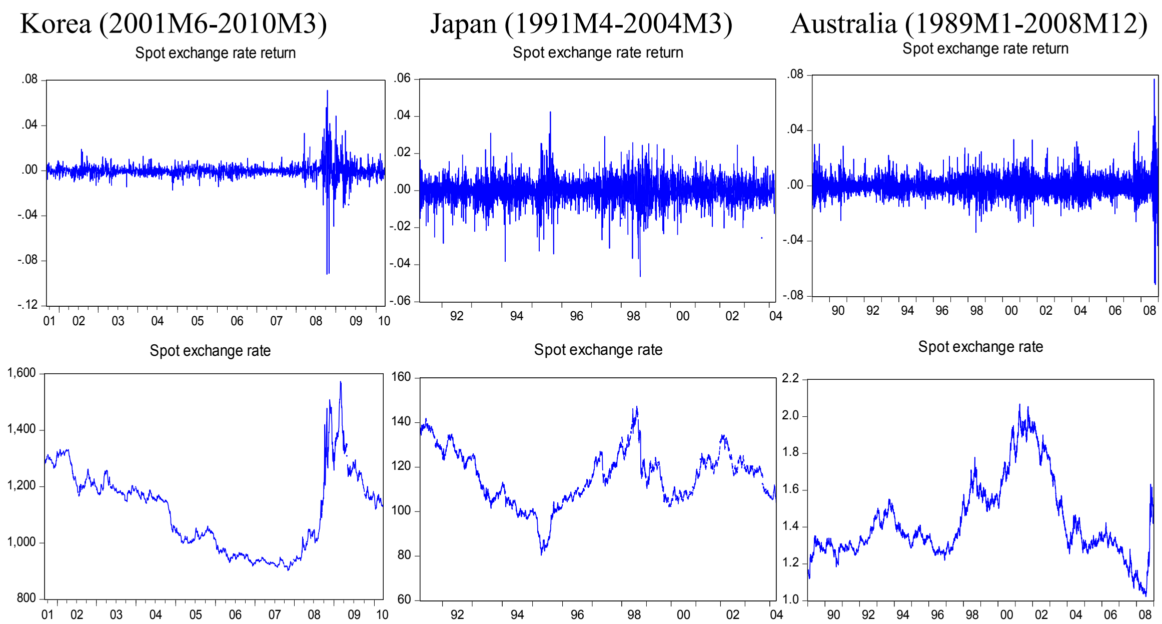
(iv) Interventions will be less profitable in emerging economies like Korea in which domestic interest rates are relatively higher than international interest rate.

We apply the ACT GARCH model with daily intervention data for Korea, Japan and Australia in order to test hypothesis (i), (ii) and (iii) and follow Ito(2003) and Becker and Sinclair(2004) methodologies to test hypothesis (iv).

3.4.2.1. Intervention effects: Asymmetric Component Threshold GARCH

Figure 3.5 shows end-day FX rates and their returns in Seoul, Tokyo and Sydney FX markets. The exchange rate returns exhibit typical volatility clustering property: large (small) changes are followed by large (small) changes. In other words, the volatility of FX rate return tends to be persistent, possibly requiring a long memory. In this case, GARCH model is considered most appropriate.

Figure 3.5 Daily FX rate returns in Korea, Japan and Australia



Data: Datastream

However, the standard GARCH model has a limit in explaining the effect of intervention on FX rate volatility. First, FX rate volatility is known to be asymmetrically affected by unexpected FX rate changes. For example, in the countries for pursuing export-driven growth, FX rate volatility tends to respond more sensitively to the domestic-currency appreciation shocks than depreciation ones. Second, standard GARCH model assumes that FX rate volatility is constant over time. However, the volatility of FX rate return has highly persistent and long memory, and long-run volatility may not be constant but time-varying (Engle and Lee 1999).

To tackle these limitations, we use an asymmetric component threshold (ACT) GARCH model suggested by Engle and Lee (1999) and applied by Guimaraes and Karacadag (2004) in intervention studies. Unlike the standard GARCH model with a constant long-term volatility, ACT-GARCH model decomposes the conditional variance into a (highly persistent long run) permanent component and a (very short-run) transitory component. The long-run component is, in general, assumed to be more persistent – equivalently, much more slowly mean reverting than the short-run one (Engle and Lee 1999 pp. 477-479). The core of this model is to allow for the mean reversion of the conditional volatility to the longer-run volatility and asymmetric responses of the conditional volatility to the unexpected exchange rate shocks. Setting up ACT-GARCH starts from the standard GARCH (1, 1) model in which a conditional variance is defined as:

(3.4.5) $$h_t = \varpi + \gamma_1(\varepsilon^2{}_{t-1} - \varpi) + \gamma_2(h_{t-1} - \varpi)$$

where h_t is the conditional variance of ε_t in the mean equation (3.3.3) $\Delta \ln S_t = \alpha + \beta \cdot INT_t + AX_{1t} + \varepsilon_t, \varepsilon_t \sim (0, \sigma^2{}_t)$: That is, $h_t = \sigma_t^2 = E(\varepsilon_t^2 \mid \Omega_{t-1})$. In standard

GARCH (1, 1) model, h_t is assumed to mean-reverts to a constant level (ϖ). Instead, we assume that h_t mean-reverts to a time-varying long-run level q_t rather than constant ϖ.

(3.4.6) $q_t = \varpi + \eta_1(q_{t-1} - w) + \eta_2(\varepsilon^2_{t-1} - h_{t-1}) = (1-\eta_1)\varpi + \eta_1 q_{t-1} + \eta_2(\varepsilon^2_{t-1} - h_{t-1})$

Then, (3.4.5) can be transformed into:

(3.4.7) $h_t - q_t = \gamma_1(\varepsilon^2{}_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1})$

Here, equation (3.4.7) is similar to (3.4.5) except that q_t replaces ϖ. The equation (3.4.6) and (3.4.7) are two components of volatility in component GARCH model.[28] ACT-GARCH model can be easily constructed by combining the component model with the asymmetric threshold ARCH model in which asymmetric effects are introduced in the transitory equation (3.4.7):

(3.4.8) $$\begin{aligned} h_t - q_t &= \gamma_1(\varepsilon^2{}_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1}) + \gamma_3(\varepsilon^2{}_{t-1} - q_{t-1})z_{t-1} \\ &= (\gamma_1 + \gamma_2 + \gamma_3 z_{t-1})(h_{t-1} - q_{t-1}) + (\gamma_1 + \gamma_3 z_{t-1})(\varepsilon^2{}_{t-1} - h_{t-1}) \end{aligned}$$

where z_t is the dummy indicating negative shocks (i.e., $z_t = 1$ if $\varepsilon_{t-1} < 0$ or $z_t = 0$, otherwise). The ACT-GARCH model consisting of (3.4.6) and (3.4.8), provides several implications: (i) Short-term transitory component $(h_t - q_t)$ mean-reverts to zero with power of $(\gamma_1 + \gamma_2 + \gamma_3 z_{t-1})$ if $0 < (\gamma_1 + \gamma_2 + \gamma_3 z_{t-1}) < 1$; (ii) The long-run permanent component(q_t) converges to the constant level(ϖ) with power of η_1, if q_t follows auto-regressive process (i.e., $0 < \eta_1 < 1$); (iii) This model assumes that $0 < (\gamma_1 + \gamma_2 + \gamma_3 z_{t-1}) < \eta_1 < 1$, which implies

---

[28] Combining the permanent volatility equation (3.4.6) and the transitory volatility equation (3.4.7) lead to:
$h_t = (1-\gamma_1-\gamma_2)(1-\eta_1)\varpi + (\gamma_1+\eta_2)\varepsilon^2_{t-1} - \{(\gamma_1\eta_1 + (\gamma_1+\gamma_2)\eta_2\}\varepsilon^2_{t-2} + (\gamma_2-\eta_2)h_{t-1} - \{(\gamma_2\eta_1 + (\gamma_1+\gamma_2)\eta_2\}h_{t-2}$
That is, the component GARCH model is a (nonlinear) restricted GARCH(2, 2) model.

that mean-reverting speed of long-run volatility component is slower than that of short-term one; (iv) $\gamma_3 > 0$ implies the existence of transitory *leverage effect*[29] in conditional volatility.

Thus, our model allows FXIs to have different effects on short-term and long-term volatility component of exchange rates. Note that, in general, "the volatility of short-term volatility is much greater than for long horizon volatility" (Engle and Lee 1999 p 476). Therefore, although the intervention effects may be the parallel movement of implied FX rate volatilities of various maturities, the magnitude of the impact is likely to be much greater for the short-term volatility. The component model enables us to examine both transitory and (relatively) permanent volatility shock caused by FXIs.

Based on the aforementioned theoretical background, our model consists of three equations: a mean equation (3.4.9) which estimates whether interventions could affect the level of FX rate return, two variance equations (3.4.10) and (3.4.11), which jointly estimate intervention effects on volatility in both short-term and long-term horizon. We include the same exogenous variables in both mean equation and two variance equations. Based on the previous studies, we consider the possibility that interventions, interest rate differential and country risk premium affect the FX rates. To avoid the downward bias caused by simultaneity problem, we include dummies for cumulative and large-sized interventions in both mean and variance equations, following Kim and Sheen (2002, 2006). Holiday or weekend effects are not considered because inclusion of dummies for the day of the week and holiday effect in variance equation may lead to degenerated likelihood surface (Doornik and Ooms 2003). We estimate effects of USD purchases and USD sales separately to see the asymmetric effects of

[29] Leverage effect indicates the asymmetric responses of market volatility to price shocks. For example, in stock markets, the volatility of stock return tends to increase more by "bad" news(negative shocks) than by "good" news(positive shocks). Likewise, if $\gamma_3 > 0$, the impact of the unexpected domestic currency appreciation ($\varepsilon_t < 0$) on the short-term volatility component ($\gamma_1 + \gamma_3$) is greater than the impact of the unexpected depreciation (γ_1)

FXIs more closely.

(3.4.9) mean equation:

$$\Delta S_t = \beta_0 + (\beta_B + \beta_{B,PERSD} PERSD_t^{\ B} + \beta_{B,SIZED} SIZED_t^{\ B}) INT_t^B$$
$$+ (\beta_S + \beta_{S,PERSD} PERSD_t^{\ S} + \beta_{S,SIZED} SIZED_t^{\ S}) INT_t^S + \beta_{diff} \Delta DIFF_t + \beta_{cds} \Delta CDS_t + \beta_{stock} \Delta STOCK_t + \varepsilon_t$$

where

ΔS_t : Log difference of end-of-the day spot FX rate (domestic currency price of USD) times 100

INT_t^B : Net purchase of USD by BOK (BOJ, RBA), which represents (average) one-off interventions in 1 trill. KRW (1 trill. JPY, 1 bill. AUD)

INT_t^S : Net sales of USD by BOK (BOJ, RBA) in 1 trill. KRW (1 trill. JPY, 1 bill. AUD)

$PERSD_t$: Intervention persistency dummy ($PERSD_t=1$ if the intervention at day t is preceded by the interventions in the same direction at day $t-1$ and $t-2$, and $PERSD_t=0$ otherwise), which represents the intensity of the successive interventions (Kim and Sheen 2006).

$SIZED_t$: Intervention size dummy ($SIZED_t=1$ if the amount of intervention at day t is larger than the whole sample average of daily net market purchase of USD (equivalent to 340 bill. KRW; 204 bill. JPY; 55 mill. AUD) or net market sales of USD (equivalent to 445 bill. KRW; 148 bill. JPY; 159 mill. AUD), and $SIZED_t=0$ otherwise), which represents large-scale interventions. (Kim and Sheen 2006)

$DIFF_{t-1}$: O/N interest rate differential (domestic minus US fed fund rate, percent per annum)

CDS_{t-1} : Credit default swap premium for 5 year Korean Treasury Bond (unit: basis point) available since September 2001 for Korea; proxy for country risk (Guimaraes and Karacadag 2004)

$\Delta STOCK_{t-1}$: Log difference of closing stock price (KOSPI, NIKKEI 225, S&P/ASX 200) times 100; proxy for the shock from asset markets(Bonser-Neal and Tanner 1996) or for portfolio investments

$\varepsilon_t \sim (0, \sigma^2{}_t)$: Error term to indicate the unexpected change in the exchange rate return

Since most interventions are conducted during trading time in all three countries, the use of end-of-day spot rate contribute to avoiding simultaneity problems. Note, however, that this method also has limits because it does not reflect the intra-daily effect of interventions and the effects of oral interventions that frequently occur after trading time. Dummy variables ($PERSD_t$ and $SIZED_t$) are included because successive or massive interventions may be considered as more credible by market participants and thus have more effects on FX rate level and volatility than one-off or usual ones, (Ito 2002, Kim and Sheen 2002, Lecourt and Raymond 2006, Newman et al. 2011). Hence, it is probable that the coefficients of one-off interventions are not significant while massive or persistent interventions are significant (Ito 2003, Lecourt and Raymond 2006). Portfolio model predicts that larger interventions would be more effective than average one-off interventions while signalling channel expects that persistent interventions are likely to have stronger effects than one-off interventions, other things being equal (Kim and Sheen 2002 p 629).

However, if interventions are inconsistent with monetary policy, it may be possible that a first or one-off intervention is significant but subsequent or persistent interventions are not significant (Dominguez 2003a). In general, expected signs of β_B , $\beta_{B,SIZED}$ and $\beta_{B,PERSD}$ are positive while β_S , $\beta_{S,SIZED}$ and $\beta_{S,PERSD}$ are negative under '*leaning-against-the-wind*.' If aforementioned coefficients have opposite signs, it implies that the CBs may *lean with the wind*. That is, the CBs wish current trends of exchange rate movement to be continued or strengthened. However, this is probably not the case in our sample. For example, Figure 3.2 shows that most USD-selling interventions occurred during the US-subprime crisis in Korea, when the CBs had to stop rapid depreciation of KRW – that is, 'lean against the wind.'

β_{diff} estimates possible impact of the changes in policy interest rate or OMOs on FX rate. For example, a rise in exogenous US policy interest rate and resultant decrease in interest rate differential may lead to an excessive overshooting(i.e. depreciation of domestic currency). β_{cds} measures the impacts of country risk and β_{stock} reflects the impact of shocks from asset markets on FX rates. Prior expected sign of β_{diff} and β_{cds} may be negative and positive, respectively, because a larger interest rate differential and lower country risk appreciate the domestic currency.

In (3.4.10), the *conditional* variance of daily exchange rate return(h_t) is explained as a function of a time-varying long-run variance(q_t), unexpected shocks relative to long-run variance in the previous period($\varepsilon_{t-1}^2 - q_{t-1}$), transitory variance component (in the previous period) measured by the deviation of a conditional variance from long-term trend ($h_{t-1} - q_{t-1}$), interventions(INT_t^B and INT_t^s), interest rate differential($DIFF_t$), country risk(CDS_t) and stock price changes($\Delta STOCK_t$).

(3.4.10) short-run variance equation:

$$
\begin{aligned}
h_t &= q_t + \gamma_1(\varepsilon^2{}_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1}) + \gamma_3(\varepsilon_{t-1}^2 - q_{t-1})z_{t-1} \\
&\quad + (\lambda_B + \lambda_{B,PERSD} PERSD_t{}^B + \lambda_{B,SIZED} SIZED_t{}^B) INT_t{}^B \\
&\quad + (\lambda_S + \lambda_{S,PERSD} PERSD_t{}^S + \lambda_{S,SIZED} SIZED_t{}^s) INT_t^s \\
&\quad + \lambda_{diff} \Delta DIFF_t + \lambda_{cds} \Delta CDS_t + \lambda_{stock} \Delta STOCK_t
\end{aligned}
$$

where z_t is a dummy indicating negative shocks (i.e. unexpected FX rate appreciations), that is, $z_t = 1$, when $\varepsilon_t < 0$, and $z_t = 0$ otherwise. In this component volatility model, an additional specification like (3.4.11) is needed to represent how time-varying long-term volatility (q_t) is determined.

(3.4.11) Long-run variance equation:

$$
\begin{aligned}
q_t &= \varpi + \eta_1(q_{t-1} - \varpi) + \eta_2(\varepsilon_{t-1}^2 - h_{t-1})_t \\
&\quad + (\psi_B + \psi_{B,PERSD} PERSD_t{}^B + \psi_{B,SIZED} SIZED_t{}^B) INT_t{}^B \\
&\quad + (\psi_S + \psi_{S,PERSD} PERSD_t{}^S + \psi_{S,SIZED} SIZED_t{}^s) INT_t^s \\
&\quad + \psi_{diff} \Delta DIFF_t + \psi_{cds} \Delta CDS_t + \psi_{stock} \Delta STOCK_t
\end{aligned}
$$

In particular, q_t depends on interventions, interest rate differential ($DIFF_t$), country risk (CDS_t), stock price changes ($\Delta STOCK_t$), its own lag (q_{t-1}) and past unexpected shock (ε_{t-1}^2). Here, q_t is allowed to evolve slowly in an autoregressive manner and converges to a constant mean (ϖ) while short-term volatility does not.

3.4.2.2 Profitability of FX interventions

The measurements of intervention profits are sensitive to the choice of sample period, end-of-sample FX rate, interest-rate differentials or whether profits are adjusted for risk. In this section, we follow a similar procedure used by Becker and Sinclair (2004) and Ito (2003). We assume that (i) an initial intervention position in the first date of the sample contains no assets and no liabilities of either currency as in Leahy (1995); (ii) we use daily average FX rates as the price applied to all intervention transactions during that day; and (iii) all foreign assets consist of USD-denominated ones; (iv) transaction costs (e.g. bid-ask spreads) are not considered. In addition, we do not account for the compound calculation of interest rates and risk adjustments as in Leahy (1995) and Becker and Sinclair (2004). Total profits (Π_t) measured in domestic currency, are calculated as the sum of realised trading profits (or capital gain)(Π_t^{rp}), unrealised trading profits(Π_t^{up}) and net interest earning (or realised carry cost)(Π_t^{ni}), at any point of time:

$$(3.4.12)\quad \Pi_t = \Pi_t^{rp} + \Pi_t^{up} + \Pi_t^{ni} = \sum_{i=1}^{t} m_i(e_i - s_i) + \sum_{i=1}^{t}(v_i - m_i)(e_i - s_i) + \sum_{i=1}^{t} e_i(r_i^f - r_i^d)\sum_{j=1}^{i}(v_j - m_j)$$

where: m_i is the reduction in an existing USD position, with $m_i > 0$ for sales of USD in a long position, and $m_i < 0$ for purchases of USD in a short position;

v_i is the addition to an existing USD position, with $v_i > 0$ for purchases of USD in a long position, and $v_i < 0$ for sales of USD in a short position;

e_i is the FX rate at which a transaction is made (domestic currency per a USD);

s_i is the weighted average FX rate at which the position is acquired; For period t, s_i is calculated as: $s_t = \left[s_{t-1} \sum_{j=1}^{t-1} (v_j - m_j) + v_t e_t \right] \div \left[\sum_{j=1}^{t-1} (v_j - m_j) + v_t \right]$

r_i^f and r_i^d are O/N domestic interest rate (i.e. unsecured call interest rate in Korea and Japan and cash rate in Australian) and US federal fund rate.

In words, Π_t^{rp} is calculated by comparing the FX rate(e_t) at which USD is bought/sold to close out a position with the average FX rate(S_t) at which the position was acquired.Note that as a CB continues to buy (sell) USD assets, the average FX rate at which its long(short) position has been acquired is recalculated. Thus, S_t can be interpreted as an average purchasing (selling) price.

Π_t^{rp} is realised only when USD long (short) position is reversed by selling (buying) USD(i.e., when $\Delta m_t \neq 0$). Π_t^{up} is the unrealised capital gain on the remaining open USD position(v_t) at the end of the period, and calculated by comparing average cost of establishing that position and the mark-to-market value of the position at the end the sample period. Π_t^{ni} is the profit (loss) stemming from the difference in interest income from holding USD assets (liabilities) and interest payments of maintaining the equivalent domestic currency liabilities (assets), summed up over the sample period.

3.5 Estimation results

3.5.1 Impacts of interventions: ACT-GARCH model

We conduct the unit root test for the variables included in ACT-GARCH. As seen in Table 3.5 intervention amounts (*INT, INT_s, INT_b*), FX rate deviation from its trend (*FXDEV*) and stock price change *(ΔSTOCK*) are I(0) while interest rate differential (*DIFF*) and CDS premium (*CDS*) are I (1) in three countries. Among the variables used only for Korea, *MSB* are I(1) whereas foreigners' net purchase of Korean stock(*NBUY*) is I(0). Thus, we use the first differences of *DIFF, CDS*, *MSB* and *STOCK,* and the levels of *INT, INT^s, INT^b, FXDEV* and *NBUY*.

Table 3.5 ADF unit root tests for intervention variables

	Korea		Australia		Japan	
	statistics	p-value	statistics	p-value	statistics	p-value
INT	-10.279	0.0000	-13.4081	0.0000	-17.317	0.0000
INT_b	-7.6644	0.0000	-10.4056	0.0000	-16.848	0.0000
INT_s	-9.1843	0.0000	-13.8492	0.0000	-55.159	0.0001
FXDEV	-2.3362	0.0189	-4.2389	0.0006	-3.4996	0.0081
DIFF	-1.3461	0.8758	-0.8656	0.9581	-0.2622	0.9917
CDS	-2.4128	0.1383	-1.0903	0.7216	-2.9257	0.1558
Δ*STOCK*	-45.5565	0.0001	-72.3719	0.0001	-61.2098	0.0001
MSB	-1.2578	0.8972	-	-	-	-
NBUY	-12.202	0.0000	-	-	-	-

Notes: 1. An intercept is included in testing FXEDV and NBUY. Both intercept and trend term are included for DIFF, MSB, STOCK and CDS; Both intercept and trends are not included in testing INT, INT_b and INT_s.
2. The number of lags is determined by SIC
3. CDS premium of Australia and Japan are only available for sub-periods (2/1/2003- 31/12/2008 for Australia and 6/1/2003-31/4/2004 for Japan)

Here, we assume that the intervention is effective when (i) USD-selling (USD-purchasing) interventions lead to the domestic-currency appreciation (depreciation) or (ii) interventions reduce FX volatility. We estimate ACT-GARCH model in two ways in order to investigate whether the model with considering the persistency and magnitude of intervention provides different estimation result from the model without them. Model 1 does not consider the size and persistence of interventions while model 2 does.

The estimated models are, in general, appropriate for most periods in that all specifications pass diagnostic tests that are presented in the estimation result. In a few models (e.g. model 2 for Korea during the post-subprime period), we cannot reject autocorrelation at 10% significant level. However, this may not be critical issues for the inference because the residuals are all not serially correlated at typical significant level (5%) and because we use Bollerslev-Wooldridge (1992)'s robust standard errors and covariance.

3.5.1.1 Korea

3.5.1.1(a) Impacts on FX rate level

The estimation results are presented in Table 3.6(a), 3.6(b) and 3.6(c)[30]. Model 2 appears to provide more detailed information about intervention effects than model 1. First, model 1 suggests that BOK interventions do not significantly affect FX rate level regardless of sample periods while model 2 suggests that *large* interventions significantly influence the FX rate level. In model 1, all coefficients on interventions are insignificant for all periods. In model 2 for the whole period, estimated β_B(–0.045) and β_s(=0.073) are significant but wrongly signed while $\beta_{B,SIZED}$ (=0.039) and $\beta_{S,SIZED}$ (= –0.095) are significant and rightly signed. This indicates that one-off average purchasing (selling) interventions are not effective, but *large-scale* USD-purchasing (selling) ones have significant effects on depreciating (appreciating) KRW.

However, both $\beta_{B,SIZED}$ and $\beta_{S,SIZED}$ (although statistically significant), appear economically trivial, because the results indicate that a large-scale purchase(sales) of USD equivalent to 1 trillion KRW leads to a rise (a fall) in KRW/USD rate by 0.039%(0.095%). Considering average amount of interventions (approximately 340 billion KRW for USD-

[30]Three tables are part of a big table that shows the results of ACT-GARCH model. Thus, the information regarding the sample size and diagnostics are coming up in the final part of Table 3.6(c).

purchasing and 445 billion KRW for USD-selling, respectively; see Table 3.3) and daily average standard deviation of KRW/USD rate movement (0.7% for the entire sample period, see Appendix 3.2(b)), the effect of both interventions may be too much small.

Second, relatively infrequent USD-selling interventions may be effective but frequent USD-purchasing interventions may not. USD-selling interventions are significant and rightly signed in all periods once they are either large or persistent. See $\beta_{S,SIZED}$(= –0.095) for the whole period, $\beta_{S,PERSD}$(= –0.124) for the pre-subprime period and $\beta_{S,SIZED}$(= –0.068) for the post-subprime period. Overall, infrequent interventions (but are persistent or large once they occur) may have more significant effects than frequent and usual ones. Intervention effects look more prominent in USD-selling interventions that have been carried out less frequently (but more intensively) than USD-purchasing interventions.

Third, country risk significantly affects FX rate level particularly for crisis period in Korea as does in other small open emerging countries (see Guimaraes and Karacadag (2004) for the case of Mexico and Turkey). Model 2 suggests that 1 basis point increase in CDS spread depreciates KRW against USD by 0.016% during the post-subprime period. Because foreigners' share in Korean stock market has maintained around 30-40%[31] during the entire sample period − highest in Asia, it appears that volatile short-term portfolio investments (which are sensitive to changes in country risk) play a crucial role in FX rate movements. This somewhat contrasts with Japan and Australia in which country risk is relatively more stable, so that it is less influential in FX rate movements.[32]

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[31] Foreigners' share in total market value of all-listed Korean equities has increased since the limit on foreigners' investments was completely lifted in 2000: 19.6%(1998)→30.1%(2000)→ 36.0%(2002)→42.0%(2004)→37.3%(2006)→29.4%(2010M11) (source: Korea Exchange - http://eng.krx.co.kr). The survey on foreigners' share in stock market among 33 countries shows that the foreigners' share is the highest in Korea among emerging countries as of the end of 2006 (Korean Financial Service Commission 2007)

[32] When we estimate mean equations with CDS spreads for the sub-periods (2/1/2003-31/12/2008 for Australia and 6/1/2003-31/4/2004 for Japan), the coefficients on CDS are insignificant in both countries. β_{cds} is 0.0042 with p-value 0.5212 in case of Japan and β_{cds} is 0.0092 with p-value 0.6874 in case of Australia.

Fourth, interest rate differential appears not to influence FX rate level in Korea as in Australia and Japan, indicating that monetary channel may not work or that there is little possibility of overshooting on a daily basis. This result appears consistent with several previous studies on the relationship between short-term interest rate and FX rates. For example, Ehrmann and Fratzscher (2005) find that the change in policy interest rates by the BOE, the Fed and the ECB do not influence FX rates. Jansen and de Haan (2007) also report that the ECB's statements of raising policy interest rate lead to a slight depreciation of euro, contrary to the standard monetary theory. The weak relationship between interest rate differential and FX rates may be because monetary policies deeply synchronized and because policy interest rates remained at a low level in major countries with international financial markets rapidly integrated during the last decade. However, our evidence may have limitations, because it considers only short-term (daily-based) impact of interest rate differential on FX rates. Intuitively, sustained large interest rate differential could encourage portfolio investments to move from low-interest-rate to high-interest-rate country, and thereby influence the FX rates.

Fifth, stock price changes do not have economically significant effect on FX rates level. Model 2 suggests that β_{stock} is insignificant in all periods. According to Model 1 for the entire period, β_{stock} (=0.00058) is statistically significant but economically trivial, because the coefficient indicates that 1% increase in stock price lead to the depreciation of KRW by 0.0006%.[33]

[33] As for the relationship between FX rates and stock price, previous studies have provided mixed results. Granger et al. (2000)'s work for Asian countries support the bivariate causality between two while Ajayi and Mougoue (1996)'s study for 8 advanced economies suggest that stock price increases cause the depreciation of domestic currency especially in the U.S. and the U.K. Ajayi and Mougoue (1996) interpret the results as follows: stock price ↑→ expectation on expanding economy ↑→ expected inflation ↑→ value of domestic currency ↓. In contrast, the positive relationship between stock price and FX rate is interpreted as follows: stock price ↑→ expectation on expanding economy ↑→ capital inflows ↑→ value of domestic currency ↑.

Table 3.6(a) Mean equation of ACT – GARCH: Korea

$$\Delta S_t = \beta_0 + (\beta_B + \beta_{B,PERSD} PERSD_t^{\,B} + \beta_{B,SIZED} SIZED_t^{\,B}) INT_t^{\,B} + (\beta_S + \beta_{S,PERSD} PERSD_t^{\,S} + \beta_{S,SIZED} SIZED_t^{\,S}) INT_t^{\,S} + \beta_{diff} \Delta DIFF_t + \beta_{cds} \Delta CDS_t + \beta_{stock} \Delta STOCK_t + \varepsilon_t$$

	sign	Whole sample(10/9/2001-23/3/2010)				Pre-subprime(10/9/2001-31/7/2007)				Post-subprime(1/8/2007-23/3/2010)			
		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant (β_0)		-0.02656***	0.0050	0.00167	0.8974	-0.03468***	0.0025	-0.02336***	0.0070	-0.03189*	0.0670	0.00713	0.6600
(ii)USD-purchasing intervention													
• One-off (β_B)	(+)	0.00117	0.8170	-0.04536***	0.0042	0.00090	0.8506	-0.03505**	0.0117	0.00809	0.2118	-0.01917	0.5456
• Persistent ($\beta_{B,PERSD}$)	(+)			0.00683	0.6627			-0.00731	0.2225			-0.02563	0.1350
• Large-scale ($\beta_{B,SIZED}$)	(+)			0.03901**	0.0131			0.04168***	0.0025			0.02793	0.3816
(iii)USD-selling intervention													
• One-off (β_S)	(-)	-0.00156	0.7868	0.07287**	0.0399	-0.00655	0.7926	0.04462	0.1855	-0.00073	0.8660	0.05967***	0.0074
• Persistent ($\beta_{S,PERSDD}$)	(-)			0.02161	0.3882			-0.12423***	0.0010			-0.00931	0.2968
• Large-scale ($\beta_{S,SIZED}$)	(-)			-0.09489***	0.0083			0.00156	0.9732			-0.06801***	0.0032
(iv) Interest differential(β_{diff})	(-)	0.11807	0.1259	0.19159	0.3121	0.17493*	0.0846	0.13774	0.1519	-0.08917	0.1268	-0.11466	0.3810
(v) CDS spread (β_{cds})	(+)	0.00315	0.2066	0.01709*	0.0568	0.00132	0.6608	0.00225	0.1170	0.01407*	0.0957	0.01577**	0.0165
(vi) Stock price (β_{stock})		0.00058**	0.0487	-0.00507	0.4991	0.00155	0.8051	-0.00533	0.3806	0.00862*	0.0599	0.00217	0.8454

Notes: 1. ***, ** and * denotes significant at 1%, 5% and 10% level, respectively.
2. The coefficients on interventions in mean equation give the impact of the intervention of purchasing (selling) USD equivalent to 1 trill.KRW.
3. Signs of coefficients indicate the prior expectation when the intervention is effective in leaning against the wind.
4. Bollerslev-Wooldridge robust standard errors and covariances are used.

3.5.1.1(b) Impacts on FX rate volatility

Table 3.6(b) and 3.6(c) present the estimation of two variance equations. In Table 3.6(b), the coefficient η_1 (that is close to 1) shows the persistence of long-term volatility components as this model expects. Overall, interventions appear not to influence the long-term volatility irrespective of model specification and sample periods concerned. All coefficients of interventions (ψ_{B}, $\psi_{B,PERSD}$, $\psi_{B,SIZED}$, ψ_{S}, $\psi_{S,PERSD}$, $\psi_{S,SIZED}$) are insignificant regardless of models, so that the long-term volatility components appears to be affected by non-intervention factors like economic fundamentals. Model 2 suggests that CDS spread increases long-term volatility components, indicating a consistent effect of country risk on long-term volatility: ψ_{cds} is significant in all periods in 3.6(b), implying that a rise in CDS spread increases long-term volatility.

Table 3.6(c) shows the factors affecting short-term FX volatility. Comparing Table 3.6(b) and 3.6(c), we can find that $(\gamma_1+\gamma_2)<\eta_1$, $\gamma_1>\eta_2$ and $0<(\gamma_1+\gamma_2+\gamma_3 z_{t-1})<\eta_1<1$, indicating that mean-reverting speed of long-run volatility is slower than that of short-term one. These results show that this model reflects higher persistence of long-term volatility than short-term volatility. Model 1 suggests that most interventions do not have significant effects on short-term volatility: λ_B and λ_S are insignificant in all periods, implying that one-off average interventions are not effective. Model 2, however, suggests that interventions possibly have an effect on reducing volatility in short-term perspective. For example, $\lambda_{B,SIZED}$ (=− 0.005)is significant at 5% level for the pre-subprime period, indicating large-scale USD-purchasing interventions reduce short-term volatility in peaceful times.

Table 3.6(b) Long-term variance equation of A CT–GARCH: Korea

$$q_t = \varpi + \eta_1(q_{t-1} - \varpi) + \eta_2(\varepsilon_{t-1}^2 - h_{t-1}) + (\psi_B + \psi_{B,PERSD} PERSD_t^B + \psi_{B,SIZED} SIZED_t^B) INT_t^B$$
$$+ (\psi_S + \psi_{S,PERSD} PERSD_t^S + \psi_{S,SIZED} SIZED_t^s) INT_t^s + \psi_{diff} \Delta DIFF_t + \psi_{cds} \Delta CDS_t + \psi_{stock} \Delta STOCK_t$$

	Whole sample(10/9/2001-23/3/2010)				Pre-subprime(10/9/2001-31/7/2007)				Post-subprime(1/8/2007-23/3/2010)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant(ω)	0.20196***	0.0005	0.44130***	0.0000	0.12673***	0.0000	0.11169***	0.0000	0.36868***	0.0008	0.41819**	0.0460
(ii) Own lag(η_1)	0.97609***	0.0000	0.83016***	0.0000	0.94445***	0.0000	0.86045***	0.0000	0.88315***	0.0000	0.97148***	0.0000
(iii) Unexpected shocks (η_2)	0.10464***	0.0000	0.04996***	0.0000	0.05921	0.8105	0.32520	0.7609	0.16539**	0.0176	0.14667	0.2056
(iv) USD-Purchasing intervention												
• One-off (ψ_B)	0.00083	0.2814	0.03632	0.5632	0.02208	0.3331	0.02623	0.7681	0.01241	0.2476	0.03086	0.2799
• Persistent($\psi_{B,PERSD}$)			-0.02744	0.7358			-0.00210	0.9328			-0.04368	0.5534
• Large-scale ($\psi_{B,SIZED}$)			-0.00251	0.9205			-0.00297	0.9459			-0.00481	0.8570
(v) USD-Selling intervention												
• One-off (ψ_S)	0.00111	0.4328	0.00293	0.7799	-0.14081	0.4327	0.01225	0.9297	-0.00198	0.4408	0.00846	0.6796
• Persistent ($\psi_{S,PERSD}$)			0.00292	0.6817			-0.01047	0.9609			-0.02621	0.1923
• Large-scale ($\psi_{S,SIZED}$)			0.00335	0.6789			0.11402	0.8005			0.01101	0.5988
(vi) Interest differential(ψ_{diff})	0.01243	0.7173	-0.01080	0.8891	-0.01531	0.9787	-0.31632	0.8141	-0.31849***	0.0015	-0.10397	0.6825
(vii) CDS spread (ψ_{cds})	0.00042	0.7139	0.00060*	0.0991	-0.00252	0.3092	0.00167**	0.0237	0.00076	0.8935	0.00011*	0.0995
(vii) Stock price(ψ_{stock})	-0.00325	0.1768	-0.00058	0.9876	-0.00995	0.7766	-0.07381	0.8005	-0.03698***	0.0100	-0.01978	0.1689

Table 3.6(c) Short-term variance equation of ACT–GARCH: Korea

$$h_t = q_t + \gamma_1(\varepsilon^2_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1}) + \gamma_3(\varepsilon^2_{t-1} - q_{t-1})z_{t-1} + (\lambda_B + \lambda_{B,PERSD} PERSD_t^{B} + \lambda_{B,SIZED} SIZED_t^{B}) INT_t^{B}$$
$$+ (\lambda_S + \lambda_{S,PERSD} PERSD_t^{S} + \lambda_{S,SIZED} SIZED_t^{s}) INT_t^{s} + \lambda_{diff} \Delta DIFF_t + \lambda_{cds} \Delta CDS_t + \lambda_{stock} \Delta STOCK_t$$

	Whole sample(10/9/2001-23/3/2010)				Pre-subprime(10/9/2001-31/7/2007)				Post-subprime(1/8/2007-23/3/2010)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Unexpected shocks(γ_1)	0.12575	0.3247	0.11325**	0.0496	0.06531	0.1005	0.16371	0.1532	0.01095**	0.0458	0.18703*	0.0589
(ii) Deviation from its long-run component(γ_2)	0.83421***	0.0000	0.67555	0.1482	0.80056***	0.0008	0.48894***	0.0019	0.16370*	0.0569	0.70863	0.5383
(iii) Negative shock (γ_3)	0.08728**	0.0472	0.16607*	0.0721	0.07551*	0.0580	0.23111*	0.0095	0.17020	0.4332	0.02336	0.7363
(iv) USD-Purchasing												
• One-off (λ_B)	-0.00146	0.6215	0.00186*	0.0522	-0.02284	0.3187	0.01478*	0.0691	-0.02192*	0.0987	-0.00379	0.9221
• Persistent ($\lambda_{B,PERSD}$)			-0.03062	0.6268			-0.00673	0.1860			-0.03549	0.6454
• Large-scale ($\lambda_{B,SIZED}$)			-0.00199*	0.0738			-0.00520**	0.0243			-0.00125	0.9591
(v) USD-selling												
• One-off (λ_S)	0.00330	0.4398	0.00511	0.8822	0.14140	0.4413	-0.02248	0.8767	-0.00316	0.4152	0.01666	0.4600
• Persistent ($\lambda_{S,PERSD}$)			0.00791	0.7537			-0.04815	0.8177			0.01039	0.6392
• Large-scale ($\lambda_{S,SIZED}$)			0.00381	0.3768			-0.10847	0.8117			-0.03324	0.1517
(vi) Interest differential(λ_{diff})	-0.00579	0.2212	-0.00812	0.3385	-0.04294	0.9402	0.30080	0.3231	0.14487	0.2032	0.01461	0.9563
(vii) CDS spread (λ_{cds})	0.00510*	0.0842	0.00045*	0.0936	0.00266	0.2790	0.00410*	0.0731	0.00795	0.1983	0.00649*	0.0634
(viii) Stock price (λ_{stock})	0.00131	0.6592	0.00145	0.9713	0.00385	0.9137	0.07444	0.7990	0.02754*	0.0616	0.00916	0.5264
Diagnostics												
• Skewness	0.116		0.226		-0.001		-0.019		0.087		0.327	
• Kurtosis	4.591		8.844		3.891		4.120		5.727		5.082	
• Q(15)	19.925	0.133	19.624	0.187	17.276	0.242	23.162*	0.075	17.693	0.221	24.712*	0.054
• $Q^2(15)$	9.244	0.815	12.461	0.132	11.873	0.616	23.837*	0.068	11.475	0.648	21.706*	0.078
• ARCH-LM test	9.316	0.860	13.277	0.580	10.686	0.775	22.038	0.107	10.832	0.764	23.986*	0.052
no. of observations	2121				1461				660			

Notes: 1. When the coefficient of the negative shock is positive (i.e. γ_3>0), an impact of the unexpected domestic currency appreciation (ε_t<0) on the short-term volatility component ($\gamma_1 + \gamma_3$) is greater than the impact of the unexpected depreciation (γ_1).
2. Q(Q^2) is the modified Ljung-Box's Q statistics for testing the null of no autocorrelation up to 15 lags for the standardised(squared standardized) residual.
3. ARCH LM test is the heteroskedasticity test with the null hypothesis that there are no remaining ARCH effects in the residual up to the number of lags in ( ).

As for the effects of USD-selling interventions (which mostly occurred during crisis periods in Korea), both models suggest that the interventions seem futile in reducing the short-term volatility in all periods. In Table 3.6(c), λ_S, $\lambda_{S,PERSD}$ and $\lambda_{S,SIZED}$ are all insignificant or positive. It may be inferred that the USD-selling interventions in small open economy (like Korea) may not stabilise short-term FX rate volatility in crises period due to the credibility problem of the USD-selling interventions. That is, USD-selling interventions are likely to be limited in terms of feasibility due to the loss of foreign reserves. This "fear of losing foreign reserves" may keep the CBs in small open economies from reacting strongly to the depreciation pressure (Aizenman and Yi 2009). In both model 1 and model 2, $\gamma_3 > 0$ for the pre-subprime period implies the existence of transitory *leverage effect* in conditional short-term variance in the non-crisis period. Hence, the impacts of unexpected appreciations on the short-term FX rate volatility appear larger than unexpected depreciation, suggesting that the KRW-appreciation may raise concerns about loss of trade competitiveness.

3.5.1.2 Japan

3.5.1.2(a) Impacts on FX rate level

Table 3.7(a) shows that BOJ's USD-purchasing interventions, in general, do not have significant effects on FX rate level in the pre-Sakakibara era, irrespective of model specifications − β_B, $\beta_{B,PERSD}$, and $\beta_{B,SIZED}$ are all insignificant. During the post-Sakakibara period, one-off or large-scale USD-purchasing interventions lead to the depreciation of JPY. For example, $\beta_B(=0.185)$ in the period indicates that USD-purchasing intervention equivalent to 1 trillion JPY results in a rise in JPY/USD rate approximately by 0.19%. In contrast, USD-selling interventions appear effective in the pre-Sakakibara period. For example, Model 2 suggests that when the intervention is large-scale one, sales of USD equivalent to 1 trillion

JPY appreciates JPY by 1.3% (see $\beta_{S,SIZED} = -1.336$ for the pre-Sakakibara period in Table 3.7(a)). Note that β_S(=1.233)for the period in model 2 is highly significant but wrongly signed, indicating one-off USD-selling interventions may not be effective. To sum up, large USD-selling interventions are effective in the pre-Sakakibara period while one-off or large USD-buying interventions are effective in the post-Sakakibara period.[34]

Although there was the largest USD-selling intervention in 10 April 1998, our estimation suggests that the USD-selling interventions were overall ineffective in the post-Sakakibara period. It is necessary to be cautious about the interpretation of this result, because the number of USD-selling intervention episodes during the post-Sakakibara period is only six (see Table 3.3), which may not be enough to evaluate intervention effects. In this case, event study on individual USD-selling episodes may be more appropriate (see Fatum and Hutchison 2003). Our finding is somewhat inconsistent with Ito (2003) that both USD-selling and USD-purchasing interventions are effective during the post-Sakakibara period. The different result may come from different model specification. Our model is different from Ito (2003) in that we consider the persistence and magnitude of interventions and USD-buying and USD-selling interventions are separately considered.

Interest rate differentials do not have significant effects on FX rate level like Korea. Increases in stock price depreciate the JPY – see β_{stock} =0.019(model 1) and 0.013(model 2) for the whole period. The significantly positive relationship between stock price and FX rate may indicate that a current rise in stock price reflects the increasing expectation on future inflation rather than the expanding economies (Ajayi and Mougoue 1996).

[34] During pre-Sakakibara period, there is a distinct episode of USD-selling interventions which are typically cited as successful ones (Dominguez 2003a). BOJ sold 28 times USDs equivalent to 787 billion JPY from 1991M3 to 1992M8 when JPY/USD rate mostly moved beyond 125JPY/USD. At that time, the BOJ's stated goal was to strengthen the JPY against the USD(see Ito 2003) and the FX rate fell from 138.7(JPY/USD) to 127.9(JPY/USD), so the interventions are typically cited as successful ones.

3.5.1.2(b) Impacts on FX rate volatility

In most cases, interventions do not help to reduce both long-term and short-term FX rate volatility. Table 3.7(b) suggests that BOJ interventions, in general, do not have significant effects on long-term volatility irrespective of samples and model specifications. Most coefficients of interventions are insignificant except for those on USD-selling interventions in the post-Sakakibara period ($\psi_{S,SIZED} = -0.127$ with p-value 0.018 in model 2).The magnitudes of η_1 are mostly 0.95 – 0.99 irrespective of model specification and estimated ω, η_1 and η_2 are mostly highly significant, implying that there is much stronger persistence of long-term volatility in Japan than in Korea where estimated η_1 is 0.83 - 0.97.

Table 3.7 (c) shows the result of short-term variance equation. Firstly, $\gamma_3 > 0$ (in both model 1 and model 2) for the post-Sakakibara period, suggests that the transitory *leverage effect* exists in the conditional variance. This result may indicate that Japanese economy became more sensitive to trade competitiveness for the post-Sakakibara period, because policy makers had very limited policy options against deepening economic depression.

Second, interventions mostly increase short-term FX volatility. In model 1, λ_B = 0.008 for the pre-Sakakibara period and the $\lambda_S = 0.431$ for the post-Sakakibara period, indicate that both USD-purchasing and selling interventions increase short-term FX volatility. In model 2, $\lambda_S = -0.09$ and $\lambda_{S,SIZED} = 0.18$ for the post-Sakakibara period, suggests that one-off USD-selling interventions reduce the short-term volatility, but large-scale USD-selling interventions increase short-term volatility. Overall, model 2 also indicates that USD-selling interventions increase short-term FX volatility, because $\lambda_S + \lambda_{S,SIZED} = 0.09 > 0$. This evidence is consistent with previous studies (Dominguez 1998, Edison et al. 2003, Kim and Sheen 2006) which generally do not decompose FX volatility. Third, interest rate differential and stock price change do not significantly influence both long-term and short-term FX rate volatility.

Table 3.7(a) Mean equation of ACT–GARCH: Japan

$$\Delta S_t = \beta_0 + (\beta_B + \beta_{B,PERSD} PERSD_t^B + \beta_{B,SIZED} SIZED_t^B) INT_t^B + (\beta_S + \beta_{S,PERSD} PERSD_t^S + \beta_{S,SIZED} SIZED_t^S) INT_t^S + \beta_{diff} \Delta DIFF_t + \beta_{stock} \Delta STOCK_t + \varepsilon_t$$

	sign	Whole sample(8/4/1991-31/3/2004)				Pre-Sakakibara(8/4/1991-30/6/1995)				Post-Sakakibara(1/7/1995-31/3/2004)			
		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant (β_0)		0.00292	0.7643	0.00300	0.7701	-0.02705*	0.0871	-0.02013**	0.0247	0.02080*	0.0984	0.01954	0.1277
(ii) USD-purchasing intervention													
• One-off (β_B)	(+)	0.06788	0.4349	-0.74779	0.3765	-0.10392	0.4176	-0.83943	0.1129	0.00520	0.5903	0.18492***	0.0095
• Persistent ($\beta_{B,PERSD}$)	(+)			0.05582	0.6473			0.17632	0.9605			-0.00605	0.6155
• Large-scale ($\beta_{B,SIZED}$)	(+)			0.74713	0.3832			0.99016	0.5636			0.18619***	0.0074
(iii)USD-selling intervention													
• One-off (β_S)	(-)	-0.17338*	0.0701	1.14692***	0.0018	-0.09150	0.8281	1.23328**	0.0127	-0.18762	0.1565	0.56565	0.2894
• Persistent ($\beta_{S,PERSD}$)	(-)			0.18299	0.1792			0.37719	0.4612			-0.04792	0.4355
• Large-scale ($\beta_{S,SIZED}$)	(-)			-1.24352***	0.0051			-1.33598***	0.0013			-0.56300	0.2935
(iv) Interest differential(β_{diff})	(-)	0.03041	0.3924	0.01555	0.6812	0.12241***	0.0000	0.07211	0.1423	-0.05355	0.2956	-0.04185	0.4067
(v) Stock price(β_{stock})		0.01865**	0.0103	0.01332*	0.0827	-0.00618	0.5506	0.00456	0.6113	0.03070***	0.0038	0.02591***	0.0093

Notes: 1. ***, ** and * denotes significant at 1%, 5% and 10% level, respectively.
2. The coefficients on interventions in mean equation give the impact of the intervention of purchasing (selling) USD equivalent to 1 trill.JPY.
3. Signs of coefficients on intervention indicate the prior expectation when the intervention is effective in leaning against the wind.
4. Bollerslev-Wooldridge robust standard errors and covariances are used.

Table 3.7(b) Long-term variance equation of ACT–GARCH: Japan

$$q_t = \varpi + \eta_1 (q_{t-1} - \varpi) + \eta_2 (\varepsilon_{t-1}^2 - h_{t-1})_t{}^B + (\psi_B + \psi_{B,PERSD} PERSD_t{}^B + \psi_{B,SIZED} SIZED_t{}^B) INT_t{}^B$$
$$+ (\psi_S + \psi_{S,PERSD} PERSD_t{}^S + \psi_{S,SIZED} SIZED_t{}^s) INT_t^s + \psi_{diff} \Delta DIFF_t + \psi_{stock} \Delta STOCK_t$$

	Whole sample(8/4/1991-31/3/2004)				Pre-Sakakibara(8/4/1991-30/6/1995)				Post-Sakakibara(1/7/1995-31/3/2004)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant(ω)	0.39747***	0.0000	0.38768***	0.0000	0.27870***	0.0000	0.37756***	0.0000	0.43197***	0.0000	0.42736***	0.0000
(ii) Own lag(η_1)	0.98508***	0.0000	0.95889***	0.0000	0.95648***	0.0000	0.98696***	0.0021	0.98460***	0.0000	0.94980***	0.0000
(iii) Unexpected shocks (η_2)	0.03805***	0.0000	0.06494***	0.0000	0.04563***	0.0328	0.04441***	0.0004	0.04252***	0.0001	0.09153***	0.0000
(iv) Purchasing intervention												
• One-off (ψ_B)	0.00027	0.8819	0.03060	0.1977	0.06656	0.1081	0.04941	0.9649	-0.00028	0.8750	0.02525	0.2417
• Persistent ($\psi_{B,PERSD}$)			-0.00992	0.1553			0.00796	0.9948			-0.00937	0.2256
• Large-scale ($\psi_{B,SIZED}$)			-0.01664	0.4888			-0.04720	0.9290			-0.01246	0.5662
(v) Selling intervention												
• One-off (ψ_S)	0.05472	0.1098	0.01591	0.2698	0.05404	0.4399	0.11753	0.8662	0.05123	0.1260	0.12631**	0.0417
• Persistent ($\psi_{S,PERSD}$)			-0.02116	0.5383			-0.45618	0.8244			0.06479	0.5900
• Large-scale ($\psi_{S,SIZED}$)			-0.01692	0.3665			-0.08407	0.8773			-0.12774**	0.0186
(vi) Interest differential(ψ_{diff})	-0.03362	0.5612	-0.03847	0.6372	0.05455	0.3869	0.02453	0.9322	-0.05064	0.5475	-0.10232	0.4457
(vii) Stock price(ψ_{stock})	0.00494	0.1705	0.00305	0.5734	0.00690	0.2815	-0.00061	0.9877	0.00492	0.3810	0.00967	0.2501

Table 3.7(c) Short-term variance equation of ACT–GARCH: Japan

$$h_t = q_t + \gamma_1(\varepsilon^2{}_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1}) + \gamma_3(\varepsilon^2_{t-1} - q_{t-1})z_{t-1} + (\lambda_B + \lambda_{B,PERSD} PERSD_t^{\,B} + \lambda_{B,SIZED} SIZED_t^{\,B})INT_t^B$$
$$+ (\lambda_S + \lambda_{S,PERSD} PERSD_t^{\,S} + \lambda_{S,SIZED} SIZED_t^{\,s})INT_t^s + \lambda_{diff}\Delta DIFF_t + \lambda_{cds}\Delta CDS_t + +\lambda_{stock}\Delta STOCK_t$$

	Whole sample(8/4/1991-31/3/2004)				Pre-Sakakibara(8/4/1991-30/6/1995)				Post-Sakakibara(1/7/1995-31/3/2004)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Unexpected shocks(γ_1)	0.00737*	0.0896	0.03676*	0.1000	0.03633	0.3706	0.00408	0.4784	0.04145*	0.0960	0.07795***	0.0058
(ii) Deviation from its long-run component(γ_2)	0.03642*	0.0903	0.24019	0.3136	0.15685	0.2462	0.09060	0.8481	0.27202	0.1632	0.46511**	0.0342
(iii) Negative shock (γ_3)	0.09174	0.1722	0.08244*	0.0694	0.06625	0.2274	0.04538	0.5477	0.10942**	0.0390	0.11573**	0.0296
(iv) USD-Purchasing												
• One-off (λ_B)	0.00773	0.5607	-0.00656	0.9367	0.00814*	0.0702	0.01690	0.9900	-0.00285	0.7609	-0.00988	0.8243
• Persistent ($\lambda_{B,PERSD}$)			-0.00825	0.6070			0.01079	0.9924			-0.00767	0.6100
• Large-scale ($\lambda_{B,SIZED}$)			-0.01457	0.8586			-0.12377	0.8926			-0.00665	0.8789
(v) USD-selling												
• One-off (λ_S)	0.41774**	0.0354	-0.00964	0.1652	0.56028	0.1414	0.02086	0.9763	0.43084**	0.0381	-0.09393*	0.0893
• Persistent ($\lambda_{S,PERSD}$)			-0.20917	0.2639			-0.13504	0.5882			-0.11331	0.1687
• Large-scale ($\lambda_{S,SIZED}$)			0.12607	0.1029			0.02572	0.9720			0.17649*	0.0905
(vi) Interest differential(λ_{diff})	0.00884	0.1167	0.08921	0.1846	0.03674	0.1349	0.11902	0.2848	0.01937	0.6748	0.02860	0.9133
(vii) Stock price(λ_{stock})	0.00077	0.9486	0.00076	0.9372	-0.00212	0.8943	-0.00640	0.6350	0.01048	0.3822	0.00049	0.9893
Diagnostics												
• Skewness	-0.258		-0.248		-0.507		-0.350		-0.063		-0.068	
• Kurtosis	5.362		5.326		6.272		6.382		4.857		4.814	
• Q(15)	18.665	0.229	15.122	0.443	20.729	0.146	23.103*	0.082	10.870	0.762	8.9598	0.880
• $Q^2(15)$	7.714	0.935	9.551	0.847	8.4111	0.906	21.837	0.112	11.611	0.708	11.803	0.694
• ARCH-LM test	7.541	0.941	8.984	0.878	8.5712	0.899	22.031*	0.096	12.357	0.652	11.770	0.696
No. of observations	3566				1272				2294			

Notes: 1. When the coefficient of the negative shock is positive (i.e. $\gamma_3>0$), the impact of the unexpected domestic currency appreciation ($\varepsilon_t<0$) on the short-term volatility component($\gamma_1+\gamma_3$) is greater than the impact of the unexpected depreciation (γ_1).

2. $Q(Q^2)$ is the modified Ljung-Box's Q statistics for testing the null of no autocorrelation up to 15 lags for the standardized(squared standardized) residual.

3. ARCH LM test is the heteroskedasticity test with the null hypothesis that there are no remaining ARCH effects in the residual up to the number of lags in ( ).

3.5.1.3 Australia

3.5.1.3(a) Impacts on FX rate level

In Table 3.8(a), the coefficients on the USD-buying interventions (i.e, β_B, $\beta_{B,PERSD,}$ $\beta_{B,SIZED)}$ are all insignificant in all periods irrespective of model specifications, implying that USD-buying interventions seem ineffective in changing FX rate level. The coefficients on the USD-selling interventions are mostly insignificant or wrongly signed except for the pre-IT period. Model 2 reports that $\beta_S = 1.30$ with p-value 0.08 but $\beta_{S,SIZED} = -1.80$ with p-value 0.09 (and thus $\beta_S + \beta_{S,SIZED} = -0.50 < 0$) for the pre-IT period, which indicates that one-off interventions are ineffective, but that large-scale sales of USD equivalent to 1 billion AUD would lead to the appreciation of AUD by 0.5 percent. This is similar to Newman et al. (2011 pp. 75-76) which suggests that the sales (purchases) of USD equivalent to 1 billion AUD appreciate (depreciate) AUD by 0.7 per cent. However, they are marginally significant. Overall, our finding suggests that RBA interventions appear to fail to reverse the trend of FX rates except for some large-scale USD-selling interventions.

Like Korea, there is a significant negative relationship between stock price and FX rate in Australia. Both model 1 and 2 suggests that $\beta_{stock} = -0.080$ for the post-IT period and $\beta_{stock} = -0.055$ to -0.065 for the whole period with p-value 0.000, indicating that a rise in stock price leads to the appreciation of AUD. This indicates that a rise in stock price may be considered as a sign of an expanding economy that induces capital inflows and thereby leads to the appreciation of AUD. The negative relationship between stock price and FX rates in Australia and Korea contrasts with the positive relationship in Japan.

3.5.1.3(b) Intervention impacts on FX rate volatility

Estimation results for two variance equations are presented in Table 3.8(b) and 3.8(c). In Table 3.8(b), η_1 is mostly close to 1, $\eta_1 > (\gamma_1 + \gamma_2) > 0$ and $\gamma_2 > \eta_2 > 0$, indicating the persistence of long-term volatility components. Both USD-purchasing and USD-selling interventions do not significantly affect the long-term FX volatility.

In Table 3.8(c), model 1 overall provides evidence that interventions increase short-term volatility: e.g. λ_B =0.56 with p-value 0.09 and λ_S = 0.34 with p-value 0.00 for the pre-IT period. In contrast, model 2 presents $\lambda_{B,PERSD} = -2.83$ with p-value 0.01 and $\lambda_{S,SIZED} = -2.02$ with p-value 0.00 for the whole period, implying that RBA's interventions have some stabilising effects on short-term volatility when the interventions are either sustained or massive. This finding is consistent with previous studies. For example, Kim and Sheen (2002) report that persistent and large interventions contribute to stabilising the level and volatility of FX rate in Australia.

Unlike Korea and Japan, γ_3 is mostly significantly negative or insignificantly positive (model 2), suggesting that there is no transitory *leverage effect* in the conditional variance. This finding indicates that the impacts of the unexpected appreciation of AUD on the short-term volatility are not significantly larger than those of unexpected depreciation are. Model 1 suggests that interest rate differential seems somewhat pertinent to explain both short-term and long-term FX rate volatility in Australia.

Table 3.8(a) Mean equation of ACT–GARCH : Australia

$$\Delta S_t = \beta_0 + (\beta_B + \beta_{B,PERSD} PERSD_t^B + \beta_{B,SIZED} SIZED_t^B) INT_t^B + (\beta_S + \beta_{S,PERSD} PERSD_t^S + \beta_{S,SIZED} SIZED_t^S) INT_t^S + \beta_{diff} \Delta DIFF_t + \beta_{stock} \Delta STOCK_t + \varepsilon_t$$

	sign	Whole sample(4/1/1989-31/12/2008)				Pre-IT (5/1/1989-31/7/1992)				Post-IT(3/8/1992- 31/12/2008)			
		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant (β_0)		-0.00869**	0.0476	-0.00763***	0.0000	-0.01852*	0.0945	0.00116**	0.0455	-0.01094	0.2114	-0.00937	0.2900
(ii) USD-purchasing intervention													
• One-off (β_B)	(+)	0.44913	0.3867	-1.11974	0.3344	0.54924	0.3052	-0.64395	0.6176	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Persistent ($\beta_{B,PERSD}$)	(+)			-0.23754	0.7860			-0.98536	0.3129	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Large-scale ($\beta_{B,SIZED}$)	(+)			1.65715	0.1859			1.59354	0.2293	n.a[1]	n.a[1]	n.a[1]	n.a[1]
(iii)USD-selling intervention													
• One-off (β_S)	(-)	0.38079*	0.0930	0.14583	0.3391	-0.12199	0.7110	1.30175*	0.0758	0.39682*	0.0901	-0.71475	0.3945
• Persistent ($\beta_{S,PERSD}$)	(-)			-0.99093	0.1588			-0.01602	0.2858			-0.90686	0.2365
• Large-scale ($\beta_{S,SIZED}$)	(-)			0.54930*	0.0634			-1.79963*	0.0883			1.41404*	0.0914
(iv) Interest differential(β_{diff})	(-)	-0.01485	0.6056	-0.02467	0.4028	0.00968	0.1575	0.00785	0.8378	-0.03646	0.4275	-0.03126	0.4893
(v) Stock price(β_{stock})		-0.05466***	0.0000	-0.06478***	0.0000	0.02093	0.1995	0.01945	0.3344	-0.08012***	0.0000	-0.07993***	0.0000

Notes: 1. RBA did not conduct USD-buying intervention in 1992M8-2008M12.
2. ***, ** and * denotes significant at 1%, 5% and 10% level, respectively.
3. The coefficients on interventions in mean equation give the impact of the intervention of purchasing (selling) USD equivalent to 1 billion AUD.
4. Signs of coefficients on intervention indicate the prior expectation when the intervention is effective in leaning against the wind.
5. Bollerslev-Wooldridge robust standard errors and covariances are used.

Table 3.8(b) Long-term variance equation of ACT– GARCH: Australia

$$q_t = \varpi + \eta_1(q_{t-1} - \varpi) + \eta_2(\varepsilon_{t-1}^2 - h_{t-1})_t^{\ B} + (\psi_B + \psi_{B,PERSD} PERSD_t^{\ B} + \psi_{B,SIZED} SIZED_t^{\ B}) INT_t^{\ B}$$
$$+ (\psi_S + \psi_{S,PERSD} PERSD_t^{\ S} + \psi_{S,SIZED} SIZED_t^{\ s}) INT_t^{s} + \psi_{diff} \Delta DIFF_t + \psi_{stock} \Delta STOCK_t$$

	Whole sample(4/1/1989-31/12/2008)				Pre-IT (5/1/1989-31/7/1992)				Post-IT(3/8/1992- 31/12/2008)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Constant(ω)	0.51992***	0.0016	0.37974***	0.0000	0.23580**	0.0292	0.26644***	0.0000	0.51078***	0.0003	0.50201***	0.0003
(ii) Own lag(η_1)	0.99393***	0.0000	0.90576***	0.0000	0.97315***	0.0000	0.85212***	0.0000	0.99327***	0.0000	0.99346***	0.0000
(iii) Unexpected shocks (η_2)	0.04827***	0.0000	0.05155*	0.0710	0.08753***	0.0006	0.07196	0.2628	0.04310***	0.0000	0.04087***	0.0000
(iv) Purchasing intervention												
• One-off (ψ_B)	-0.07287	0.1579	-0.47021	0.5598	0.02859	0.1415	0.04533	0.9634	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Persistent ($\psi_{B,PERSD}$)			0.95270	0.1923			-0.16319	0.7281	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Large-scale ($\psi_{B,SIZED}$)			-0.53620	0.4205			-0.01711	0.9870	n.a[1]	n.a[1]	n.a[1]	n.a[1]
(v) Selling intervention												
• One-off (ψ_S)	0.01766	0.6005	0.82921	0.1289	-0.07392	0.1213	0.05138	0.9652	0.02271	0.5139	-0.08244	0.6934
• Persistent ($\psi_{S,PERSD}$)			-0.50119	0.2478			0.10946	0.9637			-0.09900	0.6854
• Large-scale ($\psi_{S,SIZED}$)			-0.43531	0.4524			0.12005	0.9443			0.19443	0.5425
(vi) Interest differential(ψ_{diff})	-0.03956*	0.0776	0.02097	0.1003	0.00399	0.8229	0.00158	0.9799	-0.15016	0.2522	-0.03832	0.2867
(vii) Stock price(ψ_{stock})	-0.00487	0.1666	-0.00154	0.8806	-0.00266	0.6602	-0.00548	0.7830	-0.00767	0.1106	-0.00801*	0.0661

Note: RBA did not conduct USD-buying intervention in 1992M8-2008M12

Table 3.8(c) Short-term variance equation of ACT– GARCH: Australia

$$h_t = q_t + \gamma_1(\varepsilon^2_{t-1} - q_{t-1}) + \gamma_2(h_{t-1} - q_{t-1}) + \gamma_3(\varepsilon^2_{t-1} - q_{t-1})z_{t-1} + (\lambda_B + \lambda_{B,PERSD} PERSD_t^B + \lambda_{B,SIZED} SIZED_t^B) INT_t^B$$
$$+ (\lambda_S + \lambda_{S,PERSD} PERSD_t^S + \lambda_{S,SIZED} SIZED_t^s) INT_t^s + \lambda_{diff} \Delta DIFF_t + \lambda_{stock} \Delta STOCK_t$$

	Whole sample(4/1/1989-31/12/2008)				Pre-IT (5/1/1989-31/7/1992)				Post-IT(3/8/1992- 31/12/2008)			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(i) Unexpected shocks(γ_1)	0.03233*	0.0798	0.01788	0.6920	0.13699***	0.0000	0.01681*	0.0873	0.00807	0.6509	0.00888	0.7231
(ii) Deviation from its long-run component(γ_2)	0.23076**	0.0409	0.46601***	0.0000	0.62378***	0.0000	0.21236**	0.0413	0.84762***	0.0000	0.56765***	0.0065
(iii) Negative shock (γ_3)	-0.02154	0.5999	-0.17421**	0.0125	-0.10535*	0.0964	0.08518	0.4487	-0.02833	0.2117	-0.22418*	0.0580
(iv) USD-Purchasing												
• One-off (λ_B)	0.77713	0.1485	0.34096	0.7683	0.55538*	0.0938	0.10699	0.4526	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Persistent ($\lambda_{B,PERSD}$)			-2.82832***	0.0104			-0.16129	0.1008	n.a[1]	n.a[1]	n.a[1]	n.a[1]
• Large-scale ($\lambda_{B,SIZED}$)			1.53141	0.1599			0.11196	0.5541	n.a[1]	n.a[1]	n.a[1]	n.a[1]
(v) USD-selling												
• One-off (λ_S)	0.02514	0.8902	2.59965***	0.0001	0.33597***	0.0005	0.04688	0.9135	0.09004	0.3581	-0.60164	0.3709
• Persistent ($\lambda_{S,PERSD}$)			1.83513*	0.0823			-0.78100	0.7350			1.12412	0.1466
• Large-scale ($\lambda_{S,SIZED}$)			-2.02380***	0.0027			-0.05649	0.9785			0.48191	0.4758
(vi) Interest differential(λ_{diff})	-0.03177***	0.0052	-0.10371	0.1260	-0.03844***	0.0000	-0.01129	0.8489	-0.01590	0.8483	-0.03400	0.6261
(vii) Stock price(λ_{stock})	-0.01217	0.1567	-0.02462*	0.0757	-0.00927	0.3634	-0.00543	0.7977	-0.01183	0.1960	-0.01798	0.0876
Diagnostics												
• Skewness	0.3162		0.3903		0.4184		0.0124		0.2780		0.2868	
• Kurtosis	4.7260		6.0428		4.7660		4.9404		4.6866		4.6598	
• Q(15)	22.520*	0.075	21.796	0.113	20.496	0.154	22.972*	0.065	20.338	0.159	20.943	0.139
• $Q^2(15)$	15.591	0.410	18.928	0.217	14.924	0.457	11.776	0.696	13.994	0.526	14.387	0.496
• ARCH-LM test	15.065	0.447	18.774	0.224	14.229	0.508	11.207	0.738	13.560	0.559	13.994	0.526
No. of observations	5215				933				4283			

Notes: 1. RBA did not conduct USD-buying intervention in 1992M8-2008M12

2. When the coefficient of the negative shock is positive (i.e. γ_3>0), the impact of the unexpected domestic currency appreciation (ε_t<0) on the short-term volatility component (γ_1+ γ_3) is greater than the impact of the unexpected depreciation (γ_1).

3. Q(Q^2) is the modified Ljung-Box's Q statistics for testing the null of no autocorrelation up to 15 lags for the standardized(squared standardized) residual.

4. ARCH LM test is the heteroskedasticity test with the null hypothesis that there are no remaining ARCH effects in the residual up to the number of lags in ( ).

3.5.2 Profitability of sterilised FX interventions

Table 3.9 reports main statistics on the variables affecting intervention profits and results of profit estimations for three countries. We present the intervention profits estimated by both Ito (2003) and Becker & Sinclair (2004) methodologies. The former used the period-average figures (e.g., accumulated intervention amount and average FX rates over the entire period) while the latter calculates the profit with daily marking-to-market (See Appendix 3.3 for the detailed calculation procedures). Note that cumulative net purchases of USD are positive in Korea (67.7 bill. USD) and in Japan (540.9 bill. USD) but negative in Australia (-6.5 bill. USD). The positive (negative) cumulative net purchase of USD can be interpreted, on average, as long (short) USD position during sample periods. The estimated results are mostly consistent with prior expectations.

First, USD-selling prices are on average higher than USD-purchasing costs in all countries, so that all three CBs obtain trading margins. This indicates that three CBs mostly bought USDs cheap and sold them expensive, and thereby made *realised* trading gain from interventions. It follows that all three CBs have leaned against the wind. The domestic-foreign interest rate differential (measured by domestic O/N money market rate – US O/N fed fund rates) is positive in Korea and Australia, but negative in Japan. The positive differentials lead to interest losses to USD long-position holder (i.e., Korea) and interest earnings to USD short-position holder (i.e., Australia). On the other hand, negative differential causes USD long-position holder (i.e. Japan) to make significant interest earning.

Aforementioned, *unrealised* gains are heavily dependent on the FX rate at the day when the position is valued. When we use end-of-day FX rates, only BOK makes an unrealised gain of 1,387 billion KRW. When we use the weighted average exchange rate with daily marking-to-market, only Japan makes an unrealised gain of 1,089 billion JPY.

Table 3.9 Estimated profits from FX interventions

	Korea (2001M09-2010M03)	Australia (1989M1-2008M12)	Japan (1991M4-2004M3)
Cumulative USD purchase(a)	151.2	12.6	578.5
Cumulative USD selling(b)	83.5	19.1	37.6
Cumulative net purchases of USD (a-b) (bill. USD)	67.7	-6.5	540.9
Average FX rate to buy USD(c)	1151.28	1.2663	107.65
Average FX rate to sell USD(d)	1193.26	1.4217	131.24
Trading margin (e=d-c)	41.98	0.1554	23.59
Average FX rate	1117.57	1.4290	115.59
Interest differential (domestic-US; % per annum)	1.44	2.46	-2.76
Realised trading gains(e)	2360.8	2862.3	763.3
(bill. KRW; bill. JPY; mill. AUD)	(3664.5)	(4487.1)	(994.2)
Net interest earning(f)	-5131.8	1277.2	4485.4
	(-3777.3)	1259.7	(3954.6)
Unrealised trading gains(g)	1387.2	-1140.4	-3180.5
	(-4539.6)	(-284.0)	(1088.9)
Total profit (e+f+g)	-1383.8	3035.1	2068.2
	(-4652.4)	(5462.8)	(6037.7)

Notes: 1. FX rates are the prices of domestic currency per a unit USD.
2. Interest differential = O/N domestic money market rate -O/N US fed fund rate
3. In estimated profits, the figures in upper rows are profits based on Ito(2003) while the figures in lower rows are those with daily marking-to-market as in Becker and Sinclair (2004).
4. Realised gains and net interest earnings are total profits made during the sample periods.

Despite the conflicting results of *unrealised* profits, above estimation suggests that the interventions of BOJ and RBA were profitable but the BOK's was not. In Table 3.12, total intervention losses are estimated as 1,384 billion KRW (based on period average calculation) or 4,652 billion KRW (based on marking-to-market calculation). The losses mainly come from considerable net interest losses. In contrast, Japanese interventions appear profitable, owing to massive interest earning of 4,485 (or 3,955) billion JPY. Apparently, low domestic interest rate in Japan significantly contributed to the net interest earnings. In Australia, most of the profits came from realised trading gains.

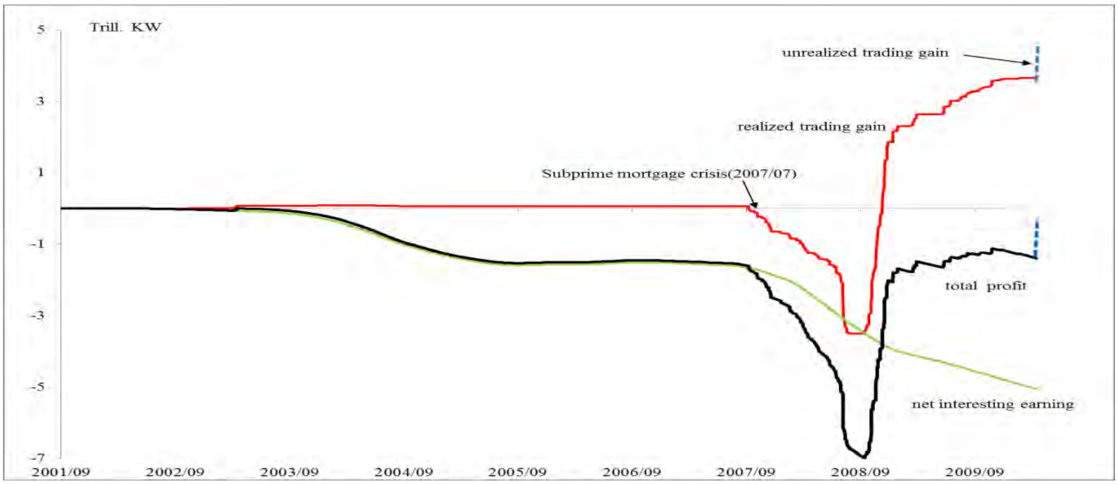
Figure 3.6 shows the accumulation of total profit and its three components over time. BOK made modest but sustained realised trading gains before the advent of sub-prime crisis in July 2007 but experienced temporary but massive realised trading losses at the early stage of US-subprime crisis. These trading losses are due to massive USD-selling interventions in response to the rapid depreciation of KRW in this period. In 2007M7-2008M8, the weighted-average FX rate at which the BOK sold USDs, i.e. average USD-selling price, was 1088 KRW/USD, which was on average much lower than average USD-purchasing cost, 1175 KRW/USD in the pre-crisis periods. As KRW/USD rates rose rapidly, the BOK could not but sell USD to defend KRW, although the FX rates at the sales of USD were below the average USD-purchasing price.

In Korea, net interest losses were made through the entire sample period and became substantial in recent years. This contrasts with the case of Australia in which domestic interest rate is higher than US interest rate. Like BOK, RBA made net interest losses in the early 1990s when RBA was net buyer of USD. However, RBA made net interest gains after 1993 because it became a net seller of USD. Steady *realised* trading gains are found in Japan and Australia. In case of Japan where USD long position is sustained during the whole period, there were a few USD-selling interventions that acted in the direction of closing out the long position. Thus, realised trading gains in Japan are relatively modest compared to those in Australia where RBA conducted frequent sales of USD to close out its long position which was acquired in the late 1980s and the early 1990s.

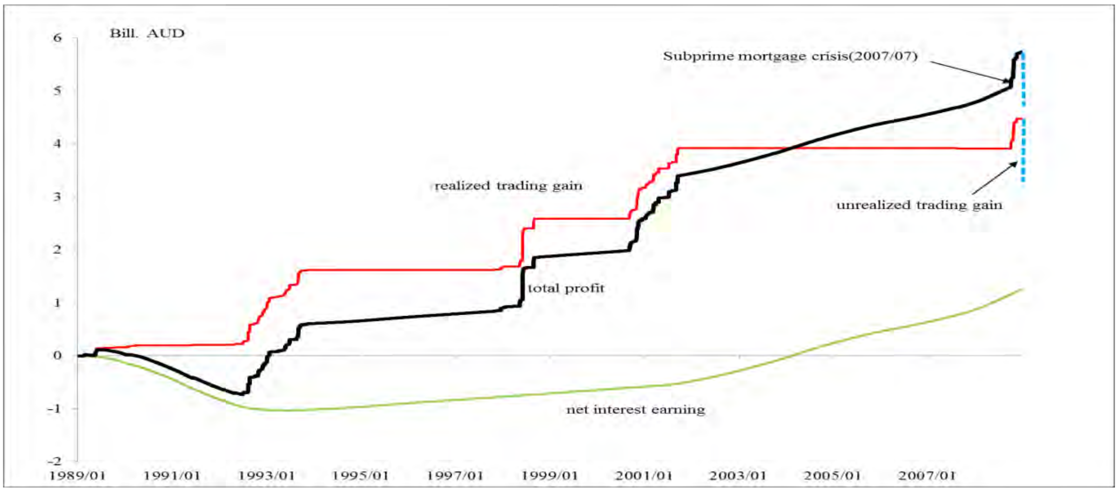
Overall findings in this section may be interpreted as evidence that interventions in Korea during 2000s were not profitable and thus appear not to contribute to stabilising the FX rates in the long term. On the contrary, BOJ and RBA look profitable fund managers in the intervention activities, implying that they are both 'stabilising speculator', in the sense that the interventions appears to help to stabilise FX rate movement. The evidences in Japan and Australia are in line with similar previous studies (Ito 2003, Becker and Sinclair 2004)

Figure 3.6 Cumulative profits of foreign exchange interventions

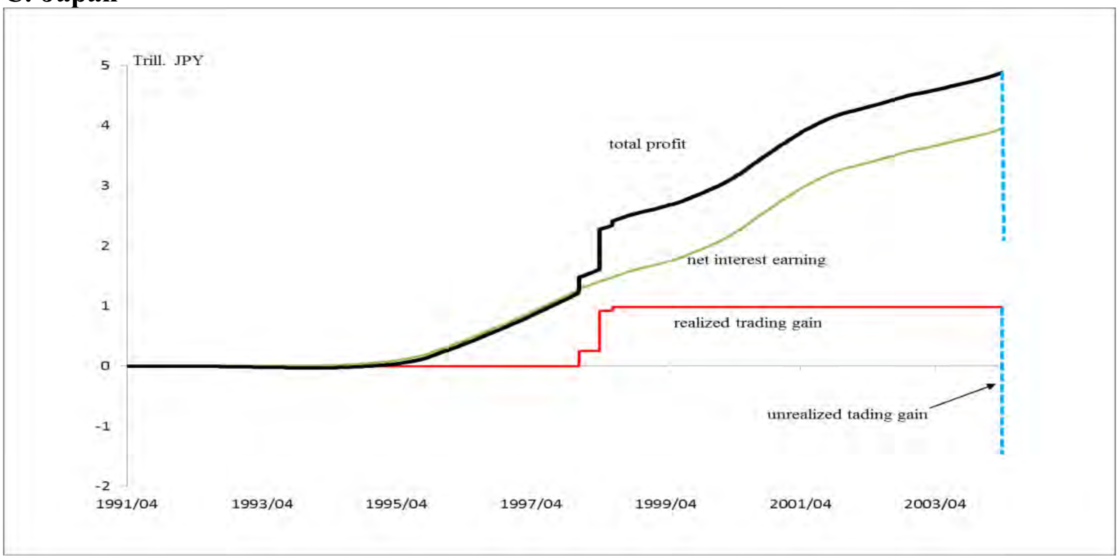
A. Korea



B. Australia



C. Japan



3.6 Conclusion

3.6.1 Summary of main findings

The purpose of this chapter is to estimate the effects of sterilised FX interventions on FX rates and intervention profit in Korea(2001M9-2010M3), Japan(1991M4-2004M3) and Australia(1989M1-2008M12) which still intervene in FX markets actively. We first apply Engle and Lee (1998)'s ACT GARCH model to the interventions in three countries with daily data to estimate the intervention effects on FX rate level and volatility. ACT-GARCH model enables one to examine the intervention effects on long-term and short-term volatility separately and to catch transient leverage effects on the conditional variance. We estimate the model in two ways. Model 1 does not differentiate the types of intervention like Guimaraes and Karacadag (2004) whereas model 2 uses dummies to reflect a large-scale and a persistent intervention. As Kim and Sheen (2002 p 621) pointed out, separate considerations of the persistence or magnitude of interventions (like model 2) may be more helpful for assessing the intervention effects accurately. Overall, estimation results support Kim and Sheen. In general, a one-off intervention appears ineffective, but large interventions affect FX rate level or volatility in three countries. For example, model 1 suggests no intervention effects on FX rate level while mode1 2 suggests that a large intervention significantly affects FX rate level in Korea. Main findings obtained from ACT-GARCH model are as follows.

First, intervention effects on FX rate level appear most significant in Korea. BOK's one-off USD-purchasing (selling) interventions are not effective while its *large or persistent* USD-purchasing (selling) interventions are effective in depreciating (appreciating) KRW, although the magnitudes seem quantitatively trivial. BOJ's large-scale USD-purchasing interventions, in general, do not significant effects on reversing FX rate level trend but large-scale USD-selling interventions appear effective in resisting the depreciation of JPY. RBA's USD-selling and USD-buying interventions appear ineffective in reversing the trend of FX rate level, irrespective of intervention amount and persistence.

Different features in FX market structures and intervention patterns may explain the different intervention effects on FX rate level in three countries. Greater significance of intervention size in Korea and Japan than in Australia appears to support portfolio balance channel rather than signalling channel. This is because intervention amount (compared to FX market turnover) in Korea and Japan is much bigger than that of Australia (see Table 3.4), and because the interventions in Korea and Japan depend more on secret intervention.

Second, interventions appear to affect short-term rather than long-term FX rate volatility in three countries. The insignificant effect on long-term volatility is consistent with previous studies (e.g. Diyatat and Galati 2005) that interventions leave volatility broadly unchanged. FX interventions have a limitation in influencing long-term volatility that is more persistent than short-term volatility. In addition, there are some differences in intervention effects on short-term volatility among countries. In Korea, USD-selling interventions seem futile in reducing the short-term volatility irrespective of the model specifications and samples. This is probably due to the lack of credibility of the USD-selling interventions since the CBs in small open emerging economies generally suffer from the "fear of losing foreign reserves" (Aizenman and Yi 2009). However, a large USD-purchasing intervention, (which may be more feasible than USD-selling interventions), may contribute to reducing short-term FX volatility, although a one-off USD-purchasing intervention increases short-term volatility. In Japan, interventions generally tend to increase short-term volatility in most cases. In Australia, RBA's one-off interventions increase short-term volatility while persistent or large interventions have some stabilising effects on short-term volatility. Unlike Korea, not only USD-purchasing but also USD-selling interventions have a stabilising effect on short-term volatility in Australia, once the interventions are sustained or larger.

Third, transitory leverage effects in conditional volatility exist in both Korea and Japan, but, not in Australia, which indicates that the authorities and market participants in two countries appear to worry more about rapid appreciation of their currency than Australian counterparty does. Hence, the news about unexpected appreciation affects short-term volatility more than those about unexpected depreciation do in two countries. This may be because both countries appear more sensitive to trade competitiveness than Australia. Relatively, RBA seems less concerned about the AUD-appreciation than the depreciation.

Fourth, interest rate differentials do not significantly affect the FX rate level and volatility in three countries, which is consistent with Guimaraes and Karacadag (2004)'s evidence for Turkey and Kim and Sheen (2002)'s evidence for Australia. As we use overnight interest rates that are controlled by the CBs, the coefficient on interest rate differentials here reflects exogenous monetary policy shocks to FX rates. Thus, insignificance of interest rate differential implies that the change in monetary operations or policy rate changes do not significantly affect exchange rates – there is no monetary channel on a daily basis. The heightened country risk proxied by a large CDS spread has significant effects on not only FX rate level but also FX rate volatility in Korea – increases in CDS spread depreciates KRW and increases FX volatility at the same time, particularly for crisis period, as does in other small open emerging countries.

Fifth, profit estimations for the three countries indicate that the interventions of BOJ and RBA were profitable but the BOK's was not. The BOK's intervention loss mainly comes from net interest losses, which is ascribed to the BOK's persistent USD-purchasing interventions under the circumstance where domestic interest is higher than foreign interest rates. Three CBs made realised gains from intervention transactions by purchasing USDs cheap and selling them expensive, implying that the CBs aim for leaning-against-the-wind and stabilise FX rate. Accumulated BOK's net interest losses may cast a question on the sustainability of its sterilised interventions.

3.6.2 Discussion and future research

Our findings, in general, suggest that large-scale interventions appear more effective in reversing current trend of FX rate level and volatility than one-off or consecutive interventions. It is generally accepted that intervention amount is important in portfolio balance channel or order flows channel while the authorities' intention or credibility of interventions (which are well reflected by a series of persistent interventions regardless of amount) is more meaningful in signalling channel (Edison 1993). Hence, the significant coefficients for size dummy and insignificant coefficients for persistence dummies and one-off interventions may suggest that portfolio balance or order flow channel rather than signalling channel works more.[35] This may be particularly true for Korea that mostly adheres to intervention secrecy. Under the secret intervention, persistent interventions may not be easily recognized by markets unless they are considerably large. Our methodology does not provide information on which channel between portfolio balance and order flows works more.

When using the dummies for large-scale and persistent interventions, we have found the cases where the coefficients for one-off, large and persistent interventions have different

[35] However, this interpretation has also limits in that the magnitudes of interventions may also signal the CB' strong will of stabilizing FX rates to markets. That is, the credibility of signal can be linked to the intervention amount because putting more money in the transaction may represent the degree of CB's commitment to stabilizing FX rates.

signs. For example, ACT-GARCH model 2 for Japan during the entire period presents λ_S=−0.09393 and $\lambda_{S,SIZED}$=0.17649, indicating that one-off USD-selling interventions help to stabilise the short-term volatility but large-scale ones increase the volatility. Newman et al. (2011, p 75) and Kim & Sheen (2002, pp. 631-632) report similar evidences that the effect of one-off interventions is different from persistent or large interventions. For example, Kim and Sheen(2002) report that a one-off USD-selling intervention is effective in stabilising FX rate by appreciating AUD whereas large or successive ones depreciate rather than appreciate AUD and thereby accelerate the depreciation trend.

The inference of these evidences looks somewhat tricky. Except for the possibility of unsolved simultaneity problem, one plausible interpretation may be as follows. Under secret intervention scheme, the direction of the effect of intensified (unusual) interventions may be not what CBs expect from initial one-off (average) interventions. This is because the lack of credibility and transparency in secret interventions frequently keeps the market participants from responding consistently to the intensified interventions. For example, one-off USD-selling interventions have an effect on reducing FX rate volatility under increasing depreciation pressure, but unusually large interventions (aiming for intensifying initially-intended effects) may not succeed or yield unexpected effects, because unusually large interventions may wrongly signal that the CB are in a desperate situation to resist the present depreciation trend and thereby cause to accelerate depreciation pace.

Although comparing the cases of secret interventions (e.g. Korea) and publicly announced case (e.g. Australia) in this chapter, we do not provide direct evidence on which practice is more effective in stabilising FX markets. Given that the issues related to communication become more important in monetary policy, it is necessary to directly estimate and compare the effect of both types of intervention practice.

CHAPTER 4 THE MOTIVATIONS OF STERILISED FX MARKET INTERVENTIONS:

Do central banks fear the appreciation of domestic currency?

4.1. Introduction

According to the trilemma hypothesis, given free capital mobility, monetary policy and exchange rate policy should not be treated as two independent instruments, and thus exchange rates should play a relatively minor role in inflation targeting (hereafter IT). It is recommended that FX rates should be benignly ignored or function as one of the information variables in setting a policy interest rate under an IT regime. A considerable degree of flexibility in exchange rates is required under a credible IT regime (Svensson 2010, Fischer 2001). An IT regime is often interpreted as an attempt to build CB independence and policy credibility while allowing more flexible exchange rates.

However, many emerging IT countries (cum *de jure* free float) have relied on sterilised interventions since the late 1990s. The interventions in these countries seem to be lenient with depreciation but strict with appreciation of domestic currency – CBs respond asymmetrically to domestic currency depreciation and appreciation (Levy-Yeyati and Sturzenegger 2007). (Hereafter, asymmetric interventions indicate stronger resistance to the appreciation of domestic currency). The preference for asymmetric interventions in these countries seems to contrast with those of developed countries under IT, which appear to abstain from interventions and seem to conduct symmetric interventions (e.g. the UK, New

Zealand, Canada) (Rose 2010, pp. 9-14).[36]

Theoretically and practically, asymmetric interventions appear more sustainable and beneficial than their counterpart, particularly in emerging economies.

First, there is no limit to interventions of selling local currency for purchasing foreign currency, since CBs can always print money. On the contrary, when conducting interventions to aim at encouraging local currency appreciation, CBs are confronted with hard budget constraints owing to the risk of exhausting foreign reserves (Bofinger and Wollmershauser 2001).

Second, considering valuation effects on foreign reserves, asymmetric interventions may be preferable in emerging countries where CBs have a considerable amount of foreign assets in their balance sheets. E-type CBs[37] are likely to have an incentive to conduct asymmetric interventions as much as possible (see Appendix 4.2). Third, asymmetric interventions and the resultant accumulation of foreign reserves are more advantageous for emerging countries to promote economic growth (Levy-Yeyati and Sturzenegger 2007) and to meet precautionary demand for foreign reserves.

In the last decade, low-inflation environments may have encouraged small open IT economies with *de jure* free floats to implicitly target a weaker exchange rate than the markets. Therefore, it could be naturally conjectured that asymmetric interventions have been effective for emerging countries to stick to *de facto* intermediate regimes. That is, CBs pursue domestically orientated interest rate policy and simultaneously target one-sided exchange rate

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[36]As of the end of 2009, 26 countries adopted IT with floating regimes, and most of them have rarely intervened in FX markets. For example, New Zealand has intervened once in June 2007 since the introduction of free float in 1985. ECB and Bank of Canada's last interventions date back to early 2000 and 1998, respectively. The UK has not intervened since the BOE acquired its independence in 1997, except for one occasion in September 2000, when the UK government, via EEA, participated in a joint G7 intervention to support the euro (see Annual Debt and Reserves Management Reports 2009 and monthly press release of the UK Treasury).
[37] E-type (ECB-type) CBs, unlike F-type (Fed-type) CBs, have considerable amounts of assets denominated by foreign currency among their total assets (Sims 2004). Most CBs are classified as E-type.

paths compatible with foreign-domestic interest rate differentials. The '*fear of appreciation*' is used as a label to describe the intervention tendency of preventing domestic currency appreciation (Levy-Yeyati and Sturzenegger 2007).

In this chapter, we examine the motives for sterilised interventions in several countries. Previous studies suggest various intervention motives. In the literature, short-term motives, such as resisting current trends and reducing excessive FX volatility, are more apparent than long-term ones such as correcting medium or long-term misalignments of exchange rates deviated from fundamentals (see Neely 2000 for details). However, the asymmetric property of FX interventions has not been profoundly explored. In particular, we attempt to look at three questions: (i) What are the determinants of intervention decisions? (ii) Do CBs favour domestic currency depreciation rather appreciation? (iii) Is there any difference in the degrees of asymmetric intervention preference among countries?

The rest of this chapter is organized as follows. Section 2 describes the global phenomenon of reserves accumulation, which may reflect the prevalence of asymmetric interventions. Section 3 reviews previous literature on intervention motives and fear of appreciation. In section 4, for the purpose of the estimation of asymmetric intervention motives, we first investigate the long-term relationship between foreign reserve changes and exchange rate movements by using a bound test (Pesaran et al. 2001) with monthly reserves data on 11 countries. A buffer stock model for reserve demand provides theoretical background for testable regression equations. However, foreign reserves cannot be a complete proxy for interventions. Hence, using a probit and friction model with daily intervention data on Korea, Australia and Japan, we delve more profoundly into intervention motives. In particular, the friction model will provide us with better insights into the characteristics of asymmetric interventions. Section 5 concludes the chapter.

4.2 Literature review

4.2.1 Intervention motives

Intervention motives are examined by a CB's reaction function. To specify the intervention motives, consider following a conventional linear reaction function frequently used in previous studies:

$$(4.2.1)\quad INT_t = \alpha_0 + \alpha_1(\ln S_t - \ln S_t^T) + \alpha_2 \Delta \ln S_t + \beta X_t + u_t \qquad u_t \sim i.i.d$$

where INT_t is the amount of intervention at time *t* (with INT_t>0 for purchases of foreign currency); S_t and S_t^T are actual and target FX rate (calculated by the moving average of past FX rates or by the long-term equilibrium rate derived from purchasing power parity), which are expressed by domestic currency price of a unit of foreign currency; Δ is a first difference operator; X_t is a vector of control variables affecting current interventions (e.g. lagged interventions, trade balance or interest rate differentials, etc.); and u_t is an error term. If CB is to stabilise FX rates around the target, coefficient α_1 is expected to have a negative sign, because CB should sell foreign currency when actual FX rates exceed the target. Under the policy of "*leaning against the wind*", a priori expected sign of α_2 should also be negative, since CB must sell foreign currency when domestic currency depreciates.

Empirical evidence shows that intervention motives are highly sample-dependent, but commonly suggest two main motives: "*smoothing"* and "*leaning against the wind*". *Leaning-against-the-wind* appears most frequently reported as a short-term intervention motive in the recent literature (Baillie and Osterberg 1997, Rogers and Siklos 2003, Kearns and Rigobon 2005, Lecourt and Rayonds 2006). However, it may be impossible for market participants to differentiate leaning-against-the-wind and smoothing unless the CB announces its intentions.

The medium to long-term objectives of FXIs are somewhat different. CBs may not intervene in markets with a short-term perspective in order to correct a severe deviation of the exchange rate from fundamentals (Almekinders and Eiffinger 1994). Thus, it is likely that the reaction function of an individual CB could be varied or be interpreted differently at different times. For this reason, previous studies have used different trends in exchange rates as intervention targets in their reaction function. For example, target rates (generally modelled as a moving average of past exchange rates) are defined and used differently in previous studies: a 5 day (Almekinders and Eijffinger 1994), 10 day (Humpage 1998) or 150 day moving average (Kim and Sheen 2002, Neely 1998).

4.2.2 Asymmetric interventions motives in small open emerging economies

Most studies suggest that CBs are likely to resist domestic-currency appreciation more strongly than depreciation in both developed and emerging economies – except for in crisis periods or in high-inflation period. Interventions appear to aim at limiting appreciation rather than depreciation in most cases (and increasingly so in the 2000s) (Levy-Yeyati and Sturzenegger 2007). For example, Almekinders and Eijffinger (1996) find that, during the post-Louvre periods, the US Fed and Bundesbank attempted to respond more strongly to the appreciation than the depreciation of their domestic currencies.

The "*fear of appreciation*" is more prominent in small open emerging economies. Asymmetric intervention motives may come from the purpose of protecting trade competitiveness (Dooley et al. 2003) or of gaining revaluation effects from foreign assets in the case of E-type CBs (see Appendix 4.2). Specifically, many studies have proposed that the main reason for massive build-ups of foreign reserves in emerging countries is not a precautionary motive for minimizing the probability of sudden reversal of capital flows, but asymmetric interventions. In particular, frequent or sustained *asymmetric* interventions and the resultant large amount of foreign reserves have been referred to as explicit evidence of the prevalence of the *de facto* intermediate regime (dirty floats) among emerging IT countries within *de jure* free float.[38]

Theoretically and practically, it has been assumed that interventions for preventing domestic currency depreciation are less sustainable than their counterpart, since the former eventually leads to increasing risk of exhausting foreign reserves (Bofinger et al. 2001). There are no limits in funds for foreign currency purchasing interventions because the CB can print money. In addition, asymmetric interventions are more helpful for strengthening trade competitiveness and for improving the CB's balance sheet. These advantages have contributed to the accumulation of foreign reserves over time in emerging economies such as China, India, Taiwan and Korea.[39]

However, sustained "*fear of appreciation*" may not only postpone necessary adjustments but also make future sterilisations more difficult. First, sustained interventions may damage the credibility of monetary policy. Particularly, under IT, sustained asymmetric interventions may weaken market credibility for the CB's will to keep inflation under control, and thus make their future tasks more difficult – there is a risk of a *"vicious circle of depreciation and inflation".* For example, according to Brenner and Sokoler (2010)'s study

[38] According to Flood and Marion (2002), Jeanne (2007) and Steiner (2010), after the collapse of the Bretton Woods system, which supposedly caused most countries to introduce more flexible exchange regimes, global international reserve holdings (as a fraction of world GDP) increased sharply from less than 2% in 1960 to 6% in 1999 and to 18% in 2006. This trend has been accelerated since the financial crisis in the late 1990s—particularly in emerging economies. Since 1990, the average ratio of reserve to GDP in emerging countries has increased from 4% to 20% while the ratio of the advanced countries has been steady at approximately 4%.

[39] Égert (2007) suggests that interventions in six Eastern European emerging countries are more effective in resisting appreciation pressures. Dooley et al. (2003) argue that East Asian economies are intentionally undervaluing their currency so as to stimulate exports to the US, as a developing strategy.

on Israel, FXIs and inflation targeting policy cannot sustain each other in the long run, because the potential conflict between the two policies incurs unbearable costs to the economy and eventually the authorities should abandon one of the two policies. Furthermore, if FXIs do not have significant effects on exchange rates, FXIs and OMOs cannot be used as independent policy tools for managing trade-off between monetary independence and exchange rate stability, even in the short run.

Second, the discretionary procedures of the interventions may conflict with an IT regime which emphasizes clear rules and transparent communications. Most IT countries seem to prefer secret and discretionary FXIs, and do not reveal even ex-post information on interventions (BIS 2005). Transparent rules such as PPP rules may be difficult to be used as a rule for FXIs due to intrinsic differences between the characteristics of exchange rates and the prices of national outputs (Frankel 1983, p 51).[40]

Third, excessive sterilisations can impose heavy fiscal costs and cause CBs to make financial losses. Particularly, severe *"fear of appreciation"* renders the CB to be the net debtor of a banking system, since the CB has to absorb the surplus of domestic liquidity caused by FXIs. As Bofinger et al.(2001) points out, CBs (aiming at targeting constant nominal exchange rates), are not able to defend a strong appreciation pressure of domestic currency for long, when the domestic interest rate is higher than the foreign rate.

As will be discussed in Chapter 6, accumulated fiscal losses (stemming from sterilisation costs) may threaten the sustainability of sterilisations and endanger the CB's independence from the government (Stella 2005). Non-market friendly sterilisation tools for reducing sterilisation costs possibly impair the stability of domestic financial systems

[40] For example, PPP rules propose that when FX rates move more than relative price levels, CBs are expected to intervene so as to ensure the PPP. However, large FX rate movement with regard to PPP is not sufficient evidence that FX rate volatility is excessive, because FX rates tend to depend on expectations rather than relative price level. Thus, interventions based on the PPP may lead to misleading results.

(Mohanty and Turner 2005). In particular, implicit and explicit sterilisation costs become prominent when inflation pressure is high, so that the "*fear of appreciation*" should be supported by effective or cost-minimizing sterilisation tools.

Empirical studies have provided evidence of significant asymmetric FXIs in emerging countries (Ramachandran and Srinivasan 2007, Pontines and Rajan 2008, Pontines and Siregar 2010).[41] On the contrary, there are only a few studies suggesting that CBs resist depreciation more strongly than appreciation (see Carlson & Lo 2004 for the case of Taiwan).

4.2.3 Optimal reserve hoarding and asymmetric interventions

The preference for asymmetric interventions or fear of domestic-currency appreciation is deeply associated with the issues of optimal reserve holding. The asymmetric interventions result in massive holdings of foreign reserves that are deviated from optimal level (Levy-Yeyati and Sturzenegger 2007). With regard to large holdings of reserves in emerging economies, many studies have typically focused on precautionary reasons. That is, reserve build-up is to insure against sudden stop and reversal of capital inflows, which are the precursors of currency crises. The resilience of the high-reserve economies during recent sub-prime crisis partly validates the self-insurance motives in emerging countries.

However, as seen in 4.1, most emerging countries meet precautionary reserve bench marks such as reserves to short-term external debt, reserves to M2 and reserves to import. Actual level of reserve holdings in these countries is well above precautionary-motive-type optimal levels. Consequently, precautionary needs or self-insurance motives have limited

[41] Ramachandran and Srinivasan (2007), using the reserve demand model, find that Indian interventions are significantly asymmetric due to concerns about export competitiveness. Pontines and Rajan (2008) find an asymmetric tendency in the interventions of 5 emerging Asian countries by using a cubic loss function. Pontines and Siregar (2010), using a regime switching model, confirm the asymmetric interventions in 4 Asian IT countries. But these studies have a limit in explaining asymmetric interventions, because they use changes in foreign reserves as a proxy for the amount of actual interventions.

explanatory power to fully account for the recent pattern of reserves accumulation. For example, Jeanne (2007) shows that, from the point of view of crisis insurance, reserve build-up was excessive in Asian emerging countries during 2000-2005 in that the vulnerability of the counties to financial crisis was too low to justify the cost of accumulated reserves.[42]

Hence, some studies have paid attention to what (other than precautionary motives) drives CBs to favour asymmetric interventions and to build up large reserves. First of all, CBs in a high degree of dollarization in the banking system may need foreign reserves to serve as a lender of last resort to the commercial banks with large (Calvo et al 2012). Second, (so called) neo-mercantilist motives account for reserves hoarding in developing countries as one of their developing strategies. When developing countries' growth is impeded by undeveloped domestic financial markets, the countries could export their gross savings in the form of foreign reserves and then have them back via more efficient channel like FDI. In this case, large holdings of reserves function as collateral for encouraging FDIs (Dooley et al 2008).

Third, some economists point out that conventional cost-benefit models of optimal reserves appear to fail to account for the reserve build-up in many emerging countries (Jeanne 2007, Levy-Yeyati 2008). According to them, precautionary motives have overlooked potentially benign side-effect of the asymmetric interventions - reduction in domestic residents' financing cost from abroad (Levy-Yeyati 2008). According to Levy-Yeyati (2008), marginal cost of holing reserves in emerging countries could be substantially reduced (e.g. by more than 50%) if the benefits of holding reserves are properly considered. Hence, our measurement of intervention profits in Ch. 3 may possibly overstate the cost incurred by USD-purchasing interventions in Korea.

[42] However, Calvo et al. (2012) find that there is no significant over-accumulation of reserve in 27 emerging countries, according to their model based on optimal level of reserves maximising expected return net of cost.

4.3 Data and methodologies

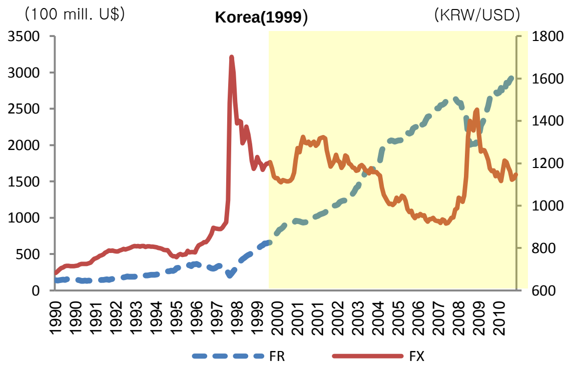
4.3.1 Foreign reserves and exchange rates in selected countries

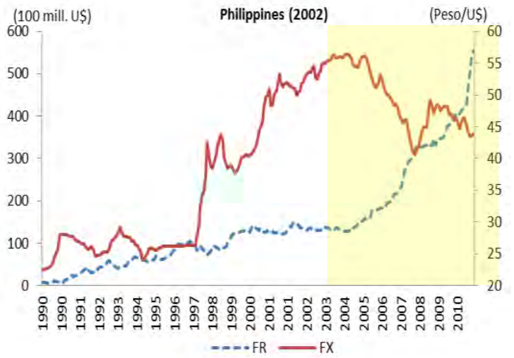
We first investigate asymmetric aspects of FX interventions in 11countries (Korea, Japan, Indonesia, Philippines, Thailand, Taiwan, Singapore, Australia, India, Brazil, Turkey) by using monthly reserves data from 1999M1 to 2010M4. Figure 4.1 presents the plots of FX rates and foreign reserves in major countries. Recently, foreign reserve accumulations appear to have been a common phenomenon in most countries, irrespective of monetary policy and exchange rate regimes. In particular, the accumulations are most prominent in Asian emerging countries, most of which experienced current account surplus or capital inflows in the last decade. Theoretically, given capital inflows, foreign reserve accumulation should be more prominent in fixed or managed float regimes than in free float regimes, because flexible exchange rates are known to adjust imbalances automatically.

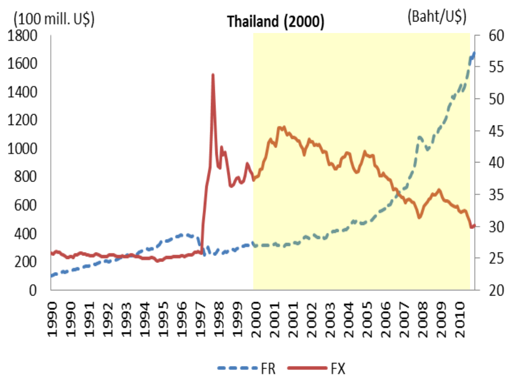
However, some countries seem to accumulate reserves more rapidly after the introduction of IT with free float regimes (see Figure 4.1(a) East Asian IT countries), which contrasts with relatively slower accumulation in countries with a longer history of IT(see Figure 4.1(c)). In this regard, there are some arguments that the continued accumulation of foreign reserves in emerging countries (even in Japan) may substantiate asymmetric interventions whose goal is to maintain competitiveness-protecting exchange rates. That is, the intervention motive is not just for *"smoothing"* (as claimed by the CBs) but for inducing domestic currency depreciation (Levy-Yeyati and Sturzenegger 2007). Foreign reserves would not consistently increase but would move around a certain level if intervention responses were symmetric to appreciation and depreciation. Asymmetric interventions would lead to not only increasing inflation in the intervening countries but also creating excessive global liquidity.

Figure 4.1 Foreign reserves (FR) and exchange rates(FX) in major countries

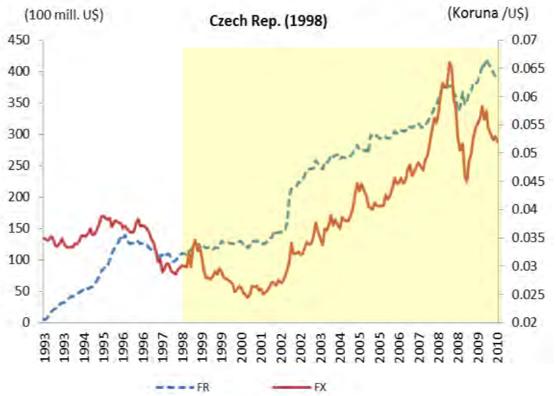
(a) East Asian IT countries

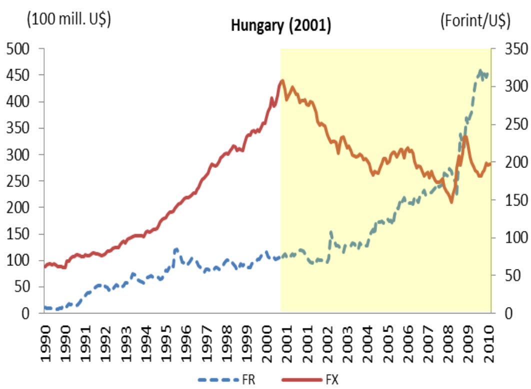


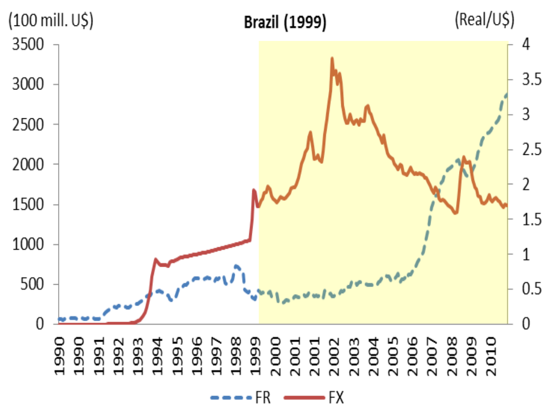


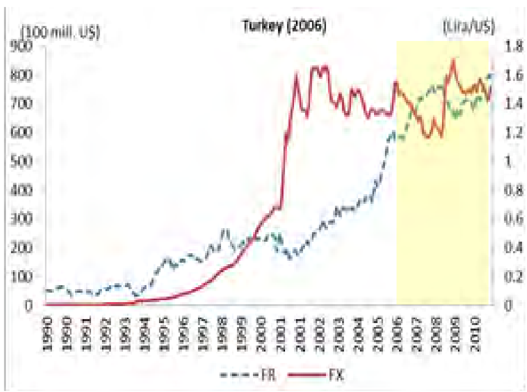


(b) Non-Asian IT countries

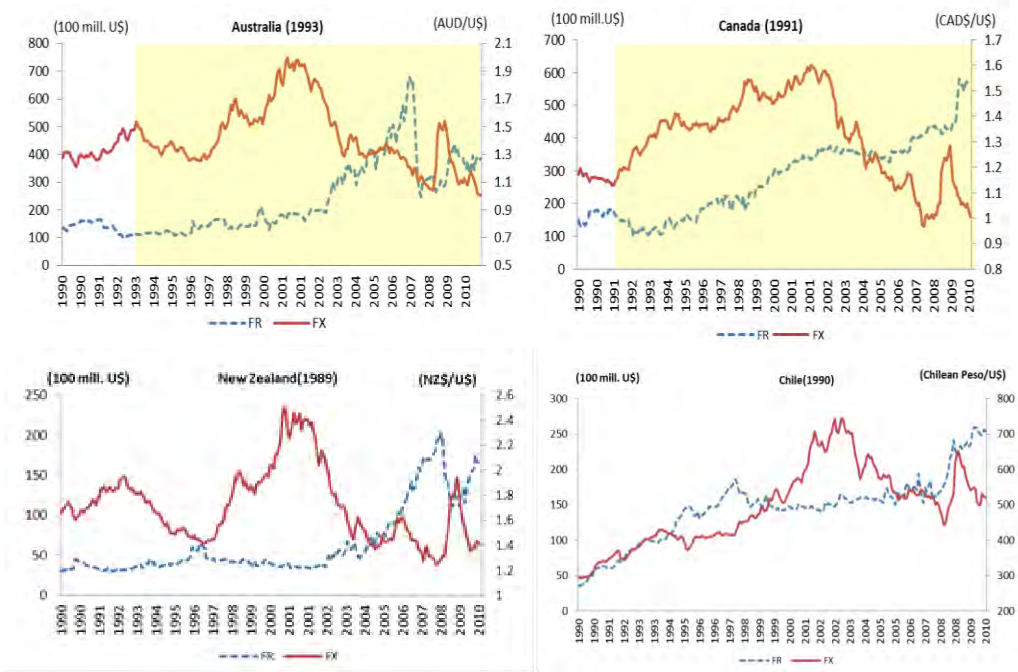




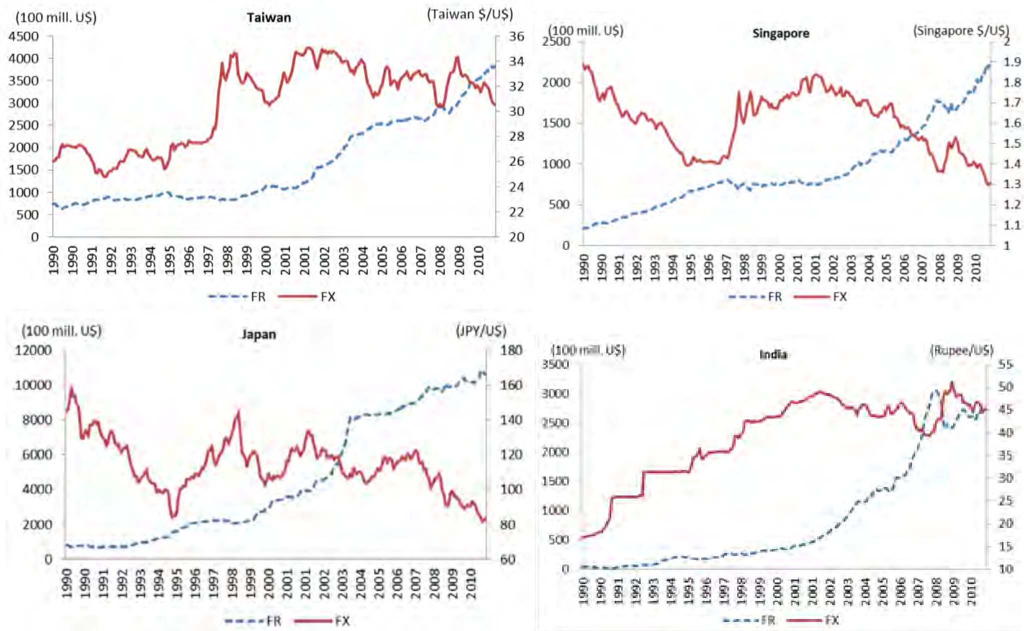




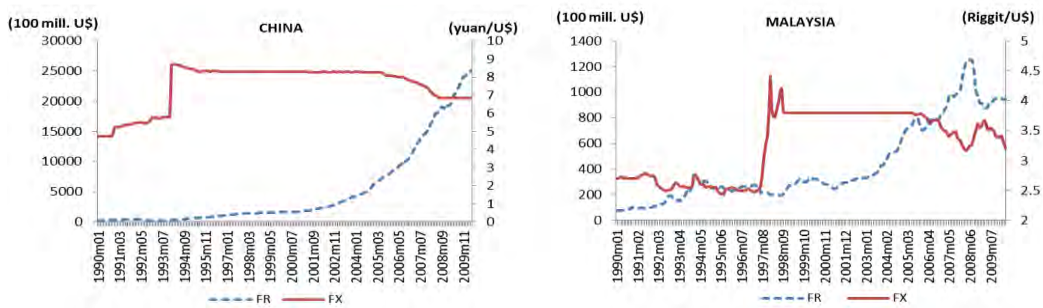
(c) Countries with a longer history of IT



(d) Non-IT countries: managed or free float



(e) Non-IT countries: fixed FX regime



Note: As for IT countries, the figures in ( ) indicate the years of introducing IT regime.
Source: IMF *IFS*

A buffer stock model may be appropriate for the analysis of the countries with either managed or free float regimes. Fixed FX regime countries (e.g. China) are excluded from samples, because the buffer stock model assumes that the demand for foreign reserves is determined by FX rate movements, volatility of reserves and the opportunity cost of holding reserves. When FX rates are invariant over time as in fixed regimes, the model does not provide significant insights into the relationship between foreign reserves and FX rate change.

Figure 4.1 suggests that foreign reserves have evolved in the opposite direction to FX rates in float or managed regime countries in recent times. This indicates that the CBs' demand for foreign reserves may be related to their responses to exchange rate movements, so the buffer stock model can be applied to the investigation of the CB intervention motives. At a glance, CBs appear to purchase foreign reserves against appreciation pressure. The inverse relation between foreign reserves and FX rates suggests the prevalence of leaning-against-the-wind. If foreign reserves continue to increase irrespective of the direction of FX rate movements, this may indicate the asymmetric preference for USD-purchasing interventions.

Table 4.1 shows the main indicators associated with foreign reserves during the non-crisis period of 2000-2007. In terms of the growth in foreign reserves, and the ratio of foreign reserves to import, M2 and foreign liabilities, there are no distinguishing features specific to Korea compared to other countries. The pattern of reserve accumulation in Korea is similar to that in Japan and other East Asian countries, except for China. China has recorded an unprecedentedly rapid increase in foreign reserves. Korea's foreign reserves (in terms of the ratios to monthly import and M2) increased while the ratios to short-term liabilities unchanged. Three indicators were all improved in Latin countries but degraded in East European countries despite the rapid increase in foreign reserves. Notice that emerging countries have accumulated foreign reserves above conventional benchmarks to cover short-term foreign liabilities. This is in contrast to developed countries, where foreign reserves are much less than a half of short-term foreign liabilities.

It may be somewhat difficult to explain the rapid accumulation of foreign reserves in emerging countries only by precautionary demands for addressing the rising volatility of external transactions, because some relevant indicators show that most emerging countries (except for Eastern Europe) have already held foreign reserves well above the appropriate levels suggested by some academic circles or international institutions. For example, reserves-to-monthly average import and reserves-to-short term liabilities in most emerging countries are well above 3 and 1 respectively, which are conventionally accepted as an appropriate level (Fisher 2001, Greenspan 1999). Thus, it is likely that the accumulation of foreign reserves may reflect the asymmetric properties of FX interventions.

Table 4.1 Main indicators of foreign reserves

	Foreign reserves(FR) (Bill. USD)			FR/monthly average import[6]		FR/M2 (%)		FR/short-term foreign liabilities[7]	
	2000(A)	2007(B)	B/A	2000	2007	2000	2007	2000	2007
Korea	**96**	**262**	**2.7**	**7**	**9**	**29**	**43**	**2**	**2**
Japan	**347**	**948**	**2.7**	**11**	**18**	**6**	**15**	**2**	**2**
Australia	**18**	**25**	**1.4**	**3**	**2**	**14**	**34**	**0**[8]	**0**[8]
China	166	1,528	9.2	9	19	10	28	8	14
Taiwan	107	270	2.5	9	16	19	34	8	7
Russia	24	464	19.3	6	23	44	78	2	5
Other Asia[1]	325	852	2.6	6	8	27	32	2	2
Latin[2]	136	397	2.9	5	7	23	32	1	3
Arab[3]	75	271	3.6	9	11	25	38	2	3
Eastern Europe[4]	66	223	3.4	5	4	39	34	2	1
Developed[5]	344	380	1.1	1	1	3	2	0[8]	0[8]

Notes: 1. Hong Kong, Indonesia, Malaysia, Philippine, Singapore, Thailand
2. Argentina, Brazil, Chile, Mexico, Columbia, Peru, Venezuela
3. Egypt, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Arab Emirate
4. Bulgaria, Croatia, Cheche Rep., Estonia, Hungary, Latvia, Lithuania, Poland, Rumania, Slovakia, Slovenia
5. Canada, Euro Area, Swiss, UK, US
6. This ratio reflects a country's current account vulnerability: 3 and 4 would be proper (Fisher 2001).
7. This measures a country's capability of servicing its external liabilities in the forthcoming year, if external financing conditions rapidly deteriorate. The ratio should be above 1 (Greenspan1999)
8. All ratios are rounded to the nearest integer.

Source: BIS(2008), BOK(2010), IMF *IFS*(2011, July)

4.3.2 Data description

Figure 4.2 depicts three CBs' net interest earning (resulting from FXIs), domestic-foreign interest rate differentials, exchange rates and the deviation of the current FX rate from a 200-day moving average. Over most of the sample periods, interest rate differentials are positive in Korea and Australia while negative in Japan.

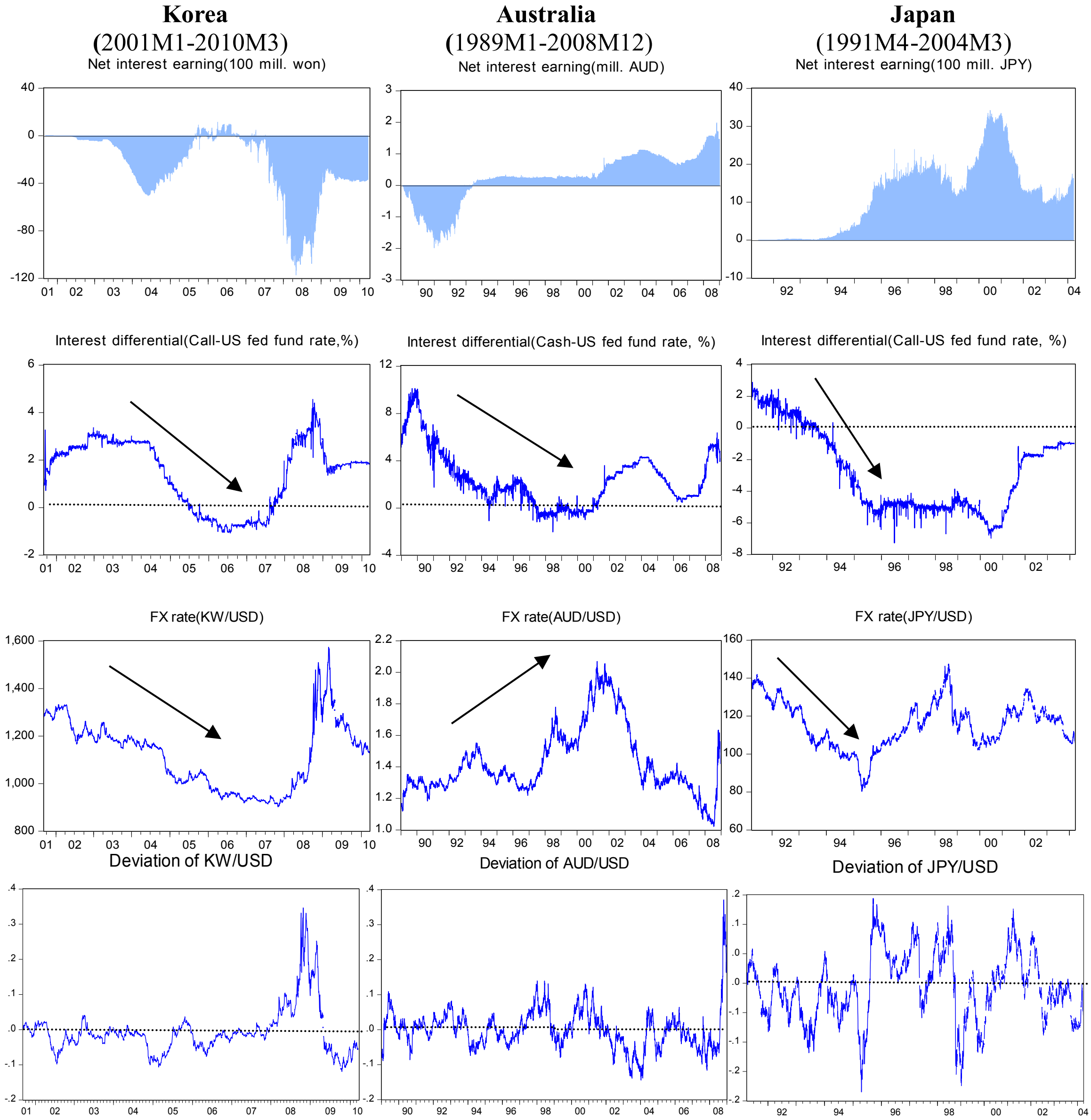
It is more apparent that FX rates move in the same direction as interest rate differentials in Korea than in Australia and Japan in the long-run perspective. Correlation coefficients between the two series are 0.70 (Korea), -0.36 (Australia) and 0.34 (Japan) during the sample period. The causality between the two variables seems different depending on theories, particularly the assumption on price. Typically, the theoretical relationship between two variables is considered to be negative in the short run due to sticky prices and positive in the long run with flexible price (Hacker et al. 2010).[43]

The persistent appreciation of KRW before the advent of the sub-prime crisis in mid-2007 may reflect current account surpluses and capital inflows. Sterilisations may have contributed to the high domestic-foreign interest rate differential in 2001-2004, which possibly induced further capital inflows. While KRW persistently appreciated before late 2007, the interest differential became negative in the mid-2000s. This may be due mainly to rapid rises in the US fed fund rates rather than falls in Korean interest rates. The plot of exchange rate deviation from its trend shows that, unlike the JPY/USD and AUD/USD rate, the KRW/USD rate persistently downwardly deviated from its trend except during the

[43] Monetary approaches provide two theoretical explanations for the relationship between nominal interest differential and nominal FX rates (Simone and Razzak 1999, pp.3-4). First is the sticky-price monetary approach, in which a relative rise in domestic interest rates will stimulate capital inflows and thereby appreciate domestic currency. Consequently, interest rate differentials and FX rates move in the opposite direction (Dornbusch1976, Frankel 1979). The flexible price monetary approach assumes that a relative rise in domestic rates indicates an increase in expected inflation, which leads to the depreciation of domestic currency by reducing demands for domestic money. In this case, interest rate differentials and FX rates move in the same direction (Mussa 1979).

subprime crisis period in 2007-2010. Hence, the BOK may have strong intervention motives for resisting the KRW appreciation.

Figure 4.2 Interest earnings, interest differentials and FX rates in three countries



Notes: 1. Interest rate differentials = O/N money market rates - O/N US fed fund rates.
2. FX rates are the price of domestic currency per one USD.
3. The calculation of net interest earning follows Ito (2003) and Becker and Sinclair (2004), See Chapter 3.
4. Deviation = current FX rate - 200 day backward moving average; both are scaled by logarithm

Sources: IMF *IFS* and each central bank homepage

4.3.3 Methodologies

In this section, we first compare the degree of asymmetric intervention preference of 11 countries by using the buffer stock model with monthly foreign reserves data. Provided that changes in foreign reserves reflect FX interventions, we examine the existence of long-run relationships between foreign reserves changes and FX rate movements via the buffer stock model. This approach enables us to conduct cross-country analysis for as many countries as possible, because we can easily access foreign reserve data on most countries. However, foreign reserve is not a perfect proxy for interventions, so we set up a reaction function for three countries (Korea, Japan and Australia) with daily data.

According to the general conclusion drawn from the previous literature, three main hypotheses are tested. First, CBs mostly lean against the wind (see Sarno and Taylor 2001). Second, CBs in small open emerging economies (e.g. Korea) have a stronger asymmetric preference for USD-buying intervention than large economies (e.g. Japan) or small open advanced economies (e.g. Australia). This hypothesis owes to the "*fear of appreciation*": asymmetric preference may be prominent in small open emerging economies which are more export-oriented for growth or are vulnerable to capital mobility. Third, CBs aim for calming down markets by reducing both deviations of FX rates from their level and volatility trend.

4.3.3.1 Analysis with monthly foreign reserves: ARDL cointegration approach

In this section, we examine the asymmetric aspects of interventions in selected countries by using demand functions for foreign reserves based on the buffer stock (or inventory) model. According to this model, the optimal level of foreign reserves should be what balances macroeconomic adjustment costs (incurred in the absence of reserves) with the opportunity cost of holding reserves (Aizenman and Marion 2004, p571). If we modify the conventional buffer stock model,[44] the demand for foreign reserves may be represented in either of the following equations (Ramachandran and Srinivasan 2007).

(4.3.1) $\log(FR_t) = \alpha_o + \alpha_1 \log(\sigma_t^2) + \alpha_2 dif_t + \gamma \Delta S_t + \varepsilon_{st}$

(4.3.2) $\log(FR_t) = \beta_o + \beta_1 \log(\sigma_t^2) + \beta_2 dif_t + \lambda_1 \Delta S_t^a + \lambda_2 \Delta S_t^d + \varepsilon_{at}$

where FR_t is the level of foreign reserves; σ_t^2 is a variance of reserves increment measured by ARCH(1,1) process; dif_t is an opportunity cost of holding reserves measured as domestic-foreign interest rate differential; ε_{st} and ε_{at} are white noise errors; ΔS_t is the log difference of FX rate; $\Delta S_t^a = dum1 \cdot \Delta S_t$ where *dum1*=1 if $\Delta S_t < 0$ (appreciation) and zero otherwise; $\Delta S_t^d = dum2 \cdot \Delta S_t$ where *dum2*=1 if $\Delta S_t > 0$ (depreciation) and zero otherwise.

The two equations are exactly same except that (4.3.2) considers asymmetric responses of reserve demand to the direction of FX rates changes. The sign of σ_t^2 and dif_t should be positive and negative respectively, because optimal reserve holdings should increase with the increase in reserve volatility or reduction in opportunity cost. The constants are expected to be positive, since they represent country-specific adjustment costs.

The interpretations of the coefficient on ΔS_t are not directly associated with the original buffer stock model. In (4.3.1), γ<0 implies that CBs lean against the wind and

[44] In the empirical context, the buffer stock model was firstly applied for examining foreign reserves by Frenkel and Jovanovic (1981) and extended by Edwards (1985) and Flood and Marion (2001). Frenkel and Jovanovic (1981) use the following equation for reserve demand: $FR^* = \sqrt{c\sigma / r^{0.5}}$, where FR^* = optimal level for reserves after restocking; c =country-specific constant to capture the fixed adjustment cost; r =opportunity cost (e.g. risk free rate); and σ =volatility of reserve increments. Thus, increases in c or σ lead to increases in the demand for reserves, while increases in r cause reserve demand to reduce. Log transformation presents a useful starting-point for the empirical specification similar to (4.3.1): $\log(FR^*) = c + 0.5\log(\sigma) - 0.25\log(r)$

exchange rate variations have a symmetric impact on reserve demands. Equation (4.3.2) considers the asymmetric responses of foreign reserves to changes in exchange rates: λ_1 and λ_2 measure the response of reserve demand to appreciation and depreciation, respectively. Note that both λ_1 and λ_2 should be negative under a "*leaning against the wind*" policy but positive under a *"leaning with the wind"* policy. For example, $\lambda_1<0$ indicates the purchase of foreign reserves ($FR_t \uparrow$) in response to appreciation (ΔS_t <0) while $\lambda_2 < 0$ implies the sales of foreign reserves ($FR_t \downarrow$) in response to depreciation (ΔS_t >0). Thus, CBs react more to appreciation than to depreciation when $\lambda_1<0$and $\lambda_2<0$and$|\lambda_1| > |\lambda_2|$ or when $\lambda_1<0$ and $\lambda_2 > 0$.

As will be shown later, we cannot use ordinary least square because the dependent variable (FR_t) is I(1) but the regressors are either I(1) or I(0). Simple OLS may be subject to a spurious regression problem. Hence, we need to see whether the variables are cointegrated. Several cointegration approaches are available, such as Engle and Granger's (1987) two-step approach, Johansen and Juselius' (1990) approach and Pesaran et al.' (1996, 2001) ARDL approach, normally called the "bounds test", etc.

Both Johansen and Juselius' approach and the bounds test can be used when variables are integrated of different orders – e.g. I(1) and I(0). In particular, provided that variables are at most I(1), Johansen's cointegrated VAR model may be appropriate. However, when Johansen approach is used in the case of a small sample with mixtures of I(1) and I(0), it is possible that the coefficient of the I(0) variables cannot be identified. In contrast, Pesaran et al.'s (2001) approach enables one to obtain more consistent estimates in the case of small sample. Considering that our sample is small, covering only 11 years,[45] and that variables are integrated of different orders with I(1) and I(0) in a single equation, the bounds test appears

[45] In estimating cointegration, what matters is the length of the period rather than the number of observations. Increasing the number of observations through using monthly data does not increase the robustness of the cointegration (Hakkio and Rush 1991b).

more appropriate.[46] To use the bounds test, we first estimate the following unrestricted error correction model (ECM) to see whether there is a long-run relationship among the variables (Pesaran et al. 2001, pp. 295-296).

$$\begin{aligned}(4.3.3)\quad &\Delta \log FR_t = a + \varpi_1 \log FR_{t-1} + \varpi_2 \log \sigma^2_{t-1} + \varpi_3 (dif_{t-1}) + \varpi_4 S^a_{t-1} + \varpi_5 S^d_{t-1} \\ &+ \sum_{i=1}^{m} b_i (\Delta \log FR_{t-i}) + \sum_{i=1}^{n1} c_i (\Delta \log \sigma^2_{t-i}) + \sum_{i=1}^{n2} d_i (\Delta dif_{t-i}) + \sum_{i=1}^{n3} f_i (\Delta S^a_{t-i}) + \sum_{i=1}^{n4} g_i (\Delta S^d_{t-i}) + \varepsilon_t\end{aligned}$$

where ϖ_i are long-run coefficients; b_i c_i d_i f_i and g_i are short-run coefficients. If we reject the null of no cointegration ($\varpi_1 = \varpi_2 = \varpi_3 = \varpi_4 = \varpi_5 = 0$), then it could be concluded that there is a long-run cointegration among FR_t , σ^2_t , dif_t , S^a_t and S^d_t . Equation (4.3.3) is an error correction version of the autoregressive distribution lag (ARDL) model of order (m, n1, n2, n3, n4). The number of lags is determined by AIC (with a maximum lag of 8). We additionally include a monthly amount of import and M2 to see whether CBs concern other precautionary demands for foreign currency. If the null is rejected, then we estimate the long-run coefficients by using the following ARDL model.[47]

$$(4.3.4)\quad \log FR_t = a_o + \sum_{i=1}^{q1} \theta_{1i} \log FR_{t-i} + \sum_{i=0}^{q2} \theta_{2i} \log \sigma^2_{t-i} + \sum_{i=0}^{q3} \theta_{3i} dif_{t-i} + \sum_{i=0}^{q4} \theta_{4i} S^a_{t-i} + \sum_{i=0}^{q5} \theta_{5i} S^d_{t-i} + v_t$$

[46] Pesaran et al.'s (2001) approach to cointegration has a advantages over Engle and Granger's (1987) and Johansen and Juselius' (1990) approach: (i) Once the order of ARDL is identified, OLS can be used for the estimation; (ii) Bounds test makes it possible to estimate consistent coefficient on I(0) variables even in the case of a small sample. However, the bounds test is feasible only in a single equation and assumes that there exists only one cointegration. So the bounds test is less general than Johansen's cointegrated VAR approach.

[47] A conditional long-term model for $\log FR$ can be obtained from the reduced-form solution of (4.3.3) when $\Delta \log FR = \Delta \log \sigma^2 = \Delta dif = \Delta S^a = \Delta S^d = 0$: $\log FR_t = -(a/\varpi_1) - (\varpi_2/\varpi_1) \log \sigma^2_t - (\varpi_3/\varpi_1) dif_t - (\varpi_4/\varpi_1) S^a_t - (\varpi_5/\varpi_1) S^d_t + (\varepsilon_t/\varpi_1)$. Under the assumption of q1=1 and q2=q3=q4=q5=0, (4.3.4) can be rewritten: $\log FR_t = a_o + \theta_{11} \log FR_{t-1} + \theta_{20} \log \sigma^2_t + \theta_{30} dif_t + \theta_{40} S^a_t + \theta_{50} S^d_{t-i} + v_t$. Thus, we can obtain coefficients; $a_0 = -(a/\varpi_1)$, $\theta_{11} = -(\varpi_2/\varpi_1)$, $\theta_{20} = -(\varpi_3/\varpi_1)$, $\theta_{30} = -(\varpi_4/\varpi_1)$, $\theta_{40} = -(\varpi_5/\varpi_1)$ .We assume that the numbers of lags in distribution lag term of (4.3.4) are the same, that is symmetric lag number (i.e., q2=q3=q4=q5).

4.3.3.2 Analyses with daily intervention data

Daily intervention data have unusual distributions due to sporadic or infrequent interventions. As for most of the daily observations, the amount of intervention has the value of zero and thus intervention series are discontinuous as seen in Figure 3.2, 3.3 and 3.4 in Chapter 3. Consequently, modelling the intervention reaction function (in which most of the dependent variables are zero while regressors are non-zero) has become a major challenge to researchers. Conventional linear reaction functions have significant limits, because (i) they are likely to confront severe simultaneity problems between FX rates and interventions; and (ii) they disregard the properties of intervention data in which most observations show zeros. Standard regression estimation without considering the features of intervention data may produce biased estimators, because errors from the regression may not be asymptotically normally distributed. Hence, as Neely (2005) points out, considerations of nonlinearity of interventions could be helpful in identifying intervention motives and lessening simultaneity problems. In this context, censored regression or limited dependent variable models tend to be preferred to linear models in modelling an intervention reaction function.

In particular, previous studies mostly modelled the probability rather than the amount of interventions by using (ordered) probit models (Baillie and Osterberg 1997; Dominguez 1998; Kim and Sheen 2002; Guimaraes and Karacadag 2004, Ito and Yabu 2007), or a logit model (Frenkel and Stadtmann 2001; Frenkel et al. 2005). If the amount of interventions rather than the probability of interventions is of interest, economists model a reaction function by using the Tobit model (Almekinders and Eijffinger 1994; Humpage 1999; Herrera and Özbay 2005) or friction model (Almekinders and Eijffinger 1996; Kim and Sheen 2002, 2006; Neely 2007; Jun 2008, Gnabo et al. 2010). A friction or a Tobit model seems preferred to a probit model in the recent literature. Recently, the friction model is considered as the most appropriate for intervention studies (Neely 2007).

In this chapter, we apply both probit and friction model. The probit models the probability of two types of interventions: USD-buying and selling interventions. The friction model considers three different states of interventions (USD-buying, USD-selling intervention and no-intervention) which are drawn from different distributions (Kim and Sheen 2002, p 636).We use the same daily intervention data on Korea, Japan and Australia as in Chapter 3. The sample periods and subsample periods are also same (see Section 3.4.1 in Chapter 3).

- Korea: pre-subprime(12/9/2001-31/7/2007), post-subprime(1/8/2007-23/3/2010)
- Japan:pre-Sakakibara(8/4/1991-20/6/1995), post-Sakakibara(21/6/1995-1/3/2004)
- Australia: pre-IT (2/1/1989-30/6/1992), post-IT (1/7/1992-30/12/2008)

It is worthwhile to note three points with regard to interventions in the subsample periods. (i) KRW was usually under appreciation pressure during the pre-subprime period (that reflects ordinary or peaceful times), while it was under strong depreciation pressure during the post-subprime (crisis) period. Thus, USD-selling interventions are concentrated in the post-subprime period.(ii) The pre-Sakakibara period was characterized by frequent and relatively small-scale interventions while the post-Sakakibara period by infrequent but large interventions. (iii) RBA never conducted USD-purchasing interventions in the post-IT period.

4.3.2.2(a) Probit model

We first estimate the probit model where the dummies for intervention and no-intervention outcomes are generated for each of two intervention types. The probit model provides us with a simple way to gain an overview on intervention motives, contributes to enhancing the robustness of estimations using the friction model, and helps us to interpret the friction model (Kim and Sheen 2002, pp. 640-642).

$$(4.3.5)\ INT_t^{buy} = a_1 + a_2 FXDEV_t + a_3 h_t + a_4 DIFF_t + a_5 \Delta CDS_t + a_6 INT_{t-1}^{buy} + a_7 \Delta MSB_t + a_8 NBUY_t$$

$$(4.3.6)\ INT_t^{sell} = b_1 + b_2 FXDEV_t + b_3 h_t + b_4 DIFF_t + b_5 \Delta CDS_t + b_6 INT_{t-1}^{sell} + b_7 \Delta MSB_t + b_8 NBUY_t$$

where $INT_t^{buy} = 1$ if USD-purchasing amount > 0, and zero otherwise

$INT_t^{sell} = 1$ if USD-selling amount > 0, and zero otherwise

$FXDEV_t = S_t - \frac{\sum_{i=1}^{200} S_{t-i}}{200}$: FX rate deviation from 200-day backward moving average[48]

h_t : Conditional volatility of daily return on FX rate change, obtained from the ACT-GARCH model in chapter 3

$DIFF_t$: Overnight interest rate differential (domestic- foreign): a proxy for potential overshooting of FX rate (Dornbusch 1976, Kim and Sheen 2002)

ΔMSB_t : 90-day backward moving average of changes in MSB (used only for Korea)

$NBUY_t$: Foreign investors' net purchase of Korean stock (used only for Korea)

Note that ΔMSB_t and $NBUY_t$ are used only in examining Korea owing to the lack of relevant historical daily data on Japan and Australia. ΔCDS_t is included in the estimation for Japan and Australia over subsample periods owing to the limited data availability. Assuming that CBs attempt to calm FX markets and to reduce the overshooting of FX rates, the expected signs of the coefficients are as follows:

(i) $a_2 < 0$: A fall in FX rate from its trend (i.e., FXDEV<0; appreciation) increases the probability of USD-buying interventions.

(ii) $b_2 > 0$: A rise in FX rate from its trend (i.e., FXDEV>0; depreciation) increases the probability of USD-selling interventions.

(iii) $a_3 > 0$, $b_3 > 0$: A high FX volatility prompts USD-buying or USD-selling interventions.

(iv) $a_4 > 0$, $b_4 < 0$: A rise (fall) in the US interest rate and resultant decrease (increase) in the interest rate differential may lead to excessive overshooting, i.e. distorted depreciation (rapid appreciation), which prompts USD-selling (USD-purchasing) interventions.

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[48] We use a 200-day (simple) moving average because this is most widely used as a main indicator to show the long-term trend of FX rates in the market. See the following articles: (http://www.bloomberg.com/news/2010-08-09/won-may-gain-5-after-break-of-200-day-moving-average-technical-analysis.html or http://www.bloomberg.com/apps/news?pid=newsarchiveandsid =a7BmtkqCaZkA)

(v) $a_5 < 0, b_5 > 0$: An increase (decrease) in a country risk and resultant depreciation (appreciation) pressure increases(decreases) the possibility of USD-selling (USD-purchasing) interventions.

(vi) $a_6 > 0$, $b_6 > 0$: Most CBs intervene consecutively in the same direction once initiating interventions.

(vii) $a_7 < 0$, $b_7 < 0$: If BOK is concerned about sterilisation costs, an increase in MSB may lead to a reduction in any kind of sterilised intervention.

(viii) $a_8 > 0$, $b_8 < 0$: Foreigners' purchase (sale) of Korean stocks causes BOK to buy (sell) USD.

4.3.2.2(b) Friction model

Because the probit model does not provide direct information on the extent of asymmetric intervention, the second step is to estimate a friction model. A friction model, firstly suggested by Rosett(1959), is appropriate to describe the interventions as cost-minimizing behaviours. In practice, CBs do not intervene whenever the FX rate deviates from its trend or fluctuates. CBs tend to intervene when FX rate changes are so severe as to breach a certain threshold set by the CB owing to the fixed costs of interventions (e.g., brokerage fees or bid-ask spreads). The friction model provides information on the threshold.

The friction model has several advantages over the Tobit model. Both models reflect the discontinuous intervention process, allowing a dependent variable (here intervention amounts) to be insensitive to its determinants over a range of values. However, the friction model appears more appropriate, since it is consistent with a reasonable assumption that CBs intervene when the intervention necessity grows beyond a certain threshold (Jun 2008, p 477; Kim and Sheen 2002, p 621). In addition, while the Tobit model may take either USD-purchasing or USD-selling amounts as the dependent variable but not both, the friction model allows both interventions to be included simultaneously in a single reaction function and thus makes the specification more parsimonious.

Following Kim and Sheen (2006), and Neely (2008), we assume that the CBs do not target a specific FX rate level under a (*de jure*) free float regime. This is because most CBs have not declared their target under free float (Rhee 2005, Kim and Sheen 2002, p 626) and because there are still unsolved disputes about equilibrium FX rates reflecting fundamentals. Instead, we hypothesize that CBs conduct interventions to achieve the following objectives: (i) correcting short-term deviations of the FX rate from its trend; (ii) smoothing FX rates; (iii) adjusting FX rate changes possibly caused by interest rate differentials; (iv) rebalancing their portfolio; and (v) limiting cumulative losses incurred by previous interventions. Considering these motives, we set up the following reaction function:

(4.3.7)
$$\begin{aligned} INT_t &= \alpha_1 INT_{t-1} + (\beta_{dev} I_{dev,t} + \beta_{cum} I_{cum,t} + \beta_{size} I_{size,t}) \times \left| FXDEV_t \right| \\ &+ (\lambda_c I_{ds,t} + \lambda_{hsize} I_{ds,t} I_{hsize,t}) h_t + \gamma_{diff} DIFF_t + \gamma_{msb} \Delta MSB_t + \varepsilon_t \end{aligned}$$

where

INT_t : Net market purchase of USD with KRW (JPY, AUD) by the BOK (BOJ, RBA), in 1 trill KRW (1 trill. JPY, 10 mill. AUD) (negative values indicate net market sales of USD)

$I_{dev,t}$: Dummy that takes +1(-1) if $FXDEV_t > 0$ $(FXDEV_t < 0)$ and 0 otherwise. $FXDEV_t > 0$ indicates that KRW (JPY, AUD) is depreciating against the USD

$I_{cum,t}$: Dummy that takes +1(-1) if $FXDEV_t > 0$ $(FXDEV_t < 0)$ for three consecutive days (i.e. t-2 to t) and 0 otherwise

$I_{size,t}$: Dummy that takes +1(-1) if $FXDEV_t > 0$ $(FXDEV_t < 0)$ and by more than 5%, and 0 otherwise

$I_{ds,t}$: Dummy that takes +1(-1) if $\Delta S_t > 0$ $(\Delta S_t < 0)$, and 0 otherwise

$I_{hsize,t}$: Dummy that takes 1 if current conditional variance is higher than unconditional (or average conditional) variance for each sample

h_t : Conditional variance of daily exchange rate returns generated from variance equation (3.4.10)

ε_t : error term, $\varepsilon_t \sim N(0, \sigma^2)$

In (4.3.7), the prior expected signs of the coefficients are as follows:

(i) If CBs lean against the wind, exchange rate fall (rise) excessively deviated from the trend in both level and volatility is likely to result in USD–buying (selling) interventions ($\beta_{dev} < 0$, $\lambda_c < 0$, $\beta_{size} < 0$, $\lambda_{hsize} < 0$). However, it is possible that the coefficients have positive signs in case of leaning-with-the-wind interventions[49].

(ii) In the case of leaning against the wind, the more persistent the deviation, the larger the intervention ($\beta_{cum} < 0$).

(iii) Large domestic-foreign interest rate differentials may result in a possibly distorting appreciation of KRW(JPY, AUD), leading to USD-buying interventions($\gamma_{diff} > 0$).

(iv) Persistent interventions may improve the intervention impact, so that interventions are likely to occur consecutively in the same direction ($0 \le \alpha_1 \le 1$).

(v) If BOK is concerned about sterilisation cost, increases in MSB weaken the motive for USD-purchasing intervention ($\gamma_{msb} < 0$).

Considering intervention costs, CBs would conduct interventions only when positive or negative thresholds were trespassed. Denoting INT_t^* as the right hand side of equation (4.3.7), excluding error terms, and δ_{I+} and δ_{I-} as the positive and negative thresholds, respectively, we can write a friction model as follows:

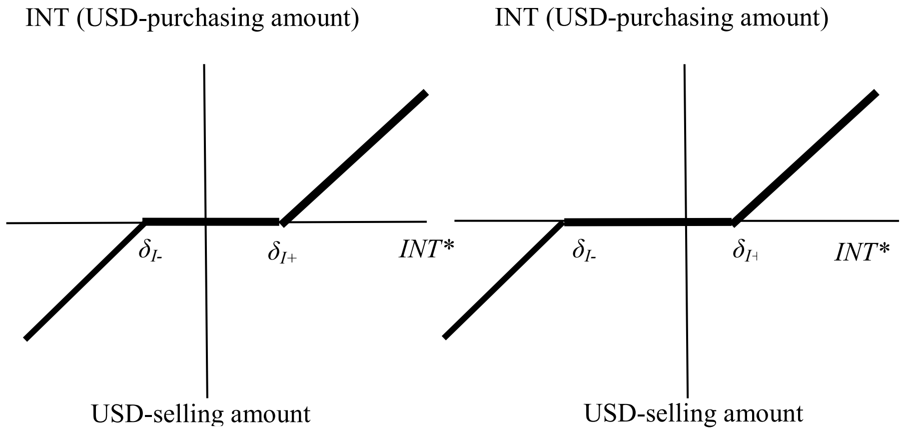
$$(4.3.8) \quad INT_t = \begin{cases} INT_t^* - \delta_{I+} + \varepsilon_t \ \text{ if } \ INT_t^* > \delta_{I+} > 0 & : \text{ USD-buying intervention} \\ 0 \qquad\qquad\qquad \text{ if } \ \delta_{I-} \le INT_t^* \le \delta_{I+} & : \text{ No intervention} \\ INT_t^* - \delta_{I-} + \varepsilon_t \ \text{ if } \ INT_t^* < \delta_{I-} < 0 & : \text{ USD-selling intervention} \end{cases}$$

Note that the latent variable INT_t^* is the desirable amount of interventions only known to the CBs, while INT_t is the actual amount of interventions. Thus, INT_t^* measures the necessary amount of the intervention when the CBs attempt to counter market misalignment

[49] Note that β_{size} is less subject to the endogeneity problem than β_{dev}. The three coefficients (β_{dev} β_{cum} β_{size}) would pick up the disaggregated effects of the deviations of the FX rate level from its trend: β_{dev} reflects an average effect of deviations, β_{cum} indicates the effect of persistent deviations, and β_{size} deals with large current deviations (Kim and Sheen 2002, p 639). Similarly, λ_c and λ_{hsize} indicate the effect of average and large deviation of the FX rate volatility from its trend, respectively.

as in a fixed exchange regime. Equation (4.3.8) suggests that, owing to intervention costs, the CBs under free float regimes conduct actual interventions only if $INT_t^* > \delta_{I+}$ or $INT_t^* < \delta_{I-}$. The estimates of two thresholds indicate the degree of asymmetric intervention. If $|\delta_{I-}| > |\delta_{I+}|$, FXIs are asymmetric in the sense that the CBs respond more sensitively to appreciation.

Figure 4.3 Friction model



(a) Symmetric intervention ($|\delta_{I-}|=|\delta_{I+}|$) **(b) Asymmetric intervention ($|\delta_{I-}|>|\delta_{I+}|$)**

The parameters in (4.3.7) and (4.3.8) can be estimated by maximum likelihood (see Almekinders & Eijffinger (1996) and Neely (2007) for details) and the likelihood function (L_t) can be written as:

$$
\begin{aligned}
L_t = & \prod_{INT_t>0} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(\varepsilon_t + \delta_{I+})^2}{2\sigma^2} \right) \\
(4.3.9) \quad & \times \prod_{INT_t=0} \left\{ \Phi\left(\frac{\delta_{I+} - (INT_t - \varepsilon_t)}{\sigma} \right) - \Phi\left(\frac{\delta_{I-} - (INT_t - \varepsilon_t)}{\sigma} \right) \right\} \\
& \times \prod_{INT_t<0} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(\varepsilon_t + \delta_{I-})^2}{2\sigma^2} \right)
\end{aligned}
$$

where Φ denotes the probability density of the N(0,1) distribution.

4.4 Estimation results

4.4.1 Long-run relationship between FX rates and reserves: Bounds test

Before examining a long-run relationship among foreign reserves (FR_t) and other variables, i.e., dif_t, σ_t^2, S_t^a, S_t^d, IMP_t and M2, we conduct ADF unit root tests for the variables. The results are presented in Table 4.2. FR_t, IMP_t and $M2_t$ are I(1) while S_t^a and S_t^d are I(0) in all countries. However, the integration properties of dif_t and σ_t^2 are different depending on countries.

Table 4.2 ADF unit root test

	Foreign Reserves (FR)	Volatility of reserve change(σ_t^2)	Interest differential (dif)	Appreciate (S^a)	Depreciate (S^d)	Import (IMP)	M2
Korea	0.404	-7.009***	-2.330	-6.795***	-9.671***	-0.440	0.182
	(0.982)	(0.000)	(0.163)	(0.000)	(0.000)	(0.898)	(0.997)
Australia	-1.702	-2.954**	-2.160	-11.683***	-10.105***	N.A	N.A
	(0.428)	(0.040)	(0.221)	(0.000)	(0.000)		
India	-0.118	-4.362***	-1.343	-7.980***	-8.042***	-2.560	-2.604
	(0.944)	(0.001)	(0.608)	(0.000)	(0.000)	(0.299)	(0.279)
Japan	0.738	-7.946***	-1.497	-12.002***	-12.760***	-2.927	-1.384
	(0.992)	(0.000)	(0.533)	(0.000)	(0.000)	(0.157)	(0.861)
Indonesia	0.617	-2.371	-2.569	-11.109***	-3.922***	-1.102	N.A
	(0.999)	(0.392)	(0.101)	(0.000)	(0.002)	(0.713)	
Philippines	0.310	-3.300*	-3.773***	-10.341***	-5.682***	-2.342	N.A
	(0.998)	(0.070)	(0.004)	(0.000)	(0.000)	(0.160)	
Thailand	2.748	-0.895	-2.615*	-9.048***	-4.572***	0.0712	N.A
	(0.999)	(0.953)	(0.091)	(0.000)	(0.001)	(0.962)	
Taiwan	-1.467	0.306	-2.806*	-11.705***	-10.358***	-1.885	N.A
	(0.836)	(0.977)	(0.058)	(0.000)	(0.000)	(0.338)	
Singapore	-1.134	-2.271	-1.143	-9.612***	-8.431***	-0.986	-0.197
	(0.918)	(0.182)	0.697	(0.000)	(0.000)	(0.757)	(0.992)
Brazil	1.554	0.498	-3.146**	-14.640***	-11.920***	-1.218	N.A
	(0.999)	(0.986)	(0.024)	(0.000)	(0.000)	(0.666)	
Turkey	-1.181	-1.250	-3.893***	-8.202***	-6.949***	-1.753	N.A
	(0.680)	(0.893)	(0.003)	(0.000)	(0.000)	(0.402)	

Notes:1 Both an intercept and a trend are included in testing FR, IMP and M2; Only an intercept is included in testing others; The number of lags is determined by AIC.
2. ***, ** and * denote the rejection of the null of unit root at the 1%, 5% and 10% level, respectively.
3. p-value in ( )
4. N.A indicates that data is not available.

For example, dif_t is I(1) in Korea, Japan, Australia, India, Japan, Indonesia and Singapore but I(0) in Taiwan, Philippines, Thailand, Brazil and Turkey. σ_t^2 is I(0) in Korea, Australia, India and Philippines, and I(1) in the other countries. All variables are at most I(1).

The results of the bounds test are presented in Table 4.3. Five variables (FR_t σ_t^2 dif_t S_t^a and S_t^d) are firstly considered (just as the original buffer stock model suggests) and then two variables (IMP_t and $M2_t$) are added sequently. After obtaining F-statistics for testing the existence of a cointegration, we select the specification for estimating long-run coefficients according to the Akaike Information Criterion (AIC).For example, as for the specification for Korea with 5 variables, AIC suggests that the most appropriate number of lags is 4, but the null of no-cointegration is not rejected in this specification. Thus, we may conclude that there exists no long-run relationship among 5 variables up to 8 lags in the case of Korea. In the case of 6 variable specifications for Korea, AIC suggests a model with 1 lag where the null of no-cointegration can be rejected. Consequently, it may be concluded that there exists a long-run relationship in the specification with 6 variables and 1 lag.

Applying the same procedures to other countries, we select the specification with 6 variables and 1 lag for Korea, Japan and India, and with 5 variables and 1 lag for Taiwan. In the 5-variable specification for Thailand, a cointegration relation is found with 4 and 8 lags at 1% significance level, but AICs suggest that the model with 1 lag is most appropriate. As a result, it may be concluded that there is no long-term relationship in the case of Thailand. As for the other 6 countries (i.e., Australia, Brazil, Indonesia, Philippines, Singapore and Turkey), the null of no-cointegration cannot be rejected in most models regardless of the number of lags and variables (see Appendix 4.1 for the result of bound test for other countries). Hence, we narrow the analysis down onto 4 countries: Korea, Japan, India and Taiwan.

Table 4.3 F-statistics for testing the existence of a cointegration

Country	Symmetric lags / No. of variable[1]	1	2	4	6	8	cointe-gration
Korea	5	4.00** <-5.191>	3.68* <-5.162>	-1.74 <-5.192>	1.13 <-5.170>	1.58 <-5.143>	No
	6	10.28*** <-5.248>	2.98 <-5.206>	1.08 <-5.185>	1.48 <-5.164>	1.16 <-5.181>	Yes
	7	3.03 <-5.253>	2.38 <-5.244>	2.47 <-5.238>	3.14* <-5.207>	3.94** <-5.299>	Yes
Japan	5	2.84 <-4.891>	2.68 <-4.832>	2.45 <-4.877>	1.83 <-4.739>	2.09 <-4.622>	No
	6	3.63* <-4.941>	2.86 <-4.875>	3.97* <-4.783>	3.05 <-4.686>	3.99** <-4.693>	Yes
	7	3.00 <-4.825>	2.53 <-4.899>	2.97 <-4.881>	2.91 <-4.910>	2.94 <-4.711>	No
India	5	3.55* <-4.451>	3.38* <-4.407>	4.71*** <-4.408>	3.65* <-4.352>	2.06 <-4.298>	Yes
	6	3.81* <-4.475>	3.49* <-4.418>	4.38** <-4.436>	4.53*** <-4.424>	1.93 <-4.405>	Yes
	7	3.34* <-4.453>	3.10 <-4.384>	3.60* <-4.401>	3.58* <-4.373>	1.79 <-4.382>	Yes
Taiwan	5	4.82*** <-5.686>	3.39* <-5.633>	3.19 <-5.545>	3.74* <-5.491>	3.30 <-5.520>	Yes
	6	3.96* <-5.649>	2.80 <-5.583>	2.41 <-5.484>	3.06 <-5.425>	2.27 <-5.418>	Yes
Thailand	5	2.93 <-4.766>	3.05 <-4.741>	4.97*** <-4.722>	3.77* <-4.602>	4.91*** <-4.634>	No
	6	2.55 <-4.766>	2.69 <-4.794>	3.94* <-4.683>	3.13 <-4.544>	4.79*** <-4.620>	No

Notes: 1. 5 variables: $FR_t, \sigma_t^2, dif_t, S_t^a, S_t^d$; 6 variables: $FR_t, \sigma_t^2, dif_t, S_t^a, S_t^d, IMP_t$ 7 variables: $FR_t, \sigma_t^2, dif_t, S_t^a, S_t^d, IMP_t, M2_t$

2. The critical value bounds are given in Pesaran et al.(2001, pp. 300-301), Table CI(iii) (unrestricted intercept and no time trend). The lower bound(FL) and upper bound(FU) are as follows:

significance	10%		5%		1%	
No. of variables	FL	FU	FL	FU	FL	FU
5	2.26	3.35	2.62	3.79	3.41	4.68
6	2.12	3.23	2.75	3.99	3.15	4.43
7	2.03	3.13	2.60	3.84	2.96	4.26

If F>FU, the null of no-cointegration can be rejected; If F < FL, the null cannot be rejected, and thus no long-run relationship exists. If FL<F<FU, the inference is inconclusive.

3. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, respectively.

4. The numbers in <> are the value of AIC and the shaded denote the best specification suggested by AIC.

Next, the existence of cointegration leads us to obtain long-run coefficients for the four countries by estimating equation (4.3.4). Table 4.4 summarizes the main results of the estimation of long-run coefficients. The signs of the coefficients are mostly consistent with what the buffer stock model suggests. The coefficients on opportunity cost (proxied by interest rate differential) are significantly negative at a 1% or 5 % level in all countries. The coefficients on reserve volatility are significantly positive for Korea and Japan.

Table 4.4 Estimates of long-run coefficients

$$\log(FR_t) = \beta_o + \beta_1 \log(\sigma_t^2) + \beta_2 dif_t + \beta_3 IMP_t + \lambda_1 \Delta S_t^a + \lambda_2 \Delta S_t^d + \varepsilon_{at}$$

coefficient	sign	Korea	Japan	India	Taiwan
Intercept(β_0)	+	0.362** (0.038)	-0.0148 (0.867)	0.077 (0.593)	0.138* (0.072)
Volatility of reserves(β_1)	+	0.004** (0.016)	0.010*** (0.006)	0.007 (0.154)	0.002 (0.198)
Interest differentia(β_2)	-	-0.003*** (0.006)	-0.002*** (0.006)	-0.003** (0.048)	0.004*** (0.002)
Import(β_3)	+	0.010 (0.529)	-0.007 (0.459)	-0.030* (0.078)	-0.019 (0.351).
Appreciation(λ_1)	**-**	**-0.288*** **(0.076)**	**-0.238**** **(0.048)**	**-0.329 (0.275)**	**-0.156 (0.520)**
Depreciation(λ_2)	**-**	**-0.039 (0.162)**	**-0.237*** **(0.084)**	**-0.927***** **(0.001)**	**-0.296 (0.208)**
F-statistics		13.922*** (0.000)	12.177*** (0.000)	7.496*** (0.000)	15.213*** (0.000)
Adjusted R^2		0.364	0.452	0.213	0.332

Notes: 1. Newey and West HAC covariance is used.
2. ***, ** and* denote the rejection of the null at 1%, 5% and 10% significance, respectively, and the numbers in ( ) are p-values.
3. The number of lags in ARDL specification is determined by AIC.AIC suggests that ARDL order of (1,0,0,0,0,0) for Korea, India and Taiwan, and (2,0,0,0,0,0) for Japan.
4. The signs are prior expectations

However, the coefficients of import are either wrongly signed or insignificant in the four countries, indicating that reserve holding may not be significantly related to precautionary needs for increasing import payments. This is because most Asian emerging countries had already retained sufficient reserves to meet import payments in the early 2000s (Gosselin and Parent 2005).[50]

The coefficients on the appreciation and depreciation, which are the main interests, show that reserves respond asymmetrically to FX rate movements in Korea and India but symmetrically in Japan. Particularly in Korea, the coefficient on KRW appreciation (-0.288)

[50] Gosselin and Parent (2005, p3) document that the main indicators (representing the adequateness of reserve holdings) were above the standard benchmark in most emerging Asian counties (such as China, India, Indonesia, Korea, Malaysia, the Philippines, Singapore and Thailand).

Indicators	benchmark	1980	1990	2000	2001	2002	2003
Reserves/short-term external debt	1	-	0.7	2.9	3.3	4.2	4.5
Reserves/monthly import	3-4	2	4	6	7	8	9

is significant – although marginally - and much larger than the coefficient (-0.039) on KRW depreciation in absolute value. This suggests that the BOK seems to buy foreign reserves in response to KRW appreciation but does not decrease reserves in case of KRW depreciation.

In contrast, the India appears to be more concerned about domestic currency depreciation. The coefficient on depreciation is significant with -0.927, much larger than the coefficient on appreciation (-0.329) in absolute value. It may be interpreted that the India appears to respond more to domestic-currency depreciation than appreciation, owing to the concern about strong inflation pressure. In particular, the monthly inflation rate of India in 1999-2010 was 0.52% on average, which is much higher than that of other countries (data: IMF IFS September 2010) – e.g. Korea (0.26%), Japan (-0.02%), Philippines (0.38%), Thailand (0.21%), Singapore (0.14%), etc. The BOJ responds symmetrically to the appreciation and the depreciation of the JPY. The coefficients of depreciation (-0.237) and appreciation (-0.238) are almost same. For Taiwan, the depreciation coefficient (-0.296) is larger than the appreciation coefficient (-0.156) in absolute value, but both are insignificant.

The above results have limits in explaining asymmetric intervention behaviours, because the changes in foreign reserves include non-intervention transactions. Hence, we need to confirm the existence of a propensity for asymmetric interventions by using more intervention-related data in the next section.

4.4.2 Measurement of the probability of interventions: Probit model

Tables 4.5, 4.6 and 4.7 report the estimation results of probit models for Korea, Japan and Australia, respectively. The signs of most coefficients are consistent with prior expectations, not only during the entire period but also during the subsample periods. Hosmer-Lemeshow's goodness-of-fit tests (H_0: the fit is sufficient to the data) have p-values over 0.10 in most cases, implying that the goodness-of-fit is quite acceptable and that we expect the forecast ability of the model to perform well.

4.4.2.1. FX rate deviation from its *level* trend[51]

FX rate deviations from its level trend have significant effects on the probability of both USD-purchasing and USD-selling interventions in three countries. In Korea, the coefficients on the deviation are significantly positive for USD-selling interventions $(b_2 = 0.0068 > 0)$ and significantly negative for USD-purchasing interventions $(a_2 = -0.0047 < 0)$ in the pre-subprime crisis period (see Table 4.5). However, the coefficients become insignificant in the post-subprime crisis period. This may be because of the "fear of losing international reserves" (Aizenman and Yi 2009)[52] that the BOK did not significantly sell USD against the rapid depreciation of KRW in the sub-prime crisis period.

a_2 is highly significant while b_2 is insignificant during the entire period, possibly indicating that BOK may pay more attention to USD-buying interventions in response to FX rate deviation from its trend (i.e., KRW appreciation). This result may provide an indirect evidence of asymmetric intervention preferences in Korea – this can be more clearly discussed in the next section by using the friction model.

In Australia, the coefficient on the deviation is significantly positive with correct signs

[51] As the probit model is based on the cumulative normal probability distribution, the interpretations of coefficients are different from the normal OLS. The coefficients indicate the effects on a cumulative normal function of the probabilities that the dependent variable(=*INT*) is one. In particular, the coefficients give the change in the z-score for a one unit change in the regressor (See Gujarati 2004).

[52] b_2 is significantly positive for USD-selling interventions in the pre-subprime periods but not in the sub-prime crisis period. At first glance, this result appears inconsistent with common sense, because the CBs in small open economies need to sell USD during financial crises when local currency is severely depreciating. However, USD-selling interventions could be less feasible in practice due to the risk of exhausting foreign reserves. This is because dwindling reserves may signal greater vulnerability of their economies. Hence, CBs cannot always sell foreign assets in line with domestic currency depreciation. In this case, the coefficients of USD-selling interventions may be insignificant with regard to the changes in FX rates.

for USD sales through all periods (see $b_2 > 0$ in Table 4.6) but not for USD purchases: a_2 is wrongly signed (positive). This evidence indicates that RBA appears to be more concerned about AUD depreciation than appreciation. In consideration of the fact that RBA has never conducted USD-buying interventions since mid-1992 when IT was introduced, RBA's more sensitive response to AUD depreciation may be related to its attempt to prevent inflation pressure caused by AUD depreciation.

Table 4.5 Intervention motives in Korea: Probit model

			Whole period (5/9/2001-23/3/2010)		Pre-subprime crisis (5/9/2001-31/7/2007)		Post-subprime crisis (1/8/2007-23/3/2010)	
			coefficient	P-value	coefficient	P-value	coefficient	P-value
Purchasing US dollar	Constant (a_1)		-1.1319***	0.0000	-1.0623***	0.0000	-1.1890***	0.0000
	Deviation from trend (a_2)	-	-0.0016**	0.0109	-0.0047***	0.0001	-0.0011	0.1167
	FX rate volatility(a_3)	+	0.0593	0.1974	-0.8649	0.1222	0.0760*	0.0930
	Interest differential(a_4)	+	-0.0164	0.9455	0.5287	0.2044	-0.2053	0.4384
	Change in CDS spread(a_5)	-	-0.0107***	0.0053	-0.0173	0.1042	-0.0092**	0.0151
	Previous intervention(a_6)	+	1.1738***	0.0000	1.2621***	0.0000	0.7140***	0.0000
	Change in MSB (a_7)	-	-1.3053	0.7083	-0.5527	0.8969	-6.3063	0.2759
	Foreigner's net buying(a_8)	+	0.0066***	0.0001	0.0101***	0.0001	0.0035*	0.0825
	Log likelihood		-978.65		-688.34		-331.16	
	LR statistics		362.11***	0.0000	324.66***	0.0000	48.11***	0.0000
	McFadden R^2		0.157		0.191		0.106	
	Hosmer-Lemeshow Statistic		7.9756	0.6312	6.1766	0.6275	4.4786	0.8116
Selling US dollar	Constant (b_1)		-1.5717***	0.0000	-2.3417***	0.0000	-0.8988***	0.0000
	Deviation from trend(b_2)	+	0.0005	0.2562	0.0068**	0.0173	-0.0005	0.3639
	FX rate volatility(b_3)	+	0.1219***	0.0000	2.6242***	0.0080	0.0754**	0.0149
	Interest differential(b_4)	-	-0.0689	0.8065	-0.4798	0.6735	0.0197	0.9491
	Change in CDS spread(b_5)	+	0.0082**	0.0217	-0.0044	0.8488	0.0081**	0.0232
	Previous intervention(b_6)	+	1.1642***	0.0000	1.1197***	0.0000	0.6701***	0.0000
	Change in MSB (b_7)	-	-2.7239	0.4837	-2.7172	0.7397	-3.0417	0.5738
	Foreigner's net buying(b_8)	-	-0.0037**	0.0126	-0.0015	0.7065	-0.0038**	0.0422
	Log likelihood		-584.31		-144.27		-359.40	
	LR statistics		223.07***	0.0000	41.82***	0.0000	54.65***	0.0000
	McFadden R^2		0.160		0.127		0.070	
	Hosmer-Lemeshow Statistic		10.9062	0.3699	0.3649	0.7261	7.0384	0.5325
No of observations			2121		1461		660	

Notes: 1. Huber-White's robust standard errors and covariances are used.
2. Hosmer-Lemeshow tests are goodness-of-fit evaluation for binary specification. A null hypothesis is that the fit is sufficient to the data.
3. + and – indicate a priori expectation about the signs of coefficients under leaning-against-the-wind.
4. ***, ** and * are significant at 1, 5 and 10% level, respectively.

In Japan, deviations from FX rate level trends have significant effects on both USD-selling and purchasing intervention decisions through all periods. In Table 4.7, $a_2(<0)$ and $b_2(>0)$ are correctly signed and significant at 1% level, which supports the evidence that BOJ tends to aim at adjusting FX rates into a certain level, e.g. 125JPY/USD in the early 1990s (Ito 2003, Ito and Yabu 2007).

In summary, BOK and BOJ *lean against the wind*: the more depreciated (appreciated) the domestic currency, the less (more) probable are USD-buying interventions and the more (less) probable are USD-selling interventions. However, BOK appears to less resist the depreciation of KRW during the post-subprime period, because of "fear of depleting foreign reserves" or its preference for asymmetric interventions. BOJ appears responds to both appreciation and depreciation of JPY. RBA appears to lean against the wind only when AUD depreciates in consideration of inflation.

4.4.2.2 FX rate volatility

In Korea and Australia, conditional volatility of the FX rate has a significant effect on the probability of USD-selling interventions but not on USD-purchasing interventions. a_3 is not significant while b_3 is significant in both countries through all periods, indicating that increasing FX volatility leads to a higher probability of USD-selling intervention in Korea and Australia but not USD-purchasing intervention. In contrast, both a_3 and b_3 are insignificant in Japan through all periods. This finding may reflect the different economic structures in three countries. That is, small open economies such as Korea and Australia are more likely to be vulnerable to turbulent and volatile FX rates (mostly stemming from rapid depreciation) than a large economy like Japan. Note that Japanese yen is one of the international vehicle currencies, so that its value is likely much safer and more stable than the currencies of small open economies.

Table 4.6 Intervention motives in Australia: Probit model

			Whole period (2/1/1989-31/12/2008)		Pre-IT (2/1/1989-30/6/1992)		Post-IT			
							CDS excluded (1/7/1992-31/12/2008)		CDS included (2/12003-31/12/2008)	
			Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Purchasing US dollar	Constant (a_1)		-2.0383***	0.0000	-0.9734***	0.0000	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	Deviation from trend (a_2)	-	0.5151*	0.0863	0.6864	0.5461	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	FX rate volatility(a_3)	+	0.0005	0.2515	0.0007	0.4576	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	Interest differential(a_4)	+	-0.1721	0.2571	-0.1213	0.3286	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	Change in CDS spread(a_5)	-	-	-	-	-	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	Previous intervention(a_6)	+	2.4009***	0.0000	1.3343***	0.0000	n.a[1]	n.a[1]	n.a[1]	n.a[1]
	Log likelihood		-692.93		-469.99					
	LR statistic		864.99***	0.0000	202.12***	0.0000				
	McFadden R-squared		0.384		0.177					
	Hosmer-Lemeshow Statistic		8.5136	0.3850	6.1641	0.6289				
Selling US dollar	Constant (b_1)		-2.1582***	0.0000	-2.1655***	0.0000	-2.1664***	0.0000	-3.2353***	0.0000
	Deviation from trend(b_2)	+	3.8762***	0.0000	4.2154*	0.0829	4.0353***	0.0000	4.3581***	0.0000
	FX rate volatility(b_3)	+	0.0014***	0.0021	0.0028*	0.0712	0.0012**	0.0129	0.0034***	0.0000
	Interest differential(b_4)	-	-0.0763	0.6209	0.0532	0.7242	-0.1212	0.5694	-0.7754	0.3595
	Change in CDS spread(b_5)	+	-	-	-	-	-	-	0.0465***	0.0023
	Previous intervention(b_6)	+	1.4811***	0.0000	1.8438***	0.0000	1.3613***	0.0000	-0.0211	0.1699
	Log likelihood		-584.34		-104.52		-475.86		-27.64	
	LR statistic		396.98***	0.0000	94.05***	0.0000	310.00***	0.0000	65.67***	0.0000
	McFadden R-squared		0.254		0.310		0.246		0.542	
	Hosmer-Lemeshow Statistic		10.7767	0.3752	6.9486	0.5422	11.0476	0.3538	0.6523	0.9996
No of observations			5216		910		4306		1563	

Notes: 1. There were no USD-purchasing interventions in 1/7/1992-31/12/2008.
2. Huber-White's robust standard errors and covariances are used.
3. Hosmer-Lemeshow tests are goodness-of-fit evaluation for binary specification. A null hypothesis is that the fit is sufficient to the data.
4. + and – indicate a priori expectation about the signs of coefficients under leaning-against-the-wind.
5. ***, ** and * are significant at 1, 5 and 10% level, respectively.

4.4.2.3 Interest rate differential

The interest rate differential appears not to influence the probability of USD-purchasing and selling interventions during all periods in the three countries. a_4 and b_4 are insignificant or wrongly signed for all periods. In particular, the insignificance of the coefficient a_4 suggests that BOK, RBA and BOJ may not consider seriously the possibility of overshooting of the FX rate caused by changes in the interest rate differential in the short run.

Another interpretation for this is that interventions may support current monetary stance by not immediately responding to the change in the interest rate differential (Kim and Sheen 2002). For example, immediate USD-buying interventions in response to a fall in US interest rates are likely to distort the current monetary stance, because the intervention leads to an increase in the monetary base.

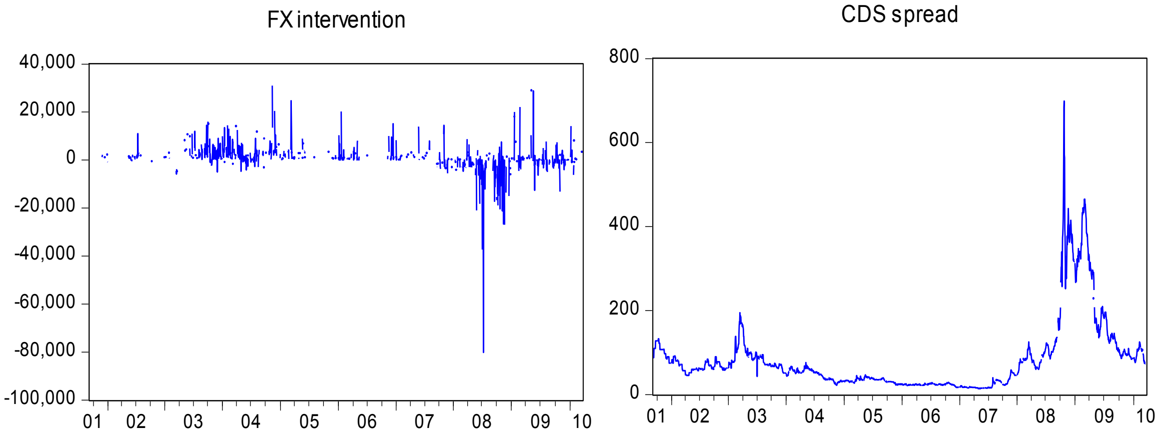
4.4.2.4 Country risk

CDS spread reflects the changes in a country risk. The country risk of emerging or small open countries may be more volatile than that of a large economy, because the former are more sensitive to external shocks than the latter. In particular, the CDS spread of emerging countries tends to fluctuate more during international financial crises, and thus the effects of CDS spreads on intervention decisions are expected to be more prominent in crisis periods.

As expected, the coefficients of CDS spread are significantly negative for USD-purchasing interventions and positive for USD-selling interventions over the entire period and the post-subprime crisis period in Korea ($a_5 < 0$, $b_5 > 0$ in Table 4.5). Figure 4.4 shows that the CDS spreads of Korea appear negatively correlated with net purchases of USD, particularly during the subprime crisis period. When CDS spread is included in the specifications for Japan and Australia in the subsamples, the coefficient on the CDS spread is significantly positive in Australia ($b_5 = 0.047 > 0$ with p-value 0.002 in Table 4.6) but not in Japan($a_5 = -0.015$ with p-value 0.889 in Table 4.7). This finding suggests that changes in country risk significantly influence intervention decisions particularly in small open economies.[53]

[53] This interpretation may be very limited, because the subsample for Australia (2003M01-2008M12) includes the US sub-prime crisis period, while the sub-sample for Japan (2003M01-2004M03) does not include any periods of international financial crisis.

Figure 4.4 FX Intervention and CDS spread of Korea



Notes: 1. FX intervention indicates the amount of net purchase of USD (equivalent to100 million KRW)
2. CDS spreads are depicted as a basis point

Data: BOK and Bloomberg

4.4.2.5 Previous intervention

The coefficients of previous interventions are significantly positive for all periods in three countries ($a_6 > 0$, $b_6 > 0$), suggesting that interventions are persistent. A USD-purchasing (selling) intervention was usually followed by another USD-purchasing (selling) intervention on the following day. CBs tend to conduct interventions consecutively over several days to reinforce their effects.

4.4.2.6 Foreigners' purchase of Korean stocks and MSB (Korea)

Foreigners' net purchases of Korean stock and changes in MSB are used only in the regression for Korea, owing to data availability. Foreigners' purchases (sales) of Korean stock significantly increase the probability of the BOK's USD-purchasing (USD-selling) interventions (a_8 >0, b_8 <0 for most sample periods in Table 4.5). This indicates that the BOK is keen to sterilise its portfolio investments on a daily basis. However, the coefficients for the subsample are somewhat different. In Table 4.5, a_8 is significant for all periods, while

b_8 is significant only for the post-subprime crisis period. This suggests that BOK is reluctant to sell USD and prefers to purchase USD particularly in peacetime, reflecting "fear of appreciation and of depleting foreign reserves" in small open emerging economies.

The coefficients on ΔMSB are not significant in all periods, indicating that BOK may not be concerned about the sterilisation costs in the short run. The results here are based on daily data, so we may not conclude that BOK does not pay attention to sterilisation costs in the medium to long run. Chapter 6 discusses whether BOK cares about sterilisation costs and whether current MSB-dependent sterilisations are sustainable in the long run.

Table 4.7 Intervention motives in Japan: Probit model

			Whole period (8/4/1991-31/32004)		Pre-Sakakibara (8/4/1991-30/6/1995)		Post- Sakakibara			
							CDS excluded (1/7/1995-31/3/2004)		CDS included (2/1/2003-31/3/2004)	
			Coeff.	P-value	Coeff.	P-value.	Coeff.	P-value.	Coeff.	P-value.
Purchasing US dollar	Constant (a_1)		-1.9008***	0.0000	-2.0289***	0.0000	-1.9207***	0.0000	-1.4429***	0.0000
	Deviation from trend (a_2)	-	-0.0554***	0.0000	-0.0926***	0.0000	-0.0452***	0.0000	-0.0811***	0.0041
	FX rate volatility(a_3)	+	0.0505	0.7461	0.1022	0.7594	0.0196	0.9032	0.3239	0.4679
	Interest differential(a_4)	+	-0.1717	0.2768	-0.2712*	0.0984	-0.0259	0.9342	0.1953	0.8930
	Change in CDS spread(a_5)	-	-	-	-	-	-	-	-0.0151	0.8889
	Previous intervention(a_6)	+	1.7657***	0.0000	1.3635***	0.0000	2.0296***	0.000	1.6271***	0.0000
	Log likelihood		-715.58		-318.53		-386.58		-144.18	
	LR statistic		684.51***	0.0000	238.29***	0.0000	455.01***	0.0000	132.60***	0.0000
	McFadden R-squared		0.3235		0.2722		0.3705		0.3150	
	Hosmer-Lemeshow Statistic		7.7676	0.4925	6.0147	0.6423	18.2201**	0.0196	10.6208	0.2241
Selling US dollar	Constant (b_1)		-2.1082***	0.0000	-1.7667***	0.0001	-4.2880***	0.0010	n.a[1]	n.a[1]
	Deviation from trend(b_2)	+	0.0199 **	0.0422	0.0729***	0.0001	0.1982***	0.0082	n.a[1]	n.a[1]
	FX rate volatility(b_3)	+	-0.8686	0.3035	-0.4900	0.6614	-0.8648	0.6780	n.a[1]	n.a[1]
	Interest differential(b_4)	-	0.4484 *	0.0872	0.3577	0.2080	0.9222	0.2239	n.a[1]	n.a[1]
	Previous intervention(a_6)	+	1.7107 ***	0.0000	1.0523***	0.0006	2.7436***	0.0000	n.a[1]	n.a[1]
	Log likelihood		-163.52		-116.19		-20.430			
	LR statistic		47.709***	0.0000	28.9741***	0.0000	42.6829***	0.0000		
	McFadden R-squared		0.127		0.111		0.512			
	Hosmer-Lemeshow Statistic		8.6206	0.3753	6.4690	0.5948	12.4587	0.3421		
No of observations			3564		1270		2294		310	

Notes: 1. USD-selling interventions did not occur during the period 2/1/2003– 31/3/2004.
2. Huber-White's robust standard errors and covariances are used.
3. Hosmer-Lemeshow tests are goodness-of-fit evaluation for binary specification. A null hypothesis is that the fit is sufficient to the data.
4.+ and – indicate a priori expectation about the signs of coefficients under leaning-against-the-wind.
5. ***, ** and * are significant at 1, 5 and 10% level, respectively.

4.4.3 Degrees of asymmetric intervention motives: Friction model

We first compare the degree of asymmetric intervention (which is our interest) and then describe the evidence which is peculiar to the friction model for each country. The results are reported in Tables 4.8 to 4.10. Most results obtained from the friction model are similar to those from the probit model. For example, coefficients of previous interventions (α_1) are significantly positive in all three countries through all periods, suggesting the persistence of the interventions. The deviations of the FX rate level from its trend, in general, prompts interventions in all countries, particularly when the deviations are large or persistent. This confirms the tendency to lean against the wind in three countries. FX rate volatility deviating from its trend causes both BOK and RBA, but not BOJ, to intervene in FX markets. Interest rate differentials do not significantly affect intervention decisions in any of the countries.

4.4.3.1 Comparison of the degree of asymmetric interventions

In absolute values, the estimated negative threshold (δ_{I-}= -3.815) is significantly larger than positive threshold (δ_{I+} =2.564) for the whole sample in Korea, while the two significant thresholds (1.881 vs. -1.816) are not much different in Japan. This suggests the asymmetric and symmetric intervention preferences in Korea and Japan, respectively. The evidence of asymmetric interventions in Korea is consistent with Gnabo et al.'s (2010) studies on small open emerging economies such as Brazil and the Czech Republic. The result of Japanese symmetric interventions corresponds to Ito (2003) that Japanese interventions were symmetric in 1991M4-2001M3 and exchange rate level of 125JPY/USD was the threshold applied to both USD-purchasing and selling interventions. All these findings support evidence obtained from the buffer stock model in the previous section.

The RBA is more prone to favour the AUD appreciation. The estimate δ_{I-} (-0.018) is significantly less than δ_{I+} (0.128) in absolute values over the entire period, implying that RBA prefer supporting AUD to devaluing it. The RBA's preference appears somewhat strengthened in the post-IT period: δ_{I-} stayed around -0.05 over time while δ_{I+} increased from 0.108 to 0.129.

BOK's preference for the KRW-depreciation and RBA's preference for the AUD-appreciation look stable over time. In contrast, Japanese intervention appears to become asymmetric in the post-Sakakibara period. Table 4.10 reports that $|\delta_{I+}|$(=1.828) >$|\delta_{I-}|$(=0.047) in the pre-Sakakibara period and $|\delta_{I+}|$(=3.097) <$|\delta_{I-}|$(=6.522) in the post-Sakakibara period, indicating that BOJ became more concerned about the JPY appreciation than the depreciation after the late 1990s. This may come from the motive for boosting trade competitiveness for the purpose of economic recovery, under quite limited policy options at that time. Note that BOJ maintained a zero interest rate policy in 1999M2-2000M8 and 2001M3-2006M6(Ito and Yabu 2007), and that the policy was reintroduced in October 2010.

4.4.3.2 Korea

The coefficients for average deviation dummy (β_{dev}) are all insignificant while the size deviation dummy (β_{size}) is significantly negative during the whole period. This implies that BOK leans against the wind when the deviation from FX rate level is large. A large fall in FX rate level from its trend (i.e., KRW appreciation) leads to USD–purchasing interventions ($INT_t>0$) while a large rise in the FX rate from its trend (i.e., KRW deprecation) incurs USD-selling interventions ($INT_t<0$). Insignificant β_{dev} and λ_c suggests that BOK, on average, does not react to (every) deviation from the FX level and volatility trend in consideration of intervention cost. This evidence of leaning against the wind is consistent with other previous studies (see Lee and Yoon 1997) and the probit estimation in the previous section. However, β_{size} became insignificant in the post-subprime periods, indicating that the motives for leaning against the wind became weaker. This reflects the fact that USD-selling interventions are limited during crisis periods owing to fear of depleting foreign reserves.

Table 4.8 Asymmetric intervention in Korea: Friction model

$$INT_t = \alpha_1 INT_{t-1} + (\beta_{dev} I_{dev,t} + \beta_{cum} I_{cum,t} + \beta_{size} I_{size,t}) \times |FXDEV_t| + (\lambda_c I_{ds,t} + \lambda_{hsize} I_{ds,t} I_{hsize,t}) h_t + \gamma_{diff} DIFF_t + \gamma_{msb} \Delta MSB_t + \gamma_{cds} CDS_t + \varepsilon_t$$

	sign	I. Whole (12/9/2001-23/3/2010)	II. Pre-subprime (12/9/2001-31/7/2007)	III. Post-subprime (1/8/2007-23/3/2010)
(i) Previous intervention(α_1)	+	0.1901***	0.1904***	0.1866***
		(0.0000)	(0.0001)	(0.0046)
(ii)Deviation from FX level trend				
• Current (average) deviation(β_{dev})	-	0.0550	-0.0208	0.1071
		(0.5641)	(0.8202)	(0.5327)
• Persistent (β_{cum})	-	-0.0909	-0.0253	-0.1504
		(0.3406)	(0.7846)	(0.3834)
• Large (β_{size})	-	-0.0280**	-0.0342***	-0.0355
		(0.0119)	(0.0032)	(0.1019)
(iii)Deviation from FX volatility trend				
• Current (average) deviation (λ_c)	-	-9.1013	24.6372	-10.4436
		(0.8648)	(0.1105)	(0.8940)
• Large (λ_{hsize})	-	-4.8181	-57.2547**	-10.8322
		(0.9271)	(0.0278)	(0.8891)
(iii) Interest differential (γ_{diff})	+	-1.1635	-2.4214	-0.8450
		(0.4955)	(0.4008)	(0.7424)
(iv) Change in MSB (γ_{msb})	-	-0.0001	-0.00002	0.00001
		(0.7471)	(0.6479)	(0.8848)
(v) CDS spread(γ_{cds})	-	-0.0216*	-0.06420*	-0.0165**
		(0.0718)	(0.0597)	(0.0470)
(vi) σ		5.3652***	3.5994***	7.1357***
		(0.0000)	(0.0000)	(0.0000)
(vii) δ_{I+} positive threshold		2.5643***	2.1230***	3.3182***
		(0.0000)	(0.0000)	(0.0010)
(vii) δ_{I-} negative threshold		-3.8146***	-2.1717***	-4.2112***
		(0.0004)	(0.0008)	(0.0000)
Log- likelihood		-2039.21	-1060.98	-896.77

Notes: 1. HAC robust standard error covariance matrix is used.
2. The numbers in ( ) are p-values.
3. ***, ** and * are significant at 1, 5 and 10% level, respectively.
4. The signs are prior expectations in case of leaning-against-the-wind. If CBs lean with the wind, it may be expected that $\beta_{dev} > 0$ and $\beta_{size} > 0$.
5. $|\delta_{I-}| > |\delta_{I+}|$ is interpreted as the evidence of asymmetric interventions which favour weak KRW.

The estimated λ_{hsize}(= -57.255) is significantly negative with p-value of 0.028 only for the pre-subprime period, suggesting that, on days of above average volatility, BOK conducts USD-purchasing (selling) interventions to address the further increase in volatility associated with KRW appreciation (depreciation). The insignificance of λ_{hsize} for the post subprime period may also be due to "fear of losing foreign reserves" which has kept BOK from responding to high FX volatility actively during the crisis period. γ_{diff} and γ_{msb} are insignificant in all periods, implying that interest rate differentials and changes in MSB do not influence intervention decisions in the short run. This result is exactly what we obtain from the probit model.

4.4.3.3 Australia

The average effect of current FX rate deviation from the level trend (β_{dev}) is significantly negative for all periods, suggesting that RBA mostly leans against the wind. β_{cum} is significantly negative in all periods, indicating that RBA reacts to correct persistent deviations from trend. However, estimated β_{size} is significantly positive in the post-IT period, which is not expected from leaning-against-the-wind. Nevertheless, the overall effects of FX level deviation on the intervention decision are still negative in all periods (i.e., $\beta_{dev} + \beta_{cum} + \beta_{size} < 0$). The overall impact of volatility deviation is negative (i.e. λ_c <0 in the post-IT period and λ_{hsize}<0 in the pre-IT period), so the RBA appears to conduct the intervention when FX rate volatility increases.

Table 4.9 Asymmetric intervention in Australia: Friction model

$$INT_t = \alpha_1 INT_{t-1} + (\beta_{dev} I_{dev,t} + \beta_{cum} I_{cum,t} + \beta_{size} I_{size,t}) \times |FXDEV_t| + (\lambda_c I_{ds,t} + \lambda_{hsize} I_{ds,t} I_{hsize,t}) h_t + \gamma_{diff} DIFF_t + \varepsilon_t$$

	sign	I. Whole (2/1/1989-31/12/2008)	II. Pre-IT (2/1/1989-31/7/1992)	III. Post-IT (1/8/1992-31/12/2008)
(i) Previous intervention(α_1)	+	0.3032*** (0.0000)	0.1168** (0.0179)	0.3483*** (0.0016)
(ii)Deviation from FX level trend				
Current deviation(β_{dev})	-	-0.1594*** (0.0057)	-0.2644*** (0.0021)	-0.3111* (0.0574)
Persistent (β_{cum})	-	-0.3389*** (0.0000)	-0.6171*** (0.0000)	-0.5323*** (0.0000)
Large (β_{size})	-	0.3419*** (0.0003)	0.2094 (0.2391)	0.6789*** (0.0000)
(iii)Deviation from FX volatility trend				
Current deviation(λ_c)	-	-0.0098 (0.3967)	-0.0007 (0.8916)	-0.0448* (0.0750)
Larger (λ_{hsize})	-	-0.0218 (0.1383)	-0.0199** (0.0166)	0.0103 (0.1631)
(iii) Interest differential (γ_{diff})	+	0.0046 (0.1465)	0.0009 (0.6373)	0.0098 (0.5249)
(vii) σ		0.1346*** (0.0000)	0.0540*** (0.0000)	0.2324*** (0.0000)
(viii) δ_{I+} positive threshold		0.1282*** (0.0000)	0.1079*** (0.0000)	0.1286*** (0.0002)
(viv) δ_{I-} negative threshold		-0.0176* (0.0524)	-0.0485*** (0.0004)	-0.0500*** (0.0000)
Log- likelihood		225.04	407.55	4.50

Notes: 1. HAC robust standard error covariance matrix is used.
2. The numbers in ( ) are p-values.
3. ***, ** and * are significant at 1, 5 and 10% level, respectively.
4. The signs are prior expectations in case of leaning-against-the-wind. If CBs lean with the wind, it may be expected that $\beta_{dev} > 0$ and $\beta_{size} > 0$.
5. $|\delta_{I-}| > |\delta_{I+}|$ is interpreted as the evidence of asymmetric interventions which favour weak AUD.

4.4.3.4. Japan

The estimated β_{dev} is significantly positive – wrongly signed or insignificant for all periods. β_{size} is significantly negative in the post-Sakakibara period, indicating that BOJ responded only to the larger deviation from FX rate level trend in the post-Sakakibara period. This is consistent with Ito and Yabu (2007) that Japanese intervention patterns shifted with the inauguration of Dr. Sakakibara in June 1995 – from frequent and small interventions to infrequent and large-scale ones.

The persistent deviations from level trend lead to a negative effect on intervention

(β_{cum}<0), but insignificant in all periods. According to Kim and Sheen (2002, pp. 643-646), the insignificance of β_{cum} may imply that if the deviation is sustained, the BOJ consider the persistent deviation to be a permanent change in the equilibrium rate, and restrain intervention to some degree. The estimated γ_{diff} is either insignificant or wrongly signed for all periods. This confirms the insignificant effects of interest rate differentials on intervention decision on a daily basis, which is consistent with the result of the probit model.

Table 4.10 Asymmetric intervention in Japan: Friction model

$$INT_t = \alpha_1 INT_{t-1} + (\beta_{dev} I_{dev,t} + \beta_{cum} I_{cum,t} + \beta_{size} I_{size,t}) \times |FXDEV_t| + (\lambda_c I_{ds,t} + \lambda_{hsize} I_{ds,t} I_{hsize,t}) h_t + \gamma_{diff} DIFF_t + \varepsilon_t$$

	sign	I. Whole (8/4/1991-31/3/2004)	II. Pre-Sakakibara (8/4/1991-30/6/1995)	III. Post- Sakakibara (1/7/1995-31/3/2004)
(i) Previous intervention(α_1)	+	0.3418***	-0.0819	0.1529**
		(0.0002)	(0.6416)	(0.0293)
(ii)Deviation from FX level trend				
• Current deviation(β_{dev})	-	0.0811	0.4291***	-0.1106
		(0.8201)	(0.0032)	(0.6524)
• Persistent (β_{cum})	-	-0.07122	-0.0903	0.1788
		(0.8374)	(0.5173)	(0.8279)
• Massive (β_{size})	-	0.0419	-0.05263	-0.2142***
		(0.6849)	(0.9436)	(0.0000)
(iii)Deviation from FX volatility trend				
• Current deviation(λ_c)	-	42.7068	-33.7380	10.6849
		(0.4235)	(0.2912)	(0.9034)
• Massive(λ_{hsize})	-	-37.3781	-40.1418	-51.3617
		(0.6024)	(0.2864)	(0.7133)
(iii) Interest differential (γ_{diff})	+	-0.6598	0.1562	-7.0104**
		(0.2451)	(0.4662)	(0.0152)
(vi) σ		2.9143***	0.9974***	3.5205***
		(0.0000)	(0.0000)	(0.0000)
(vii) δ_{I+} positive threshold		1.8806***	1.8282***	3.0974*
		(0.0000)	(0.0000)	(0.0966)
(viii) δ_{I-} negative threshold		-1.8157***	-0.0474*	-6.5220*
		(0.0009)	(0.0680)	(0.0639)
Log- likelihood		-664.45	-195.46	-345.40

Notes: 1. HAC robust standard error covariance matrix is used.
2. The numbers in ( ) are p-values.
3. ***, ** and * are significant at 1, 5 and 10% level, respectively.
4. The signs are prior expectations in case of leaning-against-the-wind. If CBs lean with the wind, it may be expected that $\beta_{dev} > 0$ and $\beta_{size} > 0$.
5. $|\delta_{I-}| > |\delta_{I+}|$ is interpreted as the evidence of asymmetric interventions which favour weak JPY.

4.5 Conclusion

4.5.1 Summary of main findings

The main objectives of this chapter are to examine various motives for sterilised FX interventions and to compare the degrees of asymmetric intervention preference in the selected countries. Using a buffer stock model with monthly foreign reserves data from 11 countries, we first examine a cointegration relationship between foreign reserves and FX rate movements. In this model, CBs' demand for foreign reserves is assumed to be determined by the appreciation or depreciation pressure of FX rates, opportunity costs of holding reserves, volatility of reserves increments and the need for payment for imports, etc.

Our main finding from the buffer stock model is that BOK tends to be more worried about appreciation than depreciation of domestic currency compared to other countries. In particular, the preference for asymmetric intervention (aiming at domestic currency depreciation) is more prominent in small open economies such as Korea than in relatively large or closed economies such as Japan and India. The buffer stock model suggests that reserve holding in these countries is not significantly associated with the precautionary needs for increasing import payments. Foreign reserve holdings are affected by the domestic-foreign interest rate differential, which is a proxy for opportunity costs. Although the buffer stock model enables us to conduct cross-country analysis with foreign reserve data which are easily available, it has limitations, in that foreign reserves are not perfect proxies for interventions. Considering this, we examine the determinants of intervention decisions by using the probit and friction model with daily data on Korea, Japan and Australia.

Probit estimation suggest that interventions are mainly affected by several common factors in three countries: the degree of current FX rate deviation from trend, the level of FX rate volatility, country risk and previous interventions. Unlike the evidence from the buffer stock model with monthly data, interest rate differentials do not have a significant effect on intervention decisions in the three countries in probit and friction model using daily data.

The appreciation (depreciation) of domestic currency deviated from its FX rate level trend leads to the increase in probability of USD-purchasing (USD-selling) interventions in the three countries, which implies that CBs lean against the wind. Korea's leaning-against-the-wind policy is somewhat different from Australia's. BOK appears not to sell USD significantly against the rapid depreciation of Korean won, particularly in the recent crisis periods. This may be associated with "fear of losing foreign reserves", which is frequently found in the studies on small open emerging countries. In contrast, RBA is willing to sells USD but reluctant to purchases USD when AUD/USD rate is deviated from its trend. RBA appears to be more worried about the depreciation of AUD than the appreciation, which may reflects the RBA's relatively stronger anti-inflation commitment than BOK and BOJ.

We have found that there is a significant difference in intervention responses to the deviation from a *volatility* trend between small open economies (Korea and Australia) and large economies (Japan). The higher probability of USD-selling or purchasing intervention is related to more volatile movement of FX rates in Korea and Australia, but not in Japan. This may be mainly because of the differences in the natures of their economy. Since Korea and Australia are small open economies (which are more susceptible to external shocks) and Japan is relatively larger economy, JPY movements are more stable than the KRW and AUD. This leads BOK and RBA to be more concerned about exchange rate volatility.

Interest rate differentials appear not to significantly influence the probability of either USD-purchasing or selling interventions in all periods in the three countries. One possible interpretation is that the three authorities may not seriously consider the possibility of overshooting of the FX rate caused by changes in interest rate differentials (e.g., a sudden rise in the US policy rate) on a daily basis. Another interpretation may be that the intervention policy may support current monetary policy, not by immediately responding to the change in interest rate differential. Interventions are significantly influenced by changes in country risk (proxied by CDS spread) in Korean and Australia but not in Japan. In Korea, foreigners' purchases (sales) of Korean stock significantly increase the probability of USD-purchasing (USD-selling) interventions. The intervention costs (represented by increases in MSBs) are not considered in the BOK's intervention decision in the short-run.

The aforementioned results of probit estimation are, in general, confirmed by the friction estimation. For example, friction estimations appear to support the BOK's claim that it intervenes in the market to smooth out severe FX volatility and to slow down (or reverse) rapid changes in FX rate levels. BOK tends to selectively intervene when FX rates are too volatile or are changing too fast. The three CBs appear not to respond to average deviations of FX level and volatility from trends. These behaviours may contribute to reducing intervention costs with allowing for more flexible movement of exchange rates.

Importantly, the friction model provides direct information on the degrees of asymmetric intervention in the three countries. The results suggest the existence of asymmetric intervention preferences in Korea and symmetric ones in Japan, implying that BOK favours interventions for inducing KRW depreciation while BOJ responds symmetrically to the appreciation and depreciation of JPY. RBA prefers interventions to support AUD. Both BOK's preference for KRW depreciation and RBA's preference for AUD appreciation remain stable over time. In contrast, Japanese intervention appears to become more asymmetric, favouring the depreciation of JPY after the mid-1990s, which may be due to the increasing motives for boosting trade competitiveness.

Considering the empirical findings in Ch. 3 and Ch. 4 together, we may come to conclusion on why small open emerging economies like Korea have adhered to sterilised FX market interventions despite little effects on exchange rates and sterilisation costs as a result of the intervention activities. First, some small open emerging countries prefer to build up foreign reserves irrespective of intervention effects in order to insure against possible sudden stop and reversal of capital flows. Indeed, some studies have noted that many emerging or developing countries were relatively more resilient to financial crises in 2008-2009 than they would have, owing to more sufficient foreign reserves and better macroeconomic and prudential polies as compared to past decades (IMF 2009). Second, intervention authorities in emerging countries need to create uncertainty in the FX market via secret interventions to prevent one-way bets or to warn speculators in FX markets (Rhee and Lee 2005). The FX markets in emerging countries tend to be more vulnerable to speculative attacks and one-way bets because of their thin market structure. Third, USD-purchasing interventions can lower local residents' financing cost from abroad because reserves accumulation contributes to lowering spreads on the service costs of the stock of sovereign debt – that is, CDS spread (Levy-Yeyati 2008).

4.5.2 Limitations of study and future research

The analyses in Chapter 3 and this chapter have several limitations. First, we assume that a CB or a government's horizon is a few days and that intervention effects are short-lived. Although most concurrent studies support the very short-term effects of interventions, it may be possible that the CB's horizon may be beyond the day or week. For example, CBs may undertake interventions in response to persistent interest rate differentials which last for a few months, although they do not respond to short-term differentials. Thus, it is necessary to investigate the medium to long-term effects of interventions. For example, Kim (2003) provides evidence of significant interrelations between interventions and monetary policy rate(i.e. interest rate differentials) by using the SVAR model with monthly data.

Second, we use different sample periods for each country. This is inevitable, because data availability is different for the countries considered and because it is difficult to obtain enough daily data. Thus, comparative interpretations in this chapter may have some limitations, although most of the sample periods for the three countries overlap. On account of the limited data availability, we may omit pertinent factors influencing intervention effects or motivations. For example, the daily data on foreigners' purchases of domestic equity are only available for Korea in our analyses.

Third, we do not sort out the impacts of oral interventions in the analyses. While actual interventions are generally undertaken when FX markets are open, oral interventions often occur after the FX markets are closed. Thus, it is possible that even a very small-scale intervention, if it is supported by oral interventions, could be much more effective than large-scale ones. In this case, the coefficient on the small-scale (actual) interventions is likely to be overestimated.

CHAPTER 5 STERILISATION AND CAPITAL MOBILITY UNDER INFLATION TARGETING:

Evidence from sterilisation and offset coefficients

5.1. Introduction

It has been generally accepted that international capital mobility weakens the effects of monetary policy. As capital mobility accelerates, domestic interest rates will be more affected by external shocks. That is, an independent monetary policy will be less effective due to increasing sensitivity of domestic interest rates to foreign shocks. A sterilised FXI is believed to mitigate the impact of foreign shocks on domestic interest rates and inflation, and thus to contribute to maintaining monetary autonomy. Accordingly, the sterilised intervention can be taken as a tool to cope over the constraint imposed by the trilemma hypothesis. In general, the more effective the sterilisations, the more controllable the domestic interest rates and the less controllable the foreign reserves (Herring and Marston 1977, p 343). Effective sterilisations of sustained capital inflows enable recipient countries to limit money growth and inflation expectations, and to reduce the appreciation pressure on domestic currency at the same time.

Most countries appear to automatically sterilise FXIs in a manner that is consistent with the day-to-day maintenance of their interest rate target, and thus attempt to maintain monetary autonomy while allowing for FX rate movements (Craig and Humpage 2001). The effects of sterilisations heavily depend on the degree of capital mobility. If domestic markets are fully integrated with international markets, any attempt to completely sterilise capital flows is fruitless (particularly in the long run), and it is impossible to avoid the trilemma constraint via sterilisations, regardless of FX rate regimes (Mundell 1963, p 475). Imperfect capital mobility is a precondition for sterilisations to be effective. Given limited capital mobility, the sterilised intervention can be used as a tool to control both domestic interest rates and FX rates, regardless of the FX regimes (Obstfeld 1982, p 45).

Many studies have pointed out that since the 1997-1998 Asian financial crisis, most emerging countries in Asia, facing capital inflows and current account surpluses, have used sterilisations to secure monetary independence while allowing for more flexible exchange rates and freer capital accounts. The countries appear successful in controlling domestic interest rates and stabilising exchange rates through sterilisations despite more open capital accounts (Reisen 1993, Ouyang and Rajan 2005). In particular, a larger amount of foreign reserves accumulated during the last decade appear related with greater and more persistent sterilisations than before (Aizenman and Glick 2009, p 777).

If the sterilisations are persistently successful, this may imply that either the degree of *de facto* capital mobility or the *de facto* exchange regime has evolved differently from what has been conjectured under the trilemma hypothesis. That is, there is a possibility that (i) emerging countries have maintained *de facto* intermediate exchange regimes (like implicit soft pegs) via sterilisations after introducing a *de jure* free float; or (ii) that *de facto intermediate exchange regimes* after the crisis. Thus, sterilisations may have functioned as a substitute for capital control.

However, it is likely that, even in a state of imperfect capital mobility, a complete sterilisation will be limited owing to its side-effects. According to Calvo (1991), a high degree of sterilisation in emerging countries might lead to excessively high domestic interest rates, thereby encourage capital inflows which, in turn, force CBs to take on high sterilisation costs stemming from additional sterilisations. This vicious circle of sterilisations may eventually hamper the credibility of the monetary policy.

With regard to sterilisations in Asian countries, another plausible possibility is that CBs occasionally conduct intentional, partial sterilisations in line with developments in macro-economic variables such as inflation. In particular, CBs with low inflation pressure and sluggish output may attempt to promote economic growth by intentionally reducing the degree of sterilisation or by non-sterilisation.[54] Therefore, the degree of sterilisation (i.e., the extent to which international capital flows can be sterilised by OMOs) and the degree of capital mobility (i.e., the extent to which OMOs are neutralised by offsetting international capital flows) are critical issues in examining not only intervention effects but also monetary policy independence. In this context, sterilisation and offset coefficients may provide straightforward but flexible methods to investigate the extent of sterilisation, *de facto* capital mobility, trilemma constraints and their interactions. Despite many previous studies estimating the coefficients, no studies on a wide range of countries have yet been carried out. In an effort to fill this gap, we estimate the coefficients for 30 countries, mainly focusing on IT countries.

The main interest of this chapter is to examine the interaction between sterilisations and *de facto* capital mobility in major inflation targeting (hereafter IT) countries during the last two decades. Our main method is to estimate sterilisation and offset coefficients. We particularly examine (i) whether there are differences in sterilisation activities and *de facto*

[54] Svensson (2001) shows that FXIs for inducing domestic currency depreciation may stimulate the economy, as do monetary expansion operations. Romer (2004, p 531) considers an unsterilised intervention as one of the specific types of unconventional OMO. Particularly where the nominal interest rate is close to zero and thus conventional OMOs are no more effective, FXIs can replace OMOs for adjusting economic fluctuations. For example, Japan – known for being the most frequent to intervene in the FX markets among advanced countries – might have intentionally reduced the extent of sterilisation during the zero-interest-rate period.

capital mobility among major countries with different institutional arrangements and (ii) whether sterilisations keep domestic interest rates from falling.

Previous studies have mostly applied individual time series models with different control variables that are chosen by the authors without explicit theoretical backgrounds. Thus, the estimated coefficients seem significantly different depending on the methodologies and regressors included in the specifications (even for the same countries with similar sample periods). This may be because the estimation of sterilisation and offset coefficients is vulnerable to problems of omitted variables and endogeneity. In order to lessen such problems, we examine panel data from 30 countries while exploiting new instrument variables as well as time-series data of individual countries.

The remainder of this chapter is organized as follows. Section 2 briefly reviews the current literature on theoretical aspects and empirical evidence. The main issue here is the interactions between net domestic assets (or monetary base) and net foreign assets (or foreign reserves), which show how CBs respond to capital flows through sterilisations. Section 3 presents the models for estimating the sterilisation and offset coefficients, based on Brissimis et al.'s (2002) theoretical foundation. We modify several constraints imposed on the CB's reaction function. Then, we specify an empirical model that estimates the effect of sterilisations on domestic interest rates, based on Edwards and Khan (1985)'s interest rate determination model. This chapter is novel in that it is based on comprehensive panel analyses for 30 countries, which have not been conducted in previous studies so far. We provide time-series analyses for selected countries for the purpose of comparing the two coefficients. The data are also described here. Section 4 discusses the main findings and section 5 concludes.

5.2. Literature review

5.2.1. Theoretical framework

The change in money supply through the foreign sector is unavoidable in open economies. CBs in small open economies (without perfect capital control) have depended on sterilisations to attain both exchange rate stability and monetary independence. Regardless of FX rate regimes, policy makers appear to view sterilisations as policy tools to control both exchange rates and monetary targets in the short run, although they doubt the long-term feasibility of sterilisations.

In general, under a fixed exchange regime and perfect asset substitutability, monetary control is totally infeasible in the short run as well as in the long run due to the complete offsetting of capital flows responding to domestic interest rate movements (Mundell 1963). In a more realistic world with imperfect substitutability, monetary independence through sterilisations may be feasible particularly in the short run, as domestic monetary policy cannot be immediately offset by capital flows (Obstfeld 1982, p 45). In the long run, the feasibility of sterilisations will disappear through the gradual adjustment procedure of offsetting capital flows. CBs under flexible FX regimes are expected to sterilise capital inflows more easily than those with fixed regimes, because the appreciation of domestic currency could absorb the impact of capital inflow.

In consideration of recent highly-integrated financial markets, the controllability of both the monetary base and exchange rate depends on the degree of capital control or sterilisations in a small open economy. As the benefits of capital mobility appear widely appreciated, the controllability of money tends to depend more on the effectiveness of sterilisations than capital control. Optimal sterilisation policy is determined by driving forces to affect the economy and the CBs' preference – particularly exchange rate regime (Haque et al. 1997). If CBs care about more stability of interest rates than of exchange rates, there will be a negative correlation between domestic credit and foreign reserves. In contrast, positive correlation indicates that the CBs aim to stabilise foreign reserves.

5.2.1.1 Measurement of sterilisation and offset coefficient

In this section, sterilisation is narrowly defined as a CB's attempt to neutralise changes in net foreign assets (NFA) by changing net domestic assets (NDA)[55] for the purpose of keeping the monetary base (MB) unaffected by capital flows. Given frequent FXIs under free capital mobility, sterilisations mitigate the impact of capital flows on domestic bank reserves, interest rates and inflation. However, the benefits of sterilisation (i.e., greater control over the monetary base and domestic interest rates) are gained at the expense of lessened control over foreign reserves (i.e. foreign exchange rates). This trade-off between monetary independence and FX stability is the gist of conventional trilemma arguments.

The following simultaneous equations, suggested by Argy and Kouri (1974) and Kouri and Porter (1974), are useful for understanding the sterilisation mechanism. (5.2.1) shows a monetary reaction function while (5.2.2) describes a BOP function.

(5.2.1) $\Delta NDA_t = a_1 + a_2 \Delta NFA_t + a_3 X_t + u_t$

(5.2.2) $\Delta NFA_t = b_1 + b_2 \Delta NDA_t + b_3 Y_t + v_t$

where a_i and b_i are the coefficients to be estimated; u_t and v_t are *i.i.d* disturbances; X and Y denote control variables affecting ΔNDA and ΔNFA, respectively. To illustrate the offset and

[55] Accounting identity drawn from a CB's B/S indicates that ΔBM = ΔNDA + ΔNFA. Since BM consists of controllable bank reserves and not-perfectly-controllable CIC, the sterilisation boils down to changing bank reserves. Alternatively, domestic credit and foreign reserves can replace NDA and NFA, respectively.

sterilisation coefficients with the above simple equations, assume a CB facing considerable capital inflows. Because uncontrolled capital inflows may fuel inflation and drive a high level of REER, CBs wish to neutralise the increase in domestic bank reserves and simultaneously to lessen the pressure of local currency appreciation. To resist the appreciation pressure, CBs would sell domestic assets for foreign assets – this procedure is reflected in (5.2.2). In this context, equation (5.2.2) may be indirectly interpreted as the CBs' FX intervention function.

However, FX interventions may increase foreign components of the monetary base and eventually cause domestic interest rates to fall to a level significantly deviating from the target, which indicates the loss of monetary independence. This situation may eventually result in increasing inflation. To prevent this, CBs have to sterilise the impacts of the FXIs by absorbing the increased NDA – this is reflected in (5.2.1). Note that this sterilisation will leave domestic interests rates higher than they would be without sterilisation, regardless of the nature of capital inflows (see Ch. 2, Section 2.1.2). From a theoretical and practical perspective, effective sterilisations enable the CBs to gain high monetary independence, at least in the short or medium run, by insulating domestic money from changes in foreign reserves. However, complete sterilisation is impossible in the long run, because the CB cannot sustain money supply that is different from the equilibrium level of money demand. The money supply is determined endogenously by money demand (Frankel 1997, p 268).

The estimated coefficients a_2 and b_2 are respectively labelled as the *"sterilisation coefficient*" and *"offset coefficient*. The a_2 indicates the CB's monetary response to capital flows, while the b_2 represents the sensitivity of capital flows to domestic monetary operations. To put it differently, a_2 estimates how much monetary operations offset the changes in foreign reserves to control money supply and b_2 measures the effectiveness of capital control or *de facto* capital mobility (Kim 1995, p 16). If $a_2 = -1$, CBs completely sterilise the impact of capital flows on the monetary base. In contrast, $a_2 = 0$ means no sterilisation. In a general case, a negative sign of a indicates systematic sterilisations. In particular, $a_2 < -1$ indicates an *over-sterilisation,* indicating that the CBs reduce the monetary base by more than one unit against a unit of foreign reserves increased. This happens when CBs conduct strong money tightening for fear of imminent inflation pressure. $a_2 > 0$ indicates monetary expansion aiming at reducing a credit crunch or adjusting an external imbalance.

On the other hand, $b_2 = 0$ implies perfect capital control in which the change in the monetary base does not affect capital flows, while $b_2 = -1$ indicates perfect capital mobility in which the change in monetary operation induces instant capital movements. The offset effect of capital flows on monetary operations empirically leads to a negative relationship between ΔNFA and ΔNDA. As the degree of capital mobility increases, sterilisations become less effective. Hence, a large a_2 and a small b_2 in absolute value generally indicate a high degree of monetary independence. Because $\Delta MB_t = \Delta NDA_t + \Delta NFA_t = 0$ under complete sterilisation, positive (negative) ΔMB_t can be interpreted as unsterilised capital inflows (outflows).

5.2.1.2 Nature of capital inflows and policy responses

The impacts of capital inflows on domestic interest rates and appropriate policy responses are determined by FX regimes and the nature of capital inflows — for instance, whether capital inflows are caused by *pull factors* or *push factors.*[56] Under highly flexible FX

[56] Among the factors inducing capital inflows, pull (or internal, country-specific) factors pull international capital into domestic markets. Examples are autonomous increases in demand for domestic money or increases in the productivity of domestic capital (and resultant increases in exports). Push (or external) factors push international capital from foreign markets to domestic markets (e.g., exogenous fall in foreign interest rates).

regimes, most sterilised interventions responding to capital inflows are likely to aim at resisting domestic currency appreciation rather than preventing inflation, because the appreciation of domestic currency tends to alleviate inflationary pressure from capital inflows. However, under a *managed* float or a *fixed* exchange rate regime, the impacts of capital inflows on inflation pressure differ depending on the nature of those capital inflows.

The general conclusion is: (i) As to capital inflows from push factors, sterilisations may be effective in controlling inflation without incurring high sterilisation costs; (ii) As to capital inflows from pull factors, monetary expansion is more appropriate than sterilisation in addressing the negative effects of capital inflows (Calvo 1991, Frankel 1997).

For example, when capital inflows are *pushed* by a fall in foreign interest rates, which is mostly a *temporary* shock, the accumulation of foreign reserves will lead to increases in the monetary base, heightened inflationary pressures, and deterioration of the external position (Haque et al. 1997, p 4). In this case, the sterilisation of selling MSBs may not significantly push up interest rates, and thus sterilisation may be the more necessary and appropriate response (see section 2.1.2.2).

On the other hand, if capital inflows are *pulled by* sustained increases in domestic money demand, they tend to push up domestic interest rates (which repress inflation expectations). Hence, an appropriate response may be not to sterilise inflows, but to increase domestic money supply. Monetary expansion will lessen the pressures of both domestic currency appreciation and interest rate increases (see section 2.1.2.1).

However, it is, in practice, not easy for CBs to differentiate the causes of capital inflows because the inflows mostly reflect a combination of various factors that affect risk and return trade-offs (IMF 2011). Although some financial indicators may help CBs to identify the cause of capital inflows – see Haque et al. (1997, pp. 4-5), many CBs tend to depend on sterilisation rather than policy rate changes to adjust the impacts of capital inflows in the short run. CBs respond to capital inflows and resultant price increases by changing interest rates from a relatively long-term perspective. Kumhof (2004) shows that an interest rate cut is more appropriate policy than an interest rate increase to lessen inflation pressure stemming from sustained capital inflows.

Particular policy responses to capital inflows influence the volume or composition of capital inflows. Sterilisations tend to increase the volume of total capital inflows by inducing short-term portfolio funds, while capital controls encourage long-term FDI and discourage short-term portfolio inflows (Montiel and Reinhart 1999).

5.2.1.3 Sterilisation peril

As mentioned previously, it is not easy for CBs to differentiate the causes of capital inflows. What happens if the CBs sterilise the capital inflows caused by increases in money demand (which could be responses to an exchange rate orientated stabilisation programme) by issuing nominal MSBs? There exists a sterilisation peril that sterilisation itself will destabilise the economy rather than stabilise it, owing to the sterilisation cost (Calvo 1991). CBs should maintain the nominal domestic interest rate high in order to keep the monetary base from increasing owing to capital inflows. Consequently, the sterilisation leaves the domestic interest rate unnecessarily high, perpetuates domestic-foreign interest rate differentials, and thereby induces further capital inflows which would bring about additional sterilisations. Subsequent stabilisation for curbing the incessant capital inflows may, in turn, lead to further increases in domestic money demand, persistent domestic-foreign interest differentials and consequent increases in sterilisation costs (Caballero and Krishnamurthy

2001). The increasing sterilisations cost frequently incurs quasi-fiscal deficits (Rocha and Saldanha 1992), which in turn limits the CB's ability to sterilise capital inflows.

This "*vicious cycle of sterilisation*" results in the persistent accumulation of MSBs and foreign reserves. As the outstanding stock of MSBs becomes increasingly large relative to GDP, the CB will have an incentive to liquidate part of its debt through surprise inflation – or to monetise these MSBs – in the future. If the public rationally expects such future monetisation and inflation, they will require higher interest rates. As a result, persistent sterilisation could face serious credibility problems in the long run and thus jeopardize the sustainability of the CB's anti-inflation policies (Calvo 1991, p 3). As a result, the vicious cycle may lead to the undesired situation in which sterilisation may have an expansionary effect. For example, when financial markets are illiquid or underdeveloped, sterilisations may have a *"backfiring"* effect, where the sterilisations stimulate short-term capital inflows and result in an expansion rather than a desired contraction in aggregate demand (Cagallero and Krishnamurthy 2001).

Persistent sterilisations cause the CBs (with financial distraught) to experience fiscal losses and occasionally to rely on financial support from their governments to recapitalise them. However, CB recapitalisation by government taxation will weaken central bank independence from the government (Stella 2005, Cukierman2006),which will eventually also pose a threat to price stability (Alesina and Summers 1993, Brumm 2006).[57]

A CB's ability to sterilise capital inflows is more limited as capital mobility is freer or the exchange rate is more fixed. Despite financial market integrations and increases in

[57] There are several consensus views of the role of the CB in major countries during the last two decades (Cukierman 2006): (i) The main objective of CBs should be price stability, even at the cost of substantial neglect of other objectives. (ii) CBs should have monetary policy instruments independently of the government. Alesina and Summers (1993) and Brumm (2006) provide evidence that stronger central bank independence is significantly related with lower and more stable inflation. However, some studies doubt that there is a significantly negative correlation between CB independence and inflation (Ismiham and Ozkan 2004, Dreher et al. 2008).

flexible regimes, many CBs in small open IT countries still seem to regard sterilised FXIs as an independent policy tool to contribute to both stabilising FX rates and targeting interest rates simultaneously. Thus, the CBs intervene in FX markets to adjust FX rates as they desire, and then automatically and routinely sterilise the effects of FXIs on the monetary base to maintain the target interest rate (Craig and Humpage 2001, pp. 1-3).

However, as the conventional trilemma emphasizes, either of the two objectives should be compromised in all cases except for the case where the driving forces of capital inflows come from the domestic monetary sector (Craig and Humpage 2001, pp. 6-9). When the shocks come from external sectors, exchange rate stability may be achieved at the cost of losing monetary autonomy. In addition, one country's greater use of sterilisation, which may be regarded as a "*beggar-thy-neighbour*" policy, tends to induce both subsequent greater sterilisation of its own and other countries' sterilisations – which may eventually destabilise output and inflation in both countries. Thus, even if the sterilised interventions affect FX rates, practices of automatic and complete sterilisation may be problematic (Daniels 1997).[58]

5.2.2 Empirical evidence

5.2.2.1 Estimation issues

Most previous studies estimated the sterilisation and offset coefficients by using reduced form equations like (5.2.1) and (5.2.2) respectively, without considering the optimisation procedure of the CBs. Hence, they have been criticized for depending on specifications that are too discretionary or ad-hoc, and for being subject to endogeneity

[58] Daniels (1997) derives the optimal sterilisation coefficient, suggesting that, in general, incomplete sterilisation is optimal under imperfect capital mobility while complete sterilisation is optimal under perfect capital mobility, although the optimal extent of sterilisation depends on the natures of the shocks and also on the CB reaction function.

problems. The endogeneity comes from systematic contemporaneous feedbacks between ΔNDA and ΔNFA. The specific directions of the feedbacks are likely to depend on which policy objective is more dominant between interest rate stability and foreign exchange rate management. The endogeneity causes OLS estimates to be biased and inconsistent.

A systematic sterilisation policy indicates $a_2 < 0$ in (5.2.1). If $a_2 < 0$, ΔNDA_t would be correlated with v_t in (5.2.2), and thus OLS estimates of the offset coefficient (b_2) in (5.2.2) is likely to be downward-biased towards −1 (algebraically) (Obstfeld 1982, Pasula 1994). In other words, a CB's attempt to sterilise the capital flows introduces an additional source of negative correlation between ΔNFA and ΔNDA. Thus, OLS estimates of b_2 tend to be larger (in absolute value), as sterilisations are stronger. If sterilisations respond to not only imminent capital flows but also lagged inflation or output, the extent of overestimating b_2 will be bigger. Therefore, the reduced-form evidence of high b_2 (i.e., high capital mobility and no monetary independence) is frequently regarded as a result of improperly taking "sterilisation bias" into account (Pasula 1994, p 684). In contrast, if CBs use a domestic credit policy to target foreign reserves rather than to sterilise capital flows, the OLS estimate of b_2 will be *upward-biased* (see Frankel 1983). When the CBs' true reaction function is not known, the direction of bias in estimating the b_2 may not be predicted a priori, although the bias is sure to exist. The endogeneity problem also exists in estimating the sterilisation coefficient from (5.2.1).

To avoid the endogeneity problem, one could estimate two reduced forms (5.2.1) and (5.2.2) simultaneously using instrument variables such as 2SLS, 3SLS or GMM. Instead, one can set up a structural model of the asset demand function, and then obtain the implied offset coefficient from the total derivative of ΔNFA with regard to ΔNDA or the estimated domestic interest sensitivity of capital flows. The choice between reduced-form and structural estimate is associated with the issues on the conventional trade-off between the two approaches. Reduced-form estimates, though subject to the endogeneity problem, may be more robust with respect to specification errors and be implemented under unlimited substitutability (Obstfeld 1982 p 46). Structural approaches allow for the interpretation of estimated coefficients based on structural parameters, but they are sensitive to specification errors.

Several studies examine the discrepancy between the reduced form and structural estimates of the coefficients.[59] Thus, it may be desirable for one to estimate the coefficient derived from the structural model and then compare the result with the reduced-form estimate (Frankel 1983) or use semi-reduced form equations which are derived from more explicit optimisation problems solved by monetary authorities (e.g., Roubini 1988, Brissimis et al. 2002). Another approach is to examine the transmission of an impulse from ΔNFA to ΔNDA by applying VAR approach (Moreno 1996, Takagi and Esaka 2001, He et al. 2005).

5.2.2.2 Main findings of previous studies

Previous studies separately estimate monetary reaction functions like (5.2.1) (Kwack 2001, Takagi and Esaka 2001, Cavoli and Rajan 2006, Aizenman and Glick 2009) or BOP equations like (5.2.2) (Pasula 1994). A typical estimation form includes some lagged variables like:

(5.2.3) $\Delta NDA_t = \lambda + \sum_{i=0}^{m} \alpha_i \Delta NFA_{t-i} + \beta_i X_{it} + \varepsilon_{1t}$

[59] Obstfeld (1982) and Pasula (1994) provide evidence of a significant difference between estimates of the *offset coefficient* obtained from the two approaches. Structural estimates are generally lower than reduced form estimates, particularly when OLS is used in a single equation like (5.2.2). Obstfeld (1982) argues that structural estimates are more appropriate because reduced form estimates of offset coefficients are biased towards -1, even for the Bretton Woods period, if CBs systemically sterilise capital flows. The overestimate of the reduced-form offset coefficients is caused by sterilisation bias and the inclusion of a speculative period in data sample. It can be shown that reduced-form OLS estimates of sterilisation coefficients have the same bias towards -1 (see Roubini 1988). In contrast, Pasula (1994) argues that reduced-form estimates are more appropriate, because structural estimates of the offset coefficient are biased towards 0 if the public has internalised government budget constraints.

where X_i denotes control variables such as current account, inflation, interest rate and exchange rate. $\alpha_0 = -1$ indicates a *contemporaneous* perfect sterilisation while $\alpha_0 = 0$ indicates no contemporaneous sterilisation. α_i $(i = 1 \ldots m)$ implies a relatively long-run sterilisation coefficient. Most studies measure either contemporaneous or one-period lagged coefficients because the CBs are known to conduct sterilisation operations (Craig and Humpage 2001, Taylor 1995) immediately or with a very short lag.

Aizenman and Glick (2009) provide evidence that sterilisations have been strengthened in the 2000s in twelve Asian and Latin American countries, implying that there have been increasing potential inflationary pressures and significant sterilisation cost problems. They find a structural break in the sterilisation behaviours in both regions around crisis periods: the 1997-1998 financial crises and the 1994 peso crisis. Cavoli and Rajan (2006) focus on the relation between the uncovered exchange rate adjusted interest differential and the degree of sterilisation in five Asian countries (Korea, Thailand, Malaysia, Indonesia and the Philippines) in 1990-1997. They find that nearly complete sterilisations in Korea, Malaysia and Philippines leave interest differentials unchanged, and in turn induce further capital inflows. In spite of its simplicity, this approach has limits in assuming that international capital flows would not respond to changes in domestic monetary conditions.

If all of the variables in (5.2.3) are cointegrated, the simultaneity problem could be avoided by using the multivariate cointegration technique. Bernstein (2000) measures cointegration-based long-run sterilisation coefficients in the G7 countries in 1973-1992, when managed exchange regimes were dominant. While the sterilisations are almost complete in Japan, UK and US (where sterilisation coefficients range from -0.95 to -1), they are relatively low in other countries like Germany, France and Canada (where sterilisation coefficients range from -0.42 to -0.80). They do not provide particular reasons for the differences between the sterilisation coefficients. Takagi and Esaka (2001) do not find a significant cointegration relation between M1 (or M2) and foreign assets in five Asian countries in 1987-1997.

Using VAR often enables one to circumvent the endogeneity problem (Moreno 1996, Christensen 2004, He et al. 2005). Impulse-response functions allow one to trace out the time path of the various shocks on the variable in the system. The typical VAR is:

$$(5.2.4)\quad \begin{aligned} \Delta NDA_t &= \alpha_{10} + \sum_{i=1}^{m} \alpha_{1i} \Delta NDA_{t-i} + \sum_{i=1}^{m} \beta_{1i} \Delta NFA_{t-i} + \gamma_{1i} X_{1t} + \varepsilon_{1t} \\ \Delta NFA_t &= \alpha_{20} + \sum_{i=1}^{m} \alpha_{2i} \Delta NFA_{t-i} + \sum_{i=1}^{m} \beta_{2i} \Delta NDA_{t-i} + \gamma_{2i} X_{2t} + \varepsilon_{2t} \end{aligned}$$

Moreno (1996) runs four variable VARs (consisting of NDA, NFA, CPI and real GDP) for Korea and Taiwan in 1981M1-1994M12. He suggests complete sterilisations but not perfect capital mobility in both countries. In particular, Korea has stronger monetary independence due to stricter capital controls and a higher degree of sterilisation. Christensen (2004) uses four variable VARs (domestic credit, foreign reserves, domestic and foreign interest rates) to examine the relationship between capital inflows and sterilisation in the Czech Republic for 1993–1996. He supports Calvo (1991). As a sterilisation stimulates more capital inflows, the initial successful sterilisation turns to increasing fiscal burden, and the sterilisation policy eventually become unsustainable. However, VAR only identifies coefficients of lagged variables, making it impossible to estimate the contemporaneous effects. In addition, VAR are often based on an assumption that NFAs are exogenous to NDAs, or all variables are treated as symmetrically endogenous, which is often empirically rejected.

The third approach obtains coefficients from a CB's optimisation problem (Herring and Marston 1977, Roubini 1988, Kim 1995, Brissimis et al. 2002, Ouyang et al. 2007, 2010). Two functional forms are derived from the small open economic model:

$$(5.2.5)\ \Delta NDA_t = \alpha_{10} + \sum_{i=0}^{m} \beta_{1i} \Delta NFA_{t-i} + \gamma_{1i} A_{it} + \varepsilon_{1t}$$

$$(5.2.6)\ \Delta NFA_t = \alpha_{20} + \sum_{i=0}^{m} \beta_{2i} \Delta NDA_{t-i} + \gamma_{2i} B_{it} + \varepsilon_{2t}$$

where A_{it} and B_{it} are the sets of control variables. If all variables are I(0), the simultaneous equation can be estimated by 2SLS, 3LS or GMM. If the variables are I(1) and cointegrated, cointegrated VAR is used to estimate the long-term coefficient. The cointegrated VAR provides both lagged and contemporaneous relationships among ΔNDA and ΔNFA.

Many previous studies suggest that nearly-complete sterilisations have been carried out in several countries, which contributes to build-up of a large amount of foreign reserves and to maintenance of monetary independence. In particular, two countries under fixed exchange regimes became "*foreign reserve sinks*" owing to their high degree of sterilisation: West Germany during the Bretton Woods regime (Brissimis et al. 2002), and China and Asian countries during the 2000s (Ouyang et al. 2007, 2010).

Brissimis et al. (2002) suggest that the Bundesbank had considerable monetary independence during 1980-1992 in that the offset coefficient is significantly lower (in absolute value)during the period than during the Bretton Woods period, while the sterilisation coefficient is not significantly different from -1 in both periods. Ouyang et al. (2007, 2010) suggest that both China (that controls capital mobility) and other emerging Asian countries (that allow relatively free capital flows) are able to completely sterilise foreign reserves in the 1990s and 2000s, although their sterilisations may have problems in terms of costs. They interestingly find that offset coefficients in eight Asian countries decrease from around -0.8 (pre-crisis) to -0.6 (post-crisis) in absolute value, which implies that *de facto* capital mobility has been more restricted since the 1997 crisis.

However, Wu (2009) finds that the cointegration-based sterilisation coefficient of China was only −0.35 in 1995-2005, which is significantly lower than Ouyang et al. (2010)'s. This indicates that China did not have monetary autonomy to a great extent. Kim (1995) examines the evolution of the two coefficients during the period 1980-1995, when Korean governments undertook capital control and actively managed exchange rates. He finds that Korea more completely sterilised current account surpluses in the late 1980s than capital inflows in the early 1990s. BOK pursued *over-sterilisation* during 1980-1985, when BOP showed deficit, and thus foreign reserves were dropping, which indicates that monetary policies might worsen BOP deficit rather than improve it.

As summarized in Appendix 5.1, previous evidence shows that the offset and sterilisation coefficients vary across countries and times. Nevertheless, several implications may be drawn from previous studies. First, estimated sterilisation coefficients in the 2000s are generally larger than those in the previous periods. Ouyang et al. (2007) report that, in five East-Asian countries, estimated sterilisation coefficients range from -1.04 to -1.27 (under the assumption of perfect foresight) in the 1990s and 2000s. The sterilisation coefficients for China range from -1.02 to -1.23 in the 2000s (Ouyang et. al 2010). These are larger than the estimated sterilisation coefficients including the 1980s and 1990s: e.g., -0.79 for 1986Q1-2007Q2 (Aizenman and Glick 2009) and -0.96 for 1999M6-2009M3 (Wang 2010). Another example is the case of Korea: the sterilisation coefficient was -0.56 in 1980Q1-1994Q4 (Kim 1995) but -0.77 in 1985Q1 - 2007Q2 (Aizenman and Glick 2009). Despite the increases in *de jure* flexible FX regimes in East Asian countries during the last decade, lower FX volatility in the 2000s than in the 1990s may be, in part, ascribed to sterilisations.

Next, emerging countries appear to retain considerable monetary independence in the 2000s. Many studies have found that sterilisation coefficients are relatively closer to −1 while offset coefficients are closer to 0 than to -1(e.g. China, Czech Republic, Mexico, etc.). It is commonly accepted that capital mobility in emerging countries has been accelerated since the early 1990s, when many developing countries began to open capital accounts. Furthermore, a series of financial crises between 1997 and 2000 are believed to contribute to the wide spread of free float and capital market openness. However, empirical evidence of low offset coefficients for the 1990s and 2000s cast a doubt on the common knowledge. For example, Ouyang et al. (2007) provide evidence that the offsetting effect of capital flows in East Asian countries is not significantly different between the pre-Asian crisis and post-Asian crisis period. Therefore, we may conjecture that *de facto* capital mobility in emerging countries was not so high in the 2000s as has been conventionally thought.

Lastly, BOK appears to increase the degree of sterilisation over time. Before the introduction of IT with a free float regime in 1997-1998, the estimated sterilisation coefficients were significantly less than 1 in absolute value: e.g. -0.56 (Kim 1995) or -0.12 (Lee and Yoon 1997). However, the studies including the period of IT with a flexible regime (i.e., after 2000) show estimated sterilisation coefficients close to or over 1 in absolute value: −0.77 (Aizenman and Glick 2009) and −1.11 (Cavoli and Rajan 2006). Most studies indicate that FXIs are completely sterilised in the short run but not in the long run, indicating that FXIs eventually lead to increases in the monetary base in the long run (Choi 1995, Lee and Yoon 1997).

5.3 Methodologies and data

5.3.1 Estimation of sterilisation and offset coefficient

5.3.1.1 Derivation of monetary reaction and capital flow function

Assuming imperfect capital mobility and following Brissimis et al.'s (2002) constraints, we construct a CB's loss function with which the CB attempts to achieve multiple policy objectives: stabilising price and output, managing exchange rates, and minimizing volatility of interest rate and exchange rate. As is typical of an intermediate exchange regime, we assume that the CB attempts to adjust the domestic monetary base (and thereby to manage domestic interest rate) and intervenes in the FX market not only to stabilise exchange rate volatility but also to affect the exchange rate level toward desired direction.[60] The CB is assumed to minimize the following loss function.

(5.3.1) Loss function: $L_t = \alpha(\Delta p_t - \overline{\Delta p_t})^2 + \beta(Y_t - \overline{Y_t})^2 + \gamma(\sigma_{r,t})^2 + \varepsilon(S_t - \overline{S_t})^2 + \nu(\sigma_{s,t})^2$

where L_t is the loss at time t; Δp_t and $\overline{\Delta p_t}$ are actual and target inflation, respectively; Y_t and $\overline{Y_t}$ are actual and potential output; S_t and $\overline{S_t}$ are current and target exchange rates; $\sigma_{r,t}$ and $\sigma_{s,t}$ are measures of volatility of interest rates and exchange rates. The parameters $(\alpha, \beta, \gamma, \varepsilon, \nu)$ are the weights assigned by the CB and are assumed to all be positive. (5.3.1) is

[60] Herring and Marston (1977) include the change in foreign reserves, inflation and output in their loss function. Recently Ouyang et al. (2010) include only ($\Delta p_t - \overline{\Delta p_t}$) and ($Y_t - \overline{Y_t}$) in the loss function. It seems more appropriate to use Brissimis et al.'s (2002) original specification, which includes exchange rate target (level) instead of foreign reserves target, because (i) the original form may be more appropriate to explain the CB behaviours that pursue the control of exchange rates even under floating regimes (i.e. *de facto* intermediate regimes); (ii) several studies have recently provided significant evidence of intervention effects on exchange rate level as well as volatility (see Chapter 3 for the detailed evidence on the intervention effects).

rewritten in a slightly different form (5.3.2) by replacing $Y_t - \overline{Y_t}$ with cyclical output ($Y_{c,t}$) and by assuming $\overline{\Delta p_t}$ =0 for simplicity.

(5.3.2) $L_t = \alpha(\Delta p_t)^2 + \beta(Y_{c,t})^2 + \gamma(\sigma_{r,t})^2 + \varepsilon(S_t - \overline{S_t})^2 + \nu(\sigma_{s,t})^2$

The CB conducts FXIs (by altering ΔNFA) and OMOs (by changing ΔNDA) to minimize the loss function, subject to the following constraints.

(5.3.3) Inflation: $\Delta p_t = \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2 \Delta p_{t-1} + \pi_3 \Delta S_t$, π_1>0, 0<π_2<1, π_3>0

Unlike Brissimis et al. (2002), we assume that ΔS_t would affect Δp_t owing to the direct effects of exchange rates on import price.[61]

(5.3.4) Cyclical output: $Y_{c,t} = \phi_1(\Delta NFA_t + \Delta NDA_t) + \phi_2 Y_{c,t-1} + \phi_3 \Delta G_t$, $\phi_1 > 0$, $0 < \phi_2 < 1$, $\phi_3 > 0$

where ΔG_t is a government budget balance ($\Delta G_t > 0$ indicates fiscal surplus). Cyclical output is affected by monetary and fiscal policy, and its past value.

(5.3.5) Balance of payment: $\Delta NFA_t = CA_t + \Delta NK_t$

where CA_t is the current account surplus and ΔNK_t is the net capital inflows. Thus, ΔNFA is the sum of the capital, financial and current account surplus. We assumed that CA_t is exogenous, for simplicity, and ΔNK_t depends on the uncovered interest parity (UIP).

(5.3.5.a) Net capital inflow: $\Delta NK_t = (1/c)\Delta(S_t - E_t S_{t+1} + r_{d,t} - r_{f,t})$

[61] Unlike Brissimis et al. (2002), we assume that (i) exchange rates directly influence price (i.e. $\Delta p_t = \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2 \Delta p_{t-1} + \pi_3 \Delta S_t$); and (ii) domestic interests are related to foreign components of the monetary base as well as domestic ones ($\Delta r_{d,t} = -\psi(\Delta NDA_t + \Delta NFA_t)$).We additionally consider the effect of government expenditures on the cyclical output.

where E_tS_{t+1} = expectation for future FX rate; $r_{d,t}$ = domestic interest rate; $r_{f,t}$ = foreign interest rate; and c = degree of relative risk aversion between domestic and foreign assets, which represents the degree of capital mobility. It is assumed that $0 < c < \infty$. In particular, c close to zero indicates that any deviation from UIP will lead to an infinite capital flow (Brissimis et al. 2002, p 66), representing a perfect substitutability between domestic and foreign assets.

(5.3.5.b) interest rate: $\Delta r_{d,t} = -\psi(\Delta MB_t) = -\psi(\Delta NDA_t + \Delta NFA_t)$, $\psi > 0$

Under the assumption of the existence of liquidity effect, $\Delta r_{d,t}$ is negatively related with ΔMB_t. ψ indicates the sensitivity of local interest rates to money supply. Using (5.3.5.a) and (5.3.5.b) in (5.3.5) and solving for S_t produces:

$$\begin{aligned} &S_t = (c+\psi)\Delta NFA_t - cCA_t + S_{t-1} + \psi\Delta NDA_t + \Delta(E_tS_{t+1} + r_{f,t}) \\ &\Rightarrow \Delta S_t = (c+\psi)\Delta NFA_t + \psi\Delta NDA_t + \Delta(E_tS_{t+1} + r_{f,t}) - cCA_t \end{aligned} \quad (5.3.6)$$

Equation (5.3.6) has several implications which are consistent with intuitive knowledge:

(i) Increases in the monetary base depreciate domestic currency: $\Delta NFA_t \uparrow$ or $\Delta NDA_t \uparrow \rightarrow \Delta S_t \uparrow$ $(\because c, \psi > 0)$. Foreign currency purchasing intervention ($\Delta NFA_t \uparrow$) or liquidity-providing OMO ($\Delta NDA_t \uparrow$) are expected to depreciate domestic currency.

(ii) Increases in the current account surplus (owing to the decrease in cyclical income or REER) lead to domestic currency appreciation: $CA_t \uparrow \rightarrow \Delta S_t \downarrow$.

(iii) A rise in foreign interest rate encourages capital outflows and eventually leads to domestic currency depreciation (overshooting): $r_{f,t} \uparrow \rightarrow \Delta S_t \uparrow$.

(iv) Although FXIs and subsequent OMOs may affect exchange rates, the FXIs usually have more significant impacts on exchange rates than OMOs, because $c+\psi>\psi$, all other things being equal.

Following Brissimis et al. (2002), we assume that $\sigma_{r,t}$ and $\sigma_{s,t}$ are related positively with past values and negatively with the amount of OMOs and FXIs: Assuming the effect of OMOs and FXIs on reducing FX and interest rate volatility, $\sigma_{r,t}=\eta_1\sigma_{r,t-1}-\theta_1|\Delta NDA_t|, \quad \eta_1,\theta_1>0$ and $\sigma_{s,t}=\eta_2\sigma_{s,t-1}-\theta_2|\Delta NFA_t|, \quad \eta_2,\theta_2>0$. Then, we transform the above two volatility equations into the following testable forms which do not include absolute terms:

(5.3.7) $\sigma_{r,t}=\eta_1\sigma_{r,t-1}-\theta_1(\Delta NDA_t-d_1\Delta NDA_t) \quad \eta_1,\theta_1>0$

(5.3.8) $\sigma_{s,t}=\eta_2\sigma_{s,t-1}-\theta_2(\Delta NFA_t-d_2\Delta NFA_t) \quad \eta_2,\theta_2>0$

where $d_1=0$ ($d_1=2$) if the money market is in liquidity shortage (surplus); $d_2=0$ ($d_2=2$) if the FX market is in excess supply of (demand for) foreign exchanges. Solving for $\partial L_t/\partial\Delta NDA_t=0$ and $\partial L_t/\partial\Delta NFA_t=0$, and then substituting the constraints into a CB loss function, yields two semi-reduced forms, (5.3.9) and (5.3.10), which provide optimal rules that the CB should follow (see Appendix 5.2 for the detailed derivative procedure).

(5.3.9)
$$\begin{aligned}\Delta NDA_t=&-\{[\alpha\pi_1^2+\beta\phi_1^2+(\alpha\pi_1\pi_3+\varepsilon\psi)(c+\psi)]/\varpi_1\}\Delta NFA_t+[c(\alpha\pi_1\pi_3+\varepsilon\psi)/\varpi_1]CA_t\\&-(\varepsilon\psi/\varpi_1)(S_{t-1}-\overline{S_t})-[\alpha\pi_1\pi_2/\varpi_1]\Delta p_{t-1}-[\beta\phi_1\phi_2/\varpi_1]Y_{c,t-1}-[\beta\phi_1\phi_3/\varpi_1]\Delta G_t\\&-[(\alpha\pi_1\pi_3+\varepsilon\psi)/\varpi_1]\Delta(r_{f,t}+E_tS_{t+1})-(\gamma\eta_1\theta_1/\varpi_2)(d_1-1)\sigma_{r,t-1}\end{aligned}$$

where $\omega_1=[\alpha\pi_1^2+\beta\phi_1^2+(\alpha\pi_1\pi_3+\varepsilon\psi)\psi+\gamma\theta_1^2(d_1-1)^2]>0$

$$
\begin{aligned}
\Delta NFA_t = & -\{[\alpha\pi_1^2+\beta\phi_1^2+[\alpha\pi_1\pi_3+\varepsilon(c+\psi)\psi]/\varpi_2\}\Delta NDA_t+\{c[\alpha\pi_1\pi_3+\varepsilon(c+\psi)]/\varpi_2\}CA_t \\
& -[\varepsilon(c+\psi)/\varpi_2](S_{t-1}-\overline{S_t})-[\alpha\pi_1\pi_2/\varpi_2]\Delta p_{t-1}-[\beta\phi_1\phi_2/\varpi_2]Y_{c,t-1}-[\beta\phi_1\phi_3/\varpi_2]\Delta G_t \\
& -\{[(\alpha\pi_1\pi_3+\varepsilon(c+\psi)]/\varpi_2\}\Delta(r_{f,t}+E_tS_{t+1})-(\upsilon\eta_2\theta_2/\varpi_2)(d_2-1)\sigma_{s,t-1}
\end{aligned}
\tag{5.3.10}
$$

where $\varpi_2=\{\alpha\pi_1^2+\beta\phi_1^2+[\alpha\pi_1\pi_3+\varepsilon(c+\psi)]\psi+\upsilon\theta_2^2(d_2-1)^2\}>0$

5.3.1.2 Implications

Our main interests are the coefficients for ΔNFA (sterilisation coefficient) in (5.3.9) and for ΔNDA (offset coefficient) in (5.3.10). Both are, in general, expected to be negative, but could be less than or greater than −1. A sterilisation coefficient less than −1 indicates a contemporaneous oversterilisation. A priori expected signs of other regressors are as follows.

First, signs of the coefficients in (5.3.9) are expected to be negative except $Y_{c,t-1}$, ΔG_t and CA_t. For example, CBs should tighten money($\Delta NDA_t\downarrow$) when a domestic currency depreciates relative to their trend or target, inflation increases or foreign interest rate rises: in abbreviation notation, $(S_{t-1}-\overline{S_t})\uparrow$, $\Delta p_{t-1}\uparrow$ or $\Delta(r_{f,t}+E_tS_{t+1})\uparrow\rightarrow\Delta NDA_t\downarrow$. The coefficient of $\sigma_{r,t-1}(d_1-1)$ is expected to be negative, because CBs have to withdraw (provide) monetary base in case of liquidity surplus (shortage) and because the magnitude of OMOs should be greater as domestic interest rates are more volatile: $\sigma_{r,t-1}\uparrow$ and $d_1=2\rightarrow\Delta NDA_t\downarrow$. However, the coefficient of CA_t is, in general, expected to be positive, as the deterioration of current account causes the CBs to reduce the monetary base to attract capital inflows: $CA_t\downarrow\rightarrow\Delta NDA_t\downarrow$. However, when the CBs attempt to induce domestic currency depreciation for boosting export via monetary expansion, CA and ΔNDA may be negatively correlated. The CBs should, in general, respond to increases in government expenditures or cyclical outputs by tight monetary operations: $\Delta G_t \uparrow \rightarrow Y_{c,t} \uparrow \rightarrow \Delta NDA_t \downarrow$. In this case, the coefficients of ΔG_t and $Y_{c,t-1}$ are expected to have negative signs. However, they could be positive when monetary loosening and fiscal expansion are concurrently carried out to stimulate the economy during a recession or when monetary tightening and fiscal contraction are conducted during a boom. For example, while cyclical outputs increase but the economy is still sluggish, expansionary monetary policy can be possibly continued (Ouyang et al. 2010, pp. 9-10).

In the BOP function (5.3.10), the expected signs of the coefficients are almost the same as in (5.3.9). If the domestic currency appreciates relative to the target or CBs aim for the domestic-currency depreciation, the CB should buy foreign reserves: $S_{t-1} \downarrow$ or $\overline{S_t} \uparrow \rightarrow$ $(S_{t-1} - \overline{S_t}) \downarrow \rightarrow \Delta NFA_t \uparrow$. Higher inflation may lead to domestic currency depreciation, increases in domestic interest rates, capital losses thereof and capital outflows: $\Delta p_{t-1} \uparrow \rightarrow \Delta NFA_t \downarrow$.An improvement in current accounts leads to an increase in foreign reserves: $CA_{t-1} \uparrow \rightarrow \Delta NFA_t \uparrow$.

A fall in foreign interest rates or an expectation for domestic currency appreciation leads to capital inflows: $r_{f,t-1} \downarrow$ or $E_t S_{t+1} \downarrow \rightarrow \Delta(r_{t-1}^f + E_t S_{t+1}) \downarrow \rightarrow NFA_t \uparrow$. The coefficient of $\sigma_{s,t}(d_2 - 1)$ may be negative, because CBs should buy (sell) foreign currencies in case of excess supply of (demand for) foreign exchanges and because more volatile exchange rates lead to larger FXIs as seen in Chapter 3: $\sigma_{s,t} \uparrow$ and $d_2 = 2$ (excess demand for foreign exchanges)$\rightarrow \Delta NFA_t \downarrow$(sales of foreign exchanges).

However, the prior expected sign of the coefficient of cyclical output increase ($Y_{c,t-1}$) is ambiguous, because the increase in $Y_{c,t-1}$ may worsen the current account (owing to the income effect) and thus reduce foreign reserves ($Y_{c,t-1} \uparrow \rightarrow \Delta NFA_t \downarrow$), while an output increase may reflect a strong economy, which encourages capital inflows ($Y_{c,t-1}\uparrow\rightarrow\Delta NFA_t\uparrow$). The expected sign for the coefficient of government spending is also unclear, because government spending increases cyclical outputs.

This model enables one to see CB interventions in both domestic money markets and foreign exchange markets. If CBs aim only at managing exchange rates (i.e., $\alpha=\beta=\gamma=0$), (5.3.9) and (5.3.10) are simplified as (5.3.11) and (5.3.12) respectively, in which CB interventions in both the money and FX markets do not rely on changes in inflation, cyclical output or domestic interest rate volatility.

(5.3.11) $\Delta NDA_t=-[(c/\psi)+1]\Delta NFA_t+(c/\psi)CA_t-(1/\psi)(S_{t-1}-\overline{S_t})-(1/\psi)\Delta(r_{f,t}+E_tS_{t+1})$

(5.3.12) $$\begin{aligned}\Delta NFA_t=&-\{[\varepsilon(c+\psi)\psi]/\varpi_2\}\Delta NDA_t+[c\varepsilon(c+\psi)]/\varpi_2\}CA_t-[\varepsilon(c+\psi)/\varpi_2](S_{t-1}-\overline{S_t})\\&-\{[\varepsilon(c+\psi)]/\varpi_2\}\Delta(r_{f,t}+E_tS_{t+1})-(\upsilon\eta_2\theta_2/\varpi_2)(d_2-1)\sigma_{s,t-1}\end{aligned}$$

where $\varpi_2=\{[\varepsilon(c+\psi)]\psi+\upsilon\theta_2^2(d_2-1)^2]>0$. In (5.3.11), the optimal sterilisation amount (=$c/\psi+1$) depends on c (degree of risk aversion) and ψ (sensitivity of interest rates to money supply). As c is larger (i.e. the substitutability between foreign and local assets is low) or ψ is smaller (i.e. local interest rates are sensitive to money supply), the degree of sterilisation becomes larger. This is consistent with the well-known fact that sterilisations are more feasible with limited capital mobility. Because $c>0$ and $\psi>0$, $c/\psi+1>1$, which indicates that over-sterilisation may be optimal.

On the other hand, if the CB cares only about inflation and income (i.e., $\gamma=\upsilon=\varepsilon=0$), a sterilisation coefficient is a unit (complete sterilisation) in Brissimis et al. (2002), while it is bigger than a unit in this model, as in the previous case of $\alpha=\beta=\gamma=0$. Hence, in most cases, the sterilisation coefficients obtained from this model would be larger (in absolute value) than those of Brissimis et al. (2002).

Under perfect capital mobility and a completely fixed exchange regime (i.e., $c=0$, σ_r=0, σ_s=0, ψ=0[62]), the two equations are simplified as:

(5.3.13) $\Delta NDA_t = -\Delta NFA_t - [\alpha\pi_1\pi_2 / \varpi_1]\Delta p_{t-1} - [\beta\phi_1\phi_2 / \varpi_1]Y_{c,t-1} - [\beta\phi_1\phi_3 / \varpi_1]\Delta G_t$

(5.3.14) $\Delta NFA_t = -\Delta NDA_t - [\alpha\pi_1\pi_2 / \varpi_2]\Delta p_{t-1} - [\beta\phi_1\phi_2 / \varpi_2]Y_{c,t-1} - [\beta\phi_1\phi_3 / \varpi_2]\Delta G_t$

where $\omega_1 = \alpha\pi_1^2 + \beta\phi_1^2 = \omega_2$. Here, both the sterilisation and offset coefficient are −1, which implies that under perfect capital mobility, CBs must conduct complete sterilisation to maintain a fixed exchange rate target. In this case, domestic market interventions (expressed by 5.3.13) and FX market interventions (expressed by 5.3.14) are identical in terms of policy response to inflation and cyclical output. As in Brissimis et al. (2002, p 69), the equivalent intervention functions (5.3.13) and (5.3.14) show the well-known *trilemma* that, given perfect capital mobility and a completely fixed exchange regime, CBs cannot conduct FXIs independently of OMOs.

5.3.2 Estimation of impacts of sterilisation on domestic interest rate

As seen in Chapter 2, sterilisations will leave a domestic interest rate higher than it would be without sterilisation, and thereby tend to perpetuate the domestic-foreign interest rate differential, regardless of the nature of capital inflows (Frankel 1997). In equations (5.3.9) and (5.3.10), the sterilisation and offset coefficients do not deliver direct information on the relation between sterilisation and interest rates. To see how sterilisations affect domestic

[62] Under a perfect capital mobility and completely fixed exchange regime, the UIP condition $r_{d,t} = r_{f,t} + E_t[S_{t+1} - S_t]$ boils down to $\Delta r_{d,t} = 0$ since $S_{t+1} - S_t = 0$ and $r_{f,t}$ is given. Then, $\Delta r_{d,t} = 0$ means $\psi = 0$ from equation (5.3.5.b). In addition, $\sigma_r = 0$ and $\sigma_s = 0$ mean that the CB does not weigh interest rate and exchange rate volatility ($\gamma = \upsilon = 0$).

interest rates, we need to explicitly associate two variables. In this context, Edwards and Khan's (1985) model has been most frequently used as a starting point to examine the effect of capital flows (or sterilisation) on domestic interest rates (see Haque and Montiel 1991, Willet et al. 2002, Cavoli and Rajan 2006). Edwards and Khan's (1985) original model explains interest rate determination (particularly) in developing countries whose economy is neither fully open nor completely closed.

In this section, we follow Willet et al. (2002) and Cavoli and Rajan (2006), both of which are based on Edwards and Khan (1985), in deriving the testable form. The model makes use of the UIP condition: $r_{d,t} = r_{f,t} + E_t(S_{t+1}) - S_t$. Let $r^*_{f,t}$ be the foreign interest rate adjusted by the *uncovered* exchange rate; $r^*_{f,t} = r_{f,t} + E_t(S_{t+1}) - S_t$. Under *imperfect* capital mobility, $r_{d,t}$ can be described as the linear combination of the interest rates under a completely open economy, i.e., $r^*_{f,t}$ (foreign interest rates adjusted by UIP, i.e. interest rate under fully-opened economy), and those under a completely closed economy, $r^*_{d,t}$ (domestic market clearing interest rate under a completely closed capital account): Note that $r^*_{d,t}$ is labelled as a *closed economy interest rate*, *shadow rate* or *autarky rate*, because it would exist if completely determined by domestic monetary conditions without any capital mobility.

(5.3.15) $r_{d,t} = \varphi \cdot r^*_{f,t} + (1-\varphi) r^*_{d,t}$, $0 \le \varphi \le 1$

where φ is a weight parameter showing the degree of capital mobility. $\varphi = 1$ denotes perfect capital mobility where $r_{d,t} = r^*_{f,t}$ while $\varphi = 0$ indicates the complete capital control where $r_{d,t} = r^*_{d,t}$. Majority of empirical works suggest $r_{d,t} > r^*_{d,t}$ for most emerging economies (Willet et al. 2002, p 425). Edwards and Khan (1985) assume:

(5.3.16) $r_{d,t}^{*} = r_{d,n} + \Delta p_{t+1}^{e} + \kappa(m_t^d - m_t^s)$

where $r_{d,n}$ is a constant and represents a long-run equilibrium real interest rate (i.e. a natural interest rate); Δp_{t+1}^{e} is an expected rate of inflation; m_t^d and m_t^s are money demand and supply, respectively, and thus $(m_t^d - m_t^s)$ reflects monetary disequilibrium; and κ is a coefficient of adjustment speed of $r_{d,t}^{*}$ to monetary disequilibrium. If a liquidity effect exists, κ is expected to be positive because $r_{d,t}^{*}$ should rise when $m_t^d > m_t^s$. Higher κ indicates a more sensitive and instant response of domestic interest rates to monetary disequilibrium.

A real money demand (m_t^d) is assumed to be the function of a real income (y_t), a long-term real interest rate ($r_{d,n}$) adjusted by an expected inflation (Δp_{t+1}^{e}) and a real money supply in the previous period (Edwards and Khan 1985, p 8).

(5.3.17) $m_t^d = \beta_1 y_t - \beta_2 (r_{d,n} + \Delta p_{t+1}^{e}) + \beta_3 m_{t-1} \ \beta_1, \beta_2 > 0$

Assume that CBs conduct sterilisations; $\Delta nda_t = a \cdot \Delta nfa_t$ where $a(\leq 0)$ denotes a sterilisation coefficient. Because $\Delta m_t^s = \Delta nda_t + \Delta nfa_t = (1+a)\Delta nfa_t$ and $m_t^s = m_{t-1}^s + \Delta m_t^s$, money supply can be expressed as:

(5.3.18) $m_t^s = (1 + \frac{1}{a})\Delta nda_t + m_{t-1}^s (a \leq 0)$

$a = -1$ indicates a complete sterilisation($\Delta m_t^s = 0$). Substituting (5.3.17) and (5.3.18) into (5.3.16) and again substituting (5.3.16) into (5.3.15) yields:

(5.3.19)
$$\begin{aligned} r_{d,t} &= (1-\varphi)(1-\kappa \cdot \beta_2) r_{d,n} + \varphi \, r_{f,t}^{*} - (1-\varphi)\kappa(1+1/a)\Delta nda_t \\ &- (1-\varphi)\cdot \kappa \cdot m_{t-1}^s + (1-\varphi)(1-\kappa \cdot \beta_3)\Delta p_{t+1}^{e} + (1-\varphi)(\kappa \cdot \beta_1) y_t \end{aligned}$$

Equation (5.3.19) shows a set of components which may affect domestic interest rates ($r_{d,t}$): $r_{d,n}$, $r^{*}_{f,t}$, Δnda_t, m^{s}_{t-1}, Δp^{e}_{t+1} and y_t. The coefficient of Δnda_t, $-(1-\varphi)\kappa(1+1/a)$, shows the effect of the sterilisation on domestic interest rates and is our area of interest. The effect depends on three factors: degree of sterilisation (a), degree of capital mobility (φ) and adjustment speed of domestic interest rate to monetary disequilibrium (κ).

Note that general implications of this model are consistent with the model in the previous section. First, a complete sterilisation ($a = -1$) keeps capital inflows from affecting $r_{d,t}$, implying that monetary autonomy can be maintained temporarily. Second, $r_{d,t}$ is determined mainly by foreign factors as φ increases. As a result, the impact of further capital inflows on $r_{d,t}$ will diminish, given a constant degree of sterilisation. In the extreme case of perfect capital mobility ($\varphi = 1$), capital inflows do not influence $r_{d,t}$, irrespective of the degree of sterilisation, and $r_{d,t} = r^{*}_{f,t}$ always holds. Third, a higher κ indicates that $r_{d,t}$ responds more sensitively to monetary disequilibrium, so that $r_{d,t}$ is more likely to react to sterilisations. (5.3.19) can be simplified:

(5.3.20) $$r_{d,t} = \alpha_0 + \alpha_1 r^{*}_{f,t} + \alpha_2 \Delta nda_t + \alpha_3 m_{t-1} + \alpha_4 \Delta p^{e}_{t+1} + \alpha_5 y_t + \varepsilon_t \ , \quad \varepsilon_t \sim (0, \sigma^2)$$

where $\alpha_0 = (1-\varphi)(1-\kappa \cdot \beta_2) r_{d,n}$; $\alpha_1 = \varphi$; $\alpha_2 = -(1-\varphi)\kappa(1+1/a)$;

$$\alpha_3 = -(1-\varphi)\cdot\kappa; \alpha_4 = (1-\varphi)(1-\kappa\cdot\beta_3); \alpha_5 = (1-\varphi)(\kappa\cdot\beta_1)$$

The testable form (5.3.20) indicates that under perfect capital mobility (where $\varphi = 1$), all estimated coefficients are expected to be 0 except α_1 (=1), and thus $E(r_{d,t}) = E(r^{*}_{f,t})$. It is expected that $0 \le \alpha_1 \le 1$, $\alpha_3 \le 0$ and $\alpha_5 \ge 0$. In most cases where money grows in line with the expansion of an economy (i.e., β_3>0), α_4 is expected to be positive. The signs of α_2 is our area of interest. In general, it is expected that $\alpha_2 < 0$ when $a < -1$ (over-sterilisation) whereas $\alpha_2 \geq 0$ when $-1 \leq a < 0$ (incomplete or complete sterilisation), because $0 \leq \varphi \leq 1$ and $\kappa \geq 0$. In other words, the domestic interest rate is likely to rise when the CB over-sterilises capital inflows, while it may fall in the case of incomplete sterilisation. A complete sterilisation leaves the interest rate unchanged.

5.3.3 Estimation strategies and preliminary considerations

Simplifying (5.3.9), (5.3.10) and (5.3.20) leads to the following testable forms.

$$\begin{aligned}\Delta NDA_{it} &= a_0 + a_1\Delta NFA_{it} + a_2(S_{it-1} - \overline{S_{it}}) + a_3\Delta p_{it-1} + a_4 Y_{c,it-1} \\ &+ a_5\Delta G_{it} + a_6 CA_{it} + a_7\Delta(r_{f,it} + E_{it}S_{it+1}) + a_8(d_1 - 1)\sigma_{r,it-1} + u_{1it}\end{aligned} \quad (5.3.21)$$

$$\begin{aligned}\Delta NFA_{it} &= b_0 + b_1\Delta NDA_{it} + b_2(S_{it-1} - \overline{S_{it}}) + b_3\Delta p_{it-1} + b_4 Y_{c,it-1} \\ &+ b_5\Delta G_{it} + b_6 CA_{it} + b_7\Delta(r_{f,it} + E_{it}S_{it+1}) + b_8(d_2 - 1)\sigma_{s,it-1} + u_{2it}\end{aligned} \quad (5.3.22)$$

$$r_{d,it} = c_0 + c_1 r^*_{f,it} + c_2\Delta NDA_{it} + c_3 m_{it-1} + c_4\Delta p^e_{it+1} + c_5 y_{it} + u_{3it} \quad (5.3.23)$$

where *i = 1,..., N* (number of countries), *t = 0,...,T* (number of quarters). (5.3.21) and (5.3.22) suggest that using simple OLS may yield biased estimators, because two-way simultaneity interactions between Δ*NFA* and Δ*NDA* give rise to a model that violates the zero-conditional-mean assumption (Baum 2006, p 186). This may be the case where we estimate the effects of sterilisations on domestic interest rates (r_d) by using (5.3.23), because ΔNDA and r_d interact with each other, so that ΔNDA may be correlated with ε_t . In estimating (5.3.21) and (5.3.22), our interest is to estimate the contemporaneous coefficients of ΔNFA and ΔNDA, because the previous literature suggest that most CBs automatically and instantly sterilise FXIs (Craig and Humpage 2001), and because the theory does not provide any guidance. In particular, we assume that when capital flows cause domestic liquidity to deviate from equilibrium level at which market interest rate (typically O/N interest rate) is maintained around policy rate, the CBs should instantly change the supply of the monetary base to steer the interest rate. In practice, assuming lagged sterilisation implies that CBs allow for interest rate deviation from their target beyond a quarter. This is not plausible in consideration of actual operation practices that most CBs in IT regime conduct market operations mostly on a daily basis or on the very short-term horizon (see Borio 1997). Except for VAR-based studies like Moreno (1996), most previous studies include no lag (Ouyang et al 2010, 2007, Aizenman and Glick 2009, Cavoli and Rajan 2006, Pasula 1994, Herring and Marston 1977). Brissimis et al. (2002) include up to two lags but lagged regressors are not significant.

As for the system consisting of (5.3.21) and (5.3.22), the two equations can be estimated either separately by 2SLS (or GMM), or simultaneously by 3SLS (or GMM). 2SLS estimators may be less efficient than 3SLS when nonspherical errors exist, but they are known to be consistent and have better small sample properties. 2SLS usually have an advantage over 3SLS in the case of possible misspecifications, because 2SLS may not spill over erroneous estimation results to other equations. In addition, it is likely that 3SLS and 2SLS are identical when two equations are exactly identified, and the error terms are spherical. This may be the case for our model, because $(d_1 - 1)\sigma_{r,t-1}$ and $(d_2 - 1)\sigma_{s,t-1}$ in (5.3.21) and (5.3.22) enable one to exactly identify both equations.[63]

[63] According to the order condition, the two equations are just identified because the number of excluded exogenous variables is equal to the number of endogenous variables in the system equation minus one: i.e. 1=2-1.

In using 2SLS, 3SLS or GMM estimation, the main challenge is to find appropriate instrument variables (IV). For obtaining more consistent and efficient estimates from IV than OLS, it is necessary to find a sufficiently large number of good instruments (Baum and Schaffer 2003 p2). The ideal instrument variables should be correlated with corresponding endogenous variables (relevant condition) and uncorrelated with (orthogonal to) the disturbances (validity or orthogonality condition). Ouyang et al. (2007) uses government expenditure and a REER as instruments for ΔNDA and ΔNFA, respectively.[64]

For this, we use FDI and currency in circulation (CIC) as instruments for NFA and NDA, respectively, in addition to up to 2 lags of other control variables in the equations. According to Wooldridge (2001, p91), the lagged variables have been naturally considered instruments that should be predetermined by construction. Hence, adding moment conditions in this way have been conventionally accepted under the assumption that the past explanatory variables are uncorrelated with the error term. The choice of FDI as the instrument for ΔNFA in (5.3.21) is based on the fact that FDI is highly correlated with ΔNFA, while CBs appear to respond less to long-term capital inflows like FDI. Thus, it is likely that ΔFDI and ΔNFA are highly correlated but ΔFDI and u_{1it} are not. ΔCIC is selected as an instrument for ΔNDA in (5.2.22) and (5.2.23). ΔCIC is closely linked with the volume of monetary operations(ΔNDA) but is not significantly related with u_{2it} and u_{3it}. ΔCIC is affected by the institutional features of payment and settlement system.

Panel analysis, regardless of whether we use fixed effect (FE) or random effect (RE) estimation, assumes that the slopes, a_i, b_i and c_i *(i >0)* in three equations are equal for all

[64] They argue that government expenditure has little effect on capital inflows. However this may not be the case, because fiscal expansion normally leads to a low interest rate, which sometimes triggers capital outflows. Zhang (2011) uses the past 12 months' FX rate volatility and dummy for the 4th quarter as an instrument for ΔNFA and ΔNDA respectively. But he does not test the validity of the instruments.

countries within a country group, while the intercepts, a_i, b_i and c_i *(i=0)* are different. FE treats the different intercepts as parameters to be estimated, while RE interprets the intercepts as random (and part of the errors). Hence, we first use time-series analyses for selected countries to see the different slope coefficients, and then apply panel analysis.

5.3.4 Data Descriptions

Our quarterly (unbalanced) panel data consist of 30 countries from 1981Q1 to 2010Q4. Country selection is primarily governed by the availability of balance sheets of individual CBs. Among the countries, 22 countries employ inflation targeting (IT) regimes and 8 countries are non-inflation targeting (Non-IT) countries as of the end of 2010, as seen in Table 5.1.

Table 5.1 Monetary policy and *de facto* exchange rate regime of sample countries

Monetary policy \ Exchange rates		Free float	Managing float	pegs
Inflation Targeting (IT)[22]	IT-advanced [7]	Australia(1993Q1), UK(1992Q4), Canada(1991Q1), New Zealand(1990Q1), Norway(2001Q1), Sweden(1993Q1), Switzerland(2000Q1),		
	IT-Asia [4]	Korea(1999Q1), Philippine(2002Q1)	Indonesia(2005Q2), Thailand(2000Q2)	
	IT-Emerging Europe [6]	Czech Rep.(1998Q1),Hungary(2001Q3), Poland(1999Q1),Turkey(2006Q1), Israel(1997Q2), South Africa(2000Q1)		
	IT-Latin [5]	Chile(1999Q3), Mexico(2001Q1), Brazil(1999Q2)	Peru(2002Q1), Colombia(1999Q3)	
Non-Inflation Targeting (Non-IT) [8]		Euro Area, Japan	India, Malaysia, Singapore	China, Argentina Hong Kong

Notes: 1. The classifications of exchange rate and monetary policy regimes follow IMF (2008) and are updated according to each CB's announcement in its homepage.
2. The figures in [ ] and ( ) denote the number of countries included and the time of introducing IT, respectively.
3. Israel and South Africa are classified as IT-Emerging Europe in consideration of their economic connection to European countries.

Sources: Author's classification based on *IMF De Facto Classification of Exchange Rate Regimes and Monetary Policy Frameworks* (2008) as of 31 April 2008 and each CB's homepage.

Considering regional or economic connections among countries, the 22 IT countries are divided into 4 country groups: IT-advanced (7 countries), IT-Asia (4), IT-emerging Europe (6) and IT-Latin (5). Most data are collected from the IMF IFS and homepages of CBs.

The definition and sources of the data are summarized in Tables 5.2(a) and 5.2(b). The cyclical output is measured as real GDP minus the Hodrick-Prescott (HP) filtered trend of real GDP. The volatility of FX rates and domestic interest rates is measured as the standard deviation of the within-quarter change of the daily average exchange rate and short-term interbank rate, respectively. We assume that the CBs have an implicit target FX rate level. Here, the 200 business day moving average is used as a proxy for the target FX rate. Assuming perfect foresight, we use actual FX rates in the next period as proxies for expected FX rates in the next period ($E_t S_{t+1} = S_{t+1}$), because credible forward FX rates do not exist for most sample countries.

Notice that the values of the NFA in balance sheets of CBs are denominated by domestic currencies, so that NFA can be changed by FX rate movements even if there were no changes in sterilisation policy. Following Ouyang et al. (2010), we adjust NFA by excluding revaluation effects. First of all, NFA is obtained by subtracting foreign liabilities from foreign assets. Considering that most CBs revalue their assets and liabilities at the end of each quarter or year, the revaluation effect (re_t) at time t will be $re_t = NFA_{t-1} * (S_{et} / S_{et-1} - 1)$, where S_{et} is the end of period nominal spot rate. Thus, adjusted net foreign assets (NFA_t^a) is measured by: $NFA_t^a = NFA_t - re_t = NFA_t - NFA_{t-1}(S_{et} / S_{et-1} - 1)$. Since the monetary base is not influenced by the revaluation, the adjusted ΔNDA is easily measured by $\Delta NDA_t^a = \Delta MB - \Delta NFA^a{}_t$. We will use ΔNFA^a and ΔNDA_t^a as variables in all regression equations. ΔNFA^a , ΔNDA_t^a , CA_t, and ΔG_t are scaled by GDP.

Table 5.2 Definition and source of variables used in regressions

(a) Dependent variables: ΔNFA[a], ΔNDA[a]

Variable	Definition	Measurement and sources
NFA	Net foreign assets	IFS: *line 11- line 16c*
ΔNFA_t^a	Adjusted net foreign assets	IFS: $NFA_t - NFA_{t-1}(S_{et}/S_{et-1}-1)$ where S_{et} is end of quarter spot FX rate
ΔNDA_t^a	Adjusted net domestic assets	IFS: Δ MB(line 14) - ΔNFA_t^a
CA_t	Current account surplus	IFS: line78, BOK(http://ecos.bok.or.kr/) When CA is unavailable, export-import gap is used
$Y_{c,t}$	Cyclical output	IFS: *[ln(real GDP)–HP filtered trend] ÷ HP filtered trend* where HP denotes Hodrick-Prescott method with smoothing parameter=1600
Δp_t	Inflation rate	IFS line 64: $ln(CPI_t)-ln(CPI_{t-1})$
ΔG_t	Government fiscal surplus	IFS and Datastream
S_t	Average FX rate	IFS, Quarterly average of daily FX rate against USD
$\overline{S_t}$	FX rate target	Bloomberg, FRB and each CBs: measured as a quarterly average in the 200-day moving average: if daily data is not available, 10 month moving average is used
$\sigma_{r,t}$	Volatility of domestic short-term interest rate change (Δr_t)	Datastream, IFS and each CB: (i) measured as standard deviation of the within-quarter change in daily domestic O/N money market rate (or bank rate) except for Hong Kong and Singapore where 3 month rates are used (ii) when daily data are not available, $\sigma_{s,t} = \frac{1}{5}\sqrt{\sum_{i=-2}^{2}(\Delta r_{t+i} - \Delta \hat{r}_t)^2}$ where $\Delta \hat{r}_t = \frac{1}{5}\sum_{i=-2}^{2}\Delta r_{t+i}$ r_t :domestic money market rates (quarterly average)
$\Delta(r_{f,t} + E_t S_{t+1})$	Change in FX rate-adjusted foreign interest rate	IFS; measured as $\Delta(r_{f,t} + \ln S_{t+1})$ under the assumption of perfect foresight ($E_t S_{t+1} = S_{t+1}$) where $r_{f,t}$ = US federal fund rate
$\sigma_{s,t}$	Volatility of exchange rate change against USD(Δs_t)	DataStream, Bloomberg, IFS and each CBs: (i) measured as the standard deviation of the within-quarter change in daily bilateral USD FX rate (ii) when daily data are not available, $\sigma_{s,t} = \frac{1}{5}\sqrt{\sum_{i=-2}^{2}(\Delta \ln S_{t+i} - \Delta \ln \hat{S}_t)^2}$ where $\Delta \ln \hat{S}_t = \frac{1}{5}\sum_{i=-2}^{2}\Delta \ln S_{t+i}$
d_1	Dummy for liquidity shortage in money markets	$d_1 = 2$ if $\Delta NDA_t^a < 0$ 0, otherwise
d_2	Dummy for excess demands in FX markets	$d_2 = 2$ if $\Delta NFA_t^a < 0$ 0, otherwise
FDI	Foreign direct investment	IFS 78: Direct investment abroad – direct investment in
CIC	Currency in circulation	IFS 34

(b) Dependent variable: domestic interest rate ($r_{d,it}$)

Variable	Definition	Measurement and sources
$r_{d,t}$	Domestic money market rate	IFS line 60b: nominal rate - inflation rate
$r_{f,t}^*$	Uncovered FX rate adjusted foreign interest rate	IFS line 60b; $r_{f,t}^* = r_{f,t} + E_t(\ln S_{t+1}) - \ln S_t$ where $r_{f,t}$ is the US fed fund rate; Under the assumption of perfect foresight $r_{f,t}^* = r_{f,t} + \ln S_{t+1} - \ln S_t$
Δp_{t+1}^e	Expected inflation rate	IFS line 64; $\Delta p_{t+1} = ln(CPI_{t+2}) - ln(CPI_{t+1})$ under the assumption of rational expectation
ΔNFA_t	Adjusted net foreign assets	IFS: $NFA_t - NFA_{t-1}(S_{et}/S_{et-1}-1)$
m_{t-1}	Real base money (in log)	IFS line 14
y_t	Real output (in log)	IFS line 66

Several descriptive statistics of the main variables used in regressions are reported in Tables 5.3 and 5.4. First, Table 5.3 shows that NFA increased in all country groups and that NDA decreased in the IT-Advanced, IT-Asia and Non-IT groups but increased in the IT-Europe and IT-Latin groups. This may partly reflect relatively successful sterilisations and consequent lower inflation in the former groups, and less successful sterilisations and resultant high money growth in the latter groups some of which experience hyper-inflation (see Table 2.1 in Chapter 2).[65] NFA increase was prominent in the IT-Asia and Non-IT groups, which are mostly large reserve builders. However, the increases in ΔNFA (capital inflows) appear to be offset by the decrease in ΔNDA. Emerging-IT countries appear to run fiscal loosening (ΔG/GDP < 0), on average, with capital inflows during the sample period.

In Table 5.3, the ratios of NFA to currency in circulation (CIC) represent the extent of liquidity surplus in the domestic money markets. The larger the NFA/CIC, the stronger sterilisation is needed, because liquidity surplus leads CBs to be in a debtor position where monetary policies become more difficult (Gray 2006). Emerging IT countries (excluding IT-Asia), in general, show larger liquidity surplus, more volatile domestic interest rate and FX rate, and higher growth in foreign reserves than the IT-advanced group. This suggests that the controllability of the domestic interest rate and exchange rate appears lower in the emerging IT group than in the IT-Advanced group. This may be related to unsuccessful sterilisation activities in these countries. Note that IT-Asia retains more stable domestic interest rates and FX rates than any other emerging IT countries, which indicates that there have been relatively successful sterilisations in the IT-Asia. Hence, we may expect a higher degree of sterilisation and incomplete capital mobility in the IT-Asia.

[65] Among the sample countries, Argentina (1989-90), Brazil (1989-90), Peru (1990) and Poland (1990) experienced hyper-inflation, according to Cagan's (1956) definition of hyperinflation that a monthly inflation rate is over at least 50%. Mexico's inflation was close to hyperinflation in the late 1980s (see Reinhart and Savastano 2003).

Table 5.3 Descriptive statistics of main variables used in regression (1981Q1-2010Q4)

	$\frac{\Delta NDA}{GDP}$ (%)	$\frac{\Delta NFA}{GDP}$ (%)	$\sigma_{\Delta r_d}$	$\sigma_{\Delta S}$	$\sigma_{\Delta FR}$	ΔFR	$\frac{NFA}{CIC}$	$\frac{\Delta G}{GDP}$
IT- Advanced	-0.46	0.72	0.003	0.016	0.132	0.022	1.972	0.003
IT-Asia	-1.29	2.10	0.008	0.014	0.166	0.031	3.571	-0.006
IT-Europe	1.09	1.65	0.024	0.033	0.179	0.035	4.032	-0.040
IT-Latin	0.67	1.32	0.012	0.026	0.156	0.025	3.337	-0.039
Non-IT	-3.12	5.17	0.003	0.010	0.080	0.029	3.708	0.022

Notes: 1. ΔFR=changes in foreign reserves(in log): $\sigma_{\Delta FR}$= standard deviation of growth of foreign reserves, ΔG= fiscal surplus

$\sigma_{\Delta S}$= standard deviation of FX rate change(in log), $\sigma_{\Delta r_d}$ = standard deviation of local interest rate changes

2. In calculating standard deviation of interest rate change, we exclude the data on Brazil(1989M2-1990M3) and Argentina(1989M5-1990M3) during hyperinflation period. See Appendix 5.3 for details.

3. The statistics for country groups are calculated as arithmetic average of all countries included (quarterly average).

Source: Author's calculation based on IMF IFS and Datastream.

Table 5.4 reports the main components of the balance of payments. IT-Asia experienced both current and capital account surplus. Accordingly, sterilizing capital inflows may be a more challenging task in the IT-Asia group than in any other country group. Capital outflows occur mostly in the IT-Advanced group and Non-IT group, and capital account deficits appear to be made up for by the current account surplus. Capital outflows from the Non-IT group mostly come from Japan. China and India experienced large amounts of capital inflows during the last two decades. Note that capital account surpluses in the IT-Asia mostly came from short-term portfolio investment and foreign borrowings rather than FDI. In contrast, most capital account surpluses in IT-Europe and IT-Latin were due to long-term FDI.

Table 5.4 Descriptive statistics of main components of BOP (1980Q1-2010Q3)

	CA/GDP	KA/GDP	FDI/GDP	PF/GDP	OINT/GDP
IT-Advanced	0.013	-0.007	-0.017	-0.019	0.025
IT-Asia	0.003	0.015	0.005	0.029	0.136
IT-Europe	-0.022	0.035	0.051	0.011	0.038
IT-Latin	-0.015	0.019	0.030	0.002	-0.002
Non-IT	0.061	-0.028	-0.059	-0.041	-0.018

Notes 1.CA=current account surplus: KA= capital account surplus: FDI=foreign direct investment (net): PF=portfolio investment (net): OINT=other investment (net)

2. See Appendix 5.3(b) for the detailed statistics of individual countries.

Source: Author's calculation based on IMF IFS and Datastream.

5.4 Estimation results

5.4.1 Time-series analysis for selected countries

5.4.1.1 Degree of sterilisation and de facto capital mobility

In this section, we first compare the sterilisation and offset coefficients of 12 selected countries and trace the evolution of the coefficients over time by using recursive estimations. In particular, the case of Korea is of our main interest because of its peculiar sterilisations depending on the MSBs. We choose 12 countries which have the longest historical data among 30countries. Samples cover the period 1981-2010 for Korea, the UK, Australia, Switzerland and Canada, the period 1990-2010 for New Zealand and Peru, and the late 1990s-2010 for Thailand, Indonesia, India, Japan and China

ADF unit root results for all relevant variables are presented in Appendix 5.4. Most variables are I(0) except domestic interest rates(r_d) and ΔG (fiscal surplus) whose order of integration is different depending on the countries. If r_d ~I(1), we use first difference of r_d as dependent variable in the regression (5.3.23). Based on the results of previous literature (Ouyang et al. 2007, Aizenman and Glick 2008) and institutional changes, we divide the sample period mainly into two subsamples. For example, the simultaneous equations for Korea are separately estimated for the pre-IT period (1981Q1-1998Q4) and the post-IT period (1999Q1-2010Q3). The analyses for each subsample may show how the degree of sterilisation and *de facto* capital mobility has evolved and to what extent sterilisation influences local interest rates in line with the changes in the exchange rate or monetary policy regimes.

Table 5.5 summarizes the GMM estimation of the sterilisation and offset coefficients for inflation targeting countries. The detailed estimation results are presented in Appendix 5.5 where most coefficients for other control variables (e.g., current account, inflation, cyclical output, etc.) are significant and of the rightly signed. Hansen's J statistics show that the null hypothesis (that a model specification has a valid overidentifying restriction) cannot be rejected. Thus, most specifications are considered as correct, except for those for Canada and Indonesia, where the null can be rejected at a 10% significant level.

Table 5.5 Sterilisation and offset coefficients in selected IT countries: GMM estimation

Country group	Country	Sterilisation coefficient		Offset coefficient	
		Pre-IT	Post-IT	Pre-IT	Post-IT
Emerging IT	Korea (1999Q1)	-0.193*	-1.019***	-0.203**	-0.879***
	Peru (2002Q1)	-0.228***	-0.935***	-0.108	-0.932***
	Indonesia (2000Q3)	n.a.	-1.171***	n.a	-0.516***
	Thailand (2000Q2)	n.a	-0.988***	n.a	-0.726***
Advanced IT	UK (1992Q4)	-0.811***	-0.424	-0.654***	-0.240***
	Australia (1993Q1)	-0.674***	-0.774***	-0.891***	-0.384***
	Switzerland (2000Q1)	n.a	-0.227***	n.a	-0.460***
	Canada (1991Q1)	n.a	0.171	n.a	-0.213**
	New Zealand (1990Q1)	n.a	-0.862***	n.a	-0.818***

Notes: 1. ***, ** and * denote the rejection of the null hypothesis at the 1%, 5% and 10% level, respectively.
2. Detailed results of system GMM estimation are presented in Appendix 5.5.
3. The figures in ( ) indicated the time when inflation targeting was employed.
4. n.a: data are not available.

Overall, the sterilisation coefficients of emerging IT countries are higher than those of advanced IT countries[66]. In emerging IT countries, the sterilisation coefficients are around 1 while the offset coefficients are less than 1 (in absolute value) during the post-IT period, indicating that the CBs conduct complete sterilisations (or over sterilisations) and *de facto* capital mobility is not perfect. This implies that sterilisations help to retain monetary independence. In contrast, both sterilisation and offset coefficients are much lower than 1 (in absolute value) in advanced IT countries. The difference between emerging and advanced IT

[66]Note that the results in Table 5.5 may not be inferred as direct evidence of higher offset coefficients for Emerging market than Advanced Economies. (i) The periods covering post-IT are different between Emerging and Advanced Economies. Post-IT periods for Advanced Economies mostly include the 1990s while post-IT periods for Emerging Economies include the 2000s.Hence, the offset coefficients for two country groups should be compared with caution. In some cases, for example, de facto capital mobility of Emerging Economies in the 2000s is possibly higher than that of Advanced Economies in the 1990s. (ii) The estimation results in Table 5.5 are based on time-series analysis for 9 individual countries selected from 30 countries. In this case, the estimates may have the problems of unobserved heterogeneity. Panel analyses in next section will make clear the comparison of Advanced-IT and Emerging-IT

countries may reflect the fact that emerging IT countries face more volatile capital flows and thus have to depend on sterilised interventions more.

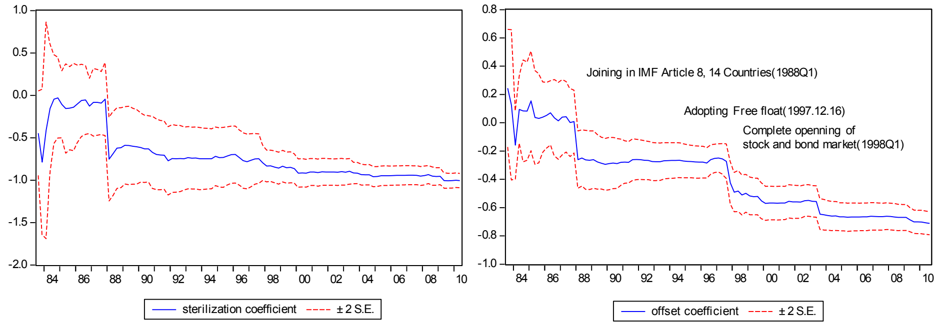
In emerging IT countries, both sterilisation and offset coefficients significantly increase (in absolute value) from pre-IT to post-IT period (e.g. Korea, Peru). For example, the sterilisation and offset coefficients in Korea increase from 0.19 to 1.02 and 0.20 to 0.88 (in absolute values), respectively. The offset coefficient of less than 1 and the sterilisation coefficient more than 1 imply that the BOK appears successful in maintaining monetary independence to some extent by increasing the degree of sterilisation during post-IT period. This result about emerging IT seems to correspond to conventional arguments (Aizenman and Glick 2009): as capital mobility has become freer, a higher degree of sterilisations helps to maintain monetary independence in East Asian emerging economies, particularly in the 2000s.

The estimated coefficients for Korea contrast somewhat with other countries which have a longer history of inflation targeting such as the UK and Australia. The coefficients for IT-Advanced countries show relatively low degree of sterilisation and *de facto* capital flows. For example, in Australia, the sterilisation coefficient increases slightly from 0.67 to 0.77 while the offset coefficient decreases significantly from 0.89 to 0.38 (in absolute value). In the UK, both the sterilisation and offset coefficients decrease from 0.81 and 0.65 to 0.42 and 0.24, respectively. Decrease in the sterilisation coefficient in IT-Advanced countries may be explained by less frequent sterilised interventions. On the other hand, the decrease in offset coefficient seems not consistent with the recent increased integration of international capital markets.

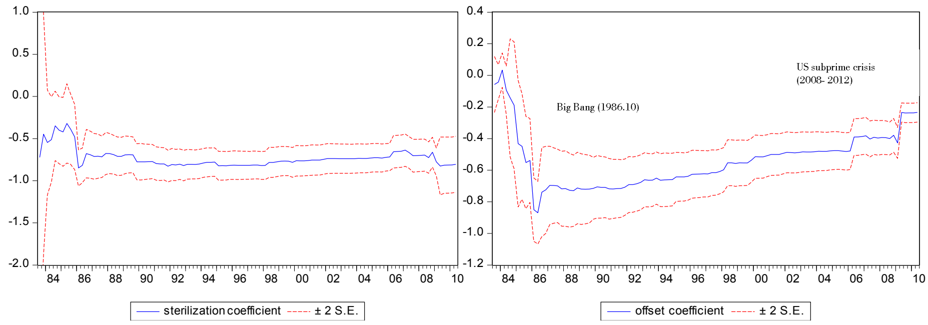
We run recursive estimations to investigate the dynamic change of the estimated offset and sterilisation coefficients over time and to investigate the stability of estimated coefficients. Figure 5.2 shows the results for several countries.

Figure 5.1 Recursive estimations of sterilisation and offset coefficients

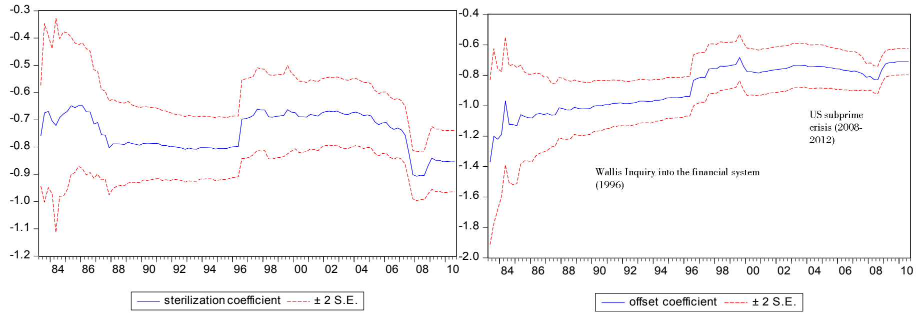
Korea



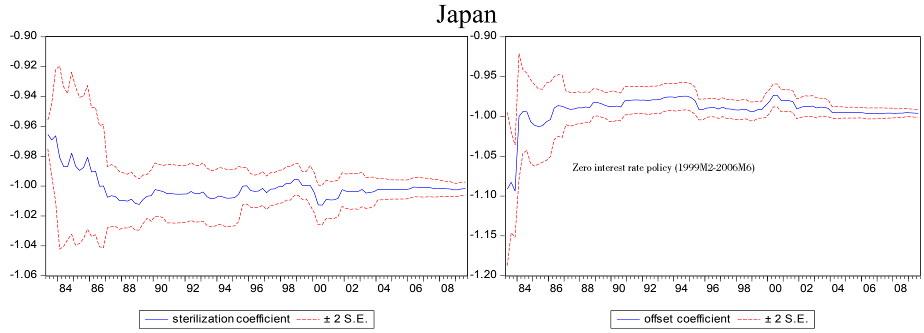
UK



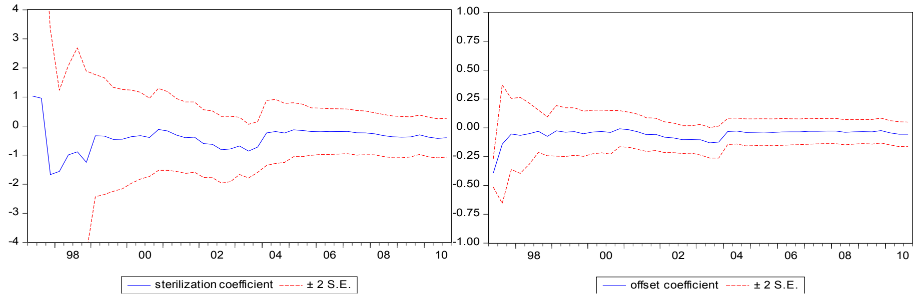
Australia



Japan



China



Note: The recursive coefficients are estimated by OLS.

The recursive offset coefficient of Korea illustrates that *de facto* capital mobility has significantly increased with institutional shifts in monetary and FX policy regime – e.g. joining The IMF Article VIII countries in 1988, and abolishing daily limits of FX rate movements and completely opening the domestic stock and bond markets in the 1997-98 financial crisis. Meanwhile, the sterilisation coefficient increases steadily notwithstanding some institutional changes such as the introduction of IT with a free float regime.

The recursive coefficients for other countries provide several implications. First, in the UK and Australia, sudden changes in the degree of sterilisations and *de facto* capital mobility are associated with occurrences of institutional changes – mainly deregulation, or financial crisis: Big Bang in the UK(1986), Wallis Inquiry into the financial system in Australia (1996) and subprime crisis (2007), etc. In both the UK and Australia, the degree of sterilisations appear to become somewhat higher while *de facto* capital mobility became lower in the recent subprime crisis period. Overall, deregulation of financial markets appears to incur both increases in capital mobility and high degree of sterilisation. Financial crisis causes to lower the *de facto* capital mobility and strengthen sterilisations. In Japan, *de facto* capital mobility has remained remarkably high despite the persistent nearly-complete sterilisations. In China, it is likely that the *de facto* capital mobility is extraordinarily limited owing to the high degree of sterilisations and capital control.

Table 5.6 reports the sterilisation and offset coefficients in three Non-IT countries: Japan, China and India. The sterilisation coefficients of Japan and China are above 1 (in absolute value), indicating over-sterilisation. This result implies that BOJ and PBOC sterilise more than capital flows or FX interventions during the sample periods, as does the BOK. There are significant differences in the offset coefficients among the countries. The low offset coefficient of China may reflect the existence of strict capital controls.

Table 5.6 Sterilisation and offset coefficients in selected Non-IT countries: GMM

	Sterilisation coefficient	Offset coefficient
Japan(2002Q3-2010Q4)	-1.010***	-0.990***
China(1995Q4-2010Q3)	-1.106***	-0.138*
India(1997Q3-2010Q1)	-0.377***	-0.100

Notes: 1. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% level, respectively.
2. Detailed results of system GMM estimation are presented in Appendix 5.5.

5.4.1.2 Impacts of sterilisation on domestic interest rates

Table 5.7 summarizes the impacts of sterilisation (ΔNDA) on domestic (real) interest rates (r_d) in twelve sample countries. See Appendix 5.6 for the detailed estimation results. In general, there is no significantly negative relationship between ΔNDA and r_d in the 2000s except for Korea and China where the sterilisation impact on r_d is marginally significant. ΔNDA and r_d are negatively correlated in most countries but insignificant, or positively correlated (e.g. UK, Japan, Switzerland and New Zealand). Hence, the estimation results indicate that most sterilisations (except for oversterilisations) appear not to raise domestic interest rates significantly.

Table 5.7 Impacts of sterilisation on domestic interest rates: GMM

	Korea	Indonesia	Thailand	Peru	UK	Australia	Swiss	Canada	New Zealand	Japan	China	India
Post-IT	-0.012*	0.020	0.034	-0.014	-0.015	-0.070	-0.047	-1.902	0.114*	0.002**	-0.133*	-0.128
Pre-IT	0.083	n.a	n.a	n.a	0.706**	-0.603*	0.470**	-3.662	n.a.	n.a.	n.a.	n.a.

Notes: 1. ***, ** and * denote the rejection of the null hypothesis at the 1%, 5% and 10% level, respectively.
2. Detailed estimation results are presented in Appendix 5.6.
3. Sample periods for Non-IT countries: Japan(2002Q4-2010Q3), China(2000Q1-2010Q3), India(1997Q4-2010Q3)
4. n.a: data are not available.

Based on aforementioned inferences, most of capital flows into emerging markets in the 2000s appear not to be pulled by the increase domestic money demand. This is because sterilisations in most countries may not lead to a significant rise in domestic interest rates notwithstanding the high degree of sterilisation in the 2000s. Rather, the capital inflows may stem from a drop in the US interest rate or increase in the expected rate of return on domestic assets (such as equity).

It is noteworthy that oversterilisations in Korea and China may cause domestic interest rates to rise and thereby interest rate differentials not to converge, which encourages further capital inflows. Coincidently, these two countries heavily depend on the issuance of MSBs. In particular, oversterilisations with MSBs could contribute to significant sterilisation cost in Korea where the domestic interest rate is higher than the foreign interest rate.[67]

5.4.1.3 Coefficients of other control variables

Appendix 5.5 and 5.6 show the estimation results of the system consisting of two equations (5.3.21) and (5.3.22), and equation (5.3.23), respectively. Many coefficients of control variables are significant and rightly signed in most countries. J-statistics suggest that GMM estimations have valid over-identifying restriction.

First, in Appendix 5.5, the coefficients for $(d_1 - 1)\sigma_r$ are highly significantly negative, indicating that most CBs conduct OMOs to stabilise domestic interest rates when they are volatile. The coefficients of $(d_2 - 1)\sigma_s$ are significantly negative in most countries (except Canada, New Zealand, Indonesia and Thailand with insignificantly negative signs). The current account surplus has significantly positive effects on both ΔNDA and ΔNFA in Korea and Thailand, but significantly negative effects in Japan, Switzerland and New Zealand.

[67] Although PBOC heavily issues MSBs for sterilizing capital inflows as BOK does, it is not likely that PBOC makes losses, because the local interest rate is lower than the US rate owing to interest rate control. China has been earning a premium from its foreign reserve accumulation due to domestic financial repression (Prasad and Wei 2005). Sterilisation costs will be reduced as CBs use market distorting instruments such as raising reserves requirement and setting loan quotas, etc. (Ljungwall et al. 2009, pp 3-4). Zhang (2011) provides evidence that PBOC's income from foreign reserves has exceeded its sterilisation costs consistently in 2003-2010. However, he expects that if local interest rates are determined by pure market forces, the increasing issuance of PBOC bills will soon impose too high a burden on the PBOC.

The coefficients of inflation (Δp_{t-1}) are not significant in most countries except Korea, the UK, and Switzerland. This result implies that CBs appear not to instantly respond to inflation by changing money supply, and inflation appears not to instantly influence foreign investment in domestic markets. Both CBs and investors need time to react to changes in inflation. Given that our samples are mostly obtained from the period of the late 1990s – 2000s, it seems that globally low inflation and the narrowing domestic-foreign interest rate differential yield statistical difficulties in detecting the true relationship between Δp_{t-1} and ΔNDA (or ΔNFA) on a quarterly basis. Note that inflation remains at a very low level in most of the countries (see Table 2-1 in Chapter 2), while ΔNFA and ΔNDA are very volatile during the 2000s (see Appendix 5.3(c)). Interestingly, the coefficient of Δp_{t-1} has a significantly positive relation with ΔNDA in Japan, implying that BOJ increases the domestic money supply even when inflation increases, probably reflecting their quantitative easing policy in the early 2000s.

The coefficients of exchange rate-adjusted foreign interest rates $\Delta(r_f+ES)$ are mostly insignificant or significant with the wrong signs in both equations, indicating that foreign interest rate changes do not have a significant and consistent effect on domestic monetary supply and capital movements. This result is not consistent with the prior expectations explained in the previous section. There may be some plausible explanations for the weak relationship between $\Delta(r_f+ES)$ and ΔNDA (or ΔNFA). First, capital flows (ΔNFA) may be influenced more by the expected rate of return on risky assets (e.g. stock) than by interest rate differentials in the 2000s (Choi and Park 2008, Verma and Prakash 2011). Second, most CBs tend to adjust their policy interest rate in line with the changes in the policy rate in the US. If we allow for the announcement effect, CBs do not always need to change the money supply when adjusting policy interest rates (Guthrie and Wright 2000).[68] Hence, $\Delta(r_f+ES)$ is unlikely to be significantly related with ΔNDA.

$(S_{t-1}-\overline{S_t})$ tends to have a significantly negative effect on ΔNFA but not on ΔNDA in most countries. This implies that the deviation of the FX rate from its trend incurs FX interventions and resultant changes in NFA, while FX rate deviation may not directly influence domestic operations (ΔNDA). The cyclical output (y_c) and fiscal surplus (ΔG) have significant effects on both ΔNDA and ΔNFA, but not in consistent ways, as we discussed in the previous section.

Appendix 5.6 reports the estimation results of equation (5.3.23). In many countries (except Japan, China, Indonesia and New Zealand), the coefficients of US fed fund rates (r^*_f) are significantly positive as expected, implying that domestic policy interest rates tend to synchronize to the US fed fund rate. In contrast, Japan and China are relatively large economies, so their policy interest rates may be less sensitive to changes in the US fed fund rate. Local rates in New Zealand and Indonesia are known to be affected by interest rate changes in Australia and Japan, respectively, as well as changes in the US fed fund rate.

The coefficients of $\Delta m_{t-1}$are not significantly negative in most countries except the UK, Canada, Korea and Switzerland, implying that changes in the money supply mostly have an insignificant effect on local interest rates in the short run. The weak relation between money supply and interest rates may be ascribed to the announcement effect and the lagged effect of money supply on interest rate. The coefficients of expected inflation (p^e_{t+1}) are not significant in most countries, implying that expected inflation does not significantly affect real interest rates.

[68] Guthrie and Wright (2000) suggest that interest rates can be changed by the CB's announcement of policy interest rate changes without actual market operations to change money supply.

5.4.2 Panel analyses

The results of time-series analyses discussed in the previous section suggest that there are some differences in the significance of the control variables (which account for ΔNDA, ΔNFA and r_d), and the magnitude of sterilisation and offset coefficients. Panel data analyses have advantages over the time-series approach (Baltagi 2008, pp. 6-11). First, panel analysis can control for unobserved country-specific variables (i.e., country heterogeneity) and thereby provide estimates which are more robust against the omitted variable bias. Consequently, we may expect more consistent signs for the coefficients, which may somewhat differ from those in the previous time-series analyses. Second, panel analyses may better measure the effect of sterilisation on local interest rates, which is not significantly detected by time-series data. Lastly, panel data are less plagued with multicollinearity than time-series data.

5.4.2.1 Preliminary considerations and post estimations of panel model

Several considerations are needed before and after panel estimations. Since our data is macro-panel with relatively small N (30 countries) and large T (120 quarters), stationarity, cross-sectional dependence and serial correlation may be significant issues to be addressed before or after the estimations.

5.4.2.1(a) Panel unit root test

A spurious regression may be problematic, particularly in an FE panel model with long time-series, because the time series components frequently follow non-stationary processes. In this case, inferences based on t-values can be highly misleading, despite seemingly significant t-values and high R^2(Entorf 1997). However, according to Phillips and Moon (1999),[69] the pooled OLS estimator can be consistent and thus asymptotic normal inferences are possible even in the spurious regression case under the conventional assumption of independent cross-sections. This is because pooling across a large cross-section of independent units can smooth out unit root dependency for each unit. Strong noise in time series regression is attenuated by pooling cross-sections and time-series. Panel methods allow for an estimation of a long-run relation among variables in cases where consideration of the time dimension alone would lead to a spurious regression (Banerjee 1999).

However, cross-sectional independence is not usually guaranteed when macroeconomic data (with strong intra-economic associations) are considered (Banerjee et al. 2004). Recent studies suggest that panel models are likely to exhibit substantial cross-sectional dependence in their errors (Pesaran 2004). This may be because of the existence of common shocks originating from an ever-increasing economic and financial integration over the last decade. In addition, when inferences are made from non-stationary panels where N= 4~8, like our sample, cross-sectional independence may not hold due to the possible *"beggar thy neighbour*"sterilisation policy. In this case, it is necessary to run panel unit root tests, which are generally known to have higher power than those based on time series.

Im, Pesaran and Shin (IPS) (2003) and Fisher-type ADF or PP panel unit root tests (Maddala and Wu 1999, Choi 2001) allow for individual unit root processes while Levin, Lin and Chu (LLC) (2002), Breitung (2000) and Hadri (2000) assume common unit root processes. All of these tests use a null of a unit root except the Hadri test, where the null is stationarity. We use a Fisher-type ADF test because (i) the LLC, Hadri and Breitung tests

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[69]Entorf (1997) shows that for $T\rightarrow\infty$ and $N<\infty$, nonsense regression holds for the spurious fixed effects model. However, Phillips and Moon (1999) show that even in case of spurious FE panel regression $Y_{i,t} = \hat{a}_i + \hat{\beta}X_{i,t} + \hat{\varepsilon}_{i,t} \quad i = 1,\ldots,N; \quad t = 1,\cdots,T$ where Y_t and X_t, are all *I(1)* without a cointegration, the pooled OLS estimator $\hat{\beta}$ is $\sqrt{n}$-consistent for β and has a limiting normal distribution.

have more restrictive assumptions about cross-sectional independence than the Fisher-type test; (ii) the Fisher-type tests outperform the IPS test with regard to size-adjusted power; (iii) unlike the IPS test, the Fisher-type test does not require a balanced panel (Baltagi 2008, pp 281-282). SIC determines an appropriate lag number. The Fisher-ADF test combines the p-value from individual unit root tests for each cross-section. Let us illustrate Fisher-ADF test with the following equation (Baltagi 2008, pp. 280-281).

(5.4.1) $$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{L=1}^{q_i} \beta_{iL} \Delta y_{i,t-L} + \gamma_{mi} X'_{mt} + \varepsilon_{it}$$

with X_{mt} denoting deterministic variables and γ_{mi} the corresponding coefficients for model m=1,2,3. The lag order q_i is allowed to vary across individuals. The Fisher-ADF test $H_0 : \rho_i = 0$ for all $i = 1, \cdots, N$ against $H_1 : \rho_i < 0$ for $i = 1, \cdots, N_1$ and $\rho_i = 0$ for $i = N_1 + 1, \cdots, N$ with $0 < N_1 \leq N$. Now, let π_{iT_i} denote a unit root test statistics for the i^{th} country where T_i indicates time-series observations. It is assumed that as $T_i \to \infty$, $\pi_{iT_i} \to \pi_i$.

Maddala and Wu (1999) and Choi (2001) suggest two test statistics by combining the p-values from the unit root tests for each country in order to test the panel unit root. $P = -2\sum_{i=1}^{N} \ln(p_i)$ and $Z = -\frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(p_i)$ where Φ is the standard normal cumulative distribution function and p_i is the p-value from unit root tests for each cross-section *i*. The null is that each series in the panel contain a unit root while the alternative is that at least one of the individual series is stationary.[70]

---

[70] Consider following the AR(1)-type process for panel data: $y_{i,t} = \rho_i y_{i,t-1} + \delta_i X_{i,t} + \varepsilon_{i,t} \quad i = 1, \cdots N; \quad t = 1, ..., T$ where X_{it} are exogenous variables; $\varepsilon_{i,t}$ are mutually *i.i.d.* y_{it} is weakly stationary if $|\rho_i| < 1$ but non-stationary if $|\rho_i| = 1$. LLC, Breitung and Hadri test assume that ρ_i are common (i.e., $\rho_i = \rho$ for all i) while the IPS and Fisher-ADF/PP test assume that ρ_i varies across cross-sections.

When using the Fisher-ADF test for the panel unit root, we remove the cross-sectional means from the series to mitigate the effects of cross-sectional dependency. In particular, the "demean" function of STATA 12 is used to deal with cross-sectional dependency.[71] The results of the panel unit root test suggest that most series are I(0) except for domestic interest rates(r_d) in the IT-advanced group, which is I(1) during the 1980s (See Appendix 5.7).

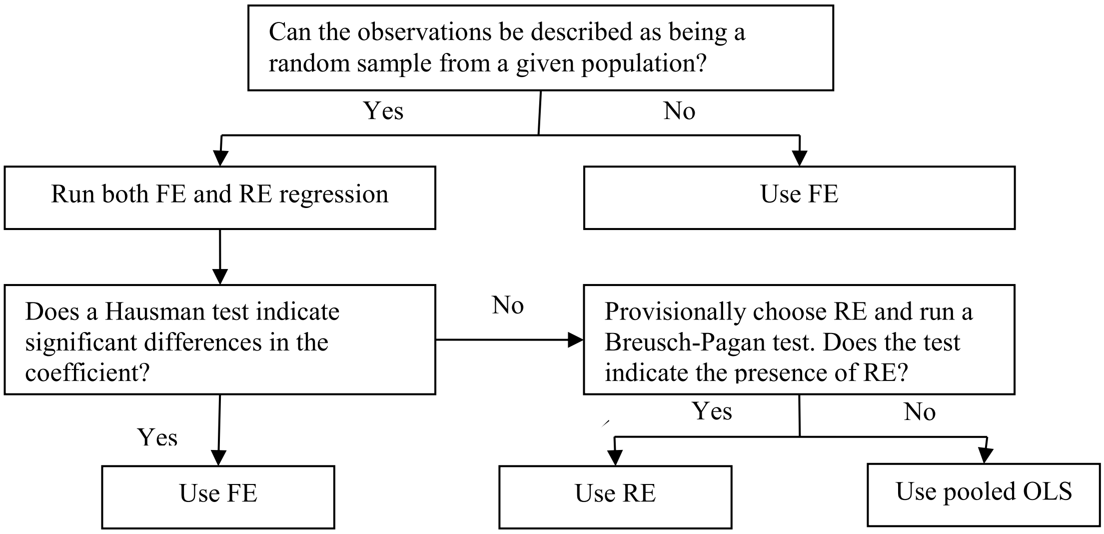
5.4.2.1(b) Durbin-Wu-Hausman test

In the previous literature (based on time series), estimated sterilisation and offset coefficients and the significance of other control variables are different depending on the specifications and institutional features of each countries. This indicates that time series analyses may not consider unobserved heterogeneity. Figure 5.2 illustrates the best practice regarding the choice of models with panel data. Intuitively, it is likely that panel analysis is more appropriate than pooled OLS for our data, because the panel allows for control for unobserved individual heterogeneity.

The choice between FE and RE depends on whether the countries in each group could be regarded as representative of a population (Snijders 2005). If the countries are randomly selected from a given population, RE is modelled. In contrast, if the country group contains most countries of interest (i.e. the countries included in a specific group represent the population), FE is appropriate. When the researcher wishes to draw a conclusion primarily about the population (from which the selected countries were drawn) rather than about particular countries, FE should be used (Snijders 2005).

[71] The 2nd generations of the panel unit root test directly deal with the existence of cross-sectional dependence. For example, Pesaran (2004) proposes a t-test for unit roots in heterogeneous panels with cross-section dependence(see Baltagi 2008, pp 273-277).

Figure 5.2 Best practice of model selection for panel data



Source: Dougherty (2006, p 421)

In this regard, the Durbin-Wu-Hausman (hereafter DWH) test provides a formal way of choosing an appropriate model between two different models: e.g. FE vs. RE, pooled OLS vs. RE. To describe the DWH test, consider following regression equation:

(5.4.2) $y_{it} = \alpha + \beta x_{it} + u_i + e_{it}$

where $i = 1,2,\cdots N$ (cross-section, i.e., country) and $t = 1,2,\cdots,T$ (time period, i.e., quarter); y_{it}=dependent variables; x_{it}=exogenous variables; α =intercept; u_i =i^{th} country specific effect; e_{it}= idiosyncratic error term with $E(e_{it}, e_{is}) = 0$ for all $s \neq t$; and $E(u_i, e_{it}) \neq 0$. Note that when estimating (5.4.2) with panel data, we restrict the slope coefficient (β) to be constant and allow for the intercept coefficient ($\alpha + u_i$) to vary over units. u_i is a fixed parameter to be estimated under FE but assumed to be randomly distributed across units under

RE.[72] The DWH test provides flexible tools for choosing a specific estimation among two options.

First of all, DWH tests H_0: $E(x_{ti}, u_i) = 0$ (i.e., orthogonality of u_i and x_{ti}).RE is appropriate if $E(x_{ti}, u_i) = 0$, while FE is preferred if $E(x_{ti}, u_i) \neq 0$. We run both RE and FE regressions for (5.3.21), (5.3.22) and (5.3.23), and then compare the RE and FE estimates. Under the null of orthogonality, both FE and RE are consistent, so the two estimates should not significantly differ from each other. Under the alternative hypothesis, RE is not consistent. Hence, if the null is rejected, FE is preferred. The statistics are computed as: $H = (\hat{\beta}^{FE} - \hat{\beta}^{RE})' \times [\text{var}(\hat{\beta}^{FE}) - \text{var}(\hat{\beta}^{RE})]^{-1} \times (\hat{\beta}^{FE} - \hat{\beta}^{RE})$. These test statistics follow x^2 distribution with M degree of freedom where M is the number of time-varying regressors.[73]

Second, after choosing model between RE and FE, we test H_0: $E(x_{2it}, e_{it}) = 0$ (where x_{2it} is assumed endogenous) to examine the existence of endogeneity. We compare the estimates of the instrument variable method (e.g. 2SLS) and FE (or RE) estimates without using IV. Under the null of no endogeneity, both estimators of the same equation provide consistent estimates. Therefore, a rejection of the null requires one to use IV techniques.

Table 5.8 summarize the result of DWH tests for selecting the model by post-estimation function of STATA 12. The selected model is different depending on country groups.

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[72] We can also assume that the intercept coefficient varies over both time and units: in this case (5.3.25) can be expressed as $y_{it} = \alpha + \beta x_{it} + u_i + \eta_t + e_{it}$ where $\eta_t \sim (0, \sigma_\eta^2)$ is the unobservable time-specific residual that accounts for period effects.

[73] We apply the Breusch and Pagan Lagrangian multiplier test (STAT command: xttest0) for testing H_0: $\text{var}(u_i) = \sigma_u^2 = 0, \forall i$, against H_1: $\text{var}(u_i) = \sigma_u^2 \neq 0, \forall i$. Note that there are no country-specific effects (u_i) under the null, while the effects assume the random variable under the alternative hypothesis. Hence, if H_o cannot be rejected, a pooled OLS is more appropriate than an RE estimation. The test results are different depending on country groups and sample period, although panel models are recommended in most cases.

Table 5.8 Durbin-Wu-Hausman tests for country-specific fixed effects and endogeneity

Objective	Choice between FE and RE				Test for endogeneity (FE vs. 2SLS FE / RE vs. G2 SLS)			
Null	$H_0 : \text{cov}(x_{it}, u_i) = 0$ If H_o is rejected, FE may be appropriate.				$H_0 : \text{cov}(x_{it}, e_{it}) = 0$ If H_o is rejected, IV estimate like 2SLS FE(or G2SLS) may be appropriate.			
STATA Command	*hausman fe re*				*hausman xtivreg xtreg*			
Equation	(5.3.21)	(5.3.22)	(5.3.23)	Model[1]	(5.3.21)	(5.3.22)	(5.3.23)	Model[1]
Advanced-IT	11.11 (0.196)	9.39 (0.310)	4.32 (0.687)	RE RE	20.66*** (0.008)	17.65** (0.014)	2.45 (0.784)	IV Non-IV
Asia-IT	19.08*** (0.000)	18.91*** (0.00)	24.32*** (0.000)	FE FE	41.62*** (0.000)	43.63*** (0.000)	74.02*** (0.000)	IV IV
Europe-IT	6.08 (0.638)	4.20 (0.839)	27.32*** (0.000)	RE FE	21.59*** (0.006)	16.82** (0.019)	5.11 (0.402)	IV Non-IV
Latin-IT	26.35*** (0.000)	32.25*** (0.000)	29.36*** (0.000)	FE FE	47.21*** (0.000)	42.54*** (0.000)	90.51*** (0.000)	IV IV
Non-IT	16.35** (0.038)	17.83** (0.023)	130.36*** (0.000)	FE FE	13.39* (0.099)	20.66*** (0.001)	9.76* (0.082)	IV IV

Notes: 1. In each column the 1st row indicates the model selected for (5.3.21) and (5.3.22). The 2nd row shows the model recommended for (5.3.23).
2. FE= fixed effect; RE= random effect; 2SLS FE= two stage least square with cross-sectional fixed effect; G2 SLS=Generalised 2 stage least square with random effects; IV=instrument variable(e.g. 2SLS FE, G2 SLS or GMM); Non-IV= FE or RE without considering endogeneity.
3. When estimating (5.3.21) and (5.3.22) with IV, we use ΔFDI and ΔCIC as an instrument for ΔNFA and ΔNDA, respectively, with a constant and up to 2 lags of other regressors. As for the (5.3.23), ΔCIC, a constant and up to 3 lags of other regressors are used as instruments.
4. The figures in ( ) indicate p-values.

First, in the estimation of (5.3.21) and (5.3.22), the DWH tests suggest that FE is appropriate for Asia-IT, Europe-IT, Latin-IT and Non-IT while RE is recommended for Advanced-IT. The DWH test statistics (x^2 =19.08, p-value 0.000) of (5.3.21) for Asia-IT suggests that the null can be rejected, so FE estimation is considered as appropriate. Second, the test statistics for endogeneity mostly support the use of instrument variables. For example, when estimating (5.3.21) for the Asia-IT, we can reject the null of $H_0 : \text{cov}(x_{it}, e_{it}) = 0$, because DWH test statistics is 41.62 with p-value 0.000. Combining the two results leads us to choose the 2SLS with FE in estimating equation (5.3.21) for the Asia-IT.

In consideration of the results of the DWH tests and best practices for model selection in the panel, it is somewhat difficult to select one specification (to be applied for all samples) over another. We primarily model with cross-sectional FE and endogeneity.[74] The reason that FE seems more appropriate is twofold. First, our sample countries are more likely to represent the population of each group rather than a random sample, so that FE may be more appropriate (Dougherty 2006 p 421). The number of sample IT countries (= 22) may represent the population (= 26 IT countries in the world as of the end of 2009). Second, the properties of the RE estimator are largely unknown for macro-panels with small N and large T (Judson and Owen 1999, p 11).

5.4.2.1(c) Test for nonspherical residual in fixed effect model

It is likely that residuals are correlated across cross-sections or over time in macro panels. As Baltagi (2008) points out, a serial correlation within a country or a contemporaneous correlation between countries (i.e., cross-sectional dependence) may be more of a problem in macro-panels than in micro-panels. For example, a serial correlation biases standard errors of the coefficients to be smaller than they actually are, and thus causes estimation results to be less efficient. The existence of a cross-sectional dependence leads to either inconsistent or biased estimators. After estimating FE panel model with IV, we conduct post-estimation tests for check the nonspherical properties of the residuals: Wooldridge serial correlation test, Pesaran cross-sectional dependence test and modified Wald test for country-level heteroskedasticity.

[74] Other econometric software like Eviews requires that, when RE is modelled, the number of cross-sections must be larger than that of the coefficients for between estimators to estimate RE innovation variance. Our sample does not meet this condition. In addition, to see if time-fixed effects are needed when running a FE, we conduct a joint test in which the null is that the dummies for all quarters are equal to zero. The restricted F-test result for Advanced-IT countries during the entire period (F = 2.17, p-value=0.000) suggests that the null is rejected, so that time-fixed effects are not needed. Other samples show similar results.

The Wooldridge test (2002) has the null of no first-order serial correlation. In particular, $H_0 : \rho = 0$ in $e_{it} = \rho e_{it-1} + v_{it}$ is used to identify a serial correlation in the idiosyncratic error term (e_{it}) in (5.4.2). The Pesaran test (2004) has a null of a cross-sectional independence − $H_0 : \text{cov}(e_{it}, e_{jt}) = 0$. A modified Wald test has the null of no heteroskedasticity − H_0: $\text{var}(e_{it}) = \sigma^2, \ \forall i$. The results of the nonspherical residual test are reported in Table 5.9.

Table 5.9 Result of post-estimation test of nonspherical residual

	1st order autocorrelation within a country level			Contemporaneous correlation across countries			Country-level heteroskedasticity		
Test method	Wooldridge's LM test of serial independence			Pesaran cross-dependence test[3)]			modified Wald test		
Null hypothesis	$H_0 : \text{cov}(e_{it}, e_{is}) = 0 \ \ \forall t \neq s$ $H_0 : \rho = 0$ in $e_{it} = \rho e_{it-1} + v_{it}$ (no 1st order serial correlation)			$H_0 : \text{cov}(e_{it}, e_{jt}) = 0$ (no cross-sectional dependence)			$H_0 : \text{var}(e_{it}) = \sigma^2, \forall i$ (no heteroskedasticity)		
STATA command	*xtserial*			*xtcsd , pesaran abs*			*xttest3*		
Equation	(5.3.21)	(5.3.22)	(5.3.23)	(5.3.21)	(5.3.22)	(5.3.23)	(5.3.21)	(5.3.22)	(5.3.23)
Advanced-IT	0.273 (0.617)	11.102*** (0.000)	68.424*** (0.000)	5.454*** (0.000)	1.932* (0.053)	20.166*** (0.000)	6271.71*** (0.000)	2151.03*** (0.000)	100.05*** (0.000)
Asia-IT	5.637* (0.098)	0.461 (0.545)	1075.52*** (0.000)	4.049*** (0.000)	2.990*** (0.003)	8.432*** (0.000)	140.00*** (0.000)	41.99*** (0.000)	461.68*** (0.000)
Europe-IT	17.814*** (0.008)	66.121*** (0.001)	95.619*** (0.000)	0.398 (0.690)	0.577 (0.563)	7.205*** (0.000)	41363.70*** (0.000)	4107.87*** (0.000)	1498.39*** 0.0000
Latin_IT	0.348 (0.586)	1.605 (0.274)	8.645** (0.042)	1.435 (0.151)	2.416** (0.015)	4.260*** (0.000)	1878.02*** (0.000)	94.96*** (0.000)	200.59*** (0.000)
Non-IT	1.112 (0.326)	0.970 (0.357)	34.672*** (0.001)	0.952 (0.341)	0.869 (0.384)	2.789*** (0.005)	17934.31*** (0.000)	10992.33*** (0.000)	16956.83*** (0.000)

Notes: 1. The figures in ( ) indicates p-value
2. ***, ** and * denote the rejection of the null hypothesis at the 1%, 5% and 10, respectively.
3. All results are obtained by STATA post-estimation commands after FE estimations with IV.

In many cases, residuals are heteroskedastic and serially-correlated within country level, and contemporaneously correlated across countries. These results require one to use the HAC-robust standard errors in inferring the estimated coefficients and the HAC-robust weak identification test in applying IV. For example, Kleibergen-Paap *F* statistics are recommended rather than Cragg-Donald statistics and the Anderson canonical correlation test in examining the weakness of IV (Baum et al. 2007, p 21). See Appendix 5.9 for the details.

5.4.2.2 Degree of sterilisation and *de facto* capital mobility

In this section, we present the estimated sterilisation and offset coefficients for five country groups. It has been argued that capital mobility has been accelerated since the liberalisations of financial markets in the 1990s and the widespread introduction of flexible exchange regimes with IT in the 2000s (IMF 2011). To examine the degree of sterilisation and *de facto* capital mobility, we divide the sample into two (or three) subsamples and then carry out separate estimations. The data before the 2000s is available only for the IT-Advanced and the IT-Asia. The estimation results of the monetary reaction and BOP function are reported in Table 5.10.

Most estimated sterilisation and offset coefficients are statistically significant at the 1% or 5% level except the offset coefficient for the IT-Advanced in the 1990s and the IT-Latin in the 2000s. For the IT-Advanced and IT-Asia, the sterilisation coefficient increases while the offset coefficient decreases over time. In the IT-Advanced, the sterilisation coefficient increases from 0.75 to 1.00 while the offset coefficient decreases from 0.93 to 0.73 (in absolute value) between the 1980s and the 2000s. In the IT-Asia, the sterilisation coefficient increases from 0.90 to 1.08 whereas the offset coefficient decreases from 0.90 to 0.42 from the 1990s to the 2000s.

During the 2000s, the sterilisation coefficients are close to or above 1, and the offset coefficients is significantly less than 1 (in absolute value) in the IT-Asia and the IT-Advanced group. The offset coefficients are notably lower than sterilisation coefficients in both groups. These results suggest that sterilisations are effective in neutralizing unwanted changes in the monetary base caused by capital flows, and that *de facto* capital mobility is not complete. The changes in NDA incurred by sterilisations are never completely offset by international capital flows. Increases in sterilisation coefficients over time indicate that the CBs in both groups attempt to intensify sterilisations in order to retain their monetary independence.

During the 2000s, the sterilisation coefficient of the IT-Advanced was much lower than that of the IT-Asia while the offset coefficient of the IT-Advanced are greater than that of the IT-Asia group, implying that the sterilisation is relatively more successful in the IT-Asia than in the IT-Advanced group. The decreases in the offset coefficients in the IT-Advanced and IT-Asia groups over time imply that both groups as a whole have experienced lower *de facto* capital mobility in the 2000s than in the 1990s. This result appears to conflict with recent discussions about the integration of international capital markets. However, the results for IT-Asia are consistent with some studies which suggest that *de facto* capital mobility has not significantly increased since the 1997-98 crises (Ouyang et al. 2007).

The reduced *de facto* capital mobility in advanced countries in the 2000s appears somewhat difficult to interpret. Two plausible interpretations have been proposed. First, more open financial market does not necessarily represent *de facto* high capital mobility in advanced countries, as Feldstein-Horioka puzzle hints at. Capital is not freely mobile in most financially-open advanced countries (Younas 2011). Second, IT-Advanced countries rarely intervened in FX markets in the 2000s, so that the ΔNFAs did not change considerably in line with ΔNDA.

Several implications can be drawn from the estimation results in the 2000s. First, the sterilisation coefficients are close to or above 1 in most groups (except for IT-Europe), which indicates that CBs conduct almost complete sterilisation or slight over-sterilisation of capital flows in the 2000s. This result from the panel data is mostly consistent with recent time-series based studies that report high degree of sterilisations in most countries: e.g. Siklos(2000a), Bernstein (2000), Cavoli and Rajan(2006), Ouyang et al(2010) and Wang(2010) (see

Appendix 5.1 for the summary of previous studies). Second, *de facto* capital mobility appears lower in IT emerging countries than in IT-Advanced countries, as expected. The offset coefficients range from -0.42 to -0.64 in IT emerging countries and -0.73 in IT-Advanced during the 2000s.[75]

Among the control variables, the volatility terms (σ_r, σ_s) interacted with the dummy variables (d_1, d_2) are, in general, significantly negative in both equations, regardless of country groups. This implies that most CBs attempt to stabilise the money and FX markets by providing monetary base when the money market is in a deficit position and by selling foreign exchange when the FX market is in excess demand for foreign currency, respectively.

The estimated coefficients for other control variables are different depending on country groups or sample periods. For example, the coefficients for current accounts are significant in IT-Asia group during the 2000s. This may reflect a relatively large amount of current account surplus in this group after 1997-98 financial crises. $(S_{it-1} - \overline{S_{it}})$, Y_c and $\Delta(r_{f,t} + E_t S_{t+1})$ are mostly insignificant and do not have consistent signs in both regressions. The coefficients for $(S_{it-1} - \overline{S_{it}})$ are not significant in IT-Advanced, IT-Asia and IT-Europe but significant in IT-Latin and the Non-IT group. Considering that Non-IT and Latin-IT include relatively more fixed exchange regime countries during the sample periods, these results are understandable. The insignificance of $(S_{it-1} - \overline{S_{it}})$ and significance of $(d_2\text{-}1)\sigma_s$ in IT-Advanced, IT-Asia and IT-Europe may suggest that CB interventions mostly aim at reducing FX rate volatility rather than changing FX rate level.

[75]The high offset coefficient (-0.98) in the Non-IT group may be because the Non-IT group includes regional financial centres such as Japan, Singapore and Hong Kong, where capital moves more freely than any other countries. China and India experienced a large amount of capital inflows despite the institutional constraints on capital flows. According to Montiel and Reinhart (1999), capital control appears to change the composition of capital flows without reducing the total volume of capital inflows.

Table 5.10 Estimated sterilisation and offset coefficients for 5 country groups: panel model

	IT-Advanced						IT-Asia				IT-Latin		IT-Europe		Non-IT	
	1981Q1-1990Q4		1991Q-2000Q		2001Q1-2010Q4		1991Q-2000Q4		2001Q1-2010Q4		2001Q1-2010Q4		2001Q1-2010Q4		2001Q1-2010Q4	
	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA
Intercept	0.002 (0.202)	0.005*** (0.001)	-0.001 (0.862)	0.002*** (0.004)	0.015* (0.094)	0.010** (0.041)	0.002 (0.647)	0.007 (0.419)	0.010 (0.183)	0.029*** (0.000)	0.008* (0.087)	0.010** (0.011)	-0.001 (0.843)	0.005** (0.028)	0.019*** (0.000)	0.012 (0.385)
Δ*NFA*	**-0.754***** **(0.000)**	-	**-0.599**** **(0.019)**	-	**-1.002***** **(0.004)**	-	**-0.902***** **(0.000)**	-	**-1.081***** **(0.000)**	-	**-0.988***** **(0.000)**	-	**-0.836**** **(0.042)**	-	**-1.022***** **(0.000)**	-
Δ*NDA*	-	**-0.933***** **(0.000)**	-	**-0.236** **(0.508)**	-	**-0.728***** **(0.010)**	-	**-0.895***** **(0.000)**	-	**-0.417***** **(0.002)**	-	**-0.639*** **(0.099)**	-	**-0.426***** **(0.004)**	-	**-0.977***** **(0.000)**
CA	0.014 (0.739)	0.016 (0.667)	-0.195* (0.096)	0.016 (0.715)	0.038 (0.835)	-0.024 (0.865)	-0.025 (0.783)	0.027 (0.719)	0.211* (0.063)	0.217*** (0.007)	0.029 (0.809)	-0.022 (0.852)	0.056 (0.589)	-0.090 (0.201)	-0.041 (0.438)	0.114 (0.529)
$\Delta(r_f+ES)$	-0.006 (0.756)	-0.008 (0.630)	0.008 (0.684)	-0.028* (0.079)	0.005** (0.035)	0.004*** (0.001)	0.001 (0.439)	0.001 (0.287)	-0.001 (0.831)	0.0002* (0.071)	-0.0004 (0.862)	-0.0001 (0.672)	0.0001 (0.973)	-0.001 (0.161)	-0.002 (0.608)	0.001 (0.799)
$(S_{it-1}-\overline{S_{it}})$	-0.019 (0.400)	0.006 (0.778)	0.056 (0.353)	0.002 (0.950)	0.072 (0.666)	0.041 (0.671)	-0.081 (0.439)	-0.040 (0.721)	0.034 (0.598)	0.085 (0.473)	-0.090** (0.012)	-0.131* (0.068)	-0.036 (0.423)	-0.035 (0.467)	-0.174** (0.022)	-0.395** (0.012)
Δp_{t-1}	-0.106* (0.100)	-0.106 (0.164)	-0.113 (0.434)	0.050 (0.431)	-1.468** (0.045)	-0.902*** (0.007)	0.045 (0.232)	0.310 (0.486)	0.002 (0.600)	0.027 (0.903)	-0.124 (0.483)	-0.241 (0.310)	-0.011 (0.936)	-0.002 (0.989)	0.244 (0.204)	0.110 (0.716)
Y_c	0.053 (0.162)	0.003 (0.933)	-0.104 (0.363)	-0.043 (0.231)	0.203 (0.502)	0.151 (0.597)	-0.053 (0.632)	-0.006 (0.942)	-0.138 (0.425)	-0.055 (0.798)	0.002 (0.960)	0.193* (0.058)	0.253*** (0.009)	0.009 (0.918)	-0.054 (0.242)	-0.028 (0.617)
Fiscal deficit	-0.037 (0.119)	-0.012 (0.565)	0.086*** (0.009)	0.017 (0.532)	-0.047 (0.194)	-0.017 (0.647)	-0.237** (0.019)	-0.211** (0.035)	0.033 (0.550)	-0.148*** (0.009)	-0.359*** (0.000)	-0.152 (0.279)	-0.148** (0.012)	-0.051 (0.244)	0.064* (0.087)	-0.001 (0.977)
$(d_1\text{-}1)\sigma_r$	-0.424*** (0.009)	-	-2.889*** (0.007)	-	-4.960** (0.025)	-	-0.309 (0.553)	-	-2.577** (0.032)	-	-1.382*** (0.000)	-	-0.676 (0.396)	-	-0.106 (0.434)	-
$(d_2\text{-}1)\sigma_s$	-	-0.097 (0.335)	-	-0.470*** (0.003)	-	-0.660*** (0.002)	-	-0.336** (0.035)	-	-1.563*** (0.000)	-	-0.264 (0.238)	-	-0.493*** (0.001)	-	-0.345** (0.066)
Observation	105	105	200	200	296	296	75	75	150	150	174	174	202	202	245	277
Wald χ^2-stat	126.30 (0.000)	145.32 (0.000)	123.41 (0.000)	119.95 (0.000)	409.48 (0.000)	114.16 (0.000)	270.90 (0.000)	80.90 (0.000)	257.68 (0.000)	196.37 (0.000)	93.76 (0.000)	123.00 (0.000)	79.02 (0.000)	191.71 (0.000)	304.81 (0.000)	371.35 (0.000)
J-statistics	0.526 (0.768)	1.587 (0.452)	0.688 (0.672)	4.231 (0.112)	1.989 (0.369)	4.002 (0.145)	0.465 (0.793)	1.469 (0.480)	5.687 (0.058)	0.596 (0.742)	2.465 (0.321)	1.234 (0.531)	4.731 (0.094)	0.935 (0.6266)	0.932 (0.628)	1.031 (0.597)
Kleibergen-Paap F statistics	13.23	22.33	15.03	8.65	19.68	11.22	19.10	8.22	10.76	15.63	10.65	12.97	11.39	21.64	23.65	12.35

Notes: 1. Panel 2 Stage Least Squares with cross-sectional fixed effect are used.
2. To obtain Newey-West type HAC estimator, we use STATA command ***xtivreg, fe*** with ***robust bw(6)*** option.
3. Δ*FDI* and Δ*CIC* are used as an instrument for Δ*NFA* and Δ*NDA*, respectively, with a constant and up to 2 lags of other explanatory variables. Instruments used are same for all country groups.
4. Hansen's J-statistics is the diagnostic test for the validity of over-identifying restriction. If the null of a valid over-identifying restriction is not rejected, the model is considered as correct.
5. Kleibergen-Paap F statistics is to test weakness of a set of instruments. If the F-statistics is at least 10, the model is assumed not to have significant problem of weak instrument.
6. ***, ** and* denote the rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.
7. P-values are in in parenthesis.

The insignificance of $\Delta(r_{f,t} + E_t S_{t+1})$ may be due mainly to the lower interest rate sensitivity of capital flows in the 2000s (Forbes and Warnock 2011). A series of financial crises since 1997 and globally low interest rates in the late 2000s appear to render market participants to recognize non-interest rate risk more seriously than interest rate risk. Consequently capital flows may become less sensitive to interest rate changes. For example, Verma and Prakash (2011) provide evidence that net capital inflows to India during the period 2000-2009 were not sensitive to interest rate differentials. Lagged inflation terms are significant and have the expected sign only in IT-Advanced countries that have a longer history of IT and relatively stronger commitments on inflation. In addition, from the statistical point of view, the insignificance of Y_c, and $\Delta(r_{f,t} + E_t S_{t+1})$ may be explained by the fact that the dependent variables (ΔNDA and ΔNFA) are quite volatile, whereas the independent variables (GDP, interest rates, etc.) are relatively stable (Ouyang 2007).

5.4.2.3 Impact of sterilisations on domestic interest rates

In the previous section, we saw that the degree of sterilisation is greater and *de facto* capital mobility is lower in IT-Asia than in IT-Advanced. The countries in IT-Asia, in particular, conducted over-sterilisations during the 2000s. Consequently, it is expected that sterilisations influence domestic interest rates more significantly in the IT-Asia than any other country group. In general, the sterilisations in emerging IT-Asian countries facing capital inflows are most likely to keep domestic interest rates from falling and cause the interest rate differential not to converge, because sterilisations are mostly money-tightening in these countries. In contrast, the sterilisations in IT-Advanced countries mostly address capital outflows, so that sterilisations are likely to be monetary expansion in many cases − See the Appendix 5.3(b) for the detailed statistics about the BOP. Hence, the sterilisation impacts on interest rates in IT-Asia may be significantly different from those in IT-Advanced. Over-sterilisations in IT-Asia are most likely to raise domestic interest rates.

The results presented in Table 5.11 appear consistent with prior expectations. In the 2000s, the sterilisation (ΔNDA) is negatively related with domestic interest rates (r_d) in all country groups except the IT-Advanced (where ΔNDA and r_d are positively correlated but insignificant). However, the estimated coefficient is significant only in the IT-Asia. The estimated coefficients of ΔNDA are -0.15 at a 5% significance level in IT-Asia, implying that 1 % decrease in $\Delta NDA/GDP$ leads to a rise in domestic interest rate by 0.15%.

This may be somewhat expected from some statistics and the analyses of sterilisation coefficient. As already seen in Chapter 2 and Appendix 5.3(b), the increases in short-term capital inflows and the consequent foreign reserve accumulation are most prominent in the IT-Asia. This indicates that strong sterilisations may have been more imperative in the IT-Asia than in any other regions. Analyses in the previous section report that the sterilisation coefficient in IT-Asia is 1.08, highest among all country groups. In addition, time-series analyses (in the section 5.4.1.2) report that significant negative relations between ΔNDA and r_d are found in Korea and China in the 2000s. Accordingly, it could be interpreted that recent oversterilisations in the IT-Asia may lead the interest rate differential not to converge and thereby help to encourage further capital inflows. This result supports previous studies such as McKinnon and Pill (1999) that the interest differential between the domestic and base countries tends to widen under free float regime in emerging economies.

As seen in the previous sections, the degree of sterilisation appears to become higher in the IT-Asia since the introduction of IT, which concurrently accompanies more flexible exchange regimes. Fear of float or fear of appreciation appears to encourage the countries in IT-Asia group to intensify sterilisations against capital flows.

Table 5.11 Effect of sterilisation on domestic interest rate: panel model

Dependent variable: real domestic interest rate

	IT-Advanced			IT-Asia		IT-Latin	IT-Europe	Non-IT
	(1981-1990)	(1991-2000)	(2001-2010)	(1991-2000)	(2001-2010)	(2001-2010)	(2001-2010)	(2001-2010)
Intercept	0.053*** (0.000)	0.034*** (0.000)	0.025*** (0.000)	0.111*** (0.000)	0.056*** (0.000)	0.080*** (0.000)	0.033 (0.118)	0.037*** (0.000)
r^*_f (adjusted foreign rate)	-0.109 (0.176)	-0.112** (0.041)	0.012*** (0.000)	-0.828*** (0.000)	0.203*** (0.001)	0.122** (0.017)	0.068 (0.385)	0.103 (0.333)
Δ*NDA/GDP* (sterilisation)	**0.186 (0.586)**	**0.026 (0.603)**	**0.032 (0.101)**	**-0.814 (0.149)**	**-0.151** (0.039)**	**-0.529 (0.247)**	**-0.645 (0.192)**	**-0.002 (0.464)**
Δm_{t-1} /GDP (change in base money)	-0.070 (0.314)	-0.023 (0.275)	-0.001 (0.604)	-0.089 (0.281)	-0.033 (0.117)	0.069 (0.267)	-0.359* (0.057)	-0.460** (0.012)
π^e_{t+1} (expected inflation)	5.124*** (0.000)	6.785*** (0.000)	2.696*** (0.001)	5.203*** (0.000)	-1.111** (0.049)	-1.465* (0.080)	3.808** (0.012)	1.888** (0.011)
Δy(growth rate)	-0.248* (0.078)	-0.167 (0.238)	0.065* (0.092)	0.095 (0.464)	0.104** (0.036)	0.091 (0.560)	0.062 (0.514)	-0.098 (0.456)
Observations	149	200	284	84	149	166	196	244
Wald $\chi 2$-statistics	1230.12*** (0.000)	1071.34*** (0.000)	1794.97*** (0.000)	364.56*** (0.000)	907.04*** (0.000)	952.31*** (0.000)	512.20*** (0.000)	287.60*** (0.000)
J-statistics	8.106 (0.423)	7.189 (0.410)	13.977 (0.174)	9.278 (0.055)	5.764 (0.330)	9.898 (0.129)	11.471 (0.243)	16.335 (0.130)
Kleibergen-Paap F statistics	14.65	12.33	18.56	26.22	36.20	15.62	12.35	8.28
Instrument rank	14	13	16	10	11	12	15	17

Notes: 1. Panel 2 stage GMM estimations (with cross-sectional fixed-effects) are used

2. To obtain Newey-West type HAC estimator, we use STATA command ***xtivreg, fe*** with ***gmm2s robust bw(6)*** option.

3. A constant, ΔCIC,and up to three lags of regressors and ΔCIC are used as instruments differently depending on country group until over-identifying restrictions become valid and the problem of weak instrument sufficiently is lessened. Thus, instruments used in each country group are mostly different as instrument rank indicates.

4. Hansen's J-statistics is the diagnostic test for the validity of over-identifying restriction. If null of a valid over-identifying restriction is not rejected, the model is considered as correct.

5. Kleibergen-Paap F statistics is to test weak identification. If the F-statistics is at least 10, the model is assumed not to have significant problem of weak instrument.

6. ***, ** and* denote the rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

7. P-values are in in parenthesis

5.5. Conclusion

5.5.1 Summary of main findings

In this chapter, we investigate the degree of sterilisation and *de facto* capital mobility in 30 main countries by estimating sterilisation and offset coefficients. For this, we modify Brissimis et al. (2002)'s unified framework which provides fully identified semi-reduced-form sterilisation and offset equation. Following previous studies and institutional features, we concern only contemporaneous sterilisation and offset coefficients. We also estimate the effects of sterilisation on domestic interest rate by applying Edwards and Khan's (1985) interest rate determination model under imperfect capital mobility.

Our analysis is differentiated from previous studies in that our sample covers 30 countries, and we apply panel analyses as well as time-series analyses. The derived models appear to explain CB interventions in both money and FX markets well. In the model, the degree of sterilisation becomes greater as capital is less mobile or local interest rate is more sensitive to money supply.

From the results of time-series analyses for 11 countries, we find that the sterilisation coefficients are significantly more than 1 or close to 1 while offset coefficient are significantly less than 1 (in absolute value) in most emerging IT countries during inflation targeting period. From pre-IT to post-IT period, both sterilisation and offset coefficient increase in emerging-IT countries (e.g. Korea, Peru). This indicates that the emerging-IT countries retained considerable monetary independence via complete-or-over sterilisations despite the increasing capital mobility. The countries increase sterilisation as *de facto* capital mobility increases.

Meanwhile, the sterilisation and offset coefficients in advanced IT countries (e.g. UK, Australia, Canada) are significantly less than 1 (in absolute value), implying that the countries does not completely sterilise capital flows. We find evidence of over-sterilisations in non-IT countries with higher reserve holdings such as Japan and China. We also find marginally significant negative correlation between sterilisation and domestic interest rates in Korea and China, implying that oversterilisations (using MSBs) may cause domestic interest rates to rise and thereby encourage further capital inflows and resultant additional sterilisations. This result suggests that oversterilisations of foreign reserves may incur considerable sterilisation costs by leaving domestic-foreign interest rate differentials as they are. Our result appears to substantiate Calvo (1991)'s argument that sterilisation peril is higher in the countries (like Korea and China) that issue nominal MSBs for sterilisation.

Considering the unobservable heterogeneity, we apply the 2 stage least square panel estimation with cross-sectional fixed effect for 5 country groups (consisting of 30 countries). During the 2000s, the sterilisation coefficients are close to or above 1 and the offset coefficients significantly less than 1 (in absolute values) in most country groups. This result implies that most countries retain monetary independence by sterilizing capital flows nearly fully, and that *de facto* capital mobility is not perfect. During the 2000s, the sterilisation coefficient of the IT-Advanced was lower than that of the IT-Asia while the offset coefficient of the IT-Advanced was greater than that of the IT-Asia. This indicates that the sterilisations in IT-Asia appear to be more successful than those in the IT-Advanced. The degree of sterilisation increases while *de facto* capital mobility decreases in the IT-Asia and IT-advanced over time. This appears to supports the conventional belief that sterilisations function as substitute for capital control (Aizenman and Glick 2009, Steiner 2011).

The degree of sterilisation in IT-Asia appears to have become higher since the introduction of IT, which concurrently accompanies more flexible exchange regimes.

Considering the estimation result for Non-IT group where oversterilisation is found, the increasing degree of sterilisation may be directly related to prevalence of flexible exchange regimes rather than inflation targeting. That is, with more flexible exchange regime prevailing in the 2000s, the fear of float or fear of appreciation appear to encourage emerging countries to intensify sterilisations against capital flows.

Sterilisation amount (ΔNDA) has a negative correlation with domestic interest rates with marginal significance in IT-Asia during the last decade, implying that oversterilisation may cause domestic interest rates to rise. The sterilisation peril appears prominent in the countries where CB issues nominal MSBs for sterilizing capital inflows (e.g Korea, China, Indonesia). We have found the negative correlations in other country groups, but they are not significant. The persistent interest rate differential in IT-Asia countries may be partly attributed to the practice of oversterilisation, which encourages further capital inflows and causes CBs to suffer sterilisation costs.

5.5.2 Limitations of study and future research

We do not consider a number of issues owing to data availability and some restricted assumptions which are worth being pursued in future research. First, we apply overnight US fed fund rate and the exchange rate against USD to the analyses of all countries. Considering the different economic structures of sample countries, weighted interest rates and FX rates may be more appropriated. For example, interbank interest rates in Euro Area and exchange rates against EURO will be more appropriate for the study on emerging European countries.

Second, the analyses in this chapter consider only contemporaneous sterilisations. This follows the results and methodologies of most previous studies (e.g. Aizenman and Glick 2009, Craig and Humpage 2001) and considers current sterilisation practices. Nevertheless, lagged sterilisations are possible in advanced countries. For example, the CBs do not need to change the supply of the bank reserves instantly in response to every change in monetary base caused by FXIs. This is because the same interest rate can coexist with different amounts of bank reserves and vice versa owing to announcement effect (Borio & Disyatat 2009 p3). Once the demand for monetary base is met, the CBs can control the O/N rate at the level they wish by announcing the level of the interest rate they want to see. This means that the CBs do not necessarily change monetary base (ΔNDA) for sterilizing every change in capital flows to keep policy interest rate. In this case, lagged sterilisation may be more realistic. Cointegrated VAR model may provide long-term and lagged coefficients and lessen simultaneity problems.

Third, we do not consider the possible change in the CB's reaction function over time. Over the entire period, the CB is assumed to have constant reaction function with same multiple objectives irrespective of the changes in monetary and exchange rate regime. However, more realistic reaction function may be time-varying in line with the policy regime changes. Forth, the efficiency and consistency of estimates in this chapter depends on the choice of good instrument variables for ΔNFA and ΔNDA. The tests of overidentifying restriction and weak instrument mostly support the appropriateness of the model used here. However, the test statistics are marginally significant in some subsamples. For example, in panel estimation, Kleibergen-Paap F statistics are mostly slightly over 10 or less than 10 (e.g. Non-IT in Table 5.11), indicating that the instrument variables used here are mostly acceptable but not strong.

Lastly, we estimate the monetary reaction function (5.3.21) and the BOP function (5.3.22) separately in fixed effect 2SLS panel estimation. It is necessary to estimate the panel system consisting of (5.3.21) and (5.3.22), which has never been carried out so far in the estimation of sterilisation and offset coefficient.

CHAPTER 6 SUSTAINABILTY OF CENTRAL BANK BOND-DEPENDENT STERILISATIONS:

Can the current path of sterilisations in Korea be sustained without exploding the stock of monetary stabilisation bonds?

6.1 Introduction

An increasing number of central banks are issuing central bank bonds (hereafter MSB: Monetary Stabilisation Bond) to sterilise the impact of capital inflows. An MSB-dependent sterilisation policy may be preferable when (i) there are not enough government bonds on issue; (ii) central banks (hereafter CBs) want to find efficient operational tools to resist domestic currency appreciation; and (iii) the issuance of the MSB may be helpful to develop local financial markets by providing benchmark interest rates, particularly when government bond markets are thin. MSBs are considered as an effective sterilisation tool to manage capital inflows and to maintain monetary autonomy in East Asian countries.

However, despite the usefulness of MSBs, several concerns have been raised about MSB-dependent sterilisations. First of all, MSBs may split the liquidity of public securities markets, as they are normally issued independently from treasury bonds. The excessive issuance of MSBs may complicate the procedures of monetary policy implementation by pressing long-term interest rates upward or by strengthening the expectation of future inflation. For example, CBs often have to provide the holders of MSBs with above-market interest rates or issue long-term bonds to encourage the public to purchase more MSBs.

Another concern is the sterilisation peril which stems from nominal MSBs (Calvo 1991). CBs in emerging economies may not earn enough returns from their foreign assets (financed by issuing the MSBs) to cover the interest paid on the MSBs, and thus experience fiscal losses (Hawkins 2005), because local interest rates are normally higher than international interest rates. A large amount of the MSBs and consequential CB's fiscal loss may lead people to doubt the CB's capability of reimbursement, meaning that they would not purchase the MSBs in the future. In this case, the CB fails to manage the level of liquidity needed for controlling their target interest rate, and cannot eventually control inflation. Consequently, excessive issuances of MSBs may weaken the soundness of a CB's balance sheet, which is crucial for the monetary policy independence and price stability (see Klüh and Stella 2008 for the relation between the economic performance and fiscal soundness of CBs).

There has been growing concern about the future course of the stock of MSBs in Korea owing to the huge amount of MSBs outstanding and several episodes of fiscal losses on the part of the BOK over the last decade. The main question arises as to whether the current MSB-dependent sterilisation will be sustainable permanently or in the long run. It seems intuitively evident that, because MSBs, unlike high-powered money, should be redeemed when they are matured, the CB could not continue issuing the bond without any constraints. However, despite numerous studies on the sustainability of government debt policies and the existence of many CBs issuing MSBs, surprisingly, there are few attempts to take account of the sustainability of MSBs. This is mainly because most of the relevant CBs are not in developed countries in which MSBs are not main sterilisation tools and because the accounts of a CB and a central government are not considered separately in most studies.

This chapter studies whether the sustainability of MSB-dependent sterilisation in Korea would provide significant policy implications for other countries that use MSBs as a main sterilisation tool. The main interests in this chapter are to answer following questions: (i) Whether current MSB-financed sterilisations are sustainable in the long run without exploding the MSB and incurring inflation; (ii) Under what conditions can CBs continue their

MSB-dependent sterilisation policy without losing its monetary independence over time; and (iii) What constraints, if any, does MSB-dependent sterilisation place on a monetary policy implementation. This chapter seeks to contribute to the theoretical and empirical understanding of MSB-dependent sterilisations by applying existing theories of fiscal debt. For this, we first briefly describe the relationships among MSBs, the monetary base and foreign reserves. Then, we derive an intertemporal budget constraint (hereafter IBC) of a CB and seek long-term sustainability conditions for the MSB-dependent sterilisation. Based on cointegration analysis and Bohn's (1998, 2004) methodology, we empirically evaluate the long-run sustainability of the MSB-dependent sterilisation policies in Korea.

The rest of this chapter is structured as follows. Section 2 describes several noteworthy, stylised facts about the balance sheet of a CB and MSBs. Section 3 outlines the theoretical aspects of the sustainability of government debt, which is the theoretical foundation of this chapter. Section 4 reviews previous empirical studies on the sustainability of government debts. Section 5 derives the optimal conditions for a sustainable MSB issuing policy and sets up empirical models for the sustainability test. Using quarterly Korean data for 1987Q1-2009Q4, we assess the sustainability of MSBs in Korea via three tests: (i) Whether the univariate debt series is stationary with a positive mean; (ii) Whether there is a cointegration relation in the CB's asset purchases and seigniorage; and (iii) Whether the CB systemically responds to changes in the MSB outstanding by adjusting its asset purchases or seigniorage. To analyse these issues, we first consider a CB's budget constraint separately from a government's, and then extend our analysis into the budget constraint of consolidated government, including both a CB and a central government. Section 6 concludes the chapter and provides several policy implications around MSB-dependent sterilisation policy.

6.2 Monetary stabilisation bond

6.2.1 Stylised balance sheet of a central bank

The links between FXIs and subsequent sterilisation operations are understood by examining the balance sheet (B/S) of a CB. Table 6.1(a) shows the initial B/S of a CB expressed in terms of *net values*. The asset side mainly consists of domestic treasury bonds, loans to the government or commercial banks, and net foreign assets (NFA). The liability side is composed of bank reserves (TR: total reserves) and currency. A net worth (or capital) appears in the liability side.

Now, suppose that CB intervenes in the FX markets by purchasing foreign assets (+ΔNFA) with base money (+ΔTR) in order to sterilise capital inflows. The intervention leads to an increase in both assets (+ΔNFA) and liabilities (+ΔTR) as shown in Table 6.1(b). Should demand for bank reserves be the same as before, the increase in bank reserve (+ΔTR) may cause short-term interest rates to deviate from a target interest rate. In order to maintain short-term interest rates close to target, the CB should sterilise the increases in bank reserves either by reducing its domestic assets (e.g., selling treasury bonds, -ΔTB), as shown in Table 6.1(c) or by increasing its liabilities (+ΔMSB), as depicted in Table 6.1(d). Note that the increase in bank reserves (+ΔTR) is withdrawn by the decrease in treasury bonds in Table 6.1(c) or the increase in MSB in Table 6.1(d).

In general, the reduction of domestic assets is chosen as a main sterilisation tool by CBs which have enough holdings of treasury bonds and other assets. This is the case for most CBs in developed countries (e.g. the USA, the Euro area, the UK, Japan, etc.). However, as their holdings of treasury bonds start to run out or if there are few assets to be sold, the CBs will depend on issuing their own bonds (e.g. Korea, China, Taiwan, Indonesia, Chile, etc.).

Table 6.1 Stylised balance sheet of a central bank

(a) Initial situation

Assets	Liabilities
□ **Net Domestic Asset (NDA)** - Domestic treasury bonds (TB) - Loans to a government or commercial banks - Other domestic securities □ **Net Foreign Asset(NFA)** - Foreign securities, Foreign deposits, etc.	□ **Total Reserves (TR)** - Required Reserves(RR) - Excess Reserves (ER) □ **Currency in Circulation** □ **Net worth (or Capital)**

(b) Foreign asset buying interventions without sterilisations

Assets	Liabilities
□ **Net Domestic Asset (NDA)** - Domestic treasury bonds (TB) - Loans to a government or commercial banks - Other domestic securities □ **Net Foreign Asset(NFA) + *ΔNFA*** - Foreign securities, Foreign deposits, etc.	□ **Total Reserves(TR) + *ΔTR*** - Required Reserves(RR) - Excess Reserves (ER) □ **Currency in Circulation** □ **Net worth (or Capital)**

(c) Foreign asset buying intervention with sterilisation by reducing domestic assets

Assets	Liabilities
□ **Net Domestic Asset(NDA) *- ΔNDA*** - Domestic treasury bonds (TB)***- ΔTB*** - Loans to a government or commercial banks - Other domestic securities □ **Net Foreign Asset (NFA) *+ ΔNFA*** - Foreign securities, Foreign deposits, etc.	□ **Total Reserves(TR) + *ΔTR - ΔTR*** - Required Reserves(RR) - Excess Reserves (ER) □ **Currency in Circulation** □ **Net worth (or Capital)**

(d) Foreign asset buying interventions with sterilisations by increasing liabilities

Assets	Liabilities
□ **Net Domestic Asset (NDA) *- ΔNDA*** - Domestic treasury bonds (TB) - Loans to a government or commercial banks - Other domestic securities □ **Net Foreign Asset *+ ΔNFA*** - Foreign securities, Foreign deposits, etc.	□ **Total Reserves(TR) *+ ΔTR - ΔTR*** - Required Reserves(RR) - Excess Reserves (ER) □ **Currency in Circulation** □ ***ΔMSBs*** □ **Net worth (or Capital)**

Notes: 1. Changes in each term have equivalent values; i.e. $\Delta NFA = \Delta NDA = \Delta TB = \Delta TR$
2. When the amount of necessary sterilisation is small, reverse repos replaces the MSBs

It is worth noting that CBs depending on the MSBs are likely to face a larger risk of B/S problems than those selling treasury bonds outright or with repurchase agreement. Sims (2004) dichotomises the types of CB as type-F (Federal Reserve type) and type-E (ECB type), according to the composition of their B/S. As shown in Table 6.2(a), the B/S of type-F is always perfectly hedged, since it consists of short-term interest-bearing nominal assets and base money liabilities with the same currency denominated, so there is almost no risk of B/S problems. However, in the case of type-E (see Table 6.2(b)), the assets consist of a larger portion of foreign assets that are subject to fluctuations of exchange rates and international interest rates, while the liabilities consist of base money denominated by the local currency. A type-E is always under risk of B/S problems that originate from the change in exchange rates and the domestic-foreign interest differential.

Table 6.2 Balance sheets of US Fed and ECB (end of year 2009)

(a) Fed

(billion USD)

Assets	2235.0	Liabilities	2235.0
Treasury Securities [1]	973.4	Banknote issued	887.8
MBS[2]	918.9	RP sold	77.7
Loan to Financial companies	166.0	Bank Reserve	977.0
Foreign Assets	25.3	Treasury Deposits	191.6
Gold	11.0	others	49.2
Others	140.4	Net worth	51.2

(b) ECB

(billion euro)

Assets	138.0	Liabilities	138.0
Foreign asset (non-euro area)	35.5	Banknote issued	64.5
Gold	12.4	Domestic liability	10.6
Foreign asset (euro area)	3.3	Foreign liability	0.2
Intra-Eurosystem[3]	70.9	Intra-Eurosystem[4]	40.2
Securities held for operations	2.2	Others	16.2
Others	13.8	Net worth	6.3

Notes: 1. including government-sponsored enterprise debt securities (167 bill. USD)
2. Federal agency and government-sponsored enterprise mortgage-backed securities
3. ECB's claims against member national central banks
4. ECB' liabilities to member national central banks

Sources: Annual report 2009 (US Fed and ECB)

Table 6.3 shows that the B/S of the BOK has become a typical E-type, as foreign assets and MSBs have occupied the majority of assets and liabilities, respectively, since the late 1990s. The proportion of foreign assets to total assets increased from 25.3% in 1980 to 88.6% in 2009 while that of domestic liabilities (exclusive of monetary base) increased from 37.3% to 76.8% during the same period. In particular, the proportion of MSB to total liabilities soared up to 58.0% in 2005 from 8.5% in 1980. It is argued that this change may stem from the BOK's sustained sterilisation for preventing the appreciation of local currency.

Table 6.3 Percentage changes in the BOK's main accounts

(%, end-of-year)

		1980	1985	1990	1995	2000	2005	2009
Assets	Domestic assets	74.7	81.7	74.3	62.8	20.3	14.5	11.4
	Foreign asset s	25.3	18.3	25.7	37.2	79.7	85.5	88.6
	Total assets	100.0	100.0	100.0	100.0	100.0	100.0	100.0
liabilities	Monetary base[1]	51.9	27.0	32.4	42.6	18.8	16.2	18.9
	Domestic liabilities[2]	37.3	62.5	66.2	56.5	75.1	76.9	76.8
	(MSB)	(8.5)	(11.9)	(36.6)	(37.5)	(44.3)	(58.0)	(41.7)
	Foreign liabilities	10.8	10.6	1.4	0.9	6.1	6.9	4.3
	Total liabilities	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: 1. Monetary base consists of currencies in circulation(CIC) and bank reserves.
2. Domestic liabilities include reverse repos, swap agreement and net worth.
Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

6.2.2 Monetary Stabilisation Bond (MSB)

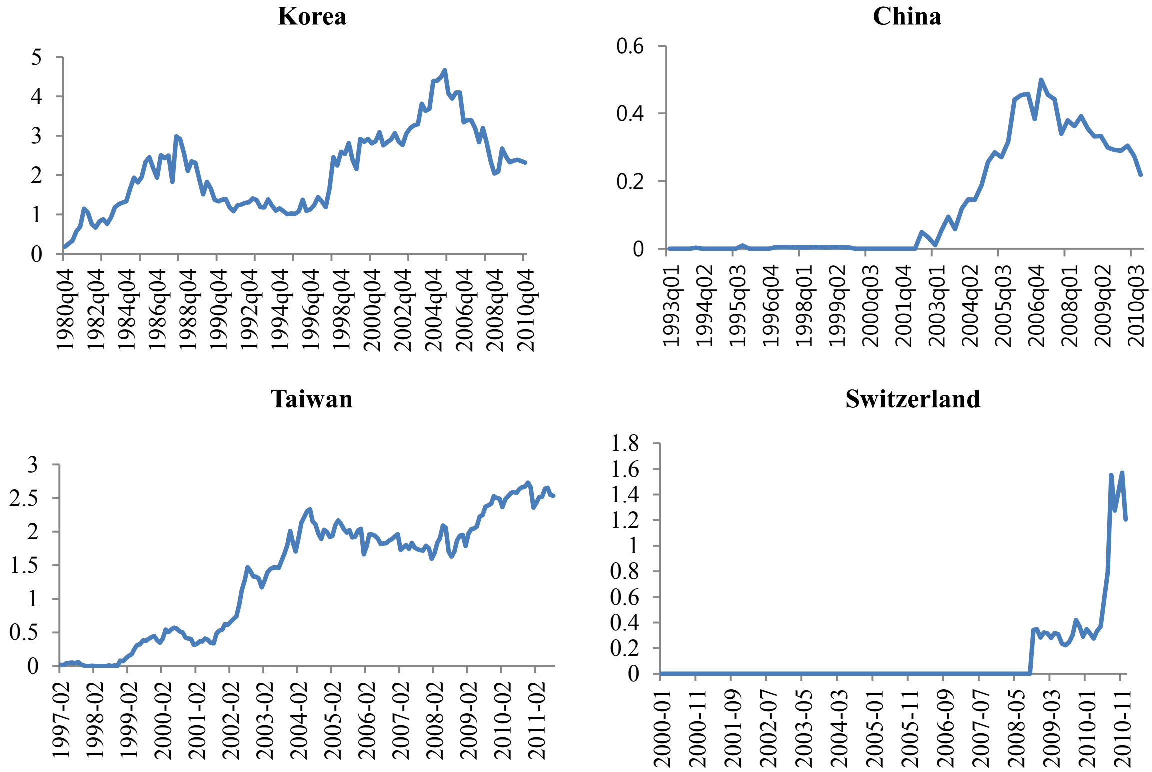
Many CBs have sold debt certificates (i.e., MSB) issued by their own names in order to absorb liquidity surplus caused by sterilised interventions. According to Hawkins (2003), approximately 31 economies have MSBs in their law or regulation regarding CBs. Sweden, Switzerland, Euro area, UK, Iceland and Denmark are developed countries and the rest are mostly emerging or developing countries. The outstanding volume of MSBs in terms of percentage of CB liabilities are mostly 10-20%, but Chile (78%), Slovenia (58%), Korea (47%) and Demark (39%) are much higher than other countries.[76] MSBs are overwhelmingly denominated in local currencies and issued at fixed interest rates.

Figure 6.1 depicts the ratios of the outstanding stock of MSBs to monetary base in

[76]MSB-dependent policies are particularly prominent in emerging countries which face massive capital inflows like Korea, China, Taiwan and Hungary. For example, Geiger (2008 p. 4) reports that the issuance of MSBs in China increased dramatically owing to the increasing need for sterilisation of foreign exchange interventions between 2003 and 2006. The portion of the issuance of MSBs to all market operations occupies 70.8% in terms of frequency of operations in 2006. The PBOC can absorb excess reserves in banking sector by issuing MSBs, and thus manage a desired expansionary policy without incurring high inflation.

four countries. The ratio has consistently increased since the late 1990s in Korea, China and Taiwan and sharply increased in Switzerland since the late 2000s. The increases may be due to the sustained sterilisations of capital inflows in the three Asian countries and the absorption of massive liquidity provided in Switzerland during the sub-prime mortgage crisis in 2008. In particular, the sustainability of MSBs may be a problem in Korea and Taiwan, which have long histories of issuing MSBs and whose stocks appear to increase consistently over time.

Figure 6.1 Ratio of MSB to monetary base in selected countries

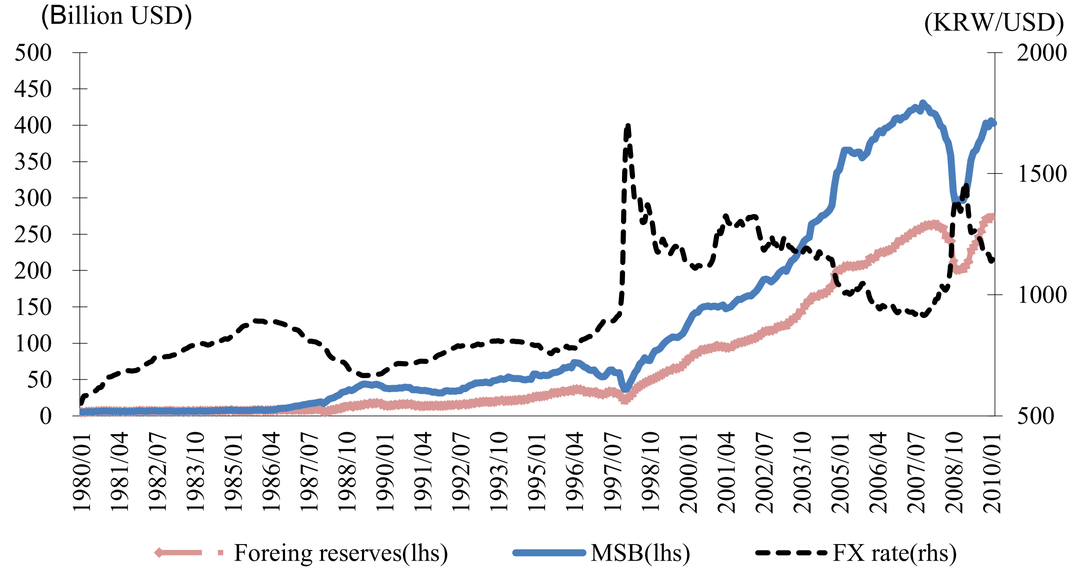


Data: Each central bank homepage

In most cases, MSBs are not included in national debts, because MSBs are mostly issued for financing foreign reserve buying interventions. Accordingly, the amount of MSBs is mostly backed by corresponding foreign reserves or other financial assets. This means that CBs can sell foreign reserves for the redemption of principals and interests of MSBs. In contrast, government bonds are issued mainly for financing a government's current and capital expenditures, so there are no backing assets corresponding to the government bonds. Thus, the governments have to issue new bonds or increase tax to make up for their fiscal deficits. In Korea, MSBs are issued by weekly competitive auction to drain structural liquidity surplus or through irregular, direct sales for fine-tuning unexpected liquidity surplus. The eleven MSB maturities range from 14 days to 2 years. In practice, the leading issue is two year MSBs, the proportion of which was about over 75% as of the end of 2009.[77]

Figure 6.2 shows that the stock of MSBs and foreign reserves has steadily increased since the late 1990s. The increases were particularly prominent after the 1997 financial crisis and foreign exchange rate (KRW per USD, hereafter KRW/USD) tended to be under consistent appreciation pressure.

Figure 6.2 Foreign reserves, MSB and nominal exchange rate in Korea



Note: The stock of MSB outstanding (originally denominated KRW) is measured in terms of USD by being multiplied by monthly average exchange rates.
Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

[77] There are 11 maturities: 14, 28, 63, 91, 140, 182, 364, 371, 392 and 546 days, and 2 years. The proportions of maturities in term of outstanding amount as of end of 2009 are as follows(Data: BOK):

Maturity	63days	91days	182days	364days	546days	2years	Total
Amount (trill. KRW)	1.5	9.9	4.8	10.6	12.5	118.8	158.1
Proportion (%)	(0.9)	(6.3)	(3.0)	(6.7)	(7.9)	(75.1)	(100.0)

The outstanding volume of MSBs increased from 29 trillion KRW as of February 1998 to around 150 trillion KRW (equivalent of 132 billion USD) as of end 2009, in line with the increase in foreign reserves from 26 billion to 270 billion USD and the appreciation of the exchange rate from 1,640 to 1,167 (KRW/USD) during the same period. Thus, the major cause of the increase in MSBs after the mid-1990 seems to be associated with the increase in foreign reserves possibly incurred by foreign currency purchasing interventions. If the interests paid on MSBs are greater than the revenues on the corresponding foreign assets, the BOK may make losses, other things being equal.

As can be seen in Table 6.4, local interest rates have, in general, been higher than foreign interest rates. The interest differential is regarded as a main factor undermining the BOK's profitability, together with the appreciation of KRW. Note that the demand for base money frequently decreases and that, even if it increases, the growth rate of base money has normally been less than that of interest payments to the MSB. Consequently, interest payment growth has consistently exceeded base money growth after the 2000s.

Table 6.4 Interest rate differential and interest payment on MSBs in Korea

(End of period, bill. KRW)

	1980	1985	1990	1995	1997	1998	2000	2005	2009
MSB outstanding	523	1,900	15,612	25,825	23,471	45,673	66,378	155,235	149,170
Interest paid on MSBs (A)	5	375	1,898	2,522	2,725	4,841	4,666	6,114	6,228
Base money (B)[1]	-224	71	993	4,101	-3,203	-1,816	-249	4,457	2,933
A/B	—	3.38	0.82	0.88	—	—	—	1.37	2.12
Rate of return of MSBs[2] (C)	28.75	12.70	15.58	13.47	12.77	12.38	7.81	3.97	2.98
Foreign interest rate[3] (D)	13.67	7.61	6.94	5.12	5.50	4.49	5.50	4.24	0.60
Interest rate differential(C-D)	15.08	5.09	8.54	8.35	7.27	7.89	2.31	-0.73	2.38

Notes: 1. Growth (annual) from the previous period
2. Monthly average rate of 1 year MSBs (except the year 1980 when average rate of return on1-year KTB and government agent bond is used.
3. Average rate of 90 day US Treasury Bill and 2 year US Treasury Bond
Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

This indicates a possible future scenario where, with the low growth rate of the monetary base and higher local interest rates than international interests, the interest payments to MSBs might explode to a level in which market participants doubt the BOK's capability of reimbursement of the MSBs or worry about future inflation. A current large amount of outstanding MSBs could possibly create 'a vicious circle': the more MSBs are issued, the more interest would have to be paid, and in turn the more MSBs issued to make these payments. As the MSB outstanding accumulates, as a result of the on-going sterilisation policy, the question of whether the BOK is running a Ponzi scheme is raised. It follows that the current MSB-dependent sterilisation policy may not be sustainable in the future.

6.2.3 Advantages and disadvantages of MSB-dependent sterilisations

Principally, discussions of CB debt policy are the same as those of government debt policy, since uncontrollable increases in outstanding stock of MSBs may lead to serious credibility problems in implementing monetary policy. MSB is a simple, flexible and efficient market-based operation tool for draining liquidity surplus. The MSB-dependent policy in Korea has been a good example of a sterilisation tool to several East Asian countries facing liquidity surplus due to capital inflows. MSBs have been useful in absorbing excess reserves in money markets, maintaining a target interest rate and thus controlling inflation. It is broadly accepted that MSBs have contributed to the development of the Korean bond markets, since MSBs provided market participants with risk-free investments and good benchmark interest rates when the KTB market was at the fledgling stage.[78]

According to Hawkins (2004, pp. 6-7), even if there is already a considerably sized government bond market, CBs have several reasons to continue issuing MSBs. (i) CBs may evade the pressure for (indirectly) lending to governments, thereby maintaining their policy independence by using their own bonds for monetary operations. (ii) By issuing MSBs, CBs

[78]Barro (1989, p 44) points out that the issuance of government bonds can amount to a useful form of financial intermediation. Thus, the yield on government bonds is a typical benchmark rate in most countries. MSBs and KTBs actually have the same credit rating, so that both are regarded as credit-risk free bonds.

can engage in crisis management operations such as a bank restructuring which requires quick methods of funding. (iii) Government bonds are sometimes not appropriate for a CB's monetary operations in terms of maturity. (iv) CBs normally prefer to separate monetary and debt management.[79]

However, there may be specific limitations on MSBs being continuously used as a liquidity draining device. A large amount of MSBs has frequently invoked controversies about a CB's fiscal soundness and monetary policy independence from the government. The BOK experienced large fiscal losses in 2003-2007 while the Korea won continuously appreciated, and the domestic-foreign interest differential widened. CBs cannot perform active and pre-emptive monetary policies while their fiscal losses persist. For example, when liquidity-providing policies are necessary in the short run, CBs may have limits in performing such policies by purchasing treasury bonds or by expanding loans to commercial banks if CB's balance sheet losses are likely to worsen.

In addition, continuing deficits may damage the public's credibility of the monetary policy. In case that a CB has to depend on financial support from a government in order to recapitalise itself,[80] there may be more room for government or political parties to interfere in the monetary policy of the CB. An excessive outstanding amount of MSBs also contributes to complicating monetary operations, crowding out treasury and corporate bonds and splitting a public bond market (see Geiger 2008).

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[79] Although there are now significant government bonds on issue, the BOK still issues its own bonds. In contrast, several CBs ceased the issuance of MSBs as (i) the Treasury issued its own securities or reversed its previous objection to the use of treasury bonds for market operations (e.g. the Philippines, Poland and Saudi Arabia); and (ii) its operations moved from money quantities to interest rate targets.

[80] According to the BOK Act, the Korean government provides the necessary funds for the BOK when the BOK exhausts its Special Reserve Fund due to consecutive deficits. "Any loss incurred by the BOK during any fiscal year shall be offset from the reserves and, should these be insufficient, the deficiency shall be made up by the government in accordance with the Budget and Accounts Act."(Bank of Korea Act, January 1998).

6.3 Literature review

6.3.1 Theoretical aspects of fiscal sustainability

Although the issues around the sustainability of a government debt have been extensively explored, those of a CB debt policy have been rarely analysed so far, in my understanding.[81] This is mainly because there have been few CBs actively using MSBs as their policy tools in developed countries. In addition, there are no specific theories on this topic. However, a significant number of CBs have issued MSBs in emerging economies (see BIS (2007b) and Ho (2008) for details on the market operations of key countries). Theories on the sustainability of government debts can be easily applied to studying MSB-dependent sterilisation. Considering this, we will review major literature on the sustainability of government debt policy.

Owing to the lack of a general agreement on the definition of what precisely constitutes a sustainable fiscal debt policy, the literature has suggested several methods to define and to evaluate the sustainability of government debts (which increase through accumulated fiscal deficits). The sustainability of government debt can be assessed differently in terms of the length of the period (short-term vs. medium or long-term sustainability), required condition (weak vs. strong form), and the definition of fiscal debt (gross vs. net debt) (Neck and Sturm 2008).Generally, two problems are raised when a government consistently runs budget deficits (Luporini 1999, p 9). First, as deficits increase to (or beyond) the level of the government's collateral or future taxing capacity, the interest rate tends to rise, and

[81] Garcia (1999) documents that many Latin countries are switching to debt financing as a means of sterilising capital inflows. He argues that the trend may, in turn, affect the sustainability of their debt through its impact on the real interest rate and reduce income growth, because high interest rates usually depress economic activities. But his study has a limitation in mainly depending on narrative methods.

investment and consumption are discouraged. Second, as the debt accumulates, agents wonder whether the government will borrow more to meet interest payments on its debts, and simply roll over its debts indefinitely. Intuitively, government debt policy is constrained by the need to finance the deficit, so that the government should balance the present value of its expenditures (including interest payments on current debts) and the present value of its revenues over the entire period. Otherwise, agents become suspicious as to whether the government is playing a Ponzi game, which ultimately leads to high inflation or debt crisis, and thus will not keep buying government bonds. However, a sustainable debt policy does not mean that a government cannot run deficit occasionally, but indicates that the government cannot continue permanent interest-exclusive deficits.

Since the concrete concept of fiscal sustainability was suggested by Domar (1944), substantial theoretical advancements have been made by Barro (1974, 1979), McCallum (1984) and Bohn (1991, 1995, 2007). Domar (1944) shows that the faster the GDP grows, the lighter will be the burden of government debt. Consequently, if GDP growth rate exceeds the after-tax interest rate on government debts and thus the government can levy enough taxes to pay for interest on the debts and other expenditures, the debt will be sustainable. According to Domar, the sustainability of public debt should be tackled by increasing GDP (which can be achieved by expanding government spending occasionally) rather than by merely reducing the public debt. However, Domar's arguments are not applicable to a dynamically efficient stochastic economy, as shown in latter studies like Bohn (1995, 1998).

Barro (1974, 1979), re-examining the Ricardian equivalence theorem,[82] provides a theoretical explanation for the determinants of government deficits. Barro suggests that a government can temporarily increase deficits in the short-and-medium term so as to smooth

[82] Barro (1979, p 940) describes public debt neutrality as follows: "Shifts between debt and tax finance for a given amount of public expenditure would have no first-order effect on the real interest rate, volume of private investment, etc."

the tax rate over time and thus to minimize the distortionary effects of taxation. It follows that the level of taxes has to be determined by the government's IBC, which states that the present value of all government expenditures should be equal to the present value of all tax revenue over the entire period. Equivalently expressed, a government under a dynamically efficient economy should balance its budgets inter-temporally by arranging the present value of debts and the *discounted* sum of expected future surpluses to be equal over entire periods. As long as the government satisfies the IBC, the debt policy is sustainable, regardless of the existence of short-term deficit.

McCallum (1984) examines the theoretical validity of the 'monetarist hypothesis' that a constant, positive *per capita* budget deficit can be maintained permanently and without inflation if it is financed by the issue of bonds rather than money. McCallum shows that the validity of the hypothesis depends on the way the deficit is defined. If the deficit is defined *exclusive* of interest payments, the monetarist hypothesis is invalid — i.e., the permanent deficit cannot be financed solely with bonds. However, a constant positive deficit *inclusive* of interest payments can be permanently financed by bond sales. It is noteworthy that, owing to McCallum, most empirical studies have focused on the relation between government revenues and expenditure *inclusive* of interest payments, rather than expenditure *exclusive* of interest payments.

Bohn (1990) analyses the optimal structure of a government debt in a *stochastic, dynamically efficient economy* where individuals are risk averse. Bohn suggests that a government should issue state-contingent bonds to smooth tax rates over states of nature as well as over time to minimize tax distortion. Bohn (1995) also proves that in dynamically efficient economies such as the infinitely-lived agent model, government debt policy always has to satisfy an IBC, regardless of the level of the interest rate, since the IBC cannot be written in terms of expected fiscal variables discounted at a fixed interest rate. Thus, even if the interest rate on the government bonds is below the growth rate of the economy, the fiscal policy is sustainable only when the government satisfies the IBC, which depends on the probability distribution of fiscal variables across states of nature.

It is noteworthy that the aforementioned theoretical aspects of fiscal sustainability are all based on the government's IBC, which is equivalent to the satisfaction of the no-Ponzi condition in government behaviours. A violation of the no-Ponzi condition would imply that the fiscal debt would explode over time and cannot be sustained permanently; therefore fiscal policy must be changed in the future. Specifically, the fiscal debt is regarded as sustainable when the debt can be offset by expected future primary surpluses of equal present value; i.e., the discounted value of the debt should go to zero at the limit (no-Ponzi condition). Unless the no-Ponzi condition was assumed, any pattern of deficits would be sustainable by financing interest on debts through the additional issuance of debts. In a real and growing economy, a fiscal policy is assumed to be ultimately sustainable if it does not lead to an ever-increasing debt-to-GDP ratio. Thus, stationarity tests of the fiscal ratios to GDP are generally used for assessing fiscal sustainability. Now, we will begin from a single-period deterministic model in order to explain the aforementioned theoretical aspects and set up empirical specifications.

6.3.1.1 Single period budget constraint of a government

The single period budget constraint is described as the following equation (6.3.1) which may be naturally derived from the accounting identity:

(6.3.1) $GE_t + (1 + i_t)D_{t-1} = D_t + T_t$

where GE_t is a (nominal) *non-interest* government expenditure in period t; D_t is a gross stock of government debts at the end of period t; i_t is the one-period nominal rate of interest payable on the government debts issued in a previous period; T_t is the nominal tax revenue. The left-hand side of the equation indicates the total spending of the government while the right-hand side expresses the source of the funds. Since (6.3.1) can be rewritten as $GE_t - T_t + i_t D_{t-1} = \Delta D_t$, the equation states that total budget deficit *inclusive* of interest payments must be financed by new debt creation. (6.3.1) can be rewritten as (6.3.2):

$$(6.3.2)\ D_t = (1+i_t)D_{t-1} + GE_t - T_t = (1+i_t)D_{t-1} + PD_t$$

where $PD_t (= GE_t - T_t = -PS_t)$ is defined as a *primary* (or non-interest) deficit. It is assumed that the deficit is not money-financed by the CB since money-financing to reduce the deficit will ultimately induce high inflation, which is not tolerable to economic agents. Note that, in practice, CB's lending to government is strictly prohibited in most advanced countries. Hence the stock of public debts at time t (D_t) is the sum of pre-existing public debt(D_{t-1}) with its interest payment $(i_t D_{t-1})$ and primary budget deficits (PD_t). It is more advisable to rearrange the relevant variables in (6.3.2) as their ratios to GDP.[83] Dividing (6.3.2) by nominal GDP_t and rearranging it yield:

$$(6.3.3)\ \frac{D_t}{P_t Y_t} = \frac{(1+i_t)D_{t-1}}{P_t Y_t} + \frac{PD_t}{P_t Y_t} = \frac{(1+i_t)}{(1+\pi_t)(1+g_t)} \cdot \frac{D_{t-1}}{P_{t-1}Y_{t-1}} + \frac{PD_t}{P_t Y_t}$$

where nominal *GDP* is calculated by $P_t Y_t$ with P_t and Y_t being the GDP deflator and real GDP, respectively; $g_t = \frac{Y_t - Y_{t-1}}{Y_{t-1}}$ is a real GDP growth rate; $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ is an inflation rate. A simplified version of (6.3.3) is

[83] In this context, the countries under EMU are urged to comply with budgetary requirements which require all members to keep their debts and deficits below 60% and 3% of their nominal GDP, respectively.

(6.3.4) $d_t = \frac{(1+i_t)}{(1+\pi_t)(1+g_t)} \cdot d_{t-1} + pd_t = \frac{(1+r_t)}{(1+g_t)} \cdot d_{t-1} + pd_t$

where $d_t = \frac{D_t}{P_t Y_t}$ and $pd_t = \frac{PD_t}{P_t Y_t}$. (Hereafter a lowercase letter denotes the value scaled by GDP). When deriving (6.3.4), we use $(1+i_t) = (1+r_t)(1+\pi_t)$. Subtracting d_{t-1} from both sides of (6.3.4), we obtain:

(6.3.5) $\Delta d_t = \frac{(r_t - g_t)}{(1+g_t)} \cdot d_{t-1} + pd_t$

Equation (6.3.5) shows that debt-to-GDP ratio increases when (i) primary deficit to GDP ratio (pd_t) is larger; (ii) real interest rate (r_t) is higher; and (iii) real GDP growth rate (g_t) is lower. Note that if the economy grows fast with a low real interest rate, i.e., $r_t < g_t$, then a government could run a primary deficit ($pd_t > 0$) without increasing the debt-to-GDP ratio (i.e. $\Delta d_t = 0$). In this case, a permanent primary deficit may be possible and hence, frequent or considerable primary deficits may not indicate an unsustainable fiscal policy (Bohn 1998, p 960). In the opposite situation, where $r_t > g_t$, even the primary surplus ($pd_t < 0$) may not be enough for reversing the increasing debt-to-GDP ratio, so it may be crucial to maintain a sufficient level of primary surplus that keeps the debt-to-GDP ratio constant. Note that a stable debt-to-GDP ratio does not always guarantee fiscal sustainability, because unsustainable polices do not necessarily display an explosive debt-to-GDP ratio (Bohn 1998, p961)

6.3.1.2 Inter-temporal budget constraint (IBC) of a government in real terms

Suppose that a real interest rate is constant and positive; $r_{t+i} = r(> 0)$ *where i=1,…, n*. Rewrite the single period budget constraint (6.3.2) in real terms and take a conditional expectation of it. Then, solving forward for *t+1, t+2,t+3,* ---,∞ leads to the following IBC.

(6.3.6) $D_t = \sum_{n=1}^{\infty} \theta^n E_t PS_{t+n} + \theta^n E_t D_{t+n}$

where E_t =expectation operator at time *t*, $PS_t = T_t - GE_t$ and $\theta = 1/(1+\mathrm{r})$ is a discount factor. Equation (6.3.6) proposes that initial public debt (D_t) should be equal to the sum of the present values (hereafter PV) of expected future primary surpluses (*PS*) and the future debts. However, the PV of expected future debts ($\theta^n E_t D_{t+n}$) should be zero when $n \to \infty$. That is, following no-Ponzi (or transversality) condition (hereafter NPC) should be satisfied:

(6.3.7) $\lim_{n\to\infty} \theta^n E_t D_{t+n} = 0$: (NPC)

If $\lim_{n\to\infty} \theta^n E_t D_{t+n} > 0$, then the government refinances its debts by continuously issuing new bonds without eventually retiring them. The term, $\lim_{n\to\infty} \theta^n D_{t+n}$ is frequently named "bubble term" in many literatures. $\lim_{n\to\infty} \theta^n D_{t+n} > 0$ means that there will be a part of public debt not to be paid by governments but to be paid by debt holders. This situation renders the investors to doubt the government's payment and eventually not to buy bonds anymore. The NPC (6.3.7) eliminates the possibility of the government's financing by endlessly rolling over its debts. To put it differently, (6.3.7) implies that the sustainable fiscal policy requires the real supply of government bonds to grow no faster (on average) than the real interest rate (Hamilton and Flavin 1986, p 811). If the NPC is satisfied, (6.3.6) becomes:

(6.3.8) $D_t = \sum_{n=1}^{\infty} \theta^n E_t PS_{t+n}$: (IBC)

Equation (6.3.8) indicates the government IBC that current debt should be equal to the present value of the expected future primary surpluses.

6.3.1.3 IBC of a government under a growing economy

It is more useful to express the variables in the IBC in terms of their ratio to GDP. Under a constant interest rate and GDP growth rate (i.e., $r_{t+i} = r$ *and* $g_{t+i} = g$ *where i=1,…,n*), the IBC condition in terms of the ratio to GDP can be expressed as:

(6.3.9) $d_t = \sum_{n=1}^{\infty} \phi^n E_t ps_{t+n} + \lim_{n \to \infty} \phi^n E_t d_{t+n}$

where $ps_t = (T_t - GE_t)/GDP_t$, d_t=(D_t/GDP_t) and $\phi = \frac{1+g}{1+r}$. Equation (6.3.9) leads to the IBC (6.3.11) if and only if the NPC (6.3.10) is satisfied:

(6.3.10) $\lim_{n \to \infty} \phi^n E_t d_{t+n} = 0 \quad where \quad \phi = \frac{1+g}{1+r}$: (NPC)

(6.3.11) $d_t = \sum_{n=1}^{\infty} \phi^n E_t ps_{t+n}$: (IBC)

The NPC (6.3.10) indicates that the present value of expected future debt-GDP ratios should converge to zero at the limit, while the IBC (6.3.11) demonstrates that a sustainable fiscal policy requires that the present value of expected future primary surpluses relative to GDP should be equal to the current debt-to-GDP ratio (d_t). In the two equations, if d_t (initial debt)>0, the sustainability condition requires $r > g$ so d_{t+n}(future debt) as to stabilise (or converge to zero at the limit). Thus, satisfying $ps_{t+n} > 0$ (which ensures the ultimate liquidation of d_{t+n}) on the average − not in every period, will be enough for sustainability. In contrast, in a growing economy with low interest rate where $r < g$, the Ponzi scheme generally corresponds to the constant debt-to-GDP ratio over time.[84] In this case, the government does not need to run primary surplus, which implies that the government debt policy may not be restricted by the IBC. Hence, theoretical models justifying (6.3.10) do not provide an appropriate framework for empirical study (Bohn 1991 p 3).

6.3.2 Empirical studies on the sustainability of government debts

6.3.2.1 Standard stationarity test

As shown in the previous section, IBC imposes a NPC which should be held under dynamically efficient economies. While early empirical studies were mostly conducted by directly checking the NPC (6.3.10) (Hamilton and Flavin 1986, Wilcox 1989), most of the later studies have focused on testing the IBC (6.3.11), either by examining the univariate properties of debts (d_t) or by testing the presence of a cointegration relationship between expenditures (GE_t) and tax revenues (T_t) (Trehan and Walsh 1988, 1991; Haug 1991, Smith and Zin 1991, Martin 2000, Bohn 1990, 1995, 2004, 2007; see Appendix 6.1 for a summary of the key studies). Note that the satisfaction of the NPC is equivalent to the fulfilment of the sustainability condition. Econometrically, an unbound increase in fiscal debts (d_{t+n})

[84] Note that, as Domar (1944) suggested, in a dynamically *inefficient* economy with $r < g$, the government might run Ponzi-game permanently. Imposing $d_t = d_{t+n}$ (i.e., debt-to-GDP ratio is constant), we can rearrange (6.3.9) as $d_t(1-\phi^n) = \phi^n(\sum_{n=1}^{\infty} ps_{t+n})$. The left-hand side is negative, since $d_t > 0$ and $(1-\phi^n) < 0$. Thus, the right-hand-side (i.e. primary surplus) should be negative for the equality to hold. This implies that a government could run a permanent primary deficit with the debt-to-GDP ratio holding constant or continuously falling (Romer 2004, pp. 563-564). Therefore, the NPC (6.3.10) is not an absolute sustainability condition applicable to all economies.

corresponds to either a non-stationary primary deficit (PD_{t+n}) or absence of a cointegration relationship between tax revenues (T_{t+n}) and (interest-inclusive) expenditures ($GE_t + i_t D_{t-1}$). (Tanner and Liu 1994, p.516)

Later, structural breaks in the cointegrating relationship were examined by Hakkio and Rush (1991a), who assumed the break point as exogenously given; and by Haug (1995), Quintos (1995) and Martin (2000), who assumed the breaks as endogenously determined.

Bohn (1995, 1998 and 2007) and Martin (2000) focus on the stochastic properties of debt-relevant series and point out the limitations in the sustainability test based on the stationarity test. Sarno (2001) and Bajo-Rubio et al. (2006) are interested in the nonlinear process of the debt-to-GDP ratio rather than in testing the fiscal sustainability itself. In addition, panel data analyses have been frequently used to test the fiscal sustainability of the countries within similar economic environment (see Afonso and Rault 2007). Overall, the empirical evidence on the US fiscal debt is mixed, depending on the definition of fiscal sustainability and the selection of sample periods.

In their seminal study, Hamilton and Flavin (1986) firstly test the null hypothesis of the NPC (i.e. $\lim_{n\to\infty} \theta^n E_t D_{t+n} = 0$) against the alternative of the existence of a speculative term ($\lim_{n\to\infty} \theta^n E_t D_{t+n} > 0$). To do this, they check the significance of the exponential terms in the equation, $D_t = A_0\theta^{-n} + \sum_{n=1}^{\infty} \theta^n E_t PS_{t+n} + \varepsilon_t$ where $\theta = 1/(1+r)$ and ε_t = white noise errors. If the coefficient A_0 is insignificant (i.e., $A_0 = 0$), equivalently if $D_t \sim I(0)$ and $\sum_{n=1}^{\infty} \theta^n E_t PS_{t+n} \sim I(0)$, the debt policy will be sustainable (i.e., $\lim_{n\to\infty} \theta^n E_t D_{t+n} = 0$) (Hamilton and Flavin 1986, p815). Intuitively, this sustainability condition requires that primary surpluses fluctuate with a certain positive mean for the entire life of the economy. Using annual US data in 1962-84, they conclude that the fiscal deficit was sustainable. However, their study has several limitations. First, they assume nonstochastic fluctuations in real interest rates. The real interest rates are assumed *ex post* constant and positive (i.e. $r_{t+n}=r>0$). Second, Hamilton and Flavin argue that the *undiscounted* debt (D_t) should be I(0) for the present value of expected future primary surpluses to be stationary. Thus, their test method cannot be used when $D_t \sim I(1)$. Third, they do not consider the existence of structural breaks in debt policy.

Wilcox (1989) extends Hamilton and Flavin (1986) by allowing for stochastic real interest rates(i.e. $r_{t+i} \sim (r, \sigma^2)$ where $i=1,\ldots,n,\ r>0$) and possible nonstationarity of the undiscounted debt series(D_t). He argues that even if *undiscounted* D_t follows I(1), the IBC could be satisfied, because the nonstationarity of D_t might just reflect the fact that deviations of the debts from the future primary surpluses persist over a longer period, not permanently. Wilcox suggests a different test method: the IBC holds if and only if the *discounted* D_t are I(0) with a zero unconditional mean. Wilcox calculates the realised values of *discounted* debts, $D_{t+n} / \prod_{j=0}^{n-1}(1+r_{t+j})$ for fixed *t=1960* and *j=0...24*, with *r* being *ex post* real returns on the debts. Using Hamilton and Flavin's (1986) data, he finds a significant structural change in US fiscal policy in 1974, and concludes that the IBC was satisfied before 1974 but not afterwards.

Later studies have used alternative tests based on a cointegration relationship between expenditures and revenues (Trehan and Walsh 1988, 1991; Haug 1991, 1995; Hakkio and Rush 1991a, Payne 1997, Baharumshah and Lau 2007). When total expenditures (TS) and tax revenues (*T*) follow (1), respectively, but their linear combination is I(0) and thus revenues do not drift too far away from expenditures, IBC would be satisfied. Trehan and Walsh (1988, 1991) suggest two stationarity tests on total deficit and primary deficit. Technically, the fulfilment of the IBC can be proved by verifying either of the following two conditions: (i) total deficit (TD_t) series are stationary while debt (D_t) series are integrated of the order one, i.e. $\Delta D_t (= TD_t = TS_t - T_t = (rD_{t-1} + GE_t - T_t)) \sim I(0)$ and $D_t \sim I(1)$, (ii) $TS_t (= rD_{t-1} + GE_t) \sim I(1)$ and $T_t \sim I(1)$ but the two series are cointegrated with a cointegration vector of (1,-1). This condition implies that, although fiscal debts consistently increase, fiscal policy could be sustainable if government expenditures and revenues follow a certain long-term pattern. This is because the government can ensure sustainability by reacting to the increase in debts through the adjustment of its expenditures or revenues within a specific range. Using US annual data for 1890-1986 and also Hamilton and Flavin's (1986) data, Trehan and Walsh (1998, 1991) conclude that the IBC has not been violated.

Hakkio and Rush (1991a) extend Trehan and Walsh (1988, 1991)'s approach. Their model is basically similar to Trehan and Walsh (1991) in that if $T_t \sim I(1)$ and $TS_t \sim I(1)$, and the two series are cointegrated with the vector of (1, -1),[85] the fiscal policy may be sustainable. But their study is different in three points: (i) they allow for stochastic and stationary real interest rates (i.e., $r_{t+n} \sim (r;\ \sigma^2)$, $r>0$); (ii) they consider the growing economy by normalizing revenues and expenditures by GDP and population; and (iii) they impose an exogenous structural break. Hakkio and Rush, using quarterly data for 1950-1988, find that no cointegration between T and TS existed from the mid-1970s, particularly in the 1980s. It is interpreted that the US fiscal deficit became a serious problem after the advent of the Reagan administration.

Quintos (1995) firstly introduces a *weak* sustainability condition. While a *strong*

[85] Consider the specific empirical form: all variables are scaled by GDP, $T_t = \beta \cdot TS_t + \varepsilon_t$. If $TS_t \sim I(1)$, $T_t \sim I(1)$, and $T_t - \beta \cdot TS_t = \varepsilon_t \sim I(0)$, then TS_t, and T_t are cointegrated with a cointegration vector $(1, -\beta)$. Although Hakkio and Rush (1991) demonstrate that $0<\beta\leq 1$ is a sufficient condition for sustainability, they consider only $\beta=1$ as a sustainability condition, because $\beta<1$ indicates that, at the limit, the undiscounted debts will reach infinity and make the debt unbounded, which gives an incentive for the government to default on its debts. However, later studies such as Quintos (1995) prove that the debt can be sustainable under the condition of $0<\beta<1$.

condition corresponds to the sustainability condition of Hamilton and Flavin (1986), Trehan and Walsh (1988) and Hakkio and Rush (1991), the *weak* condition allows a bubble term to go to zero at a rate slower than the stronger version. Technically, the *weak* condition is satisfied when $D_t \sim I(2)$ and ΔD_t $(=TS_t-T_t=TD_t=rD_{t-1}+GE_t-T_t) \sim$ I(1) (Quintos 1995, pp. 409-410). Thus, the weak condition requires that *T* and *TS* are I(1) and cointegrated with a cointegrating vector of $(1, -\beta)$ where $0<\beta<1$. In other words, when the total deficit process can be integrated or even mildly explosive, the deficit will still be sustainable, as long as the growth rate of the debt does not exceed the growth rate of the economy. He finds that US fiscal debt was sustainable despite the non-existence of cointegration between expenditures and tax revenues in the 1980s - i.e., the failure of the 'strong 'condition - since the debt process satisfied the 'weak' sustainability condition. Bergman (2001) agrees with Quintos (1995) on the point that he distinguishes the weak and strong forms of sustainability.

6.3.2.2 Estimation of fiscal reaction function (Bohn test)

Bohn (1995, 1998) questions the validity of the traditional stationary tests that involve unit root test of debts and cointegration tests between expenditures and revenues, since they are all based on strong assumptions about discount rates and stochastic process of future fiscal variables, which are difficult to obtain from a single set of observed time series. Bohn (1998, pp. 949-962) particularly notices several limitations of the stationarity-based tests: (i) The tests are highly sensitive to the choice of discount rates; (ii) The tests frequently cannot reject a unit root in debt-GDP ratio even if debt-GDP ratio is declining; (iii) The tests are not connected with the government's corrective actions to the debt-GDP ratio, because the debt-GDP ratio is bounced around by various shocks such as temporary business cycle.

In particular, traditional tests explicitly or implicitly assume a real interest rate on government debt above average growth rate, i.e. *r>g* in the equation (6.3.10). However, as Bohn (1991, p3) comments, dynamic efficiency and *r<g* are both key characteristics of historical US data. In this case, we do not use (6.3.10) as empirical framework for empirical analysis.[86] In addition, cointegration-based tests do not distinguish the source of sustainability. When cointegration exists, the cointegration may stem either from policy responses or just luck, i.e., the temporary business cycle (which affects the value of fiscal variables but is not controlled by the government). In this regard, Bohn (2007, pp. 1840-1845) derives the following three propositions associated with the properties of fiscal variables and sustainability conditions:

(i) *If* $D_t \sim I(m)$ *for any finite m≥0, then* $\lim_{n\to\infty} \theta^n D_{t+n} = 0$ *and* D_t , T_t *and* TS_t *satisfy the IBC. In words, low order of integration of debt series, for example,* $D_t \sim I(0)$, *I(1) or I(2) is not necessary for the IBC to be satisfied.*

(ii) *If* $TS_t \sim I(m_{TS})$ *and* $T_t \sim I(m_T)$, *possibly with* $m_{TS} \neq m_T$ *and not necessarily cointegrated,* $D_t \sim I(m)$ *with* $m \le \max(m_{TS}, m_T) + 1$, *so NPC and IBC hold. In words, a cointegration between* TS_t *and* T_t *is not a necessary condition for the fulfilment of the IBC.*

(iii) *If* D_t *and* PS_t *follow the error-correction specification,* $PS_t - \alpha D_t = \varepsilon_t \sim I(m)$ *for some* $\alpha \in (0, 1+r]$ *where r is a constant interest rate, then* D_t *satisfies the IBC. In words, if a government responds positively to the debt (*$\alpha > 0$*), the IBC holds, and this is not affected if we allowed for the unit root property of the debts.*

Bohn argues that the standard stationarity or cointegration tests tend to prefer the conclusion of non-sustainability because the cyclical or temporary variations in fiscal variables are not captured by the standard cointegration test. He suggests a different test based

[86] Bohn's definition of the IBC is more general than the conventional concept explained in the section 6.3.1, because Bohn considers risk-averse individuals. Technically, Bohn's IBC and NPC may be expressed as: $d_i = \sum_{n=1}^{\infty} E_i(u_{t,t+n} \cdot ps_{t+n})$: IBC, $\lim_{n\to\infty} E_t\left(u_{t,t+n} \cdot d_{t+n}\right) = 0$: NPC, where $u_{t,t+n}$ is marginal rate of substitution between *t* and *t+n*. Note that the discount rate is not just real interest rate. The discount rate "depends on the probability distribution of debt across state of nature and on the correlation of debt with the marginal rate of substitution"(Bohn 1991 p4). In case of risk neutral, Bohn's IBC reduce to the IBC (6.3.11).

on a government's corrective reaction of adjusting primary surplus in response to changes in debt. If the government responds to debts, such responses would implement an error-correction-type mechanism that stabilises debts or at least produces cointegration between debts and primary surplus (Bohn 2004 pp. 9-10). Bohn argues that the government response to an increase in debt-to-GDP ratio (by raising the primary surplus) can be obscured by wartime spending or by cyclical fluctuations. If the fluctuations in spending and in aggregate income are corrected, fiscal sustainability will be found more than the previous stationarity tests suggested (Bohn 1998, p 962). The simplest testable form based on Bohn is:

(6.3.12) $ps_t = \rho \cdot d_t + \eta_t = \rho \cdot d_t + A_{it}x_{it} + \varepsilon_{t\,t}, \ \eta_t = A_{it}x_{it} + \varepsilon_t, \ \varepsilon_t \sim N(\mu, \sigma^2)$

where $ps_t = t_t - ge_t$, $t_t = T_t/GDP_t$, $ge_t = GE_t/GDP_t$, $d_t = D_t/GDP_t$, x_{it} is a control vector of non-debt determinants that cyclically influence the variations in the primary surplus. He shows that the coefficient ρ can be interpreted as an alternative test for fiscal sustainability. $\rho > 0$ means that the government takes action to counteract the changes in debts, so that the fiscal policy may be sustainable. The regression (6.3.12) indicates that, for example, if $d_t \sim I(1)$ and $ps_t \sim I(1)$ while $\eta_t \sim I(0)$, a cointegration regression is valid without additionally modelling the η_t. If $d_t \sim I(0)$ and $ps_t \sim I(0)$, simple OLS can be applied.

In the Bohn test, it is crucial to find the appropriate non-debt control vector (x_{it}), because of omitted variable problem. To find the appropriate x_{it}, Bohn utilises Barro's tax smoothing model (Bohn 1998, pp. 951-952). The tax smoothing model considers a government optimisation that minimises the cost of taxation by smoothing marginal tax rates over time. The key feature of this theory is that the tax rate should be dependent on noncyclical (permanent) fiscal expenditures and debt levels. Bohn (1998, 2004) uses two control variables extracted from Barro (1986): the level of temporary government spending (*GVAR*) and a business cycle indicator (*YVAR*).[87] As seen from (6.3.12), Bohn test does not require any assumption about interest rates, so that it does not matter whether discount rate is above the growth rate or not.

It is noteworthy that Bohn (2007) does not deny the validity of the stationarity-based sustainability test. Rather, he argues that stationarity (or cointegration) are not necessary but sufficient conditions, because stationarity-based tests do not consider the possibility of higher order integration in the debt-related series. Correspondingly, Bohn argues that reaction function-based tests are more appropriate for testing sustainability. Bohn test has particular explanatory power for large deficits and debt accumulation during war time.

As Bohn (1995, 1998) points out significant limits in the standard tests based on the assumption of the linearity in debt-related series, several studies address the non-linear property of debt dynamics (Sarno 2001, Bajo-Rubio et al. 2006). They argue that the linearity assumption is not plausible because the adjustments toward the long-run equilibrium of debt-to-GDP ratio appear to occur in discontinuous or nonconstant ways. For example, fiscal policies may have nonlinear effects in the sense that both the size and the sign of the response of macro variables to fiscal policy could be different depending on the type of policy actions and the magnitude of primary deficits at the time when the policies are enacted.

Bohn test, however, has limits in explaining why fiscal debts in developed countries continuously accumulated from the 1970s to the early 1990s and how changes in relevant fiscal variables influence each other in the relatively short term perspective(Persson and Tabellini 2000). The latter point implies that Bohn does not reflect the fact that fiscal deficits are likely to be affected by changes in the political system and decision making process.

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[87] GVAR and YVAR are measured as $GAVR_t = (GE_t - GE_t^*)/y_t$ and $YAVR_t = -\{(y_t - y_t^*)/y_t\}\{GE_t^*/y_t^*\}$, respectively, where GE_t =government expenditure, y = GDP and * indicates the trend of the series.

6.4 Methodologies and data

As discussed in the literature review, the standard stationarity tests and Bohn test could complement each other, because the choice of test depends in most cases on the availability of data and properties of the relevant time series. In this section, both methods will be used to obtain more robust estimation results. After deriving the IBC for a CB, we first adapt the standard stationarity tests for the sustainability of MSB-dependent sterilisation policies. Then, we use modified Bohn's methodology.

6.4.1 Derivation of intertemporal budget constraints of a central bank

The single-period budget constraint of the CB can be expressed as (6.4.1), which is derived from its accounting identity. All variables are real terms. We assume that the CB does not money-finance its budget deficits, because printing money induces *instant* inflation, and thus the monetary base is provided only to adjust money demand for controlling interest rates.

(6.4.1) $\Delta MSB_t + \Delta H_t + r_t^* NA_{t-1} = r_t MSB_{t-1} + \Delta NA_t$

where MSB_t is the stock of MSB at the end of period t; NA_t is the amount of net assets held by the CB at the end of period t, and thus ΔNA_t is the expenditure on purchasing net assets in period t; H_t is the monetary base at the end of period t, and thus ΔH_t is the CB's seigniorage revenue in period *t*; r_t^* is the rate of return on net assets (mostly foreign reserves) in period *t*; r_t is the rate of return paid to the MSB in period *t*. The right-hand side of the equation indicates the CB's total expenditures while the left-hand side implies the funding source for the expenditures. (6.4.1) simply indicates that the CB purchases foreign assets and pays the interests and principal of the MSBs through financing from newly issued MSBs, newly printed money or interest received from its assets. Rewriting (6.4.1) shows the one-period dynamics of the MSBs in discrete time: $\Delta MSB_t = r_t MSB_{t-1} + \Delta NA_t - \Delta H_t - r_t^* NA_{t-1}$. The increase in the stock of MSBs in time *t* stems from the interest payments on the MSB issued in the previous period, the increase in asset purchases, the decrease in the monetary base or decrease in interest income from net assets.

To transform the above budget identity into budget constraint, we assume a constant interest rate and GDP growth rate (i.e., $r_{t+i}=r$, $r^*_{t+i}=r^*$ and $g_{t+i}=g$ where $i=1,\ldots,n$). Then, rearranging (6.4.1) and solving forward leads to the following IBC:

$$(6.4.2)\ MSB_t = \sum_{i=1}^{n} \theta^n E_t (TR_{t+i} - \Delta NA_{t+i}) + \theta^n E_t MSB_{t+i}$$

where $\theta = \frac{1}{1+r}$, $TR_t = \Delta H_t + r^* NA_{t-1}$ = total revenue (*TR*) which consists of seigniorage and interest income from net assets and E_t = expectation operator. Ruling out Ponzi schemes, ($\lim_{n\to\infty} \theta^n MSB_n = 0$), we can simplify (6.4.2) as:

$$(6.4.3)\ MSB_t = \sum_{n=1}^{\infty} \theta^n (E_t PS_{t+n})$$

where $PS_t = \Delta H_t + r^* NA_{t-1} - \Delta NA_t$ is the primary budget surplus. Equation (6.4.3) indicates that the current MSB-dependent sterilisation policy would be sustainable when the current stock of the MSB outstanding is equal to the present value of the expected future primary surpluses. Correspondingly, the CB will have to ensure future primary surpluses whose present value adds up to the current value of the MSBs by increasing future seigniorage (ΔH_{t+n}), by increasing future interest income from assets ($r^* NA_{t-1+n}$) or by reducing future purchases of assets (ΔNA_{t+n}) so that its sterilisation can be permanently sustainable. Note that (6.4.3) can be easily transformed into the equation in terms of the ratio to GDP. In this case, the discount factor will be $\phi = \frac{1+g}{1+r}$ rather than $\theta = \frac{1}{1+r}$.

Equation (6.4.3) provides several implications concerning MSB-dependent sterilisation policy. The CB cannot continue a policy that does not satisfy the IBC, because it will eventually lead to the explosion of the MSBs. The current stock of MSBs must eventually be financed by future seigniorage or interest incomes from net assets with the current sterilisation policy unchanged. In other words, current sterilisation policies should eventually be replaced in the future by the policy of increasing money supply or by raising the rate of returns on assets. However, increasing future money supply in accordance with the developments of the MSB may not be feasible, owing to inflation risk without the money demand increasing.

Allowing somewhat higher inflation than now (equivalently allowing policy interest rate deviation from target) will reduce the necessity of sterilisation and thus contribute to decreasing the stock of MSB. The option of raising the rate of returns on foreign reserves appears not practical either, because most CBs in small open economies give priority to the precautionary demands, i.e., safety or liquidity – not profitability – of foreign reserve (Aizenman et al. 2007). Hence, the most feasible option is to reduce the purchase of foreign reserves, to reduce the degree of sterilisation or to find alternative sterilisation tools to decrease the sterilisation cost.

It is noteworthy that MSB-dependent sterilisations would not get rid of inflation permanently but allow the CB to postpone imminent inflation into the future. Under the assumption of a constant increase in net assets, the substitution of a MSB for a current money increase does not influence permanent money that is the weighted average of current money and expected future money. For a given path of the CB's purchase of assets, a current MSB-financed decrease in monetary base leads to higher future money increases that have the same present value as the initial decrease. If the policy does not affect permanent money, it does not influence inflation, interest and income. Therefore, unbounded sterilised interventions by issuing MSBs eventually lead to an increase in future money supply and higher inflation. This argument is built on Barro's (1989) Ricardian equivalence of government debt applied to the CB's debt

6.4.2 Test for the long-term sustainability of MSB-dependent policy

In line with stationary tests for fiscal debts, the crucial question about the sustainability of the MSB-dependent policy is whether $\lim_{n\to\infty} \theta_n MSB_n = 0$ or whether the CB's total revenues ($\Delta H_t + r^* NA_{t-1}$), non-interest expenditures (ΔNA_t) or their linear combination follows the stationary process. The alternative is associated with the CB's reaction function, which can be set up by modifying Bohn (1998, 2007). With regard to Bohn test, the key question is whether the CB responds to increases in the MSB by increasing its primary budget surplus. These two alternative methodologies complement each other, so we can use both approaches to obtain more robust results.

6.4.2.1 Standard stationarity test

To obtain a testable form, first rearranging the budget identity (6.4.1) yields:

(6.4.4) $\Delta MSB_t = (\Delta NA_t + r_t MSB_{t-1}) - (\Delta H_t + r_t^* NA_{t-1}) = TS_t - TR_t$

where $TS_t = \Delta NA_t + r_t\ MSB_{t-1}$ is the total spending (inclusive of interest payments on the MSB) and $TR_t = \Delta H_t + r_t^* NA_{t-1}$ is the total revenue. Here, we need some assumptions on r_t to transform (6.4.4) into a budget constraint. Assuming that r_t and r_t^* are any stochastic stationary process with unconditional mean equal to *r(>0)* and r^* *(>0)* respectively,[88] we can rewrite (6.4.4) as:

(6.4.5) $MSB_t - (1+r)MSB_{t-1} = AS_t - TR_t$

where $AS_t = \Delta NA_t + (r_t - r)MSB_{t-1}$ is the CB's *adjusted* total spending with interest rates taken around a zero mean. Solving (6.4.5) forward leads to:

(6.4.6) $MSB_{t-1} = \sum_{i=1}^{\infty} \theta^{i+1} E_t(TR_{t+i} - AS_{t+i}) + \lim_{i\to\infty} \theta^{i+1} E_t MSB_{t+i}$ where $\theta = \left(\frac{1}{1+r}\right)$

Applying the difference operator in (6.4.6) and using (6.4.4), we can rewrite (6.4.6) as:

(6.4.7) $TS_t - TR_t = \sum_{i=0}^{\infty} \theta^{i+1} E_t(\Delta TR_{t+i} - \Delta AS_{t+i}) + \lim_{i\to\infty} \theta^{i+1} E_t \Delta MSB_{t+i}$

Note that the left-hand side of the equation (6.4.7) includes the CB's total spending that includes not only purchases of assets but also interest payments on the MSBs issued previously. So the left-hand side ($TS_t - TR_t$) can be named as a *total budget deficit (TD)* which contrasts with a *primary budget deficit (PD)* that excludes interest payments. Again, the NPC indicates that:

[88]That is, the interest rate is a stationary stochastic process with a positive mean: i.e. $r_t \sim (r, \sigma_r^2)$ $r^*_t \sim (r^*, \sigma_{r^*}^2)$, and $r>0$, $r^*>0$. This assumption is required for interest payments $(r_t - r)MSB_{t-1}$ to have similar properties of ΔNA_t in (6.4.5) and broadly accepted by many studies such as Hakkio and Rush (1991a), Quintos (1995), Payne (1997), Afonso and Rault (2007), and Baharumshah and Lau (2007), etc.

(6.4.8) $\lim_{i\to\infty}\theta^{i+1}E_t\Delta MSB_{t+i}=0$

(6.4.9) $TS_t - TR_t = \sum_{i=0}^{\infty}\theta^{i+1}E_t(\Delta TR_{t+i} - \Delta AS_{t+i})$

To test the sustainability of the MSB-dependent sterilisation policy, we can use either (6.4.8) for testing the stationarity of ΔMSB_{t+i} or (6.4.9) for testing the cointegration between two series TS_t and TR_t . For instance, assuming that both TR_t and AS_t are following a random walk with drift: $TR_t=\alpha_1+TR_{t-1}+\varepsilon_{1t}$ and $AS_t=\alpha_2+AS_{t-1}+\varepsilon_{2t}$, then equation (6.4.9) can be rewritten as:

(6.4.10) $TS_t=\alpha+TR_t+\lim_{i\to\infty}\theta^{i+1}E_t\Delta MSB_{t+i}+\varepsilon_t$

where $\alpha=\sum_{i=0}^{\infty}\theta^{i-1}(\alpha_1-\alpha_2)=\frac{1+r}{r}(\alpha_1-\alpha_2)$ and $\varepsilon_t=\sum_{i=0}^{\infty}\theta^{i-1}(\varepsilon_{1t}-\varepsilon_{2t})=\frac{1+r}{r}(\varepsilon_{1t}-\varepsilon_{2t})$.

Assume a NPC (i.e, $\lim_{i\to\infty}\theta^{i+1}E_t\Delta MSB_{t+i}=0$). Then, if the variables in the right-hand side of (6.4.10) are stationary, for (6.4.10) to hold, the left-hand side variable must be also stationary. Since TS_t and TR_t are I(1), these two variables must be cointegrated. Consequently, the sustainability tests include following cointegration regression:

(6.4.11) $TR_t=\alpha+\beta\cdot TS_t+\varepsilon_t$

where $TS_t=\Delta NA_t+rMSB_{t-1}$ and $TR_t=\Delta H_t+r^*NA_{t-1}$. Equation (6.4.11) implies that a sustainable policy requires the existence of a stable long-run relationship between total spending (=the sum of the asset purchase and interest payments on the MSBs) and total revenue (= the sum of seigniorage and interest incomes from net assets).

6.4.2.2 Modification of Bohn's methodology

Modifying Bohn (1998, 2007), we set up a simple reaction function to describe the CB's sterilisation policy and investigate whether the CB responds to increases in the MSB-to-GDP ratio.

(6.4.12) $ps_t = \rho \cdot \Delta msb_{t-1} + \eta_t = \rho \cdot \Delta msb_{t-1} + A_{it}x_{it} + \varepsilon_t$

where $ps_t = (\Delta H_t + r_t^* NA_{t-1} - \Delta NA_t)/GDP_t$ is the ratio of primary surplus to GDP; $\Delta mab_t = \Delta MSB_t / GDP_t$; x_{it} is a vector of determinants other than MSBs that influence the variations in ps_t such as cyclical components of the CB's budget; all variables are real; $\eta_t = A_{it}x_{it} + \varepsilon_t$; and ε_t is an i.i.d error. Equation (6.4.12) indicates that if MSB increases, a sustainable policy should be characterized by the increase in the primary surplus, accomplished by increasing money demand ($\Delta H \uparrow$), reducing purchases of net assets ($\Delta NA \downarrow$) or raising the rate of return on foreign reserves ($r_t^* \uparrow$). Finding a positive and sufficiently large $\hat{\rho}$ could be interpreted as evidence of the long-run sustainability of the sterilisation policy. Note that the decrease in the purchase of foreign assets can be accomplished mainly by fewer FX interventions, because most of the increases in NA have been incurred by the increase in NFAs (see Figure 6.6 in the next section).

The detailed specifications of regression (6.4.12) are as follows. We use Δmsb_{t-1} instead of Δmsb_t, msb_t or msb_{t-1}, because the BOK's MSB issuance quota is normally made one quarter in advance by Monetary Policy Committee, because policy makers are likely to be forced to care more about the amount of the MSB increase during the previous quarter than about its level itself and because not using a contemporaneous variable enables us to simplify our analysis by avoiding a simultaneity problem between ps_t and Δmsb_t. Regression (6.4.12) indicates that if Δmsb_{t-1} and ps_t are both non-stationary while $\eta_t \sim I(0)$, we can use cointegration analysis between two variables for the stationarity test without additionally modelling the η_t. However, if $\Delta msb_t \sim I(0)$ and $ps_t \sim I(0)$, we use simple OLS with additional control variables (x_{it}).

6.4.2.3 Sequence of sustainability test for MSB-dependent policy

Figure 6.3 illustrates the sequential procedures for testing MSB-dependent sterilisation policy. First, we perform unit root tests for the levels, differences and their ratios to GDP of the following series: discounted and undiscounted stock of MSBs, total revenues, changes in net asset purchases, total spending,[89] primary surplus and total deficit. Calculating the total spending of the BOK (i.e. $TS_t = r_t MSB_{t-1} + \Delta NA_t$), we use a one-year rate of return on MSBs since the average maturities of the MSBs outstanding in the 2000-2009 was approximately 11 months. Note that when TS_t and TR_t are not integrated to the same order, we first have to depend on the results of the unit root tests for MSBs. That is, the CB's sterilisation policy is assumed to be sustainable: (i) if $MSB_t \sim I(0)$ and $\theta^n\left(\sum_{n=1}^{\infty} PS_{t+n}\right) \sim I(0)$; or alternatively (ii) if $\theta^n \sum_{n=0}^{\infty} MSB_{t+n} \sim \mathrm{I}(0)$ with a zero unconditional mean.

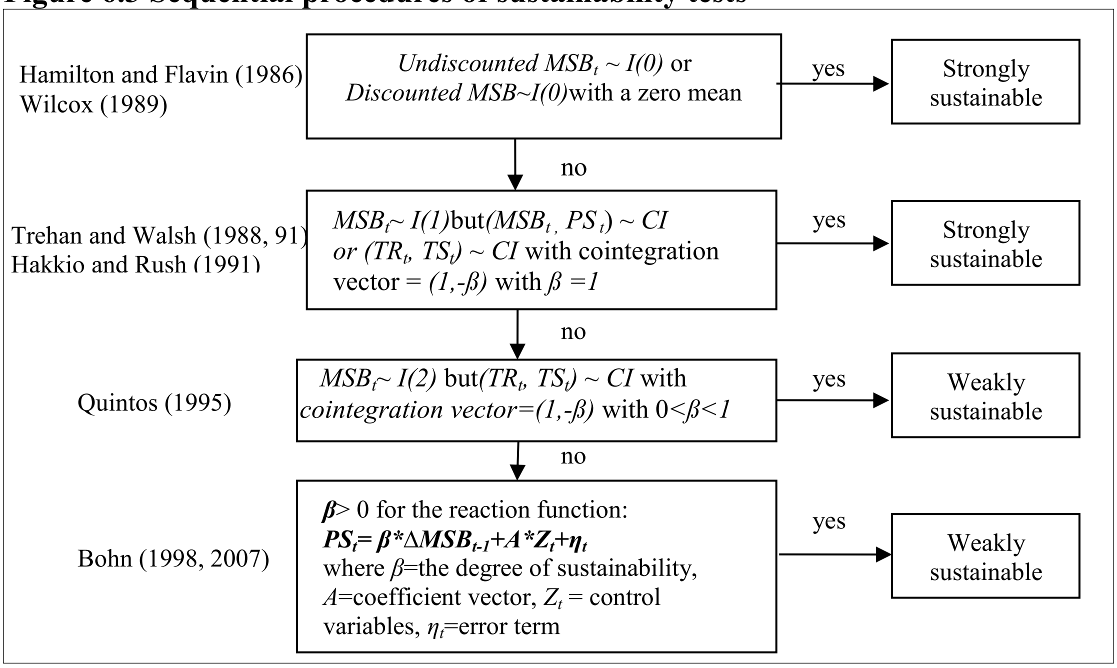
Second, if TR_t and TS_t or alternately $(tr_t = TR_t / GDP_t)$ and $(ts_t = TS_t / GDP_t)$ are integrated of order 1 at most, we run the cointegration regression given by (6.4.11). When TS_t and TR_t are cointegrated with the cointegration vector $(1, -\beta)$, the CB's current

[89] Note that we apply a zero interest rate in calculating the interest income from the negative value of NDAs. Negative NDA indicates that the BOK has more domestic liabilities (most of which are bank reserves) than domestic assets. Since the BOK does not pay interest on bank reserves, the assumption of a zero interest rate on negative NDAs is acceptable.

sterilisation is: (i) *"strongly"* sustainable if $\beta = 1$; (ii) *"weakly"* sustainable if $0 < \beta < 1$ and (iii) unsustainable if $\beta \leq 0$ (Martin 2000, Quintos 1995). The case of $\beta > 1$ does not need to be considered because it implies that the CB's revenue is growing at the rate faster than total expenditures – the CB runs a budget surplus.

A *strong* sustainability means that the IBC holds and, at the time, both the undiscounted MSB series and the primary surplus of the CB follow the *I(0)* process. It also leads to stationarity both in total budget deficits $(TD_t = TS_t - TR_t)$ and in ΔMSB_t owing to (6.4.4): $\Delta MSB_t = TS_t - TR_t$. A w*eak* sustainability indicates that the IBC holds, but with MSBs increasing at a rate which is less than the GDP growth rate. The sterilisations are *unsustainable* when MSBs are exploding at a rate which is equal to or faster than the GDP growth rate. According to Bohn, however, even if MSBs are growing faster than GDP, MSB could be sustainable when CBs adjust their primary surplus in response to ΔMSB.

Figure 6.3 Sequential procedures of sustainability tests



Notes: 1. All variables are real in volume or their ratio to GDP.
2. CI indicates cointegration.

6.4.3 Consolidated budget constraints of government and central bank

If a CB cannot repay the principal and interest on the MBS, the government should provide financial support to the CB by increasing taxation. Thus, we need to extend the analysis of the sustainability by combining the B/S of the two authorities. Rewriting the single period budget constraints (6.3.1) and (6.4.1) leads to (6.4.13) and (6.4.14):

(6.4.13) $\Delta D_t + T_t = r_t D_{t-1} + GE_t$: Government

(6.4.14) $\Delta MSB_t + \Delta H_t + r_t^* NA_{t-1} = r_t MSB_{t-1} + \Delta NA_t$: CB

For simplicity, we assume that interest rates applied to government bonds and MSBs are same. Combining (6.4.13) and (6.4.14) leads to a single-period budget constraint of *consolidated* government:

(6.4.15) $T_t + \Delta H_t + \Delta D_t + \Delta MSB_t + r_t^* NA_{t-1} = GE_t + \Delta NA_t + r_t (D_{t-1} + MSB_{t-1})$

Following the same procedure as in the previous sections, the IBC of the *consolidated* government is as follows:

(6.4.16) $(d_t + msb_t) = \phi^n E_t \left(\sum_{n=1}^{\infty} cps_{t+n} \right) + \lim_{n \to \infty} \phi^n E_t (d_{t+n} + msb_{t+n})$

where $\phi = \dfrac{1+g}{1+r}$ (g: growth rate, r: real interest rate)

$cps_t = (TR_t + \Delta H_t + r_t^* NA_{t-1} - GE_t - \Delta NA_t) / GDP_t$: Consolidated primary surplus

$d_t = D_t / GDP_t$: Government debt scaled by GDP

$msb_t = MSB_t / GDP_t$: MSB scaled by GDP

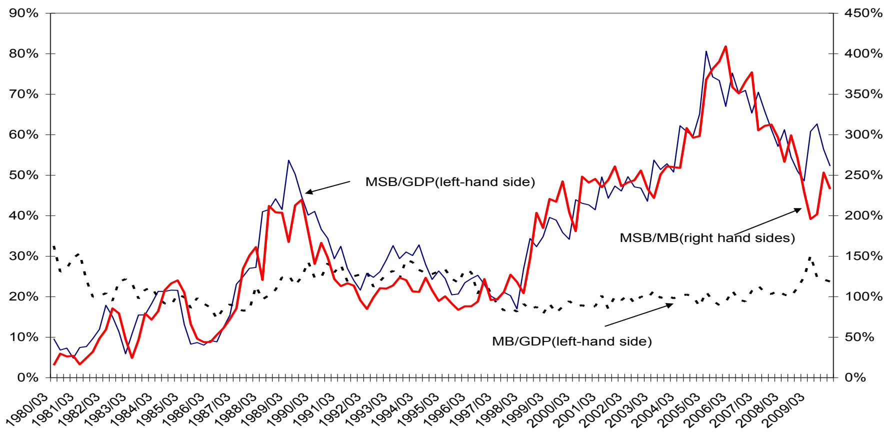
The NPC requires that $\lim_{n \to \infty} \phi^n E_t (d_{t+n} + msb_{t+n}) = 0$. Hence, equation (6.4.16) indicates that a sustainable policy requires that the government's and the CB's current stock of debt outstanding should be equal to the present value of the future primary surplus of two authorities, which is defined as the sum of tax and seigniorage less the sum of the government's expenditures and the CB's net asset purchases. Given the path of consolidated expenditures, the increase in MSBs and treasury bonds lead to increases in tax and monetary base in the future. Note that even if the CB cannot afford the financing for its sterilisation policy for itself and thus violates its IBC, but if the government maintains a sound budget stance, the sterilisation is considered sustainable in the perspective of the whole country. In this case, however, it is unlikely that the CB could conduct its monetary policy independently from government and political parties.

6.4.4 Data descriptions

Quarterly data for outstanding amounts of MSBs, assets and liabilities of the BOK and other macro variables are obtained from the "main accounts of the BOK" and "main indicators" in the BOK's economic statistics system (*http://ecos.bok.or.kr*). All relevant data are available for the period 1987Q1-2009Q4 for the BOK and 1994Q1-2009Q4 for the Korean government. Figure 6.4 demonstrates that the MSB-to-GDP ratio increases from approximately 10% to over 50% despite the short-term fluctuations, while the MB-to-GDP ratio has been stable with a range between 20% and 30% in 1980-2009. In particular, the MSB-to-GDP ratio began to increase rapidly after the 1997 financial crisis and soared up to over 80% in the third quarter in 2005. The MSB-to-MB ratio increased from approximately 20% to over 200% during the same period. These statistics show that increasing seigniorage may not be a feasible option for the sustainability of MSB-dependent sterilisation in Korea.

Note that Figure 6.4 suggests that there might be possible structural breaks in the time series of the MSB-to-GDP ratios. The possible structural breaks have two implications for the analysis of the sustainability of MSB issuing policy. First, if the breaks are brought about by exogenous shocks (e.g. financial crises), they might be responsible for not rejecting the null hypothesis of unit root in relevant fiscal series, even though the series is stationary within a certain sub-period. Second, the existence of breaks may indicate that the BOK may respond more to its primary deficit when the outstanding MSB is particularly large – the possibility of a non-linear response to variations of the MBS.

Figure 6.4 Ratio of monetary base and MSBs to nominal GDP



Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

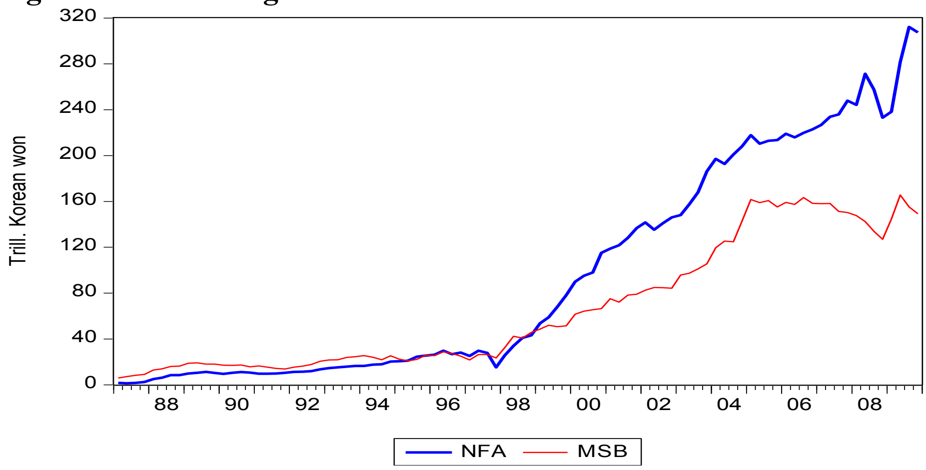
At the times close to 1989Q3 and 2006Q4, the increasing trend of the MSB seemed to be temporarily reversed, so the MSB-to-GDP ratios declined. Nonetheless, the MSB-to-GDP ratio, overall, looks non-stationary. In this regard, the interesting question is whether the temporal declines of the MSB-to-GDP ratios are due to high economic growth or policy responses. The MSB-dependent sterilisation policy will be more sustainable if the declines stem from changes in the BOK's adjustments (by reducing the purchase of assets, increasing the demand for MB or introducing alternative liquidity-absorbing tools).[90] If the declines are

[90] In reality, BOK introduced a marginal reserve requirement system in 1989, which aimed at withdrawing the excess reserve incurred by pegging FX rates. The marginal requirement system was abolished right before the introduction of the managed float in March 1990. In December 2006, BOK raised the required reserve ratio from 5 to 7 %. In November 2007, BOK strengthened the control for the issuance of MSB by letting the Monetary Policy Committee set the limit of issue amount quarterly. In April 2008, BOK changed its monetary operational scheme from Fed-style to ECB style, which enabled it to less stick to controlling short-term market interest rates.

just due to luck (i.e., economic growth), however, the policy may be less sustainable.

Figure 6.5 illustrates that nominal MSBs sharply increased from 1998Q1 to 2006Q4 and appears to show a somewhat stable path since 2006Q4. Unlike figure 6.4 where the MSB scaled by the GDP, the nominal MSB consistently increased until 2005. It seems obvious that the growth of both NFA and MSB began to accelerate after the 1997 financial crisis due to the increasing sterilised interventions.

Figure 6.5 Net foreign assets and MSBs



Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

Table 6.5 shows the dilemma that the BOK faces. In the 2000s, the NDA shows continuously increasing negative values while the NFA had increasingly positive values. This implies that as foreign reserves flood in, domestic liquidity conditions could be too loose to stabilise inflation or too tight to resist the appreciation pressure of domestic currency. The increase in NFA mostly comes from the accumulation of foreign reserves. The NDA has turned to a negative value since 2000 owing to the increasing domestic liabilities such as bank reserves or deposits received from financial institutions through sterilisation.

Consequently, the increases in MSBs appear approximately to correspond to those in the NFA, as can be also seen from Figure 6.5. The difference in values between MSB and NFA reflects the facts that (i) the BOK used alternative sterilisation tools other than MSB (e.g., raising required reserve ratio, reverse repos, etc.); and (ii) the value of NFA is subject to FX rate movements, while that of MSB is not.

Table 6.5 Main accounts in the balance sheet of the BOK

(End of period, bill. KRW)

	1980	1985	1990	1995	1997	1998	2000	2005	2009
Monetary base(A)	3,244	4,319	13,811	29,305	22,519	20,703	28,238	43,249	67,779
MSB(B)	530	1,900	15,612	25,825	23,471	45,673	66,378	155,235	149,170
A+B=C+D=Net Asses	3,774	6,219	29,423	55,130	45,990	66,376	94,616	195,484	216,949
NDA(C=e-f) 1)	2,656	4,930	18,818	29,711	30,749	23,249	-20,602	-18,049	-90,468
Domestic assets(e)	5,294	13,277	32,454	44,002	82,587	61,364	31,721	39,189	41,360
Securities 2)	12	-	2,154	2,069	7,859	13,556	6,496	5,397	12,670
Loan to government	1,376	2,636	865	968	788	1,218	779	829	1,116
Other liabilities(f) 3)	2,638	8,347	13636	14,291	51,838	38,115	52,323	57,238	131,828
NFA (D=g-h)	1,118	1,289	10,605	25,419	15,241	43,128	115,218	213,533	307,417
Foreign Assets(g)	1,790	2,983	11,212	26,068	29,833	66,501	124,323	232,071	322,673
Securities	1,013	1,085	6,874	16,364	6,168	48,061	113,748	204,964	291,110
Due from banks	507	1,332	3,681	8,330	21,721	16,493	6,978	23,433	19,575
Foreign Liabilities(h)	672	1,694	607	649	14,592	23,374	9,095	18,538	15,257

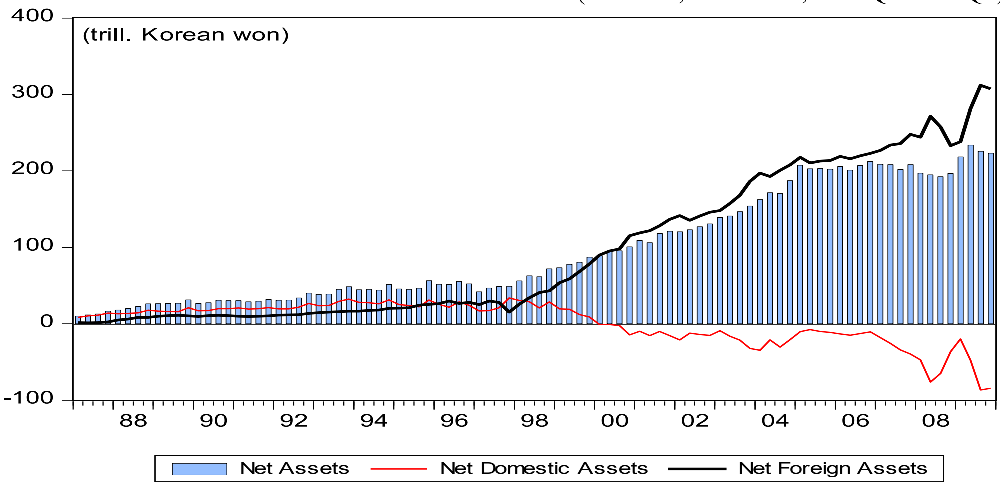
Notes: 1) For simplicity, net wealth is included in NDA by treating it as domestic liabilities because most of positive net worth is not reserved in the BOK account and should be transferred to government account.
2) Most are bonds issued by government and government agencies
3) Other liabilities = domestic liabilities - MSB – MB: e.g., reverse repos with banks, excess reserve, etc.

Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

Figure 6.6 confirms that the increase in net assets has mostly come from the increase in NFA during last two decades, and that NFA has rapidly increased since the 1997 financial crisis when Korea introduced the free float regime and inflation targeting, and considerably reformed the financial markets.

Figure 6.6 Components of the BOK's net assets

(Nominal, trill. KRW, 1987Q1-2009Q4)



Data: IFS and BOK Economic Statistics System (http://ecos.bok.or.kr)

Table 6.6 reports that both the mean and variance of MSB-to-GDP ratio have sharply increased since the 1997 financial crisis, together with the NFA-to-GDP ratio. All these statistics appear to indicate that the sustainability of the MSB-dependent sterilisation policy is getting weaker over time.

Table 6.6 Average and volatility of main accounts in BOK's balance sheet

(%)

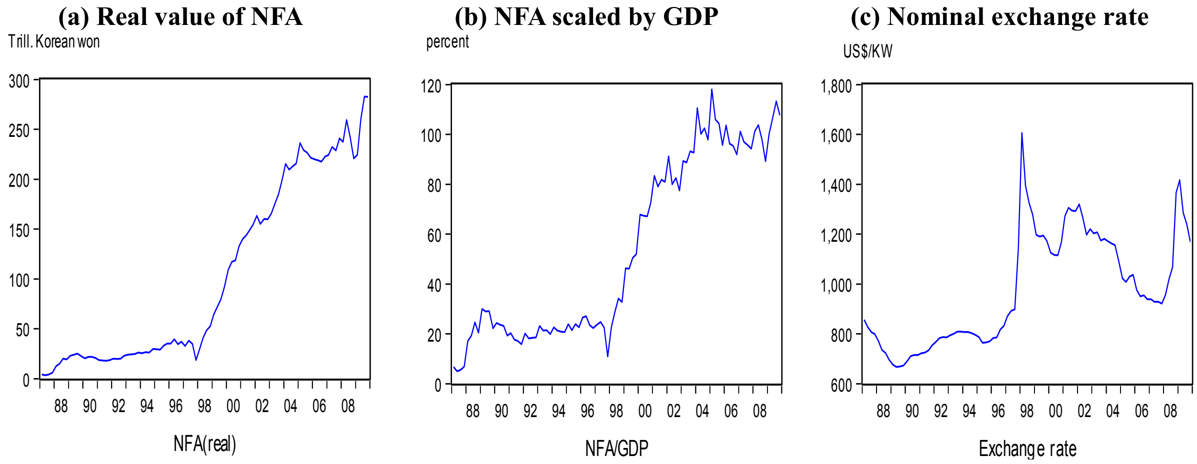
Average	NDA(a)	NFA(b)	MB+MSB	MB(c)	MSB(d)
1980-1997	31.3	14.2	45.5	22.7	22.8
1998-2009	-8.3	81.5	73.2	20.0	53.3
1980-2009	15.6	41.2	56.7	21.7	35.1
Variance					
1980-1997	0.7	0.7	1.6	0.2	1.3
1998-2009	1.6	5.5	2.0	0.2	1.7
1980-2009	4.9	13.5	3.6	0.1	3.6

Note: All numbers are relative to nominal GDP
Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

As all fiscal variables in the BOK's balance sheet are denominated by local currency, the effects of exchange rates on the NFA are already reflected in the data. For example, the value of foreign assets and liabilities are revalued and booked in local currency every six months. The exchange rate plays a decisive role in the developments of the stock of MSBs (i) because of its effects on the BOK's motivation for FX market interventions (as seen in Ch. 4); and (ii) due to the valuation effects of foreign reserves. The more appreciated the local currency, the larger the stock of MSB is likely to be, because the BOK tends to intervene to resist local currency appreciation and subsequently needs to issue MSBs for sterilisation. Note that the value of foreign reserves denominated by local currency decreases when local currency is appreciated. Thus, the values of the NFA can be changed by exchange rate movements even when there are no changes in sterilisation policy.

Figure 6.7 illustrates the developments and trends of the NFA, its ratio to GDP and nominal exchange rate (KRW/USD). The real values of the NFA and the NFA-to-GDP ratio have continued to increase since the 1997 financial crisis, when international capital flowed in, and exchange rate overall appreciated, with exception for the period of the recent subprime mortgage crisis. These plots suggest that increases in NFA mainly come from increases in purchases of foreign reserves rather than the increase in valuation caused by KRW-depreciation.

Figure 6.7 NFA and exchange rate rates



Data: BOK Economic Statistics System (http://ecos.bok.or.kr)

Table 6.7 demonstrates that the BOK experiences primary surplus but the total balance (inclusive interest payment) records deficits on average, which may be attributable to the increasing stock of MSBs and the resulting increase in interest payments. The total spending is much more volatile than total revenue.

Table 6.7 Statistical summary of BOK's main fiscal variables used in regressions

		Total Revenue(A)	Total spending(B)	Total surplus(A-B)	Primary surplus	Interests on MSB
Real (bill. KRW)	Mean	2,101	4,254	-2,154	136	1,798
	Std. Dev.	3,256	6,367	5,588	6,817	1,206
Scaled by GDP (%)	Mean	1.40	2.86	-1.45	0.11	1.03
	Std. Dev.	2.34	4.24	3.31	4.05	0.40

Notes: 1987Q1-2009Q4, quarterly average
Data: Author's calculation based on BOK Economic Statistics System (http://ecos.bok.or.kr)

6.5 Estimation results

6.5.1 Sustainability tests for the budget of the BOK

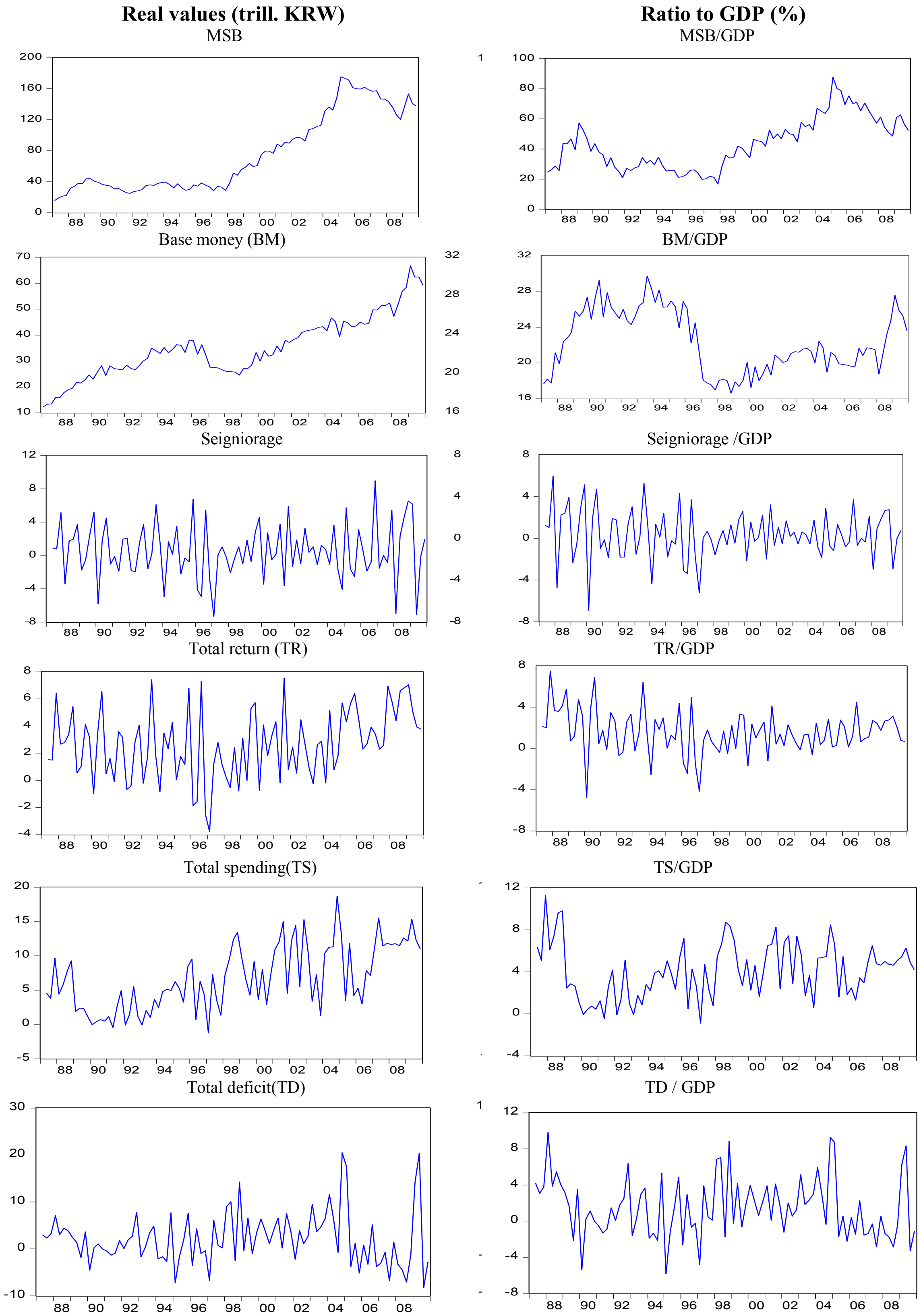
6.5.1.1 Plotting fiscal variables of the BOK

Before conducting unit root tests, we plot relevant fiscal variables to get a feel for the data. All plots of the seasonally-adjusted fiscal variables of the BOK are presented in Figure 6.8(a). Most variables fluctuate a great deal with large variances, except undiscounted MSB and the monetary base, which are trending upwards over time. The upward trend of the MSB series is consistent with that of government debts observed particularly after the 1980s in the US, Japan, many European countries (see Bohn 2004) and Korea. As seen in Figure 6.8(b), a government's expenditures and revenues tend to increase over time (and thus mostly show a non-stationary property) as the economy grows, while the government's budget surpluses shows fluctuations within a certain range (and thus appear stationary). However, most of the BOK's fiscal data (excluding MSB series) in Figure 6.8(a) appear to show significantly less increasing trend than government's with more fluctuations over time. For example, the seigniorage, total spending and total revenues mostly fluctuate around a certain positive level.

The total budget balance shows deficits over considerable periods. Note that MB-to-GDP ratios in the 2000s are much lower than those in the 1990s, while MSB-to-GDP ratios show a steady increase with several significant fluctuations – which implied that seigniorage, became a less important factor in the BOK's budget balance. This phenomenon may be partly related with the monetary regime changes (from monetary targeting to inflation targeting) and decreases in money demand.

Figure 6.8 Plots of main fiscal variables of the BOK and Korean government

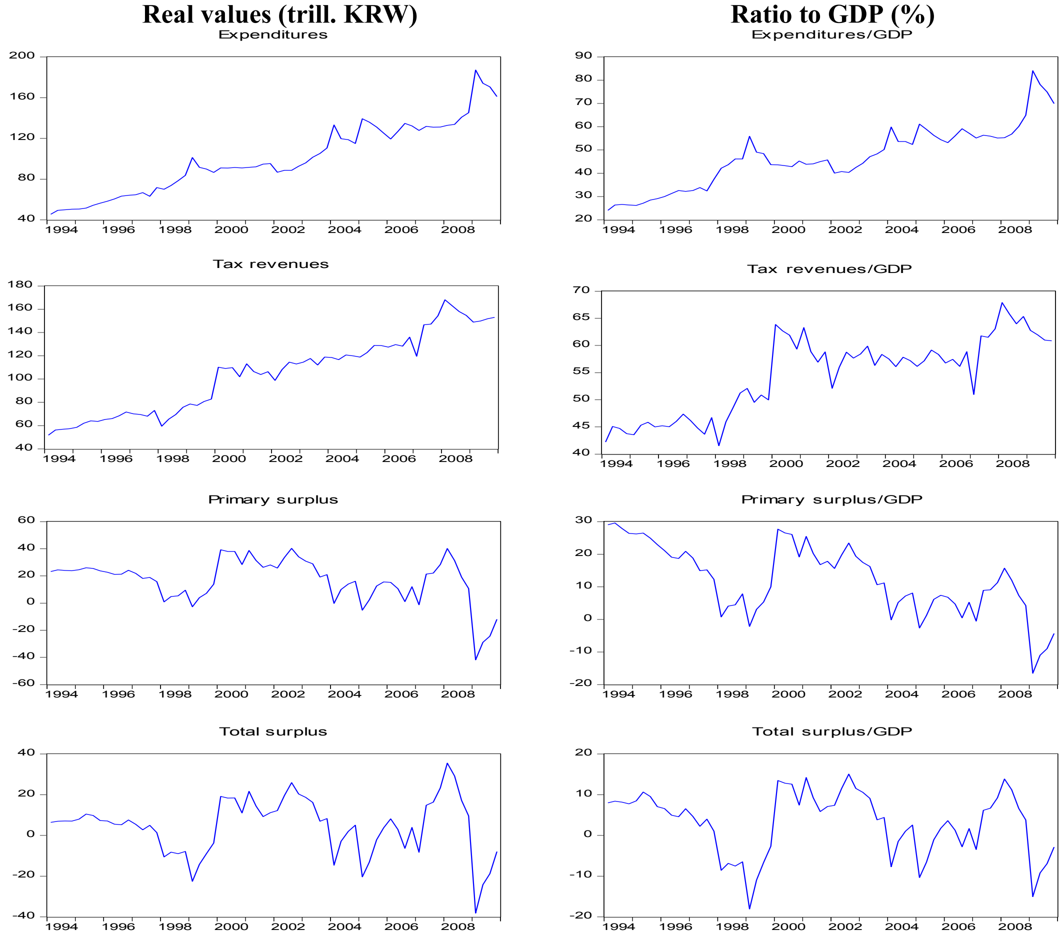
(a) BOK (1987Q1 – 2009Q4)



Data: BOK database (http://ecos.bok.or.kr).

(b) Korean government (1994Q1 – 2009Q4)

Real values (trill. KRW) **Ratio to GDP (%)**



Data: BOK database (http://ecos.bok.or.kr).

6.5.1.2 Unit root tests

In a standard test for fiscal sustainability, the results of the unit root test are crucial, so we use the Augmented Dickey Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Phillips-Perron (PP) tests in which an intercepts are mostly allowed in test forms. The number of lags in the test form is determined by the Akaike Information Criteria (AIC) with a maximum lag of 12. The null hypothesis is I(1) in the ADF and PP tests and I(0) in the KPSS test. We also apply the Zivot-Andrews (1992) test for the I(1) series in order to see whether the I(1) series actually trend stationary once the break is considered. Zivot-Andrews (1992) tests the null of I(1) against the alternative of I(0) with one endogenously determined break.

Table 6.8 shows the results of unit root tests for the BOK's fiscal variables in level and their ratios to GDP. First, *undiscounted* MSBs (at both level and their ratio to GDP) follow I(1). Although the ADF test suggests the I(2) property of MSB-to-GDP ratio, the test result may be affected by the broken trend around 2004, as shown in Figure 6.8(a).[91] The Zivot-Andrews test suggests that MSB series are I(1). It is worth recalling that allowing the I(2) property of the MSB-to-GDP ratios may not indicate non-sustainability but rather weak sustainability, according to Quintos (1995, pp 409-410).

Second, non-interest spending (ΔNA) and primary surplus (PS) are I (0) in both levels and their ratios to GDP. Third, with regard to total revenue (TR) and total spending (TS), three tests provide different results: TR and TS are (1) according to ADF and KPSS test but I(0) according to PP test. As seen from the plots in Figure 6.8, the ambiguous integration property of the BOK's TS and TR series contrasts with clear nonstationarity of government revenue and expenditures. For example, both government revenues and expenditures in all G-7 and major emerging countries are I(I) in levels, per-GDP and per-capita (Payne 1997, Kalyoncu 2005), because they tend to increase with economic growth or over time as in Figure 8.6(b). A few exceptions are that both revenue-to-GDP and expenditure-to-GDP ratios are I(0) for the US and revenue level is I(2) for Japan (Payne 1997).On the other hand, CBs' seigniorage (revenue) and growth in net asset purchases (spending)appear not to significantly increase with economic growth or over time as in Figure 8.6(a). Rather, they are related to changes in monetary policy or FXIs. Note that although TR and TS may be possibly integrated at different orders, we can use Johansen's cointegration test, because they are at most I(1).

[91] As seen in Figure 6.8(a), the MSB-to-GDP ratio appear to be more smoothly and more slowly changing than the real value of MSB which is I(1). This is one of the characteristics observed in the I(2) series. The properties of I(2) are found in some time-series like prices, wages, money balances and stock variables(Haldrup 1998). Other unit root tests also provide conflicting results: Elliott-Rothenberg-Stock test statistic suggests I(1) while Ng-Peron modified unit root test and Dickey-Fuller test with GLS de-trending test support I(2).

Table 6.8 Unit root test results of BOK's fiscal variables

Variables \ Test statistics		Levels ADF	Levels KPSS	Levels PP	1st difference ADF	1st difference KPSS	1st difference PP	2nd difference	Zivot-Andrews	verdict
MSB										
Real	*c,t*	-0.843(4)	1.084***	-0.796	-3.253**	0.128	-8.308***	n.a	-3.622	I(1): All
Ratio to GDP	*c,t*	-1.227(8)	0.815***	-1.125	-2.168	0.198	-10.378***	-5.621*** (ADF)	-4.427	I(1): PP, KPSS I(2): ADF
Total Revenue (TR)										
Real	*c*	-2.198	0.568**	-9.096***	-4.620***	0.226	-52.599***	n.a	-3.921	I(0): PP I(1): ADF, KPSS
Ratio to GDP	*c*	-2.767*	0.472**	-9.642***	-5.176***	0.204	-41.985***	n.a	-4.123	I(0): PP I(1): ADF, KPSS
Non-interest spending (ΔNA)										
Real	*c*	-3.590***	0.121	-9.718***	-11.687***	0.105	-46.662***	n.a	n.a	I(0): All
Ratio to GDP	*c*	-3.398**	0.116	-9.887***	-12.876***	0.106	-48.259***	n.a	n.a	I(0): All
Total Spending (TS)										
Real	*c*	-2.617*	0.984***	-5.381***	-5.429***	0.020	-15.250***	n.a	-3.741	I(0): PP I(1): ADF, KPSS
Ratio to GDP	*c*	-3.271**	0.112	-5.782***	-6.064***	0.018	-14.308***	n.a	n.a	I(0): All
Primary surplus (PS)										
Real	*c*	-3.284**	0.130	-8.649***	-11.358***	0.091	-41.395***	n.a	n.a	I(0): All
Ratio to GDP	*c*	-3.154**	0.139	-8.984***	-11.851***	0.110	-44.309***	n.a	n.a	I(0): All
Total deficit (TD)										
Real	*c*	-8.333***	1.135	-8.333***	-9.792***	0.164	-57.430***	n.a	n.a	I(0): All
Ratio to GDP	*c*	-8.577**	0.114	-8.636***	-10.112***	0.166	-46.079***	n.a	n.a	I(0): All

Notes: 1. The series are measured as follows: $TR_t = \Delta H_t + r^* NA_{t-1}$; $TS_t = \Delta NA_t + rMSB_{t-1}$, $PS_t = TR_t - \Delta NA_t$, $TD_t = TS_t - TR_t$ where r=rate of return on 1 year MSB and r^* =rate of return on 1 year US Treasury bond measured as an average rate of return on 90-day US Treasury bill & 2 year US Treasury bond

2. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, respectively.
3. Null hypothesis is I (1) in ADF and PP test and I(0) in KPSS test. In Zivot-Andrews test (maximum lag=12), null is I(1) and alternative is I(0) with one structural break.
4. *c* and *t* indicate that unit root test form includes an intercept and deterministic trend term, respectively.
5. When we include both time trend and intercept in the test form for TR, TS and PS (or exclude time trend in the test for MSB), the test results are same.
6. In KPSS and PP test, the spectral estimation method is Bartlett kernel, and bandwidth is selected by Newey-West's method.

6.5.1.3 Stationarity of discounted MSB series: Wilcox test

We cannot use the Hamilton & Flavin test, because the stationarity of the undiscounted MSB series (i.e., $msb_t \sim I(0)$) is a necessary condition for the test. Thus, we use the Wilcox test, which allows the nonstationarity of *undiscounted* MBS series. According to Wilcox, we can simply generate the series, i.e., the realised values of discounted MSBs in real levels and in their ratio to GDP, using the following measurements:

(6.5.1) discounted MSB_t ($dMSB_t$) $= MSB_{t+n} \cdot \prod_{k=0}^{n-1} (\theta_{t+k})^{-1}$ where $\theta_{t+k} = 1 + r_{t+k}$

(6.5.2) discounted $msb_t(=dmsb_t) = (MSB/GDP)_{t+n} \cdot \prod_{k=0}^{n-1} \phi_{t+k}$ where $\phi_{t+k} = (1 + g_{t+k})/(1 + r_{t+k})$

where t is fixed at 1987Q2 and n = 0…91; r is the ex-post real return on the MSBs that is assumed to reflect the future stochastic movements of interest rates; g is the growth rate of the economy. The BOK's policy is assumed to be sustainable if the generated series follow the *I(0)* process with a zero unconditional mean.[92]

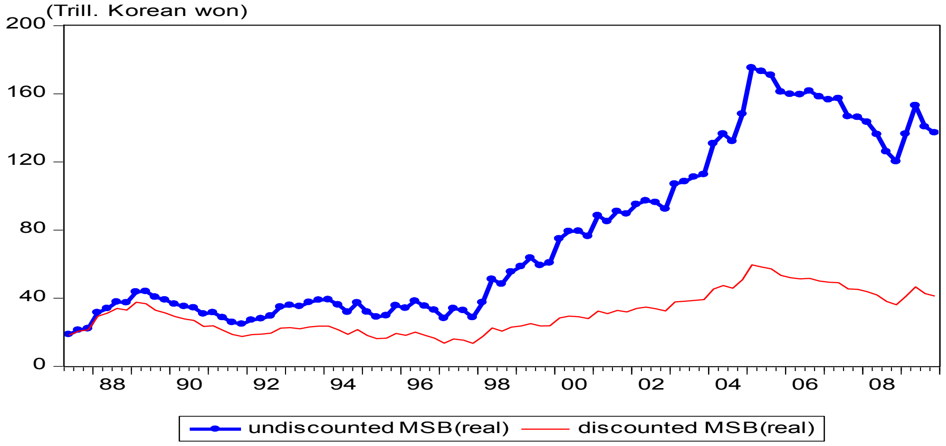
Figure 6.9 plots the two series generated by the Wilcox methodology. In real terms, the discounted values of real MSBs appear different from their undiscounted values. The undiscounted value of MSB has, in particular, shown apparently upward trend since 1997, while the discounted value looks relatively stable. The relatively similar movements between undiscounted (MSB/GDP) and discounted (MSB/GDP) stem from the fact that there was no significant difference between r_{t+k} and g_{t+k} during the sample period – the averages of

[92] That is, a zero-mean stationarity is required. More specifically, suppose that MSB_t follows a general ARIMA process: $(1-\rho(L))((1-L)^d msb_t - a) = (1-\theta(L))e_t$ where $\rho(L)$ and $\theta(L)$ are polynomials with an order of p and q, respectively; a is the unconditional mean of the stationary series $(1-L)^d msb_t$; and msb_t is the discounted value of MSBs scaled by GDP. Assume that $\rho(L)$ and $\theta(L)$ satisfy the conditions for stationarity and invertibility, then the equation provides a convenient framework for investigating the properties of msb_t; under a sustainable policy, msb_t should be stationary(*d=0*) and the unconditional mean of the msb_t should be zero(a=0) (Seo 2000).

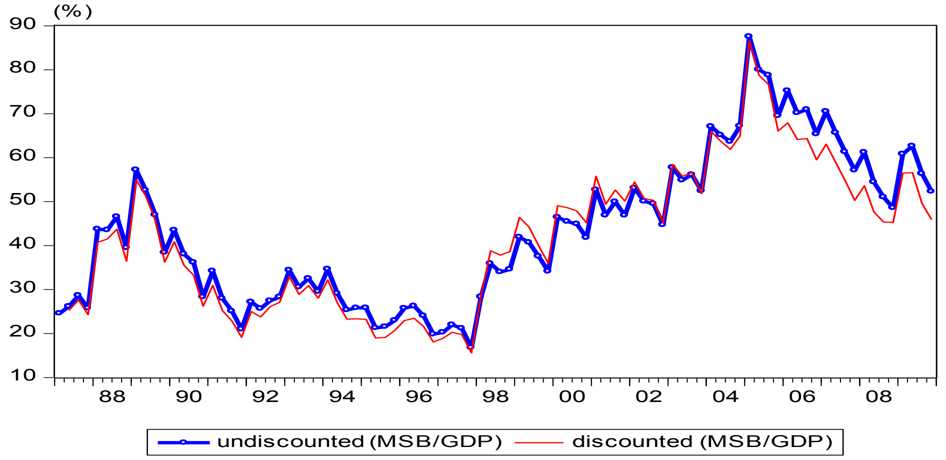
r and g (quarter to quarter) were 1.42% and 1.34%, respectively. Note that the discount factor, $\prod_{k=0}^{n-1}\{(1+g_{t+k})/(1+r_{t+k})\}$ becomes close to 1 when $g = r$.

Figure 6.9 Market value of MSB (real) and MSB-to-GDP ratio

A. Discounted MSB and undiscounted MSB(real)



B. Discounted (MSB/GDP) and undiscounted (MSB/GDP)



Data: Author's calculation based on BOK Economic Statistics System (http://ecos.bok.or.kr)

The two plots suggest that the sustainability appears more favourable in terms of real MSB than (MSB/GDP). The results of ADF and KPSS unit root test report that both discounted real MSBs and MBS-to-GDP ratios are I(1), as seen in Table 6.9. The Zivot-Andrews unit root test suggests that a break point of discounted MSB and (MSB/GDP) are 2003Q1 and 2000Q1, respectively, but both are not significant. Thus, we may state that the stock of MSBs may not be unsustainable at this stage.

Table 6.9 Stationarity test for the discounted MSB and MSB-GDP ratio: Wilcox test

Variables \ Test statistics		Levels ADF	Levels KPSS	First difference ADF	First difference KPSS	Break Zivot -Andrews	Verdict
Real MSB	*c*	-1.378(4)	0.762***(7)	-3.362** (3)	0.107(2)	-3.920	I(1)
	c,t	-2.877(4)	0.206**(7)	-3.380* (3)	0.113(2)		
MSB-GDP ratio	*c*	-1.361(8)	0.762***(7)	-4.203*** (4)	0.129* (10)	-3.858	I(1)
	c,t	-3.051(8)	0.156**(7)	-4.176*** (4)	0.092(10)		

Notes: 1. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, respectively.
2. *c* and *t* indicate that unit root test form includes an intercept and deterministic trend term, respectively.
3. Null hypothesis is I(1) in ADF and I(0) in KPSS test. The figures in parentheses indicate the number of lags selected by AIC in ADF test and Newey-West bandwidth estimated by Bartlett kernel in KPSS test.
4. Null hypothesis is I(1) and the alternative is I(0) with a break in Zivot-Andrews test (maximum lag=12). The series are tested with an intercept.

Considering the limited power of the unit root test for the stationary series with near-unit root, we additionally examine whether the unconditional means of msb_t is zero. We check whether the constant in the following autoregressive model (6.5.3) is statistically different from 0. In the Wald test for the stationary series, the hypothesis of zero-constant can be tested by the restriction: $\alpha = 0$.

(6.5.3) $dmsb_t = \alpha + \mu_t$

where $dmsb_t = (MSB/GDP)_{t+n} \cdot \prod_{k=0}^{n-1} \phi_{t+k}$, $\mu_t = \sum_{i=1}^{n} \beta_i \mu_{t-i} + \varepsilon_t$ and ε_t = white noise errors. As for both discounted MSB and discounted (MSB/GDP) series, the null hypothesis of the constant zero ($\alpha = 0$) is rejected at a 1% significance level in all autoregressive models with a lag of 1 through 6.[93] We check for a possible structural break in the coefficients by using the Quandt-

[93] The estimation results for regression (6.5.3) are as follows. The number of lags is determined by SIC: the optimum number of lags is 1 for the level of discounted MSB and 6 for the discounted (MSB/GDP). Here, the numbers in parenthesis are p-value.
(i) discounted real MSB(=*dMSB*): AR(1)

$dMSB_t = 40.265 + \mu_t$, $\mu_t = 0.972\mu_{t-1}$

(0.000) (0.000)

$\overline{R^2}$: 0.95, F-statistics: 1682.97(0.000), Breusch-Godfrey correlation LM test: 14.925 (0.245)
(ii) discounted (MSB/GDP)(=*dmsb*): AR(6)

$dmsb_t = 0.43 + \mu_t$ $\mu_t = 1.11\mu_{t-1} - 0.24\mu_{t-2} - 0.04\mu_{t-3} + 0.71\mu_{t-4} - 0.89\mu_{t-5} + 0.32\mu_{t-6}$

(0.00) (0.00) (0.06) (0.66) (0.00) (0.00) (0.00)

$\overline{R^2}$: 0.93, F-statistics: 186.94(0.000), Breusch-Godfrey correlation LM test: 12.644 (0.262)

Andrews breakpoint test with 15% trimmed observations. The test statistics (Wald F-statistics) suggest that 2003Q1 may be the mostly likely point of structural break, where three Wald F-statistics are at a maximum at a 1% or 5% significance level.[94] When we allow a structural break at 2003Q1, Wald test rejects the null of zero-constant at 1% significance level for any sub-periods. That is, we can reject the null hypothesis of the zero unconditional mean, not only for the whole sample but also for the subsample periods suggested by the structural breakpoint tests. As a consequence, we may firmly conclude that the current MSB issuing policy series is not sustainable according to Wilcox's test.

6.5.1.4 Cointegration between total revenue and total spending

Since the ratios to GDP rather than real values provide more credible information about the fiscal series (Bohn 2005, pp. 11-15), we test for cointegration between *tr(=TR/GDP)* and *ts(=TS/GDP)*. If *tr* and *ts* are cointegrated with $\beta = 1$, i.e., if the cointegration vector is (1, -1) in the equation ($tr_t = \alpha + \beta \cdot ts_t + \varepsilon_t$), a strong form of sustainability is satisfied. The lack of cointegration (i.e., $0 < \beta < 1$) implies the weaker sustainability condition. We employ Johansen's methodology to test for cointegration between *tr* and *ts*. Before conducting the cointegration test, we need to specify the appropriate number of lags in the VAR system. To do this, considering the quarterly frequency of the data and the BOK's budgetary planning process (which ends one or two quarters before the new fiscal year), we assume that the

[94] But likelihood ratio(LR) F-statistics suggest conflicting results: the null of no break points cannot be rejected.

Statistic	Suggested break point	Value	P-value
Maximum LR F-statistic		3.410	0.313
Exp LR F-statistic	1998Q1	0.850	0.850
Ave LR F-statistic		1.541	0.166
Maximum Wald F-statistic		15.145**	0.011
Exp Wald F-statistic	2003Q1	4.850***	0.009
Ave Wald F-statistic		5.148**	0.034

Note: *** and ** denote the rejection of the null of no structural break at 1%and 5% significance level, respectively.

appropriate number of lags is no longer than 6. The information criteria suggest VAR (4) with a constant.[95]

In the Johansen methodology, the trace test (λ_{trace}) and maximum eigenvalue test ($\lambda_{\max}$) are used to determine the number of cointegration vectors (*r*). In the λ_{trace} test, we test the null that the number of cointegrating vectors is less than or equal to *r* against the alternative of more than *r*. In the $\lambda_{\max}$ test, we test the null that the number of cointegrating vectors is *r* against the alternative that of *r+1*. Table 6.10 shows that the trace test and maximum eigenvalue test reject the null of no cointegration (*r=0*) and suggest a rank of 1 at 5% and 10% significance level, respectively.

Table 6.10 Johansen maximum likelihood cointegration test

	null	alternative	statistics	p-value
Trace test(λ_{trace})	$r = 0$	$r \geq 1$	21.563**	0.0329
	$r \leq 1$	$r \geq 2$	7.363	0.1085
Maximum eigenvalue test($\lambda_{\max}$)	$r = 0$	$r = 1$	15.892*	0.0905
	$r \leq 1$	$r = 2$	7.363	0.1085

Notes: 1. ** and * indicate the rejection of the null hypothesis of no cointegration at 5% and 10% significance level, respectively.
2. *r* stands for the number of cointegration vectors.

Hence, we may preliminarily assume that there is one cointegration vector between *tr* and *ts* and then construct the VECM. Because no trends appear in the two series as seen in Figure 6.8(a), no time trend terms are included both in the difference variable part and in the

[95] The results of the test for VAR lag structure are as follows. When extending the maximum number of lags up to 12, we obtain the same results.

	With constant			No constant		
Lag	AIC	SC	HQ	AIC	SC	HQ
0	-8.575402	-8.517928*	-8.552285	n.a.	n.a.	n.a.
1	-8.570775	-8.398353	-8.501422	-8.020929	-7.905980	-7.974693
2	-8.499123	-8.211753	-8.383535	-8.225210	-7.995313	-8.132739
3	-8.693360	-8.291041	-8.531536	-8.651456	-8.306611	-8.512750
4	-9.022556*	-8.505288	-8.814496*	-8.979754*	-8.519960*	-8.794812*
5	-9.018941	-8.386725	-8.764646	-8.938559	-8.363817	-8.707381
6	-8.936006	-8.188843	-8.635476	-8.858242	-8.168552	-8.580830

Notes : 1) * indicates lag order selected by the criterion
2) AIC: Akaike information criterion, SIC: Schwarz information criterion,
HQ: Hannan-Quinn information criterion

cointegration part of the VECM. An intercept is included in the cointegration part but not in the difference variable part. Thus, the two variables *tr* and *ts* have the following model with 4 lags:

$$
(6.5.4)\quad
\begin{aligned}
\Delta tr_t &= \gamma_{TR}(tr_{t-1} - \alpha - \beta \cdot ts_{t-1}) + \sum_{i=1}^{4} \gamma_{11}(i)\Delta tr_{t-i} + \sum_{i=1}^{4} \gamma_{12}(i)\Delta ts_{t-i} + \varepsilon_{tr.t} \\
\Delta ts_t &= \gamma_{TS}(tr_{t-1} - \alpha - \beta \cdot ts_{t-1}) + \sum_{i=1}^{4} \gamma_{21}(i)\Delta tr_{t-i} + \sum_{i=1}^{4} \gamma_{22}(i)\Delta ts_{t-i} + \varepsilon_{ts,t}
\end{aligned}
$$

where β = the coefficient of the cointegration vector given by $tr_t = \alpha + \beta \cdot ts_t + \varepsilon_t$; $\varepsilon_{tr,t}$ and $\varepsilon_{ts,t}$ = white noise errors; i = number of lags. The coefficient γ_{TR} (γ_{TS}) is interpreted as the speed of adjustment toward long-run equilibrium. The coefficients, $\gamma_{jk}(i)$ j,k=1,2 and i=1,2,3,4 indicate short-run responses. We check the appropriateness of the estimated VECM by testing the properties of the residuals (e.g., serial correlation, normality and heteroskedasticity).

The results are presented in Table 6.11. The normalised cointegration coefficient (β) is -0.062 but is not significant. Furthermore, the magnitude of the cointegration vector is close to zero. To see whether β is significantly different from 0, we impose a restriction on cointegration vector $(1, \beta) = (1,0)$ and test the validity of the restriction. We cannot reject the null of (1, 0). This indicates that there is no long-term relationship between TR and TS in terms of their ratios to GDP. Now, we can conclude that the current MSB-dependent sterilisations may not be sustainable in the long run.

A close look at the differential variable parts enables us to see the BOK's short-term adjustment of its revenues (in the current period) to the expenditures in the previous period. The shaded area of the third column in Table 6.11 may suggest that the BOK seems to adjust its spending in line with its revenue in the short run, because the current changes in spending

($\Delta TS_t/\Delta GDP_t$) depend on revenues in the previous periods ($\Delta TR_{t-i}/\Delta GDP_{t-i}$). The expenditure increases in previous periods ($\Delta TS_{t-i}/\Delta GDP_{t-i}$) lead to the revenues decrease in the current period ($\Delta TR_t/\Delta GDP_t$), but insignificantly (see the shaded area of the second column).[96]

Table 6.11 VECM (4) estimates for the BOK's revenue and expenditures

Cointegration term: $(TR/GDP)_{t-1}$ − 0.117*** − **0.062** × $(TS/GDP)_{t-1}$
(0.00467) (0.0615)
[-3.7222] [-1.0056]

Regressors \ Dependent variables	$\Delta(TR/GDP)_t$	$\Delta(TS/GDP)_t$
cointegration term	-0.773197*** (0.23550) [-3.28327]	-1.473358** (0.62267) [-2.36619]
$\Delta(TR/GDP)_{t-1}$	-0.508346** (0.23065) [-2.20395]	1.080302* (0.60986) [1.77138]
$\Delta(TR/GDP)_{t-2}$	-0.373263 (0.22613) [-1.65066]	1.461459** (0.59790) [2.44430]
$\Delta(TR/GDP)_{t-3}$	0.097373 (0.19756) [0.49288]	2.028353*** (0.52237) [3.88299]
$\Delta(TR/GDP)_{t-4}$	0.101339 (0.13195) [0.76803]	0.679433 (0.34888) [1.94748]
$\Delta(TS/GDP)_{t-1}$	-0.041205 (0.04686) [-0.87923]	-0.930041*** (0.12391) [-7.50555]
$\Delta(TS/GDP)_{t-2}$	-0.042878 (0.05117) [-0.83793]	-0.750474*** (0.13530) [-5.54668]
$\Delta(TS/GDP)_{t-3}$	-0.048485 (0.05029) [-0.96406]	-0.662421*** (0.13298) [-4.98149]
$\Delta(TS/GDP)_{t-4}$	-0.026888 (0.04327) [-0.62134]	-0.008632 (0.11442) [-0.07544]
Adj. R-squared	0.679029	0.656545
F-statistic	23.47770	21.31061
Log likelihood	244.5049	160.8850
Mean dependent	-0.000394	-0.000314
S.D. dependent	0.026291	0.067201
Log likelihood	407.1461	
Diagnostic: Adjusted Q	42.12110 < 0.1900>	
Diagnostic: Serial correlation LM test	4.020257 <0.4033>	
Diagnostic: Normality	1.795622 < 0.5570>	
Diagnostic: White Heteroskedasticity test	70.77518* <0.0624>	

Notes: 1.Standard errors in ( ) and t-value in [ ]. P-value in < >.
2. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, respectively (critical value: 1.67, 1.99 and 2.64 at 10%, 5% and 1% significant level).
3. Multivariate LM test for serial correlation up to lag 12 : null is no residual autocorrelations.
4. Multivariate extensions of the Jarque-Bera residual normality test under the null of normality. Inverse square root of residual correlation matrix (Doornik and Hansen 1994) is used.
5. Multivariate extensions of White's heteroskedasticity test: null is no heteroskedasticity.

[96] Pairwise Granger causality test (1987Q1-2009Q4, lag=4) suggests that ΔTR granger causes ΔTS.

Null Hypothesis:	Obs	F-Statistic	Prob.
Δ(TR/GDP) does not Granger Cause Δ(TS/GDP)	78	2.08232	0.0343
Δ(TS/GDP) does not Granger Cause Δ(TR/GDP)		1.48764	0.1583

Accordingly, it may be interpreted that the BOK's expenditure on the purchase of foreign reserves appears to be subject to its revenues in previous periods in the short run, so that the BOK appears to make short-term efforts to some extent to adjust its expenditures within its budget constraints.

6.5.1.5 Modified Bohn test based on general-to-specific methodology

6.5.1.5 (a) General unrestricted model (GUM)

Bohn test for the sustainability of MSB-dependent policy begins from (6.5.5). Since ps_t and Δmsb_t are I(0), as seen in Table 6.8, the ordinary least square can be used.

(6.5.5) $ps_t = \beta_0 + \rho \cdot \Delta msb_{t-1} + A_i x_{it} + \varepsilon_t$

where A_i =coefficients and x_{it} = non-debt explanatory variables which reflect cyclical business and should be stationary. In (6.5.5), it is crucial to find the control variables (x_{it}) which should be non-debt related variables that affect ps_t .

In this section, following Bohn's (1998, 2004) argument, we first construct several variables to possibly cause cyclical changes in the net asset purchases and seigniorage of a CB. However, Bohn test, basically applying a specific-to-general strategy, may not be mechanically applicable to the analysis of a CB's debt policy, because non-debt determinants of a CB's primary surplus may be different from those of a government. For example, the tax rate should depend only on permanent government expenditures and on the debt level, and should be smoothed over time, according to Barro's tax smoothing theory. However, a CB's seigniorage is mostly determined by the private sector's money demand that is not controlled by a CB but affected by the growth of the economy.

Hence, it is necessary to consider additional variables to avoid omitted variable problems when we apply Bohn test to the analysis of the CB debt policy. Because there are no firm theories on CB debt policies, our approach is to specify a general unrestricted model (GUM) which includes all possible non-debt variables (with lags) to influence a CB's primary budget. The selection of candidate variables included in the GUM is based on the modification of theories of fiscal sustainability and evidence of CB sterilisation behaviours already discussed in Chapter 3 through Chapter 5. Then, we reduce the GUM to the most specific model without distorting data through Hendry's general-to-specific (GETS) modelling principle (see Campos et al. 2005). In particular, after checking the significance for coefficients of candidate variables and running diagnostic tests (e.g. autocorrelation, ARCH, normality, heteroskedasticity, RESET), we reduce the number of the variables and finally reach the most parsimonious regression forms (final model) with the relevant variables remaining. The process of model reduction is carried out by the function "Autometrics" offered by Oxmetrics 6.1.

Using impulse-indicator saturation (IIS) at α(significant level)=0.001 in Autometrics, we also detect all possible outliers and structural breaks. IIS is a recent and general method for detecting structural breaks and outliers,[97] suggested by Hendry et al. (2009). IIS allows an impulse indicator for every observation among the candidate variables, so that potential explanatory variables can be more than the sample size. The IIS procedure can be summarized

[97] It is well known that unless outliers or breaks are not modelled, this can distort a model's fitness, parameter estimates and constancy (Hendry et al. 2010, p 4). In particular, not modelling breaks can lead to estimated models showing unit roots when none exist. Outliers mostly result from sudden behaviour shifts or data measurement errors. IIS is the most general method for detecting breaks, encompassing other structural break tests like the Bai-Peron multiple structural test and Quant & Andrews's single structural break test. See Hendry et al.(2009) and Hendry et al. (2010) for the application of the IIS.

as follows (Hendry and Mizon 2010):

(i) Create impulse indicator for every observation, $1_{\{t=s\}}\ \forall s$, still including a constant.

(ii) Divide the indicators into *k* blocks (that form a set of initial GUMs) and then estimate each them.

(iii) Select the significant indicators from each block in terminal model and record them.

(iv) Formulate the joint model which is the union of *k* terminal models, estimate the model and reselect the indicators.

(v) Under the null of no outliers, αT indicators will be retained in a sample of T observations on average at significance level α.

IIS enables one to check that the times of known shifts are correct when we use dummies for them and that all outlying events are included in the model. In addition, as IIS is a kind of robust estimation, it can jointly deal with data measurement errors and fat-tailed distribution by removing extreme values, as well as location shifts and innovation outliers (Hendry et al. 2010, p 5).

Table 6.12 summarizes the candidate variables used to specify the GUM. All candidate variables reflect cyclical, domestic or external factors affecting the sterilisation operations and primary surplus of the CB. We first, based on Bohn (1998, 2004), choose cyclical non-debt variables that only temporarily affect the primary surplus: NVAR, SVAR, GVAR. NVAR and SVAR [98] reflect the cyclical variation of net asset purchases and seigniorage revenues. GVAR indicates a business cycle indicator.

[98]NVAR and SVAR indicate the very short-term fluctuations of foreign reserves and monetary base caused by the CB's sterilised interventions to address the sudden reversal of capital flows and the resultant instability in the financial markets.

Additional cyclical variables are selected to reflect the degree of temporary deviation from their trends. RVAR, FVAR and IVAR measure the temporal variation in the real interest rate differential between Korea and the US, exchange rate changes and inflation, respectively. The primary surplus is expected to be negatively related with NVAR and RVAR, but positively related with SVAR and FVAR.[99] But the relation between primary surplus and GVAR or IVAR is theoretically unclear.[100]

Before describing other candidate variables, it is worth commenting briefly on the problem of spurious cycles which may be caused by using filtered data. In Table 6.12, we obtain cyclical components by using the Hodrick-Prescott (HP) filter. The HP filter extracts a nonlinear trend component from an observed series by minimising a weighted average of the variability in the trend and its deviations from the actual data. The trend value is obtained by minimizing the following loss function: $\min_{X_t^T} L = \sum_{t=1}^{n}(X_t - X_t^T)^2 + \lambda \sum_{t=2}^{n-1}(\Delta X_{t+1}^T - \Delta X_t^T)^3$ where X_t and X_t^T are the logs of observed and trend respectively, *n* is the number of observations and λ is a smoothing parameter: larger λ indicates smoother estimates for trend and consequently a larger cyclical component. It is known that when *integrated* or *nearly integrated* series are filtered, mechanical use of HP filtering may create spurious cycle or unreal comovements which are not present in the original raw data (Cogley and Nason 1995). In addition, when

[99] With other things being equal, temporary increases in net asset purchase (NVAR↑) is likely to exacerbate primary budget balance (ps↓); increases in temporal money supply (SVAR↑) lead to increases in seigniorage (ps↑); reduction in interest rate differential (RVAR↓) may increase interest incomes from foreign assets and reduce interest payments on the MSBs and thus improve primary budget balance(ps↑); depreciation of domestic currency (FVAR↑) improves primary budget (ps↑) by increasing the domestic-currency value of NFA when NFA>0.

[100] When the economic growth is temporarily higher than its trend (GVAR↑), growth rate of MSBs will be less than economic growth rate and thus PS-GDP ratio may be improved (ps↑). However, temporary economic growth may also lead net foreign assets to increase faster than their trend because of increasing sterilisation of (short-term) capital inflows, and thus PS-GDP could be worse where domestic interest rate is higher than foreign foreign interest rate. Given real interest rates, inflation leads to an increase in nominal interest rates which imposes an additional interest burden on the MSBs. However, the real value of the MSBs also reduces as inflation goes up, and thus the two effects may be offset.

filtered series are used in dynamic econometric models, the models are likely to suffer the omitted variable problem and the autocorrelation problem.

To tackle these problems, we first HP-filter only the stationary variables except real GDP. Second, we adjust the data using the same smoothing parameter (λ =1600) for all variables, to get consistent estimators. Third, considering the possibility of inconsistent and inefficient estimates stemming from HP-filtering, we carefully examine the possible residual autocorrelation and also use HAC standard errors.

The noncyclical factors included in the GUM are the determinants of monetary operations or sterilised FX interventions, which ultimately affect a CB's primary budget. A CB's operations in domestic and FX markets are influenced by FX volatility (SDFX), interest rate volatility (SDRATE), deviation of FX rate from its trend (FXDEV), stock price change (STOCK),[101] short-term capital flows measured by net portfolio investments and short-term borrowing from non-residents (PFOT), current accounts (CA), oil price changes (OIL), and government budget balance (FIS). DVAR represents the CB's non-linear adjustments of its primary budget to changes in MSB. The coefficient of DVAR is expected to be positive if the CB responds more to the larger changes in MSBs. The ADF unit root test suggests that all candidate variables are stationary, as shown in Table 6.12, so that OLS can be applied.

Considering the unit period of the BOK's fiscal accounting (1 year) and the average maturity of the MSBs (11.2 months as of the end of 2009), we use the following ARDL specification with contemporaneous values and four lags of each variable:

$$(6.5.6)\quad ps_t = \alpha_0 + \sum_{i=1}^{4}\alpha_i ps_{t-i} + \sum_{i=1}^{4}\rho_i \cdot \Delta msb_{t-i} + \sum_{i=0}^{4}\beta_i \cdot NVAR_{t-i} + \sum_{i=0}^{4}\gamma_i \cdot SVAR_{t-i} + \cdots + \varepsilon_t,\ \ \varepsilon_t \sim N(0,\sigma^2)$$

---

[101] The share of foreigners in Korean stock markets (in terms of market value) has maintained at approximately 35-40% in the 2000s, which is the highest in Asia. Consequently, Korean stock price mostly rises when foreigners, rather than domestic investors, increase the purchase of Korean stock. So, a stock price rise leads to the BOK's USD purchasing interventions, which increases sterilisation cost in most cases and ultimately exacerbates the primary budget of the BOK.

Table 6.12 Candidate variables used in the GUM

Name	Implication	Measurement	ADF test
(a) Cyclical variables: based on Bohn's argument(1998, 2007)			
NVAR	Level of temporary net asset purchases	$(\Delta NA_t - \Delta NA_t^*)/y_t$ where NA = net asset purchases; y = real GDP (Bohn 1998)	-2.8653 (0.0046)
SVAR	Level of temporary seigniorage revenues	$(\Delta H_t - \Delta H_t^*)/y_t$ where H= real money base (Bohn 1998)	-2.9015 (0.0042)
GVAR	Business cycle indicator	$(y - y_t^* / y_t)(GE_t^* / y_t)$ where GE = government expenditure (Bohn 1998)	-5.1967 (0.0000)
RVAR	Level of temporary variation in interest rate differential	$(diff_t - diff_t^*)/diff_t^*$ where $diff$ = difference between unsecured O/N call money rate and US fed fund rate	-9.1519 (0.0000)
FVAR	Level of temporary variation in FX rates	$(\Delta S_t - \Delta S_t^*)/\Delta S_t^*$ where S = spot exchange rate (in log)	-6.8911 (0.0000)
IVAR	Cyclical variation in inflation	$(\Delta p_t - \Delta p_t^*)/\Delta p_t^*$ where p=CPI (in log)	-8.1071 (0.0000)
(b) Domestic factors related to OMOs: based on empirical results of Ch3 to 5			
FIS	Government budget surplus(or deficit)	Share to GDP; indicative of a CB's concern about a government budget status	-3.0789 (0.0332)
STOCK	Growth rate of stock market price	Log difference of Korean stock price index(KOSPI); Indicative of foreigners' investment sentiment (or foreigners' demand for domestic currency)	-5.7534 (0.0000)
SRATE	Volatility of O/N interest rate	Standard deviation of unsecured O/N call money rate; indicative of uncertainty in money market	-3.0507 (0.0356)
DVAR	Non-linear behaviour of a CB	$(\Delta msb_{t-1} - \overline{\Delta msb})^2$ where $\overline{\Delta msb}$ = unconditional mean; non-linear reactions of the CB to ΔMSBs	ADF:-0.7234(0.0756) PP: -8.1640(0.0000)
(c) External factors related to sterilised FXIs: based on empirical results of Ch3 to 5			
FXDEV	FX rate deviation from its trend	$(FX_t - FX_{t,200ma})/FX_{t,200ma}$ where $FX_{t,200ma}$ = 200 day backward moving average of KRW-USD spot rate; indicative of the necessity of FXI	-5.0258 (0.0001)
SDFX	Volatility of spot exchange rate	Standard deviation of daily spot FX rate within a quarter; indicative of uncertainty in FX market and the necessity of sterilised FXI	-3.7398 (0.0056)
CA	Current account	Share to GDP; indicative of the degree and direction of sterilised FXI	-2.3004 (0.0218)
PFOT	Short-term capital flows	Share to GDP; sum of short-term borrowing and portfolio investments from non-residential(net); indicative of the degree and direction of sterilised FXI	-6.0114 (0.0000)
OIL	Oil price change	Log difference of Dubai spot price index; Indicative of the demand for foreign exchanges	-6.8512 (0.0000)

Notes: 1. * indicate the HP-filtered trend of each series.
2. KPSS test for DVAR cannot reject the null of I(0) at 1% significance level.
3. The figures in ( ) indicate the p-values.
Sources: IMF IFS, Datastream, BOK

6.5.1.5(b) Final model

The final model selected by Autometrics has 11 regressors, which include different lags as presented in the Table 6.13(a).

Table 6.13 Information on final model: Bohn test for MSBs

(a) Regression model :dependent variable = PS_t (primary surplus/GDP)

	Coefficient	Std.Error	t-value	p-value
constant	0.006	0.002	2.88	0.006
PS_{t-4}	0.642	0.044	14.70	0.000
ΔMSB_{t-1}	-0.849	0.034	-25.10	0.000
ΔMSB_{t-3}	-0.069	0.026	-2.67	0.010
ΔMSB_{t-4}	0.658	0.038	17.30	0.000
$NVAR_{t-1}$	-8.102	1.724	-4.70	0.000
$SVAR_{t-4}$	10.223	3.571	2.86	0.006
$FVAR_{t-2}$	0.126	0.021	5.87	0.000
$FVAR_{t-3}$	-0.061	0.022	-2.79	0.007
$IVAR_t$	0.003	0.001	4.42	0.000
$STOCK_{t-2}$	-0.032	0.011	-3.06	0.003
$STOCK_{t-4}$	0.020	0.010	2.04	0.046
ΔOIL_t	0.033	0.008	4.00	0.000
OIL_{t-1}	0.026	0.008	3.11	0.003
OIL_{t-4}	-0.018	0.008	-2.19	0.033
$SDRATE_t$	4.157	0.749	5.55	0.000
$SDRATE_{t-1}$	-4.006	0.744	-5.39	0.000
$SDFX_t$	-0.256	0.099	-2.59	0.012
FIS_{t-2}	-0.105	0.027	-3.85	0.000

Note: Contemporaneous values and four lags of the series are used in the GUM.

(b) Additional information

Sigma ($\hat{\sigma}$)	0.0089	RSS	0.0045
R^2	0.9634	F(18,57)=	63.97 (0.000)
Adjusted R^2	0.9519	log-likelihood	262.206
no.of observations	76	no.of parameters	19
Mean (ps)	0.0031	se(ps)	0.0404

Note: p-value in ( )

(c) Residual diagnostic test output

Test(null)	Distribution	Statistics	p-value
No Autocorrelation	F(5,52)	1.7290	0.1444
No ARCH	F(4,68)	0.3664	0.8317
Normality	$\chi^2(2)$	0.4180	0.8114
No Heteroskedasticity	F(36,39)	1.2947	0.2149
Correct functional form(RESET)	F(2,55)	0.3681	0.6937

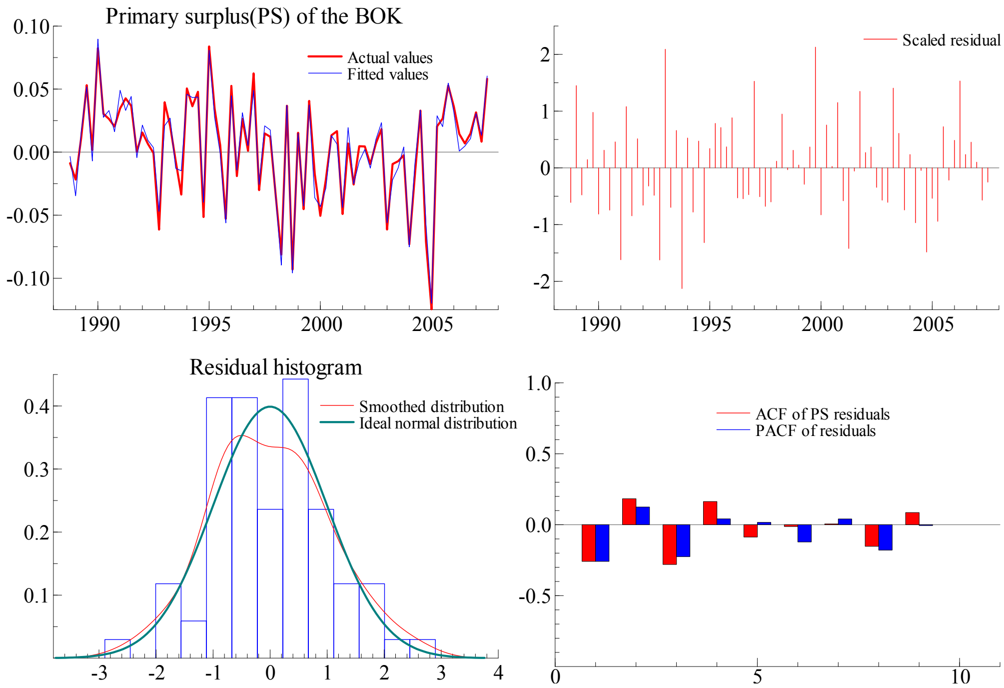
The signs of the coefficients are, in general, consistent with prior expectations and also significant. Particularly, primary surpluses are positively related with SVAR, FVAR and

OIL, and negatively related with NVAR, SDFX and FIS. For example, the estimated coefficient of $NVAR_{t-1}$ is significantly negative, indicating that current cyclical increases in foreign asset purchases worsen the BOK's primary surplus in the next quarter. On the other hand, the coefficient of $SVAR_{t-4}$ is significantly positive, which indicates that a cyclical increase in monetary base will improve the primary budget with time lags. Estimated coefficients for ΔMSB_{t-1}, ΔMSB_{t-3} and ΔMSB_{t-4} of interest to us, are -0.85, -0.07 and 0.66 respectively and all significant at 1% level. This suggests that the increase in MSBs in previous periods does not induce the BOK's budget adjustment in the current period. Since the sum of the coefficients is negative, the dynamic effects of ΔMSB on the primary surplus appear to be negative, implying that the current sterilisation is unsustainable.

Table 6.13(b) provides some information on the degree of fitness of the final model. Because estimated standard deviation, sigma $(\hat{\sigma})$=0.0089, is much smaller than the standard deviation of the dependent variable, se(ps)=0.0404, the model explains some of the variation in primary surpluses well. Adjusted R^2=0.95 and highly significant. F test statistics also support the excellent fitness of this model. Table 6.13(c) shows that the final model passes all misspecification tests.

Figure 6.10 shows a plot of the actual and fitted values of the final model, a plot of scaled residual over time, a residual histogram and an autocorrelation function (ACF) and partial autocorrelation function (PACF). These plots suggest that the final model fits primary surpluses very well, that residuals are homoscedastic and non-autocorrelated, and that the estimated density is close to the ideal normal distribution, as already confirmed by the residual diagnostic tests in Table 6.13(c).

Figure 6.10 Fitted value and residual from final model for BOK primary surplus



However, the aforementioned final model is quite difficult to interpret due to the lagged dependent variables and the regressors with lags. Thus, we consider the long-run solution or equilibrium between the variables, which strips out all dynamics. The error correction type model (ECM) provides steady state impacts of the explanatory variables on the primary surplus. The coefficient of each regressor can be considered as the sum of all partial derivatives to infinity, e.g. the full impact of a change in MSBs in the current quarter on primary surplus over an indefinite horizon (Reade 2011, p180). The static long run solution produced via Oxmetrics is:

$$\begin{aligned}
\textbf{ECM: PS} &= \mathbf{0.0154} - \mathbf{0.7300^{*}\Delta MSB} - \mathbf{22.6396^{*}NVAR} + \mathbf{28.5690^{*}SVAR} \\
&\quad\ (0.005)\qquad (0.000)\qquad\qquad (0.000)\qquad\qquad (0.006) \\
&\quad + \mathbf{0.1807^{*}FVAR} + \mathbf{0.0085^{*}IVAR} - \mathbf{0.0358^{*}\Delta STOCK} \\
&\quad\ (0.001)\qquad\qquad (0.000)\qquad\qquad (0.387) \\
&\quad + \mathbf{0.1159^{*}\Delta OIL} + \mathbf{0.4207^{*}SDRATE} - \mathbf{0.7162^{*}SDFX} - \mathbf{0.2933^{*}FIS} \\
&\quad\ (0.006)\qquad\qquad (0.615)\qquad\qquad (0.009)\qquad\qquad (0.001)
\end{aligned}$$

WALD test: $\chi^2(2) = 106.81\ (0.000)$

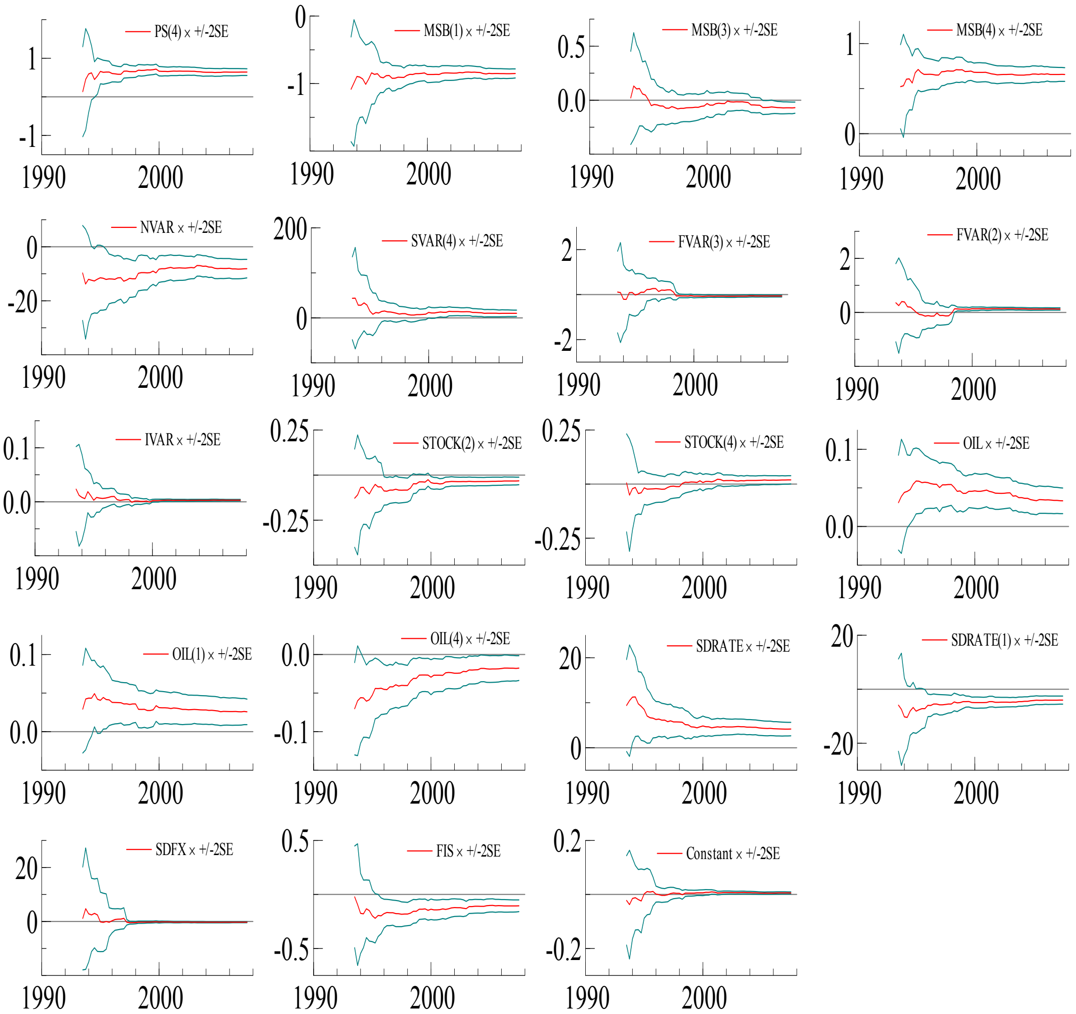
Note: p-values in ( )

Most of the steady state coefficients are significant except those on ΔSTOCK and SDRATE. The coefficients for ΔMSB have a significantly negative value of -0.73, which implies that the BOK's primary surplus-to-GDP ratio decreases by about 0.73% against a 1% point increase of the ΔMSB-to-GDP ratio. This indicates that the BOK does not attempt to increase its primary budget in response to the increase in MSBs. This result supports evidence of standard stationary tests that current MSB-dependent sterilisation is not sustainable.

The negative coefficient on FIS indicates that as Korean government attempts to run fiscal surplus, the burden of the BOK's involvement in FXIs will be larger and thereby the BOK's primary budget will become worse. That is, it is likely that the BOK would be asked to take a larger share of the financing for sterilised interventions if the government is in financial distress. A high volatility of the FX rate (SDFX) leads to a high degree of sterilisation and hence increases sterilisation cost. A rise in oil prices is likely to induce increasing demand for USD and thereby depreciate domestic currency in an oil-importing country like Korea, because oil price is mostly denominated in USD. Accordingly, the resultant depreciation of KRW will lead to an increase in the BOK's sales of foreign assets. The sales, in most cases, have positive effects on the BOK's primary surplus due to the intervention profit that is realised (see Chapter 3). In addition, the depreciation of nominal exchange rates is positively related to the increase in primary surplus owing to valuation effect. The signs of the coefficients for ΔSTOCK and SDRATE are negative and positive as expected, but not significant.

Figure 6.11 shows recursive estimates of all coefficients from the final model for the BOK's primary surplus. This figure enables us to see whether the coefficients are constant over the entire period. There seem to be no apparent structural breaks because the coefficients all settle down to their final values quickly and remain there.

Figure 6.11 Recursive estimates of regression coefficients



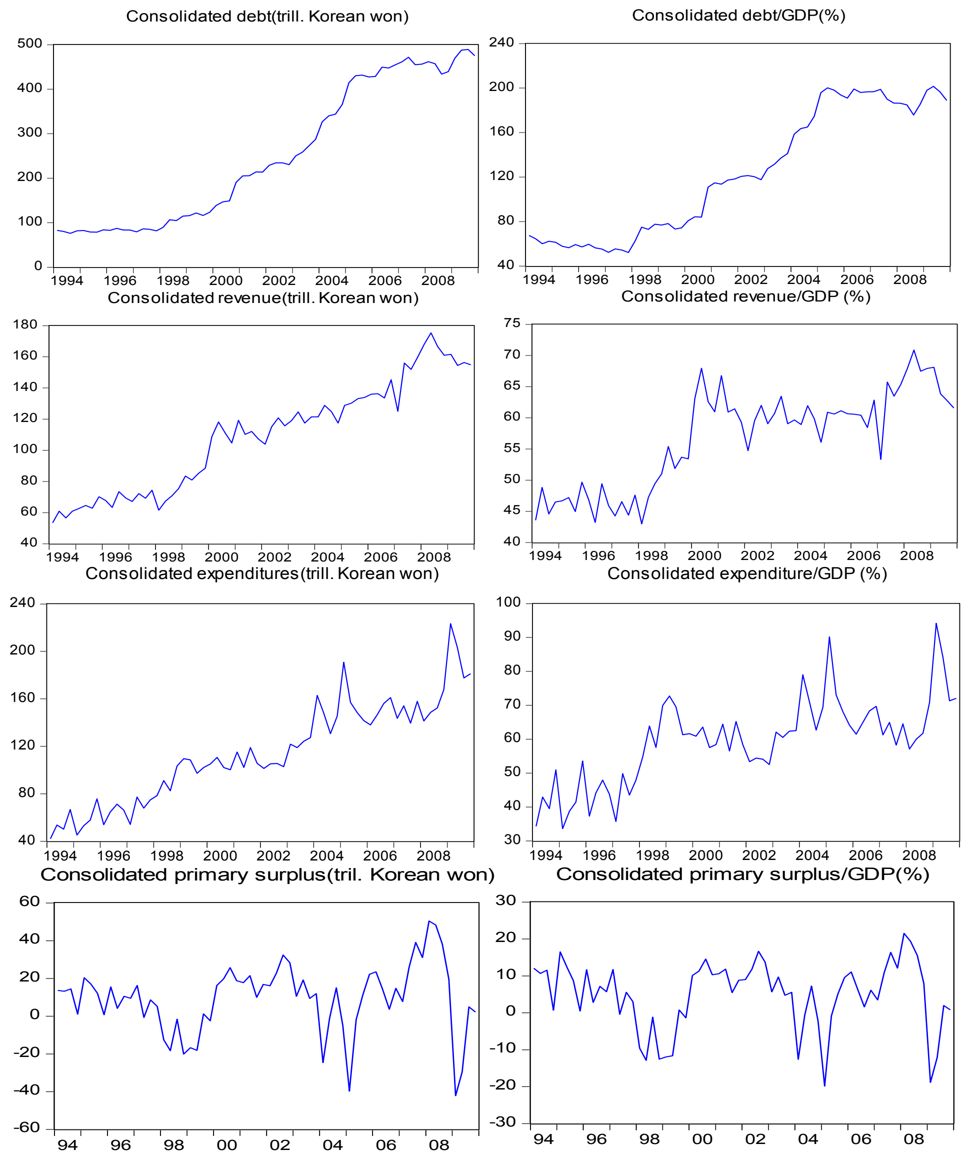
6.5.2 Test for consolidated debts of Korean government and the BOK

6.5.2.1. Univariate stationary test for consolidated fiscal variables

In the previous sections, considering only the budget constraints of the BOK, we see that three different tests all support the non-sustainability of the BOK's MSB-dependent sterilisation. In this section, we consolidate the balance sheets of the Korean government and the BOK to evaluate the MSB-dependent sterilisations at a national-level perspective. We use quarterly fiscal data for the Korean government which is only available for the period

1994Q1-2009Q4. The plots of the consolidated fiscal series are presented in Figure 6.12.

Figure 6.12 Plots of consolidated fiscal variables of the Korean government and BOK



Data: Ministry of Strategy and Finance of Korea, BOK

Consolidated debts (CD), revenues (CTR) and expenditures (CTE) show increasing trends over time in real terms. However, the plots of the variables scaled by GDP show somewhat different patterns. In particular, both CTR and CTE seem to grow less than GDP in the 2000s. Consolidated primary surplus (CPS) has fluctuated over the entire period. In 1998, 2004 and 2008 when the Korean economy was depressed or under financial crisis, the consolidated budget showed huge deficits.

The procedures of sustainability test in this section are exactly the same as those in the previous sections. Table 6.14 presents the results of unit root tests for the level, first difference of real fiscal variables and their ratios to GDP. Overall, the results of stationarity test for the consolidated fiscal series are similar to those for the BOK's fiscal data, with a few exceptions. First, consolidated (undiscounted) debts *(CD=Korean treasury bonds+MSBs)* scaled by GDP and in real terms are tested as I(1) by both the KPSS and PP unit root test, and as I(2) by the ADF test. Note that the second difference stationarity of a debt series is a necessary condition for weak sustainability (Quintos 1995) and is often found in the series of government debt. Second, consolidated total revenues (*CTR = tax revenue + seigniorage + interest income from net foreign assets*) and consolidated total expenditures (*CTE=government expenditure+foreign asset purchase of the BOK+interest payments on treasury bonds and MSB*) are at most I(1) at both their level and their ratio to GDP. Third, consolidated primary surplus (*CPS=CTR – non-interest expenditures of government and BOK*) and total budget surplus (*CTS=CTR-CTE*) are I(0). Because both CTR and CTE are I(1) at most, we can use the Johansen cointegration test.

We first use Wilcox tests for the discounted consolidated debt (CD) in real terms and its ratio to GDP. As presented in Table 6.15, both the discounted CD and CD-to-GDP ratio are non-stationary, so that we may, at this stage, conclude that the current sterilisation is unsustainable. However, notice that the Wilcox condition is not a necessary condition for sustainability. Thus, we proceed to the next step for sustainability test – cointegration based test.

Table 6.14 Unit root tests for consolidated fiscal variables

(Sample: 1994Q1 – 2009Q4)

Variables \ Test statistics		Levels ADF	Levels PP	Levels KPSS	First difference ADF	First difference PP	First difference KPSS	verdict
Consolidated Debt(CD)								
Real[1]	c,t	-0.392	0.292	0.972***	-2.419	-5.833***	0.290	I(1): PP, KPSS; I(2): ADF
Real per GDP	c,t	-1.117	-0.634	0.951***	-2.130	-10.660***	0.153	I(1): PP, KPSS; I(2): ADF
Consolidated total revenue (CTR)								
Real	c,t	-0.729	-1.031	0.983***	-12.549***	-12.559***	0.077	I(1): all
Real per GDP	c,t	-1.630	-2.912**	0.789**	-3.779***	-18.727***	0.220	I(1): ADF, KPSS; I(0) :PP
Consolidated total expenditures (CTE)								
Real	c,t	-1.700	-1.382***	0.987	-7.821***	-22.467***	0.252	I(1): ADF; I(0): PP, KPSS
Real per GDP	c,t	-3.634***	-3.525**	0.721**	-4.284***	-20.485***	0.403*	I(0): ADF, PP; I(1):KPSS
Consolidate primary surplus (CPS)								
Real	c	-3.853***	-3.913***	0.142	-7.018***	-11.478***	0.195	I(0): all
Real per GDP	c	-4.080***	-4.069***	0.068	-9.800***	-12.106***	0.027	I(0): all
Consolidated total surplus(CTS)								
Real	c	-3.633***	-3.670***	0.254	-6.922***	-9.487***	0.130	I(0): all
Real per GDP	c	-3.822***	-3.688***	0.256	-9.493***	-9.877***	0.197	I(0): all

Notes: 1. The series are measured as follows: $CD_t = MSB_t + D_t$; $CTR_t = \Delta H_t + r\,NA_{t-1} + T_t$; $CTE_t = \Delta NA_t + r_t(MSB_{t-1} + D_t) + GE_t$; $CPS_t = CTR_t - \Delta NA_t - GE_t$; $CTS_t = CTR_t - CTS_t$

2. Although ADF test suggests that CD is I(2), we assume that CD is I(1) because KPSS and PP test suggest that CD is I(1).

3. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance, respectively.

4. c and t indicate that unit root test form includes an intercept and deterministic trend term, respectively

5. When we include both time trend and intercept in the test form for CPS and CTS (or exclude time trend in the test for CD,CTR and CTE), the test results are same.

6. In KPSS and PP test, the spectral estimation method is Bartlett kernel, and bandwidth is selected by Newey-West's method.

Table 6.15 Wilcox test for the discounted consolidated debt and its ratio to GDP

Variables \ Test statistics		Levels ADF	Levels KPSS	First difference ADF	First difference KPSS	Breaks Zivot-Andrews	verdict
Consolidated debt(CD)	c	0.111 (0)	0.939^{***} (6)	-5.832^{***} (0)	0.266 (2)	-4.012	I(1)
	c,t	-1.996 (0)	0.149^{**}(6)	-5.777^{***} (0)	0.214^{*} (1)		I(1)
CD-GDP ratio	c	-1.059 (5)	0.942^{***} (6)	-3.773^{***} (4)	0.169 (12)	-3.925	I(1)
	c,t	-1.285 (5)	0.134^{*}(5)	-3.766^{***} (4)	0.162 (12)		I(1)

Notes: 1. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, respectively.
2. *c* and *t* indicate that unit root test form includes an intercept and deterministic trend term, respectively.
3. Null hypothesis is I(1) in ADF and I(0) in KPSS test. The figures in parentheses indicate the number of lags selected by AIC in ADF test and Newey-West bandwidth estimated by Bartlett kernel in KPSS test.
4. Null hypothesis is I(1) and the alternative is I(0) with a break in Zivot-Andrews test (maximum lag=12). The series are tested with an intercept..

6.5.2.2 Cointegration between consolidated revenues and expenditures

We employ Johansen's methodology to test for cointegration between consolidated *total revenue (ctr=CTR/GDP*) and consolidated *total expenditure* (*cte=CTE/GDP*). Considering the budget planning process explained in the previous section, the maximum number of lags is assumed to be 6. The information criteria suggest 4 lagged VAR with constant.[102] Table 6.16 shows that both the trace test and maximum eigenvalue test reject the null of no-cointegration (*r=0*) and suggest a cointegration rank of 1 – at a 1% significance level.

[102] The results of the test for VAR lag structure are as follows. When extending the maximum number of lags up to 12, we obtain the same results.

	With constant FPE	With constant AIC	With constant SC	With constant HQ	Without constant FPE	Without constant AIC	Without constant SC	Without constant HQ
0					4.39e-05	-4.358744	-4.287694	-4.331069
1	1.74e-05	-5.284311	-5.142211	-5.228960	1.54e-05	-5.404964	-5.191814	-5.321938
2	1.20e-05	-5.658575	-5.374376*	-5.547874	1.19e-05	-5.663027	-5.307778*	-5.524650
3	1.25e-05	-5.619071	-5.192772	-5.453019	1.26e-05	-5.605269	-5.107921	-5.411542
4	9.87e-06*	-5.853943*	-5.285545	-5.632540*	1.02e-05*	-5.820080*	-5.180633	-5.571003*
5	1.02e-05	-5.825716	-5.115219	-5.548963	1.05e-05	-5.802408	-5.020860	-5.497979
6	1.16e-05	-5.697590	-4.844993	-5.365487	1.19e-05	-5.676722	-4.753075	-5.316943

Notes : 1. * indicates lag order selected by the criterion
2. FPE: Final prediction error, AIC: Akaike information criterion,
SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 6.16 Johansen maximum likelihood cointegration test

	Null	Alternative	Statistics	p-value
Trace test(λ_{trace})	r = 0	r ≥1	19.107***	0.003
	r ≤ 1	r ≥2	1.759	0.217
Maximum eigenvalue test($\lambda_{\max}$)	r =0	r =1	17.348***	0.004
	r ≤ 1	r =2	1.759	0.217

Notes: 1. Asterisks (***) indicate the rejection of the null hypothesis of no cointegration at 1% significance level, respectively.
2. r stands for the number of cointegration vectors.

Now, we preliminarily assume that there is one cointegration vector between *ctr* and *cte* and then construct the VECM. No time trend terms are included either in the differential variable part and or the cointegration part of the VECM. An intercept is included in the cointegration part but not in the difference variable part. Thus, the two variables *ctr* and *cte* have the following model with four lags:

$$(6.5.7)\quad \Delta ctr_t = \gamma_{TR}(ctr_{t-1} - \alpha - \beta \cdot cte_{t-1}) + \sum_{i=1}^{4} \gamma_{11}(i)\Delta ctr_{t-i} + \sum_{i=1}^{4} \gamma_{12}(i)\Delta cte_{t-i} + \varepsilon_{ctr,t}$$

$$\Delta cte_t = \gamma_{TS}(ctr_{t-1} - \alpha - \beta \cdot cte_{t-1}) + \sum_{i=1}^{4} \gamma_{12}(i)\Delta ctr_{t-i} + \sum_{i=1}^{4} \gamma_{22}(i)\Delta cte_{t-i} + \varepsilon_{cte,t}$$

where β = the coefficient of the cointegration vector given by $ctr_t = \alpha + \beta \cdot cte_t + \varepsilon_t$, $\varepsilon_{ctr,t}$ and $\varepsilon_{cte,t}$ = white-noise errors. We check the appropriateness of the estimated VECM by testing the properties of the residuals. The results are presented in Table 6.17. The normalised cointegration coefficient (β) is -0.96 at 1% significant level. At first glance, the coefficient indicates that the sterilisation policy is sustainable in the context of the weak form. To see whether the coefficient (-0.96) is statistically different from -1, we impose the restriction of the cointegration vector $(1, \beta)$ = (1, -1) and test the validity of the restriction. The likelihood ratio (LR) test (Chi-square 0.0287, p-value 0.87) suggests that the estimated correlation vector is not significantly different from (1, -1).

Table 6.17 VECM (4) estimates for the consolidated revenue and expenditure

Cointegration term: $(CTR/GDP)_{t-1}$ − 0.05 − **0. 96*****× $(CTE/GDP)_{t-1}$
(0.092) (0.169)
[-0.524] [-5.699]

Regressors \ Dependent variables	Δ(CTR/GDP)$_t$	Δ(CTE/GDP)$_t$
cointegration term	-0.239580*** (0.08790) [-2.72550]	0.315889* (0.17214) [1.83508]
Δ(CTR/GDP)$_{t-1}$	-0.579019*** (0.13635) [-4.24666]	-0.610011** (0.26701) [-2.28463]
Δ(CTR/GDP)$_{t-2}$	-0.073099 (0.15637) [-0.46749]	0.007156 (0.30621) [0.02337]
Δ(CTR/GDP)$_{t-3}$	-0.045991 (0.15288) [-0.30082]	0.062345 (0.29939) [0.20824]
Δ(CTR/GDP)$_{t-4}$	0.176856 (0.13845) [1.27742]	0.281379 (0.27112)[1.03784]
Δ(CTE/GDP)$_{t-1}$	-0.213191** (0.09589) [-2.22336]	0.023111 (0.18777) [0.12308]
Δ(CTE/GDP)$_{t-2}$	-0.352178*** (0.09417) [-3.73964]	-0.174666 (0.18442) [-0.94711]
Δ(CTE/GDP)$_{t-3}$	-0.306156*** (0.09807) [-3.12181]	0.011496 (0.19205) [0.05986]
Δ(CTE/GDP)$_{t-4}$	-0.069447 (0.09681) [-0.71738]	0.257234 (0.18957)[1.35690]
Adj. R-squared	0.551326	0.305077
F-statistic	9.908741	4.182807
Log likelihood	113.4813	73.82935
Mean dependent	0.001942	0.004435
S.D. dependent	0.057334	0.090216
Log likelihood	192.1273	
Diagnostic		
Adjusted Q	21.01067< 0.9703 >	
Serial correlation LM test	5.662224< 0.2258>	
Normality	1.931491< 0.3807 >	
White Heteroskedasticity test	163.9952< 0.4414>	

Notes: 1. Standard errors in ( ) and t-value in [ ]. P-value in < >.
2. ***, ** and * denote the rejection of the null at the 1%, 5% and 10% significance level, Respectively (critical value: 1.67, 1.99 and 2.64 at 10%, 5% and 1% significant level).
3. Multivariate LM test for serial correlation up to lag 12: null is no residual autocorrelations.
4. Multivariate extensions of the Jarque-Bera residual normality test under the null of normality. Inverse square root of residual correlation matrix (Doornik and Hansen 1994) is used.
5. Multivariate extensions of White's heteroskedasticity test: null is no heteroskedasticity.

The existence of cointegration vector close to (1-1) indicates that the source of fiscal adjustments in Korea is evident in the long run, so that we may now conclude that the sterilisation policy is strongly sustainable. This result contrasts with the case where there is no cointegration relation between the total revenues and total expenditures of the BOK. Hence, based on the cointegration analysis, we conclude that the current MSB-dependent sterilisation appears sustainable, but that the source of sustainability comes from the Korean government's taxation capacity or budget surplus, not from the BOK's adjustment activities.

To see the short-run dynamics of CTE and CTR, we consider the signs and significance of the coefficients for the difference part of the VECM (see the shaded area of the second column in Table 6.17). The coefficient of cointegration (or error-correction) term is significant with −0.2396, indicating that if disequilibrium occurs owing to a percentage point increase in CTE-to-GDP in one period, CTR-to-GDP will increase 0.2396 percentage points during the next quarter to restore equilibrium, and vice versa. In the second column of Table 6.17, the coefficients of $\Delta(CTR/GDP)_{t-1}$ are significantly negative, indicating on average a negative autocorrelation in CTR. The coefficients for $\Delta(CTE/GDP)_{t-i}$ are, in general negative and highly significant (up to lag 3), indicating that increases in CTE in previous periods lead to decreases in current CTR. It may be interpreted that the authorities appear not to react to changes in spending by increasing revenues in the short term.

To sum up, although the Korean government and the BOK appear not to respond to the increasing MSBs in the short run, they have adjusted their consolidated budgets in order to maintain long-term equilibrium between total revenues and total expenses. This finding provides evidence that the current MSB-dependent sterilisation policy may be sustainable in the long run. However, the source of the sustainability is not the BOK's budget strength but that of the Korean government.

6.5.2.3 Modified Bohn test based on general-to-specific methodology

In this section, we estimate whether the BOK and the Korean government adjust their (consolidated) budget together to changes in their consolidated debt. We use same general-to-specific methods as we did in the Bohn test for the BOK's budget constraint in the previous section. We use cyclical variables to influence not only the CB's budget but also the government's fiscal status. Based on Bohn (1998), we use the same candidate variables (shown in Table 6.12) in the GUM, except that SVAR and NVAR are replaced by EVAR and REVAR. EVAR and REVAR indicate the level of temporary expenditure and revenues of consolidated government, respectively. They are measured as $EVAR = (CTE - CTE_t^* / y_t)$ $REVAR = (CTR - CTR_t^* / y_t)$. With other things being equal, temporary increases in consolidated expenditure (EVAR↑) are likely to worsen primary budget balance (cps↓). Increases in temporary consolidated revenue (REVAR↑) improve the consolidated primary budget (cps↑). Hence the coefficients on EVAR and REVAR are expected to have negative and positive sign respectively. We include all candidate variables in the GUM with 4 lags and IIP (impulse indicator saturation) at α=0.001. The specification of the GUM is:

$$(6.5.7)\quad cps_t = \alpha_0 + \sum_{i=1}^{4}\alpha_i ps_{t-i} + \sum_{i=1}^{4}\rho_i \cdot \Delta cd_{t-i} + \sum_{i=0}^{4}\beta_i \cdot EVAR_{t-i} + \sum_{i=0}^{4}\gamma_i \cdot REVAR_{t-i} + \cdots + \varepsilon_t,\ \varepsilon_t \sim N(0,\sigma^2)$$

where $cps_t = (TR_t + \Delta H_t + r_t^* NA_{t-1} - GE_t - \Delta NA_t)/GDP_t$ and $cd_t = d_t + msb_t = D_t/GDP_t + MSB_t/GDP_t$. The final model is presented in Table 6.18. Most of the coefficients have expected signs and are significant. For example, the coefficients on $EVAR_t$ and $RVAR_{t-2}$ are negative, indicating that temporary increases in consolidated expenditures and domestic-foreign interest rate difference lead to a worsening of the consolidated primary budget. The coefficients on cyclical revenue increase (i.e., $REVAR_t$ and $REVAR_{t-4}$) are all positive. In particular, the coefficient on Δcd_{t-1}, of interest to us, is 0.21 with a p-value 0.016, indicating that the increase of 1% point in consolidated debt-to-GDP ratio in the current quarter leads to a 0.21 % point increase in consolidated primary surplus-to-GDP ratio in the next quarter. Although the coefficient on Δcd_{t-2} has a negative value with -0.08, the coefficient is much less than the coefficient on Δcd_{t-1} in absolute value, and insignificant. This indicates that current MSB-dependent sterilisations may be sustainable, which is consistent with the results of the cointegration analysis in the previous section.

Table 6.18 Information on final model: Bohn test for consolidated debt

(a) Final regression model: dependent variable consolidated primary surplus (CPSt)

	Coefficient	Std.Error	t-value	P-value
Constant	0.041	0.010	4.20	0.000
cps_{t-1}	0.466	0.072	6.51	0.000
Δcd_{t-1}	0.208	0.082	2.54	0.016
Δcd_{t-2}	-0.080	0.077	-1.04	0.306
$REVAR_t$	1.208	0.225	5.37	0.000
$REVAR_{t-4}$	0.022	0.003	7.83	0.000
$EVAR_t$	-1.269	0.232	-5.46	0.000
$RVAR_{t-2}$	-0.015	0.003	-4.33	0.000
$IVAR_{t-2}$	-0.008	0.003	-2.92	0.006
$GVAR_{t-2}$	-0.018	0.004	-4.63	0.000
$SDRATE_{t-2}$	7.531	2.333	3.23	0.003
$SDRATE_{t-3}$	-8.981	2.114	-4.25	0.000
I_{1997Q2}	-0.091	0.029	-3.14	0.003
I_{2004Q1}	-0.218	0.030	-7.25	0.000
I_{2005Q1}	-0.291	0.031	-9.25	0.000

Note: The final model is selected from a GUM with 4 lags and IIS at α=0.001

(b) Additional information

Sigma ($\hat{\sigma}$)	0.0275235	RSS	0.0265139933
R^2	0.9254	F(18,57)=	31.01 (0.000)**
Adj. R^2	0.89556	log-likelihood	117.606
no. of observations	50	no. of parameters	15
mean(cps)	0.041984	se(cps)	0.0851669

Note: p-value in ( )

(c) Residual diagnostic test output

Test(null)	Distribution	Statistics	p-value
No Autocorrelation	F(4,31)	2.5140	0.0616
No ARCH	F(4,42)	0.99252	0.4222
Normality	$\chi^2(2)$	3.1779	0.2041
No Heteroskedasticity	F(22,24)	0.60048	0.8833
Correct functional form(RESET)	F(2,33)	0.19862	0.8208

The impulse-indicator saturation suggests three dummy variables: 1997Q2, 2004Q1 and 2005Q1. That is, the main impulses in the final model are large drops in consolidated primary surplus in 2004Q1 and 2005Q1 and relatively smaller impacts in 1997Q2. These outliers are due mainly to the fiscal deficit during the 1997 financial crisis and rapid increases in government bonds due to institutional changes in 2004-2005. That is, after the 1997 financial crisis, the Korean government raised public funds for financial sector restructuring by issuing Deposit Insurance Fund Bonds and Non-performing Asset Resolution Fund Bonds (which were not included in government bonds at the time when they were issued). The public bonds were redeemed by newly issued government bonds for 2003-2005. This result support previous studies that the debt of the Korean government began to enter the unsustainable region in the aftermath of the 1997 crisis (see Croce & Juan-Ramon 2003).

Figure 6.13 (together with above Tables 6.18(b) and 6.18(c)) suggests that the final model fits the consolidated primary surpluses very well. Thus, we can proceed to the next step to estimate the long-run coefficients. The long-run solution yields following steady-state coefficients:

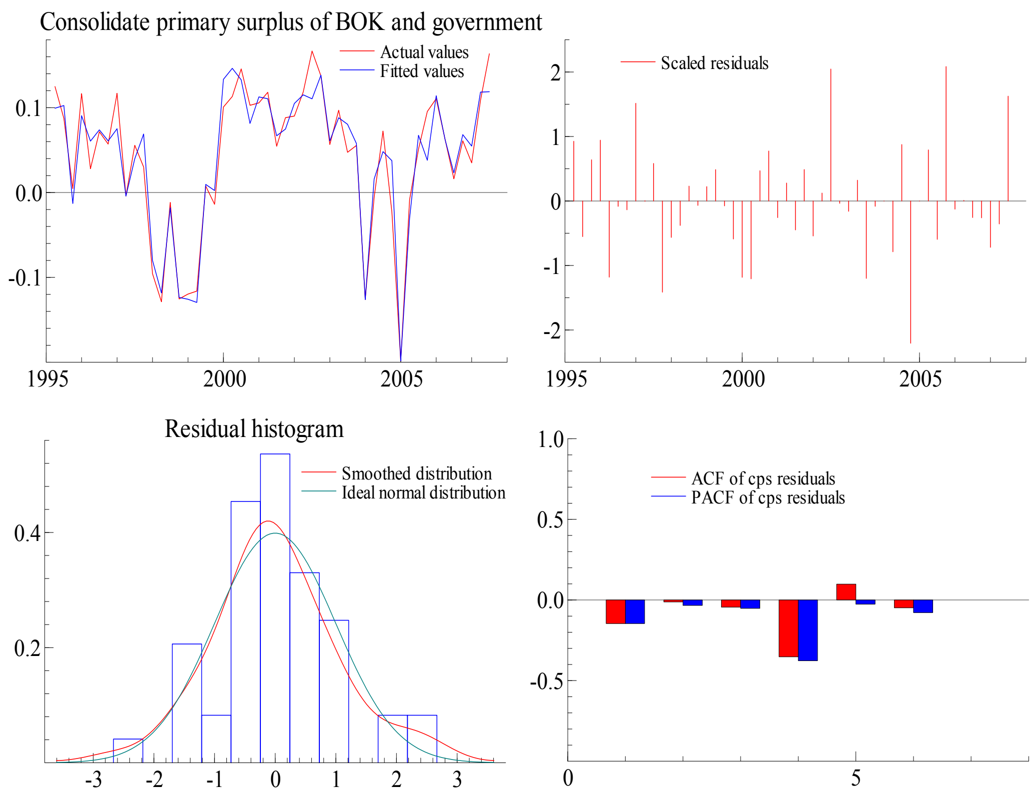
ECM: $\mathbf{cps = 0.0766 + 0.2403^{*}\Delta cd + 2.3053^{*}REVAR - 2.3774^{*}EVAR}$
(0.0000) (0.0291) (0.0002) (0.0002)

$\mathbf{- 0.0277^{*}RVAR - 0.0150^{*}IVAR - 0.0334^{*}GVAR - 0.7158^{*}SDRATE}$
(0.0008) (0.0096) (0.0005) (0.1246)

WALD test: $\chi^2(10) = 67.5094$ (0.000)
Note: p-value in ( )

The coefficient on Δcd indicates the steady-state impact of the increase in consolidated debt(CD) on the consolidated primary surplus (CPS). A percentage point increase in the CD-to-GDP ratio will lead to a 0.24 % point long-term increase in CPS-to-GDP. This indicates that the BOK and Korean government jointly increase their primary surplus in response to the increasing MSBs or government bonds. Consequently, we conclude that when government budgets are considered, the BOK's MSB-dependent sterilisation may be sustainable. This finding is consistent with the result from the cointegration tests in the previous section.

Figure 6.13 Fitted value and residual from final model for consolidated primary surplus



6.6 Conclusion

6.6.1 Summary of main findings

This chapter examines the sustainability of the CB's sterilisation policy depending on the CB's interest bearing bonds (i.e., MSBs). The main purpose is to answer the question about whether the current amount of the MSB outstanding is too large for the CB to continue its sterilisation policy. For this, we decompose the "consolidated" government intertemporal budget constraints into the separate budget constraints of a CB and a government. The separate consideration of the budget constraints of these two authorities (which are considered as a single entity in most studies) provides an analytical tool to assess the sustainability of the CB's sterilisations using MSBs.

Based on the theories on fiscal sustainability, we first derive the intertemporal budget constraint (IBC) of a CB, and then view the sustainability conditions. The IBC postulates that the current MSB-dependent sterilisation policy will be sustainable if the current stock of the MSB outstanding is equal to the present value of the CB's future primary surplus (=seigniorage+interest incomes from foreign reserves−purchases of net foreign assets). The IBC requires that the CB ensure the future primary surplus whose present value adds up to the current value of the MSBs by increasing seigniorage, by increasing interest income from foreign assets or by decreasing purchases of foreign assets in the future, so that its current sterilisations are permanently sustainable. Then, we set up several empirical models and provide the sequential test procedure for evaluating the sustainability of the MSB-dependent sterilisation policy.

Three test methods modified from fiscal sustainability theory are investigated: (i) univariate stationary tests for discounted MSBs; (ii)cointegration test for the CB's revenues and expenditures; (iii) Bohn's reaction function-based test. Unlike the first two stationarity-based tests, Bohn test emphasizes the CB's intentional response of adjusting the primary surplus to the change in MSBs irrespective of the effects of cyclical business factors on fiscal variables. Since neither the stationarity-based tests nor the Bohn test provide the necessary condition but sufficient condition, we need to use the sustainability tests together or selectively depending on data availability.

Three sustainability tests using quarterly Korean data for 1987-2009 suggest that, overall, MSB-dependent sterilisation policy in Korea may not be sustainable when only the BOK budget is considered, but sustainable when the government budget is analysed together with that of the BOK. In particular, when limiting the estimation only to the BOK's intertemporal budget constraints, all three tests present evidence against the sustainability of the MSB-dependent policy in Korea. The BOK's current sterilisation policy may not be sustainable, because the BOK has neither increased seigniorage nor reduced the build-up of foreign reserves significantly. This may be related with the shift of monetary policy regime in 1999 and strong necessity of sterilisation for the increasing domestic liquidity caused by a huge amount of capital inflows and current account surplus during the 2000s.

However, the tests for the consolidated budget of the BOK and the Korean government show that current sterilisation policy is sustainable. Consequently, the sustainability of the current MSB-dependent sterilisation policy may not come from the BOK's adjustments of its budget constraint but the Korean government's taxation capacity or budget surplus. This may ultimately impair the BOK's monetary policy independence from the Korean government.

6.6.2 Limitations of study and future research

As explained so far, fiscal sustainability theories can be, in principle, applied to the investigation on the sustainability of CBs' MSB-dependent sterilisation policies. However, it is noteworthy that there are two limitations in such an application in practice. First, CBs would not be able to easily increase their revenues in response to weakening sustainability of their current policy as governments do. This is because increases in seigniorage or interest income from foreign reserves are beyond most CBs' control particularly in small open emerging economies. For example, raising seigniorage may conflict with CBs' main objectives – price stability. Return on foreign reserves is determined mainly by international interest rates rather than by CBs investment. Meanwhile, governments can increase tax revenues when they suffer severe fiscal debts. Second, most CBs in emerging counties are subject to government directives in interventions in FX markets. Hence, even if CBs face with serious sustainability problems, they cannot make their own decisions to change intervention behaviours. That is, they cannot reduce or stop foreign-currency buying interventions for their own accord owing to political pressure. For example, even the Fed has still at times unwillingly participated in interventions initiated by US Treasury because "appearing not to cooperate in a legitimate policy action of the administration would raise market uncertainty and could sabotage the operation's chances for success"(Bordo et al. 2011). Congress has frequently cautioned that the FRB should conform to the Treasury's intervention policies.

Several assumptions used in this chapter are worth being loosened for further research. First of all, we assume that all foreign reserves consist of USD-denominated assets when testing the sustainability of BOK's MSB-dependent policy. This is somewhat inevitable because Korea like other nations does not reveal the currency composition of its foreign reserves. However, this is truly unrealistic. For example, according to IMF statistics on Currency Composition of Official Foreign Exchange Reserves, USD-denominated assets occupy 61.0 per cent of world foreign exchange reserve holding as of the end of 2011Q1: Euro (26.5%), British pound (4.1%), Japanese yen (3.6%), etc. The changes in composition of foreign assets would have significant effects on the result of sustainability test. Hence, it is, for example, worthwhile to compare the results of sustainability test in line with the change in currency composition of foreign reserves. In addition, the choice of interest rates affect the result of the cointegration-based sustainability test, as Bohn (2007) points out. We use US Treasury Bill rate with 1 year maturity as a foreign interest rate. It is more appropriate to use weighted average interest rate than single foreign interest rate in order to reflect the actual currency composition of foreign reserves.

The empirical test in this chapter focuses on Korea’s case owing to the lack of data. Time-series analysis is known as vulnerable to omitted variable bias owing to unobserved heterogeneity. Hence, it would be interesting to extend the sustainability test methodologies (by using panel analyses) to other countries such as China and Taiwan in which MSBs are main sterilisation tool. Lastly, when disaggregating main accounts in balance sheets of the central bank and government, we can measure the revenue and expenditures more accurately.

CHAPTER 7 CONCLUSION AND POLICY IMPLICATIONS

7.1 Summary of main findings

During the last two decades when capital mobility has accelerated in emerging countries, many CBs have used sterilisation as a main tool to maintain monetary independence while stabilising the FX rate fluctuations simultaneously. Despite the considerable benefits of the sterilisation, it has limitations in being continuously used as a policy tool to address capital inflows due to sterilisation cost. In this thesis, we have examined the impacts and sustainability of sterilised intervention policy – in particular, sterilisations depending on the issuance of monetary sterilisation (or sterilisation) bonds (MSBs).

We first overview some theoretical aspects and statistical facts regarding sterilisations and capital flows in key countries. Conventional trilemma theory proposes that sterilisation may be possible in the short run under limited capital mobility. With regard to the feasibility of sterilisation, there have been two opposite arguments. Calvo (1991) emphasizes the difficulty in sterilisation owing to sterilisation peril from a theoretical perspective while Reisen (1993) considers the sterilisation as a more feasible policy tool from a practical perspective. Theoretically, the impacts of sterilisation are different depending on the natures of capital flows (Frankel 1997). Sterilisation is more feasible when the capital inflows stem from push factors (e.g. a fall in foreign interest rates) rather than pull factors (e.g. an increase in domestic money demand).

Statistics in the chapter 2 appear to support Reisen (1993), because both FX rate and interest rate became less volatile after CBs employed inflation targeting (IT) with more flexible FX rates and freer capital markets, in most emerging economies from around 2000. Inflation rate remained lower in the 2000s than in the 1990s. This is somewhat contradictory to theoretical expectation that FX rates would be more volatile after the introduction of IT with more flexible FX regime than before. It is noteworthy that both exchange and short-term interest rates are more stable in countries holding larger amounts of foreign reserves, implying that most emerging countries may fear domestic-currency appreciation more. Overall, sterilisations mostly backed by asymmetric interventions appear feasible and effective in stabilising both FX and interest rate (and thereby inflation) in most emerging IT countries.

However, the sterilisations may lead to considerable sterilisation peril owing to foreign-domestic interest rate differentials in most emerging countries. In particular, Korea has been confronted with the quandary that as foreign reserves rushed in, domestic liquidity could have become too “loose” to stabilise inflation or too “tight” to resist the pressures for the domestic currency appreciation. The BOK has issued MSBs to solve the dilemma. However, a large stock of MSB outstanding imposes a substantial burden to the BOK with regard to inflation control and sterilisation costs. In particular, significant financial losses of the BOK in recent times have raised the question about the sustainability of MSB-dependent policy. The statistical intuitions obtained from chapter 2 are examined in the following chapters with recent econometric techniques.

Chapter 3 investigates the impacts of sterilised FX interventions on FX rate level and volatility by applying ACT-GARCH model with daily data on Korea, Japan and Australia. We find that one-off interventions appear ineffective, but that large interventions affect FX rate levels and volatility in the three countries. Notably, in Korea and Japan interventions appear more effective in reversing the current trend than in Australia. The differences in intervention effects on the FX rate level in three countries may be explained by different features of their FX market structures and intervention patterns. Interventions appear not to affect long-term FX rate volatility significantly but increase short-term volatility. Transitory leverage effects on conditional volatility exist in both Korea and Japan – but not in Australia, indicating that concerns about the domestic-currency appreciation are larger than those about depreciation in Korea and Japan. Simple estimations of the intervention profits show that the BOJ and RBA did make profits, whereas the BOK experienced intervention losses mainly because of the interest rate differential. Different signs of the coefficients for size (or intervention persistency) dummies and one-off interventions in Korea and Japan imply that, large or persistent interventions possibly produce unexpected side effects opposite to what the initial (one-off) intervention aims for. This is partly due to secret intervention practices in these countries.

Chapter 4 explores the intervention motives in major countries focusing on their asymmetric intervention preferences for inducing domestic-currency depreciation. Based on Pesaran et al.'s cointegration analysis between foreign reserves and FX rate changes in 11 countries, we find a preference for asymmetric interventions inducing domestic-currency depreciation in small open economies like Korea rather than relatively large or closed economies such as Japan and India. Considering the limitations of using foreign reserves as a proxy for interventions, we apply probit and friction model with daily intervention data. Probit estimation suggests that various common factors affect interventions in the three countries: the degrees of current FX rate deviation from trend, levels of FX rate volatility, country risks, and previous interventions. We find a significant difference in intervention response to deviation from volatility trend between the small open economies (Korea and Australia) and the large economy (Japan). Importantly, the friction model provides direct information on the degrees of asymmetric interventions. The Korean authorities tend to react more to the appreciation than to the depreciation of Korean won, while their Japanese counterparts seem to respond symmetrically. The RBA prefers interventions for supporting Australian dollar. Interest rate differentials and changes in MSBs appear not to be considered in the FXI decision-making process in the very short-run.

Chapter 5 examines the degrees of sterilisation and *de facto* capital mobility by estimating sterilisation and offset coefficients with quarterly panel data on 30 countries. Estimation results provide evidence that most emerging countries – in particular, emerging IT-Asia countries – significantly increased their sterilisations from the late 1990s (when most of the sample countries introduced IT regime with flexible FX rate regimes), and practiced nearly-complete or over-sterilisations in the 2000s. Time-series analyses for individual countries provide evidence that oversterilisations were prevalent in East Asian countries during the 2000 − Korea, China, Japan, Indonesia, etc. The evidence of increasing sterilisations leads us to expect that *de facto* capital mobility may not have changed significantly in Asian IT countries between the 1990s and the 2000s, despite the considerable institutional changes (e.g. capital market opening and more flexible FX regime) that took place. The estimated offset coefficients seem to support this. The evidence of nearly-complete or excessive sterilisations hints at possible sterilisation peril in emerging countries. Our finding appears to weakly support the possibility of sterilisation peril in emerging countries, because high degrees of sterilisation tend to raise local interest rates in emerging IT-Asia countries. In Korea, we find over-sterilisation and an increase in the degree of sterilisation over time since the introduction of IT, which may contribute to the huge accumulation of MSBs and consequent high sterilisation costs.

Chapter 6 attempts to provide analytical methodologies to assess the sustainability of MSB-dependent sterilisation policies. Based on such fiscal sustainability theories, we first derive the intertemporal budget constraint (IBC) of the CB that uses MSBs as its main sterilisation tool. The IBC postulates that the current MSB-dependent sterilisation policy will be sustainable if the current stock of MSBs is equal to the present value of the CB's future primary surplus (= seigniorage + interest income from foreign reserves - purchases of net assets). Empirical study on the case of BOK suggests that, considering only the CB's budget constraint and behaviour, the BOK's current sterilisation policy may be unsustainable. However, the test for the consolidated budget of the BOK and the Korean government suggests that current sterilisation policy may be sustainable. Thus, we may conclude that the sustainability of the current BOK's MSB-dependent sterilisations may not come from the BOK's adjustments of its budget but the government's taxation capacity or budget surplus. This may ultimately impair the BOK's anti-inflation efforts and monetary policy independence from the Korean government.

7.2 Policy implications for sterilised FX intervention and its sustainability

The main findings of this thesis, in general, imply that the sterilised FX interventions cannot generate permanent changes in FX rates, as many other previous studies have indicated. FX interventions may be able to address unwarranted FX rate changes stemming from temporary shocks and thereby help to slow down the pace of FX rate movement. As a substitute for capital control, the sterilised intervention in emerging countries may be possibly effective in adjusting both FX and interest rates to some extent only in the short run.

However, if sterilized interventions are persisted for a long time, there is a sterilisation peril, which may eventually lead to the failure of the sterilisation policy for controlling inflation in the long run. In this respect, persistent asymmetric FX interventions widely spread in emerging countries should be reconsidered, because they could occasionally conflict with monetary policies for price stability, incur considerable sterilization costs and impair CB independence in the long run. In particular, over-sterilisations for capital inflow (which heavily rely on MSBs) possibly cause sterilisations peril.

As noted in section 3.2, the body responsible for implementing monetary policy and that responsible for FX interventions are separated in many countries. In addition to trilemma issues between monetary independence and exchange rate stability given high capital mobility, such an institutional arrangement presents additional challenges pertaining to the FX intervention effects, CB balance sheet issues, potential conflicts of interest between two institutions and sustainability of sterilisation policies. In general, mutual consistency of FX interventions and domestic monetary policies should be maintained for the efficacy of sterilised interventions (Willet 2002). Accordingly, strengthening the coordination between two institutions would be crucial.

With regard to intervention patterns to intensify FX intervention effects and to reduce sterilisation cost, chapter 3 suggests that sterilised intervention should be selective in terms of its frequency and magnitude. Infrequent and large-scale interventions would be more effective than frequent and small ones. However, under secret interventions, large-scale or persistent interventions possibly have an effect that is not initially intended. For example, although initial one-off interventions contribute to reducing FX rate volatility, large-scale ones would possibly increase volatility. Large-scale or persistent interventions do not always intensify the effect of initial one-off intervention under secret intervention practices. To prevent possible wrong signalling of interventions, appropriate communication strategy need to be considered with regard to FX intervention policies as in monetary policies.

Chapter 4 provides evidence on significant asymmetric intervention preferences in small open emerging countries like Korea. Theoretically, asymmetric interventions can be sustained under inflation targeting when the rate of return on domestic assets (i.e. MSBs) should be higher than that on foreign assets, so that there is an excess supply of foreign exchanges at the CB's desired exchange rate target (Bofinger 2001). However, given high capital mobility and inflation targeting, targeting the level of exchange rate may be not feasible even in the short run. Furthermore, higher domestic interest rate than international one may cause the sterilisations to be unsustainable in the long run. When the CB is involved in asymmetric interventions initiated by the government, there should be transparent cost-sharing scheme between two institutions to avoid CB's operational losses and need for recapitalisation. In addition, short-run political pressure for boosting export should be insulated to lessen the extent of asymmetric interventions.

In Chapter 5, we found the prevalence of oversterilisations in East-Asian countries such as Korea, Indonesia and China, etc. Despite the benefits of the sterilisations, the over-sterilisations of capital inflows possibly lead to sterilisation peril by leaving domestic interest rate unnecessarily high and thereby encouraging further capital inflows. This may be true for the countries in which long-term MSBs are used as a main sterilisation tool and domestic-foreign interest rate differential is persistent. To choose a suitable sterilisation tool with little peril, it is imperative to monitor the natures of capital flows. There should be also limits to the degree of sterilised interventions over medium or long run to suppress the increasing sterilisation cost by allowing for more fluctuations of the target interest rate or FX rate. As seen in section 2.1.6, excessive uses of MSBs in sterilisation operations are, in general, undesirable in that they possibly fragment public bond markets and contaminate the short-term interest rate targeted by the CB. From an integrated perspective of the public sector, the use of government bonds would be more desirable in the long-run (Nyawata 2012) in that it insulates all sterilisation operations (initiated by governments) from normal day-to-day liquidity management (conducted by CBs), makes the governments to recognise the cost of sterilisation operations explicitly in their budget constraint and reduces the need for CB's recapitalisation.

Chapter 6 emphasises that CB's operational independence depends on the degree of CB's fiscal soundness, which is often impaired by MSB-dependent sterilisation policy. In this regard, where the FX interventions are primarily determined by the government, the CB should be particularly mindful of its net worth so as to maintain its operational independence. Hence, there should be clear guidelines pertaining to accounting practices, transfer of profit from CB to government, coverage of fiscal loss and recapitalisation (see Nyawata 2012).[103]

Once a CB is involved in the FX interventions with using MSBs as a main sterilisation tool, the IBC of the central bank suggests that, for the current MSB-dependent sterilisation to be sustainable without lessening the present degree of sterilisation, the CB should (i) find a way to increase seigniorage without inflation; (ii) raise the rate of returns on its foreign reserves by rebalancing its portfolio composition or by placing more weight on the profitability of foreign reserves management; (iii) introduce less expensive sterilisation instruments than MSBs. Among the three options, increasing seigniorage may not be effective under the inflation and short-term interest rate targeting regime, because money demand may not increase with economic growth as it did under the monetary targeting regimes. Increasing seigniorage is possible when the CB stimulates money demand and thereby increases money

[103] Although the use of MSBs stems partly from the motive for ensuring CB independence, the use of treasury bill could be more helpful for CB's operational independence in the long run. This is because the latter enable the government to recognise the sterilisation costs directly within its budget. According to Nyawata(2012 p 21), the choice of sterilisation tool between government securities and MSBs should be "guided by the extent to which they: (i) facilitate the transmission of monetary impulse; (ii) assist in the development of liquid markets; and (iii) ensure operational independence for the central bank."

supply proportionally with money demand. However, money demand is mainly determined by the evolution of payments and settlements of the private sector. Raising investment returns from foreign reserves has limits in improving the central bank's primary balance in small open economy like Korea. Because the central bank should always be prepared for incidents of a sudden stop and reversal of international capital, the liquidity and security of foreign reserves may have priority over profitability.

Introducing new cost-efficient sterilisation tools may be the most practical and feasible option. This is because the past exacerbation of the BOK's primary budget balance mainly came from the higher growth rate of the interest payment on the MSBs rather than the reduction in growth rate of the sum of seigniorage and interest income from foreign reserves. Candidate tools may include ECB's term deposit, BOE's voluntary reserve ratio system, or Fed's reserve requirement with remunerations. The interest rates applied to these tools are generally lower than the interest rates on MSBs, which helps to reduce the sterilisation cost, because they are mostly overnight interest rates.

If the aforementioned options are unavailable, the sustainability condition implies that the central bank changes its current involvement in sterilised FX interventions in the near future to prevent its recapitalisations financed by government taxation, which would eventually impair the CB's operational independence. In other words, the CB should limit its sterilisations of capital inflows by allowing the appreciation of domestic currency or by less sticking to the stability of policy interest rate.

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Appendix 3.1 Recent studies on interventions in Japan and Australia, and profitability

(a) Japan

Authors	Samples and methods	Evidence on impacts and motives of interventions
Hillebrand & Schnabl (2003)	1991-2002, GARCH	• FXIs affect FX rate level and volatility on intervention day • Results are highly dependent on sample period - 1991-1998: JPY purchases were unsuccessful in changing FX rate level and increased FX rate volatility - 1999-2002: JPY purchases had short-term effects on FX rate level and reduced FX rate volatility
Dominguez (2003a)	1991M1–2002M6, event-study and time series	• FXIs have short-term effects in the desired direction • Mostly effective within 2 days; - in one case, effective within 3 months
Ito (2003)	1991M4–2001M3, OLS, GARCH(1,1)	• Most USD-selling(USD-buying) FXIs were conducted when the JPY/USD rate was above (below) 125 • Interventions in 1991M4–1995M6 were more frequent and more predictable than those in 1995M7-2001M3 - ineffective:1991M4–1995M6; effective:1995M7–2001M3 • More effective when the FXIs are coordinated
Ito (2004)	2003M1–2004M3,GARCH(1,1)	• Effective in 2003–2004 • Initial FXIs are more effective than subsequent ones • Magnitude of impacts is smaller in 2003-2004 than in 1995–2002
Fatum & Hutchison (2004)	1999M1–2004M3, Matching methods	• Effective in 1999-2002 when interventions are infrequent (3% of business days) • Ineffective in 2003 when interventions are frequent (35% of business days) and in 2004Q1(85% of business days)
Galati et al. (2005)	1993M9-2000M4	• Interventions in support of USD do not have statistically significant effect on FX rate level. • Neither contemporaneous nor deferred impact of intervention on the forward rate • Different intervention motives over time - 1993M9-1996M4: to target some JPY/USD spot rate level and to reduce uncertainty - 1997M11-2000M4: to respond only to excessively increasing market uncertainty
Fatum & Hutchison (2006)	1991M4-2000M12, Non-parametric sign test and matched-sample test	• Effective irrespective of whether or not supported by interest rate changes and whether or not secret • Effective when coordinated with other CBs • Effective within 30 days
Ito & Yabu (2007)	1991M4-2002M12 Ordered probit	• A regime change in 1995M6: small-scale frequent → large-scale infrequent interventions

(b) Australia

Authors	Samples and methods	Evidence on impacts and motives of interventions
Kim & Sheen (2002)	1983M12-1997M12, EGARCH, Friction	• Determinants: FX rate deviation from its 150 day moving average, interest rate differentials, profitability • Short horizon aim of leaning against the wind
Edison et al. (2003)	1984M1-2001M12, Event study	• Reduce depreciation tendency of AUD in 1997-2001 • Interventions increase volatility but the effects on FX rate level are quite weak
Rogers & Siklos (2003)	1989-1998, Implied volatility	• RBA responds to excessive FX rate volatility (measured as implied volatility of foreign currency futures options) • Interventions, in general, do not affect FX volatility
McKenzie (2004)	1983M12-1997M12, Probit, GARCH	• Whether FXIs reduce or augment volatility is not clear
Kearns & Rigobon (2005)	1986-1993, GMM	• Measure contemporaneous effect: AUD purchase equivalent to 100 mill.USD → 1.8 % appreciation of AUD • Most effects occur during intervention day • RBA leans against the wind
Reitz et al.(2010)	1984M1-2008M12, smooth transition autoregressive target zone GARCH	• Mean reversion increases with the degree of FX rate misalignment • Strengthen FX traders' confidence in fundamental analysis → coordination channel
Newman et al.(2011)	1989M1-2010M12, GARCH	• Effects on FX rate level exist only on intervention day • Effect of a one-off FXIs is different from consecutive one

(c) Intervention profitability

	Assumption and methodology	Result and limitation
Taylor (1982)	• 9 countries; 1973-1979, monthly • Consider realised trading profit • FXIs are evenly distributed across the month	• Loss over the entire period • Interest rate and risk adjustment are not considered
Jacobson (1983)	• US, 1973-1981, daily • USD amount of foreign currency purchase valued by end-of-period FX rates minus trading cost	• Profit over the entire period, but loss for 1973-79 • No interest rate adjustment is assumed
Andrew & Broadbent (1994)	• Australia, 1983M12-1994M6, daily • Three profits: realised trading profits + unrealised trading profits + net interest earning	• Profitable for 3 profit components
Leahy (1995)	• US, 1973-1992, daily • FXIs do not affect interest rates and FX rates • CBs lean against the wind	• Profit over the entire period • Profits are not merely the outcome of chance
Sweeny (2000)	• US, 1985-1991, daily • Risk-adjusted intervention profit	• US Fed earned significant profits • Time-constant risk premium is assumed
Pilbeam (2001)	• UK, 1973-1995, daily • CBs lean against wind • Consider interest rate differential	• Profitability is heavily biased depending on the amount of cumulative interventions
Ito(2003)	• Japan, 1991M4-2001M3, daily	• Profitable in 3 profit components
Fischer (2003)	• Switzerland, 1986–1995, daily, weekly, monthly, quarterly • Compare profit measured by 3 methods (Taylor 1982, Leahy 1995, Sweeny 1997)	• Profitable independently of different measurement and frequency • Profit estimates with daily data may be deviated further from true profit
Becker & Sinclair(2004)	• Australia, 1983-2004, daily • Similar method to Andrew & Broadbent(1994)	• Profitable in 3 profit components

Appendix 3.2 Statistical summary of FX markets and interventions

(a) Main indicators of foreign exchange markets in major economies

		2007	2010
Daily average turnover(bill. USD)	Korea	35.2	48.3
	21 Developed[1]	169.3	201.3
	Hong Kong, Singapore, Luxemburg	155.6	179.0
	28 Emerging[2]	7.7	8.9
	Average	79.3	95.4
Daily turnover/nominal GDP (%)	Korea	3.4	5.3
	21 Developed	13.6	15.9
	Hong Kong, Singapore, Luxemburg	104.6	109.2
	28 Emerging	3.1	3.4
	Average	12.8	14.4
Daily turnover/trade volume (%)	Korea	9.6	13.2
	21 Developed	23.8	32.4
	Hong Kong, Singapore, Luxemburg	45.2	53.7
	28 Emerging	3.0	4.1
	Average	13.6	18.3

Notes: 1. OECD member countries less Korea, Luxemburg, Czech Rep., Hungary, Iceland, Poland, Slovakia, Turkey, Mexico, Chile, Israel
2. Czech Rep., Hungary, Poland, Slovakia, Turkey, Mexico, Chile, Israel, etc.,
3. Nominal GDP and trade volume are those as of year 2009

Source: BOK (2010), BIS (2010), World Economic Outlook (IMF 2010), International Trade Data (WTO 2010)

(b) Main statistics on interventions and FX rates movements in three countries

		Japan	Korea	Australia
I. Interventions		unit: 100 mill.JPY	100 mill. KRW	mill. AUSD
(i)Amount[1]				
Average[2]	USD-buying	2,037	3,395	55
	USD-selling	1,483	4,445	160
Maximum	USD-buying	16,664	31,000	461
	USD-selling	26,201	80,200	1,305
Total	USD-buying	635,402	1,687,500	16,016
	USD-selling	48,933	955,700	28,699
Net USD-buying		586,469	731,800	-12,683
Std. Dev.		1,114	3,825	53
Skewness		2.70	-4.49	-13.10
Kurtosis		152.32	113.99	257.94
Jarque-Bera		3,318,532	1,098,434	14,279,553
(probability)		(0.00)	(0.00)	(0.00)
(ii) Frequency (interventions/total obs)		345/3,567	772/2126	473/5218
USD-buying		313	497	293
USD-selling		32	215	180
II. FX rate change(log difference of daily rate)		unit: 100JPY/USD	KRW/USD	AUD/USD
Mean		-7.93E-05	-5.60E-05	4.04E-05
Maximum		0.0426	0.071	0.077
Minimum		-0.0465	-0.091	-0.071
Std. Dev.		0.005	0.007	0.007
Skewness		-0.38	-0.93	0.38
Kurtosis		7.21	42.17	14.53
Observations		3,566	2,125	5,217

Notes : 1. Actual intervention(Japan, Australia), daily change in foreign reserves (Korea)
2. Average amount per an intervention = total intervention amount ÷ frequency.

Data: BOK, Korean Ministry of Strategy and Finance, BOJ, Japanese Ministry of Finance, RBA

Appendix 3.3 Detailed procedure for calculating intervention profits

Here, we present a simple example of calculating the three components of intervention profits. First, suppose that the BOK initially buys USD at the FX rate 1000 KRW/USD and builds up a long position of USD100. When the BOK additionally buys USD100 at the FX rate of 2000 KRW/USD, the average FX rate at which its long position has been acquired is 1500 KRW/USD. The average FX rate applied to USD long position, i.e., average purchase price of the USD, is recalculated as the BOK continues to buy USD. When the BOK sells USD, average selling prices are calculated in the same way.

Realised trading gains are measured whenever the USD long position (short position) is reversed by selling (purchasing) USD. For example, if the BOK sells USD100 at the FX rate of 1200 KRW/USD, this trade incurs the loss of KRW300 to the BOK, because the selling price is less than average USD-purchasing price (1500 KRW): (1200-1500) KRW/USD*100USD = − 30000 KRW (realised loss). Thus, trading profits are realised when the FX rate at the sales of USD is higher than the average USD-purchasing price. If the BOK continuously sells USD, the sales result in the creation of realised profits (or losses) at each time of the sales until the USD long position is fully closed out. In case of USD short position, trading gains (losses) will be realised whenever USDs are purchased until the short position is completely closed out. In particular, trading profits will be realised when USD buying price is lower than average USD-selling price in the previous periods. Note that we estimate economic profit rather than accounting profit.

Net interest earning is calculated by multiplying the amount of USD long (short) position and interest rate differential between US fed fund rate and domestic interbank rate. Interest earning is converted into domestic currency by using end-of-day exchange rate at every day.

Unrealised profits are calculated on the outstanding USD position at the end of the sample period by comparing average USD-buying (or selling) price and the end-of-period exchange rate (Ito 2003). In most cases, unrealised profits (losses) are assumed to be made on the last day of sample period. If the USD position is valued every day, unrealised profits or losses are made every day (Becker and Sinclair 2004; Fisher 2003; Pilbeam 2001).

Example: Calculation of intervention profits without daily marking-to-mark

		Korea(2001M9-2010M3)		Australia(1989M1-2008M12)		Japan(1991M4-2004M3)		Calculation methods
		USD Purchase	USD Sales	USD purchase	USD Sales	USD Purchase	USD Sales	
Denomination	Domestic currency(a)	168750 bill. KRW	95570 bill. KRW	16016 mill. AUD	28699 mill. AUD	63540 bill. JPY	4893 bill. JPY	• Intervention data released • Cumulative amount during sample period
	USD Equivalent(b)	151.2 bill. USD	83.5 bill. USD	12615 mill. USD	19177 mill. USD	578.5 bill. USD	37.6 bill. USD	• Intervention amount(USD) = *(a)**daily average FX rate • Intervention amounts(USD) at each day are cumulated separately for selling USD and for buying USD
Inventory		67.7 (=151.2-83.5)		-6562.0 (=12615-19177)		540.9 (=578.5-37.6)		• Cumulative USD long position at the end-day
Period average FX rate (c=a/b)		1116.01 (KRW/USD)	1144.28 (KRW/USD)	1.2696 (AUD/USD)	1.4965 (AUD/USD)	109.83 (JPY/USD)	130.13 (JPY/USD)	• Average USD purchasing(selling) price = cumulative purchasing(selling) amounts denominated by domestic currency ÷ USD equivalents
End-of-period FX rate(d)		1136.5 (31 Mar. 2010)		1.4434(30 Dec. 2008)		103.95(31 Mar. 2004)		
Realised trading gains (e)		**2360.8 bill. KRW** =83.5*(1144.28-1116.01)		**2862.3 mill. AUD** = 12615*(1.4965-1.2696)		**763.3 bill. JPY** =37.6*(130.13-109.83)		USD long position : Realised profits = USD amount sold *(average selling price – average buying price) USD short position: Realised profits = USD amount bought*(average selling price – average buying price)
Net interest earning(f)		**-5131.8 bill. KRW**		**1277.2 mill. AUD**		**4485.4 bill. JPY**		Net interest earning = interest income–interest payment (i) USD long position*O/N fed fund rate – domestic currency short position*O/N domestic rate (ii) USD short position*O/N fed fund rate – domestic-currency long position*O/N domestic interest rate Cumulated interest earning = sum of daily net interest earning during the sample period
Unrealised trading gains (g)		**1387.2 bill. KRW** =67.7*(1136.5-1116.01)		**-1140.4 mill. AUD** = -6562.0*(1.4434-1.2696)		**-3180.5 bill. JPY** =540.9*(103.95-109.83)		• Difference between mark-to-market at the end of period and average inventory cost or sales price (i) USD long position*{*(d)*–average purchasing price)} (ii) USD short position*{(average selling price – *(d)*)
Total profit (=e+f+g)		**-1383.8 bill. KRW**		**3035.1 mill. AUD**		**2068.2 bill. JPY**		

Notes: 1. FX rate is the price of local currency per a unit USD.

2. RBA's initial USD long position was reversed to short position in May 1998. That is, cumulative USD sales are exactly same as USD purchases at the time. Since then, RBA have never bought USD during the rest of sample period.

Sources: Korea Ministry of Strategy and Finance, BOK, Japanese Ministry of Finance, RBA.

Appendix 4.1 F-statistics for testing the existence of cointegration

No. of variables \ Symmetric lags		1	2	4	6	8
Singapore (1999M1-2010M4)	5a	1.29	1.67	1.29	1.98	1.69
	6a	1.08	1.33	1.09	1.57	1.31
	7a	2.14	1.94	2.14	2.66	2.67
	4s	1.15	1.78	0.83	1.30	1.02
	5s	0.91	1.39	0.85	1.31	1.04
	6s	2.19	2.25	2.58	2.86	2.97
Australia (1999M1-2010M4)	5a	0.58	0.96	0.64	0.85	0.54
	4s	0.68	0.69	1.17	0.81	0.80
Philippine (1999M1-2010M4)	5a	3.69	4.97	2.43	2.18	1.58
	6a	3.00	4.05	2.16	1.75	1.41
	4s	4.61**	6.47***	3.33	2.53	2.39
	5s	3.61*	5.07***	2.77	1.88	1.84
Brazil (1999M1-2010M4)	5a	2.33	0.71	0.15	0.29	0.45
	6a	2.02	0.56	0.48	0.39	0.43
	4s	3.00	0.64	0.16	0.39	0.37
	5s	2.51	0.52	0.64	0.56	0.32
Turkey (2002M1-2010M4)	5a	2.15	2.71	1.64	2.02	1.34
	6a	2.10	2.59	0.99	1.56	1.05
	4s	2.03	3.02	1.89	1.98	1.63
	5s	1.53	2.52	1.30	1.20	1.44
Indonesia (1999M1-2010M4)	5a	0.30	0.27	0.13	0.49	0.52
	6a	0.32	0.32	0.19	0.66	1.09
	4s	0.25	0.27	0.13	0.41	0.55
	5s	0.27	0.32	0.12	0.56	0.93

Notes: 1. $4s: FR_t, \sigma_t^2, dif_t, S_t$ $5a: FR_t, \sigma_t^2, dif_t, S_t^a, S_t^d$ $5s: FR_t, \sigma_t^2, dif_t, S_t, IMP_t$

$6a: FR_t, \sigma_t^2, dif_t, S_t^a, S_t^b, IMP_t$ $6s: FR_t, \sigma_t^2, dif_t, S_t, IMP_t, M2_t$ $7a: FR_t, \sigma_t^2, dif_t, S_t^a, S_t^d, IMP_t, M2_t$

2. The critical value bounds are given in Pesaran et al.(2001, p300-301), table CI (iii) (unrestricted intercept and no time trend). The lower bound (FL) and upper bound (FU) are as follows:

Significance	10%		5%		1%	
No. of variables	FL	FU	FL	FU	FL	FU
3	2.72	3.77	3.69	4.89	4.29	5.61
4	2.45	3.52	3.25	4.49	3.74	5.06
5	2.26	3.35	2.62	3.79	3.41	4.68
6	2.12	3.23	2.75	3.99	3.15	4.43
7	2.03	3.13	2.60	3.84	2.96	4.26

If F > FU, the null of no cointegration can be rejected;
If F < FL, the null cannot be rejected, and thus there is no long-run relationship.
If FL< F < FU, the inference is inconclusive.

3. ***, ** and* denote the rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

Appendix 4.2 Exchange rates, interest rate differential, intervention profitability and asymmetric intervention motives

The FXIs do not affect a CB's profit under the assumption that interest rate parity holds and FXIs do not have effects on the FX rates with the free float regime. To see this, assume that FX rate follows a random walk process and thus the FX rate is not affected by the FXIs. This assumption may be consistent with the results of many previous studies, in that the FXIs may not affect the FX rate level, at least in the long run. The CB purchases foreign reserves (FR) funded by issuing its debts (MSBs) in period t-1. The FXIs will be shown on the balance sheet of the CB as (A.4.1):

(A.4.1) $S_{t-1} \cdot FR_{t-1} = MSB_{t-1}$

where S_{t-1} is the spot FX rate in period t-1 (domestic per unit of foreign currency). The right hand side indicates the MSBs issued for funding the FXIs and the left hand side denotes FR purchased by issuing MSBs. Then, the *economic profit (π)* of the intervention in period t can be expressed by:

(A.4.2) $\pi = S_t \cdot (1 + r^*_{t-1}) \cdot FR_{t-1} - (1 + r_{t-1}) \cdot MSB_{t-1}$

where r^* is foreign interest rate and r is local interest rate. Under uncovered interest rate parity (UIP) i.e. $S_t / S_{t-1} = (1 + r_{t-1})/(1 + r_{t-1}^*)$, (A.4.2) can be rewritten in (A.4.3) in which the economic profit of interventions (π) is zero *ex ante*;

(A.4.3) $\pi = \dfrac{1 + r_{t-1}}{1 + r^*_{t-1}} \cdot S_{t-1} \cdot (1 + r^*_{t-1}) \cdot FR_{t-1} - (1 + r_{t-1}) \cdot MSB_{t-1}$

$= (1 + r_{t-1}) \cdot S_{t-1} \cdot FR_{t-1} - (1 + r_{t-1}) \cdot MSB_{t-1}$ ($\because$ (A.4.1) $S_{t-1} \cdot FR_{t-1} = MSB_{t-1}$)

$= (1 + r_{t-1}) \cdot MSB_{t-1} - (1 + r_{t-1}) \cdot MSB_{t-1} = 0$

From (A.4.3), we can discuss several implications about the FXIs and their impacts on sterilisation policy. *First, when UIP holds, (A.4.3) holds and thus $\pi = 0$ regardless of domestic-foreign interest rate differential*. If $r_{t-1} > r^*_{t-1}$, S_t falls (i.e., local currency depreciates) to offset the interest rate differential. Consequently, the loss from the interest rate differential would be offset by the increase in the domestic value of foreign reserves incurred by local currency depreciation. However, when $r_{t-1} > r^*_{t-1}$, the more CB intervenes, the bigger *accounting* loss it makes. The accounting profit (π^a) shown in the profit/loss statement of the CB can be expressed as:

$$(A.4.4)\quad \pi^a = S_t \cdot r^*_{t-1} \cdot FR_{t-1} - r_{t-1} \cdot MSB_{t-1}$$

Substituting (A.4.1) and the UIP condition into (A.4.4) yields:

$$(A.4.5)\quad \pi^a = \frac{1+r_{t-1}}{1+r^*_{t-1}} \cdot S_{t-1} \cdot r^*_{t-1} \cdot FR_{t-1} - r_{t-1} \cdot MSB_{t-1} = \frac{r^*_{t-1} - r_{t-1}}{1+r^*_{t-1}} \cdot MSB_{t-1}$$

Equation (A.4.5) indicates that the FXIs always incur an *accounting* loss when $r_{t-1} > r^*_{t-1}$.

Second, if the intervention amount is positively related to the effect of the FXIs, as several studies suggest, (see Ito 2003, Lecourt and Raymond 2006), the FXIs may have a self-fulfilling property that intervention profits (or losses) depend on the intervention amount. To see this, assume that UIP does not hold, i.e., $(S_t / S_{t-1}) = (1+r_{t-1})/(1+r_{t-1}{}^*) + \varepsilon_t$ where ε_t is a random variable to reflect risk premium. Then, CB may make an *economic* loss or profit *ex post* as shown in (A.4.6).

$$\begin{aligned}(A.4.6)\qquad \pi &= \left(\frac{1+r_{t-1}}{1+r^*_{t-1}} + \varepsilon_t\right) \cdot S_{t-1} \cdot (1+r^*_{t-1}) \cdot FR_{t-1} - (1+r_{t-1}) \cdot MSB_{t+1} \\ &= \left[(1+r_{t-1}) \cdot S_{t-1} \cdot FR_{t-1} - (1+r_{t-1}) \cdot MSB_{t-1}\right] + \varepsilon_t (1+r^*_{t-1}) \cdot S_{t-1} \cdot FR_{t-1} \\ &= \varepsilon_t \cdot (1+r_{t-1}{}^*) \cdot MSB_{t-1} \qquad (\because S_{t-1} \cdot FR_{t-1} = MSB_{t-1})\end{aligned}$$

If $\varepsilon_t < 0$, i.e., the local currency is not depreciated by an amount equal to the interest differential, the CB may make a loss *ex post* (π <0). It follows that if the intervention is successful in depreciating local currency, and thus the negative value of ε_t deceases or $\varepsilon_t >$ 0, then the CB could reduce losses or earn profits. Therefore, the CB, once it initiates FXIs for inducing domestic currency depreciation, is likely to intervene as strongly as possible in order to maximize the effects of the intervention and thus prevent losses from the intervention. This assertion may partly explain why foreign reserves have been rapidly built up with frequent episodes of interventions in East Asian countries where considerable interest rate differentials exist. If the CB intervenes in a moderate way with a small amount, it is likely that the intervention may fail to depreciate the local currency and eventually incur losses. Consequently, under the circumstance in which $r_{t-1} > r^*_{t-1}$, asymmetric interventions for inducing the depreciation of a local currency may be helpful for protecting the soundness of the CB's balance sheet, all other things being equal.

Third, revenues from interventions are generally influenced not only by interest rates but also by FX rate changes. In particular, the revenue growth of foreign reserves has a linear relationship with the current level of the spot FX rate. The higher the FX rate is at the valuation time, the larger the revenue growth. Foreign reserves are divided into two types: hold-to-maturity reserves (FA^H), which will not be sold, and tradable reserves (FA^T), which will be sold before their maturities. The total returns from FR consist of interest income (I_t) and capital gain (C_t):

(A.4.7) $I_t = S_t \cdot r^*_t \cdot (FR^T_{t-1} + FR^H_{t-1}) = S_t \cdot r^*_t \cdot FR_{t-1}$

(A.4.8) $C_t = S_t \cdot FR^T_t - S_{t-1} \cdot FR^T_{t-1} + (S_t - S_{t-1}) \cdot FR^H_{t-1}$

(A.4.7) indicates that *realised* interest incomes from two different types of foreign reserves. (A.4.8) suggests that capital gains are sum of *realised* profits from FR^T (i.e. $S_t \cdot FR^T_t - S_{t-1} \cdot FR^T_{t-1}$) and *unrealised* profits from FA^H (i.e. $(S_t - S_{t-1}) \cdot FR^H_{t-1}$). Unrealised profits are calculated by regular valuation procedures which are somewhat different depending on the accounting principles employed. For simplicity, we consider only realised capital gains.

Net interest earnings (π^a) from FXIs can be expressed as (A.4.9) by subtracting interest payment (equation A.4.5) from interest income (equation A.4.7)

(A.4.9) $\pi^a = I_t - r_{t-1} \cdot MSB_{t-1} = S_t \cdot r^*_{t-1} \cdot FR_{t-1} - r_{t-1} \cdot MSB_{t-1} = \left(\frac{r^*_{t-1} - r_{t-1}}{1 + r^*_{t-1}} + \varepsilon_t \cdot r^*_{t-1} \right) \cdot MSB_{t-1}$

The *realised* capital gain is expressed in (A.4.10):

(A.4.10) $C_t = S_t \cdot FR_t^T - S_{t-1} \cdot FR_{t-1}^T$

Assume that a book value of foreign reserves has a linear relation with a market value, (i.e. $FR_t^T = \lambda \cdot FR_{t-1}^T$) and the UIP does not hold. λ represents the rate of return on foreign reserve investments which depend on the ability to forecast the interest rates and FX rates. Then (A.4.10) can be rewritten as:

(A.4.11) $$C_t = \left(\left(\frac{1+r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \right) \cdot \lambda - 1 \right) \cdot S_{t-1} \cdot FR_{t-1}^T$$

Total net profit (shown on the balance sheet of the CB) is the sum of net interest revenue (A.4.9) and realised capital gain (A.4.11).

(A.4.12) Net profit = $\pi^a + C_t$

$$= \left(\frac{r_{t-1}^* - r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \cdot r_{t-1}^* \right) \cdot MSB_{t-1} + \left(\left(\frac{1+r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \right) \cdot \lambda - 1 \right) \cdot S_{t-1} \cdot FR_{t-1}^T$$

$$= \left(\frac{r_{t-1}^* - r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \cdot r_{t-1}^* \right) \cdot S_{t-1} \cdot (FR_{t-1}^T + FR_{t-1}^H) + \left(\left(\frac{1+r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \right) \cdot \lambda - 1 \right) \cdot S_{t-1} \cdot FR_{t-1}^T$$

$$= \left(\frac{(1-r_{t-1}) \cdot (\lambda - 1)}{1+r_{t-1}^*} + \varepsilon_t \cdot (\lambda + r_{t-1}^*) \right) \cdot S_{t-1} \cdot FR_{t-1}^T + \left(\frac{r_{t-1}^* - r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \cdot r_{t-1}^* \right) \cdot S_{t-1} \cdot FR_{t-1}^H$$

The derivative of net profit with respect to λ leads to:

(A.4.13) $$\frac{d(\pi^a + \mathrm{C_t})}{d\lambda} = \left(\frac{1-r_{t-1}}{1+r_{t-1}^*} + \varepsilon_t \right) \cdot S_{t-1} \cdot FR_{t-1}^T = S_t \cdot FR_{t-1}^T.$$

(A.4.13) indicates that the net profit growth depends heavily on the current level of the FX rate (S_t). Thus, although the CB does not yield a high investment return from its foreign reserves, if S_t is high, then the CB's investment will be appreciated as excellent in terms of local currency denominated value. Consequently, E-type CBs (considerable parts of whose assets are foreign ones) have an incentive to conduct an asymmetric intervention to induce the depreciation of local currency, all other things being equal. See Cha (2007) for more detailed discussion on this issue.

Appendix 5.1 Estimated sterilisation and offset coefficient in previous studies

Author(s)	Methodologies	Country	Sample period	Estimated coefficient	
				Sterilisation	Offset
Argy & Kouri (1974)	Reduced: OLS: ΔNDA=f(CA or KA, ΔY, Δi^f, seasonal dummies)	Germany Italy Netherlands	1963:3-1970:4(Q) 1964:1-1970:4(Q) 1964:1-1970:4(Q)	-0.34(CA); -0.19(KA) -1.37(CA); -0.67(KA) -0.74(CA); -0.87(KA)	n.a
Kouri & Porter (1974)	Reduced: OLS: CI =f(ΔY, Δi^f, ΔNDA, CA, ΔRR, speculative dummies, seasonal dummy)	Germany Australia Italy Netherlands	1960:1-1970:4(Q) 1961:3-1972:3(Q) 1964:1-1970:4(Q) 1960:1-1970:4(Q)	n.a	-0.74 -0.47 -0.43 -0.59
Herring & Marston (1977)	Structural: OLS: ΔM=f(ΔFR, RR, ΔINF, ΔY, seasonal dummy)	Germany	1973:4-1975:7(M)	-0.91	n.a.
Laney (1979)	Reduced; OLS: ΔNDA =f(lagged ΔFR) ΔFR=f(lagged ΔNDA)	Belgium Canada France Germany Italy Japan Netherlands Sweden Switzerland UK	1964:2-1977:6(M) 1963:1-1977:11(M) 1963:8-1977:9(M) 1964:2-1977:9(M) 1966:2-1977:10(M) 1966:3-1977:10(M) 1958:1-1977:11(M) 1962:8-1977:5(M) 1963:4-1977:6(M) 1964:1-1977:2(M)	-0.69 -1.00 -1.20 -0.68 -0.83 -1.69 -0.80 -1.13 -0.07 -1.31	-0.53 -0.22 -0.61 -0.73 -0.70 -0.53 -0.96 -0.41 -0.50 -0.57
Obstfeld (1982)	Reduced: OLS: KA=f(DC, i^f, CA, speculative and seasonal dummies)	Germany	1960:1-1970:4(Q)	n.a.	-0.93(OLS) -0.97(Cochrane-Orcutt method)
Cumby & Obstfeld (1983)	Reduced and structural: 2SLS: M(or DA)=f(FA, RER, G, IP, RR, seasonal dummy)	Mexico	1971:3-1979:4(Q)	-1.15(2SLS) -1.45(2 step 2SLS)	-0.37(2SLS) -0.31(2step 2SLS)

Note: 1. M: money(M1 or M2), MB: monetary base, DC: domestic credit, FA: foreign asset, DA: domestic asset, i^d: domestic interest rate, i^f: foreign interest rate, Δ: difference operator, S: spot FX rates, S*: target FX rate or FX rate trend, RER: real exchange rates, Y: GDP, g: GDP growth, INF: inflation, CI: capital inflows CA: current account, KA: capital account, G: government budget balance, RR: reserve requirement, IP: industrial production, W: nominal wealth, mm: money multiplier, $\sigma(i^d)$:volatility of i^d, SP: stock price, IP: industrial production

2. The estimated sterilisation (offset) coefficients indicate contemporaneous relationship through which the changes in NFA (NDA) affect the course of domestic credit policy (capital flows) during same month or quarter.

(Continued) Appendix 5.1 Estimated sterilisation and offset coefficient in previous studies

Author(s)	Methodologies	Country	Sample period	Estimated coefficient	
				Sterilisation	Offset
Pasula (1994)	Structural and reduced: OLS: FR (or CI) = f(M, Δi^d, Δi^f, GDP)	 Germany Canada Netherlands UK	 1957:3-1971:1(Q) 1962:3-1970:1(Q) 1957:3-1971:1(Q) 1957:3-1971:2(Q)	n.a.	structural:reduced -0.60 ; -1.08 -0.72 ; -0.95 -0.24 ; -0.85 -0.30 ; -0.93
Kim (1995)	Reduced: GLS and 2SLS: Offset: CI =f(ΔNDA, CA, $\Delta(i^f$+S), Y, W, dummies) Sterilisation:ΔNDA=f(ΔNFA,REER,IP,dummies)	Korea	1980:1-1994:4(Q)	-0.56	-0.26
Moreno (1996)	4 variable VAR: FA, DC, S, CPI Provide impulse-response analysis	Korea Taiwan	1981.1-1994.12(M)	n.a.	n.a.
Celasun et al. (1999)	Reduced: IV estimation: ΔDA =f(ΔNFA, RER, y, ΔRER, ΔG, seasonal dummy)	Turkey	1990.2-1996.6(M)	-0.37	n.a.
Emir et al. (2000)	Reduced: 2SLS: ΔNFA=f(ΔNDA, lagged ΔNDA, CA, KA, $\Delta(i^f$+ S)) ΔNDA=f(ΔNFA, ΔG, INF, $\sigma(i^d)$, SP)	Turkey	1990-93(M) 1995-99(M)	-0.54 -0.88	-0.29 -0.78
Siklos (2000a)	Reduced: OLS and 2SLS: ΔM2=f(ΔFA, CA, g, ΔREER, S-S*, i^d-i^f, reform dummy)	Hungary	1992:1-1997:3(M)	-1.00 to -1.14	n.a.
Bernstein (2000)	Cointegration between NFA and NDA: NDA=f(NFA , i^d, i^f , S, Y)	6 advanced countries	1973:1-1992:4(Q)	US:-0.95, Canada:-0.70, Germany:-0.41, France: -0.80, UK and Japan:-1.00	n.a.
Takagi & Esaka (2001)	Reduced: OLS and VAR: Real M2 =f(lagged FA. CPI, Y, i^d, dummies)	5 Asian Emerging countries	1987:1-1997:2(Q)	Philippines(-0.11) Insignificant: Indonesia, Korea, Malaysia, Thailand	n.a.
Brissimis et al. (2002)	Semi-reduced: 2SLS and 3SLS: Sterilisation:ΔNFA=f(lagged ΔNDA,S-S^*,G,CA,$\Delta(i^f$+ S),(S)) Offset: ΔNDA=f(lagged ΔNFA, S-S^*, G, CA, $\Delta(i^f$+ S), $\sigma(i^d)$)	Germany	1980:2-1992:2(Q)	-0.74(2SLS) -0.96(3SLS)	-0.22(2SLS) -0.40(3SLS)
Christensen.(2004)	4 variable VAR(1): DC, FR, i^d , i^f	Czech Rep.	1993:1-1996:1(M)	-0.11(one-period lagged coefficient)	-0.15
He et al.(2005)	4 variable VAR(1): ΔNFA, ΔNDA, ΔDC, Δi^d	China	1998:1-2004:12(M)	-1.00(one-period lagged coefficient)	n.a.

(Continued) Appendix 5.1 Estimated sterilisation and offset coefficient in previous studies

Author(s)	Methodologies	Country	Sample period	Estimated coefficient	
				Sterilisation	Offset
Ouyang & Rajan (2005)	Semi-reduced: 2SLS and OLS $\Delta NFA=f(\Delta NDA,S,\Delta mm,INF,\Delta REER,G,\sigma(S))$ $\Delta NDA=f(\Delta NFA,S,\Delta mm,INF,\Delta REER,G,\sigma(i^d))$	China	1995:1-2004:4(Q)	-0.73 to -0.84	-0.56 to -0.53
Cavoli & Rajan (2006)	Reduced: OLS $\Delta DA=f(\Delta FA$, lagged $\Delta FA)$	5 Asian countries	1990:01-1997:5(M)	Korea(-1.11), Thailand(-0.91), Indonesia(-0.77), Malaysia(-0.94), Philippines (-0.98)	n.a.
Ouyang et al. (2007)	Semi-reduced: Panel with random effect Specification is same as Ouyang et al.(2005)	Korea, Thailand, Indonesia, Malaysia, Philippines	1990:1-2005:3(Q) Pre-crisis:1990:1-1997:1 Post-crisis:1998:3-2005:3	Pre: -1.05(perfect foresight) -0.97(static expectation) Post: -1.27(perfect foresight) -0.85(static expectation)	Pre: -0.80(perfect foresight) -0.60 (static expectation Post:-0.84 (perfect foresight) -0.51(static expectation)
Lavigne (2008)	Sterilisation ratio = $\Delta NDA/ \Delta NFA$	35 countries	Pre-crisis:1990-1996 Post-crisis:2000-2006	pre:-0.6(Argentina)-0.78(Russia) post: 0.05(Argentina)-3.20(Chile)	n.a
Aizenman & Glick (2009)	Reduced; OLS DC =f(FR with lag 1, Y, g, crisis)	8 emerging countries	1985:1-2007:2(Q)	China(-0.78),Korea(-0.77) Thailand(-0.93), Malaysia(-0.86), Singapore(-0.94), India (-0.82), Argentina(-0.99) Brazil(-0.86), Mexico(-0.96)	n.a
Wu (2009)	Reduced: cointegration between ΔFA and ΔNDA; $\Delta^2 DNA=f(\Delta^2 FA , Y)$	China	1995-2005	-0.35	n.a
Ouyang et al. (2010)	Semi reduced: 2SLS and 3SLS: Specification is same as Ouyang et al.(2005)	China	2000:6– 2008:9(M)	-1.02(2SLS) -1.23(3SLS)	-0.52 (2SLS) -0.70(3SLS)
Wang (2010)	Reduced: OLS $\Delta NFA=f(\Delta NDA, \Delta i^f, \Delta mm, INF, \Delta REER$, sport-forward FX rate spread, ΔRR, SP, G)	China	1999:6-2009:3(M)	-0.96	-0.30
Zhang (2011)	2SLS $\Delta NFA=f($lagged $\Delta NDA,\Delta mm, INF, CA, Y, \sigma(S),G, \Delta(i^f+ S))$, $\Delta NDA=f($lagged $\Delta NFA, \Delta mm, INF, CA, Y, \sigma(i^d), G, \Delta(i^f+S))$	China	1995:1-2010:2(Q)	-0.79 to -0.93	-0.49 to -0.65

Appendix 5.2 Derivation of offset and sterilisation coefficient

The loss function of the CBs is:

(A-1) $L_t = \alpha(\Delta p_t)^2 + \beta(Y_{c,t})^2 + \gamma(\sigma_{r,t})^2 + \varepsilon(S_t - \overline{S_t})^2 + \upsilon(\sigma_{s,t})^2$

The constraints faced by the CBs are:

(A-2) $\Delta p_t = \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2 \Delta p_{t-1} + \pi_3 \Delta S_t$

(A-3) $Y_{c,t} = \phi_1(\Delta NFA_t + \Delta NDA_t) + \phi_2 Y_{c,t-1} + \phi_3 \Delta G_t$

(A-4) $\Delta NFA_t = CA_t + \Delta NK_t$ where $\Delta NK_t = (1/c)\Delta(S_t - E_t S_{t+1} + r_{d,t} - r_{f,t})$

(A-5) $\Delta r_{d,t} = -\psi(\Delta NDA_t + \Delta NFA_t)$

(A-6) $S_t = (c+\psi)\Delta NFA_t - cCA_t + S_{t-1} + \psi \Delta NDA_t + \Delta(E_t S_{t+1} + r_{f,t})$

(A-7) $\sigma_{r,t} = \eta_1 \sigma_{r,t-1} + \theta_1(d_1 - 1)\Delta NDA_t \quad \eta_1, \theta_1 > 0$

(A-8) $\sigma_{s,t} = \eta_2 \sigma_{s,t-1} + \theta_2(d_2 - 2)\Delta NFA_t) \quad \eta_2, \theta_2 > 0$

The CBs minimises the loss function by choosing two policy instruments, i.e. money market operations (ΔNDA_t) and foreign exchange market interventions (ΔNFA_t), subject to above constraints:

(A-9)

$$\partial L_t / \partial \Delta NDA_t = (\partial L_t / \partial \Delta p_t)(\partial \Delta p_t / \partial \Delta NDA_t) + (\partial L_t / \partial Y_{c,t})(\partial Y_{c,t} / \partial \Delta NDA_t)$$
$$+ (\partial L_t / \partial S_t)(\partial S_t / \partial \Delta NDA_t) + (\partial L_t / \partial \sigma_{r,t})(\partial \sigma_{r,t} / \partial \Delta NDA_t) + (\partial L_t / \partial \sigma_{s,t})(\partial \sigma_{s,t} / \partial \Delta NDA_t) = 0$$

(A-10)

$$\partial L_t / \partial \Delta NFA_t = (\partial L_t / \partial \Delta p_t)(\partial \Delta p_t / \partial \Delta NFA_t) + (\partial L_t / \partial Y_{c,t})(\partial Y_{c,t} / \partial \Delta NFA_t)$$
$$+ (\partial L_t / \partial \sigma_{r,t})(\partial \sigma_{r,t} / \partial \Delta NFA_t) + (\partial L_t / \partial S_t)(\partial S_t / \partial \Delta NFA_t) + (\partial L_t / \partial \sigma_{s,t})(\partial \sigma_{s,t} / \partial \Delta NFA_t) = 0$$

The partial derivatives gained from the constraints are:

$\partial L_t / \partial \Delta p_t = 2\alpha \Delta p_t$

$\partial L_t / \partial Y_{c,t} = 2\beta Y_{c,t}$

$$\partial L_t / \partial S_t = 2\varepsilon(S_t - \overline{S_t})$$

$$\partial L_t / \partial \sigma_{r,t} = 2\gamma\sigma_{r,t}$$

$$\partial L_t / \partial \sigma_{s,t} = 2\upsilon\sigma_{s,t}$$

$$\partial \Delta p_t / \partial \Delta NDA_t = \pi_1 = \partial \Delta p_t / \partial \Delta NFA_t$$

$$\partial \Delta Y_{c,t} / \partial \Delta NDA_t = \phi_1 = \partial \Delta Y_{c,t} / \partial \Delta NFA_t$$

$$\partial S_t / \partial \Delta NDA_t = \psi$$

$$\partial S_t / \partial \Delta NFA_t = c + \psi$$

$$\partial \sigma_{r,t} / \partial \Delta NDA_t = \theta_1(d_1 - 1)$$

$$\partial \sigma_{s,t} / \partial \Delta NFA_t = \theta_2(d_2 - 1)$$

$$\partial \sigma_{r,t} / \partial \Delta NFA_t = 0 = \partial \sigma_{s,t} / \partial \Delta NDA_t$$

Substituting the above partial derivatives into (A-9) and (A-10) lead to:

(A-9)' $\alpha\pi_1\Delta p_t + \beta\phi_1 Y_{c,t} + \varepsilon\psi(S_t - \overline{S_t}) + \gamma\theta_1(d_1 - 1)\sigma_{r,t} = 0$

(A-10)' $\alpha\pi_1\Delta p_t + \beta\phi_1 Y_{c,t} + \varepsilon(c+\psi)(S_t - \overline{S_t}) + \upsilon\theta_2(d_2 - 1)\sigma_{s,t} = 0$

Plugging (A-2), (A-3), (A-6), (A-7) and (A-8) into (A-9)' and (A-10)', we can obtain two semi-reduced form equations (5.3.9) and (5.3.10).

(5.3.9)

$$\begin{aligned}\Delta NDA_t = &-\{[\alpha\pi_1^2 + \beta\phi_1^2 + (\alpha\pi_1\pi_3 + \varepsilon\psi)(c+\psi)]/\varpi_1\}\Delta NFA_t + [c(\alpha\pi_1\pi_3 + \varepsilon\psi)/\varpi_1]CA_t \\ &-(\varepsilon\psi/\varpi_2)(S_{t-1} - \overline{S_t}) - [\alpha\pi_1\pi_2/\varpi_1]\Delta p_{t-1} - [\beta\phi_1\phi_2/\varpi_1]Y_{c,t-1} - [\beta\phi_1\phi_3/\varpi_1]\Delta G_t \\ &-[(\alpha\pi_1\pi_3 + \varepsilon\psi)/\varpi_1]\Delta(r_{f,t} + E_t S_{t+1}) - (\gamma\eta_1\theta_1/\varpi_2)(d_1 - 1)\sigma_{r,t-1}\end{aligned}$$

where $\omega_1 = [\alpha\pi_1^2 + \beta\phi_1^2 + (\alpha\pi_1\pi_3 + \varepsilon\psi)\psi + \gamma\theta_1^2(d_1 - 1)^2] > 0$

(5.3.10)

$$\begin{aligned}\Delta NFA_t = &-\{[\alpha\pi_1^2 + \beta\phi_1^2 + [\alpha\pi_1\pi_3 + \varepsilon(c+\psi)\psi]/\varpi_2\}\Delta NDA_t + \{c[\alpha\pi_1\pi_3 + \varepsilon(c+\psi)]/\varpi_2\}CA_t \\ &-[\varepsilon(c+\psi)/\varpi_2](S_{t-1} - \overline{S_t}) - [\alpha\pi_1\pi_2/\varpi_2]\Delta p_{t-1} - [\beta\phi_1\phi_2/\varpi_2]Y_{c,t-1} - [\beta\phi_1\phi_3/\varpi_2]\Delta G_t \\ &-\{[(\alpha\pi_1\pi_3 + \varepsilon(c+\psi)]/\varpi_2\}\Delta(r_{f,t} + E_t S_{t+1}) - (\upsilon\eta_2\theta_2/\varpi_2)(d_2 - 1)\sigma_{s,t-1}\end{aligned}$$

where $\varpi_2 = \{\alpha\pi_1^2 + \beta\phi_1^2 + [\alpha\pi_1\pi_3 + \varepsilon(c+\psi)]\psi + \upsilon\theta_2^2(d_2 - 1)^2] > 0]$

Appendix 5.3 Descriptive statistics of panel data

(a) Main variables used in regression (1981Q1-2010Q4)

Country	NFA/CIC	ΔG/GDP	ΔFR	$\sigma_{\Delta FR}$	$\sigma_{\Delta r_d}$	$\sigma_{\Delta S}$
Australia	1.398	-0.003	0.026	0.180	0.003	0.018
Canada	0.060	-0.005	0.024	0.153	0.003	0.008
Norway	4.251	0.056	0.018	0.093	0.004	0.017
New Zealand	3.938	0.013	0.032	0.187	0.004	0.016
Sweden	1.762	-0.003	0.021	0.118	0.004	0.017
Swiss	2.084	-0.005	0.022	0.112	0.003	0.018
UK	**0.315**	-0.030	0.010	0.084	0.003	0.016
IT-Advanced	**1.972**	**0.003**	**0.022**	**0.132**	**0.003**	**0.016**
Indonesia	2.195	-0.014	0.024	0.104	0.013	0.022
Korea	4.154	0.009	0.038	0.122	0.004	0.012
Philippines	3.116	-0.017	0.025	0.280	0.009	0.012
Thailand	3.484	-0.006	0.039	0.078	0.006	0.010
IT-Asia	**3.571**	**-0.006**	**0.031**	**0.166**	**0.008**	**0.014**
Czech Rep.	2.360	-0.023	0.050	0.114	0.005	0.018
Hungary	2.098	-0.059	0.031	0.147	0.005	0.015
Israel	7.208	-0.026	0.025	0.099	0.057	0.017
Poland	2.107	-0.030	0.042	0.111	0.005	0.097
South Africa	2.439	-0.008	0.033	0.309	0.004	0.023
Turkey	**0.853**	-0.102	0.036	0.168	0.059	0.023
IT-Europe	**4.032**	**-0.040**	**0.035**	**0.179**	**0.024**	**0.033**
Brazil	2.435	-0.006	0.033	0.170	0.014(8.257)	0.042
Chile	4.222	0.017	0.018	0.094	0.004	0.016
Colombia	2.075	-0.037	0.015	0.117	0.006	0.011
Mexico	2.217	-0.008	0.031	0.215	0.022	0.019
Peru	4.076	-0.123	0.027	0.157	0.014	0.041
IT-Latin	**3.337**	**-0.039**	**0.025**	**0.156**	**0.012**	**0.026**
Argentina	0.606	-0.001	0.017	0.264	0.002(5138.688)	0.051
China	1.835	0.123	0.059	0.108	0.002	0.009
Euro	0.703	-0.021	0.003	0.052	0.001	0.016
Hong Kong	6.957	0.014	0.027	0.050	0.003	0.002
India	0.720	-0.053	0.031	0.155	0.012	0.010
Japan	0.046	-0.009	0.031	0.063	0.001	0.018
Malaysia	6.364	0.038	0.026	0.095	0.002	0.009
Singapore	9.331	0.064	0.029	0.036	0.002	0.008
Non-IT	**3.708**	**0.022**	**0.029**	**0.080**	**0.003**	**0.010**

Notes: 1.ΔFR: growth of foreign reserves, ΔG: fiscal surplus $\sigma_{\Delta FR}$: standard deviation of growth of foreign reserves, $\sigma_{\Delta S}$: standard deviation of foreign exchange rate change, $\sigma_{\Delta r_d}$: standard deviation of domestic interest rate changes

2. The figures of each group are simple arithmetic average of the countries included.
3. In calculating standard deviation of interest rate change in IT-Latin and Non-IT, we exclude the data on Brazil(1989M2-1990M3) and Argentina(1989M5-1990M3) during hyperinflation period. The figures in ( ) are calculated by the data from whole samples

Source: Author's calculation based on IMF International Financial Statistics and DataStream.

(b) Balance of payment: 1980Q1 – 2010Q4

	CA/GDP	KA/GDP	FDI/GDP	PF/GDP	OINT/GDP
Australia	-0.044	0.047	0.022	0.082	0.011
Canada	-0.002	0.003	-0.002	0.007	-0.002
Norway	0.069	-0.045	-0.046	-0.182	0.022
New Zealand	-0.049	0.043	0.045	0.019	0.029
Sweden	0.023	-0.015	-0.024	-0.021	0.015
Swiss	0.110	-0.098	-0.086	-0.099	0.081
UK	-0.014	0.013	-0.030	0.061	0.017
IT-Advanced	**0.013**	**-0.007**	**-0.017**	**-0.019**	**0.025**
Indonesia	0.007	0.003	0.015	0.024	0.062
Korea	0.010	0.009	-0.023	0.068	0.231
Philippines	-0.015	0.032	0.007	0.006	0.027
Thailand	0.018	0.007	0.034	0.012	0.060
IT-Asia	**0.003**	**0.015**	**0.005**	**0.029**	**0.136**
Czech Rep.	-0.032	0.065	0.143	0.020	0.020
Hungary	-0.060	0.085	0.061	0.027	0.061
Israel	-0.012	0.021	0.025	-0.024	0.024
Poland	-0.034	0.062	0.053	0.035	0.039
South Africa	-0.002	0.003	0.003	0.007	0.001
Turkey	-0.020	0.026	0.059	0.032	0.093
IT-Emerging Europe	**-0.022**	**0.035**	**0.051**	**0.011**	**0.038**
Brazil	-0.012	0.021	0.038	0.038	-0.016
Chile	-0.003	0.014	0.062	-0.059	0.004
Colombia	-0.021	0.028	0.038	0.001	0.010
Mexico	-0.005	0.007	0.010	0.006	-0.001
Peru	-0.033	0.031	0.022	0.003	0.000
IT-Latin	**-0.015**	**0.019**	**0.030**	**0.002**	**-0.002**
Argentina	0.000	-0.001	0.006	0.003	-0.006
China	0.023	0.001	0.017	na	na
Euro	-0.002	na	na	0.021	0.000
Hong Kong	0.090	-0.045	0.001	-0.154	0.068
India	-0.007	0.032	0.017	0.018	0.030
Japan	0.007	-0.005	-0.006	-0.009	0.000
Malaysia	0.133	-0.063	-0.008	-0.015	-0.119
Singapore	0.180	-0.119	-0.340	-0.155	-0.100
Non-IT	**0.061**	**-0.028**	**-0.059**	**-0.041**	**-0.018**

Notes: 1. CA: current account surplus KA: capital account surplus, FDI: foreign direct investment(net), PF: portfolio investment(net), OINT: other investment (net)
2. na: data are not available
3. The figures of each group are simple arithmetic average of the countries included.

Source: Author's calculation based on IMF International Financial Statistics and DataStream

(c) Changes in NDA and NFA over time

group	country	NDA/GDP (%)								NFA/GDP (%)							
		1981-1990		1991-2000		2001-2010		1981-2010		1981-1990		1991-2000		2001-2010		1981-2010	
IT-Advanced	Australia	-0.06	(2.32)	0.20	(1.58)	-0.59	(4.43)	-0.15	(3.01)	0.48	(2.44)	0.04	(1.76)	0.43	(3.06)	0.32	(2.47)
	Canada	0.02	(0.22)	0.04	(0.24)	0.04	(0.18)	0.04	(0.21)	0.02	(0.20)	0.00	(0.28)	0.00	(0.05)	0.00	(0.20)
	Iceland					-1.49	(14.21)	-1.49	(14.21)					2.42	(13.98)	2.42	(13.98)
	Norway	-1.11	(4.96)	-0.48	(6.83)	-1.05	(5.59)	-0.91	(5.79)	1.34	(4.67)	0.82	(6.59)	1.13	(3.84)	1.09	(5.15)
	New Zealand	-1.49	(5.10)	0.17	(2.90)	-0.46	(5.46)	-0.36	(4.48)	1.65	(5.21)	-0.05	(2.80)	1.04	(4.90)	0.68	(4.21)
	Sweden					-0.84	(9.97)	-0.84	(9.97)					0.78	(6.50)	0.78	(6.50)
	Switzerland	-1.59	(4.80)	-0.30	(5.64)	-3.10	(10.44)	-1.67	(7.66)	0.84	(7.09)	0.48	(6.33)	3.95	(12.13)	1.76	(8.96)
	UK	0.32	(1.85)	0.26	(1.46)	1.15	(4.84)	0.58	(3.10)	-0.09	(1.74)	-0.15	(0.98)	0.04	(1.88)	-0.07	(1.57)
	Average	-0.50	(3.44)	-0.02	(3.87)	-0.78	(7.89)	-0.46	(5.79)	0.60	(4.11)	0.19	3.96)	1.21	(7.33)	0.72	(5.61)
IT-Asia	Indonesia			0.47	(4.21)	0.25	(8.75)	0.12	(7.09)			1.31	(7.27)	0.95	(5.45)	1.15	(6.42)
	Korea	-0.01	(3.75)	-1.22	(6.70)	-2.42	(8.49)	-1.06	(6.72)			1.61	(6.27)	2.88	(7.89)	1.59	(6.13)
	Philippines			1.02	(6.84)	-2.57	(5.29	-2.57	(5.29)			-0.22	(6.89)	3.61	(3.95)	3.61	(3.95)
	Thailand					-4.89	(5.75)	-2.49	(7.00)					5.47	(6.21)	3.32	(7.12)
	Average			0.00	(6.07)	-2.40	(7.50)	-1.29	(6.78)	-0.01	(3.75)	0.98	(6.80)	3.21	(6.29)	2.10	(6.30)
IT-Latin	Chile					0.00	(4.19)	0.00	(4.19)					0.92	(3.93)	0.92	(3.93)
	Colombia					-0.09	(3.28)	-0.09	(3.28)					0.97	(1.80)	0.97	(1.80)
	Mexico					-0.09	(0.58)	-0.09	(0.58)					0.21	(0.50)	0.21	(0.50)
	Peru	6.94	(4.31)	0.70	(3.40)	-2.04	(4.95)	1.82	(5.66)	0.26	(4.77)	1.67	(3.58)	3.24	(4.92)	1.74	(4.59)
	Average	6.94	(4.31)	0.70	(3.40)	-0.66	(3.98)	0.67	(4.75)	0.26	(4.77)	1.67	(3.58)	1.47	(3.46)	1.32	(3.71)

(Continued) Appendix 5.3(c) Changes in NDA and NFA over time

group	country	NDA/GDP(%)								NFA/GDP(%)							
		1981-1990		1991-2000		2001-2010		1981-2010		1981-1990		1991-2000		2001-2010		1981-2010	
IT-Emerging Europe	Czech					-2.55	(6.00)	-2.63	(5.94)					2.55	(5.94)	2.55	(5.82)
	Hungary					-1.6	(10.06)	-1.88	(9.86)					2.30	(9.07)	2.51	(8.92)
	Turkey					0.25	(4.23)	0.25	(4.23)					1.29	(2.92)	1.29	(2.92)
	Poland					-0.88	(4.42)	-0.88	(4.42)					1.78	(2.85)	1.78	(2.85)
	South Africa					-0.28	(0.46)	-0.28	(0.46)					0.41	(0.41)	0.41	(0.41)
	Israel	15.18	(22.05)	0.09	(3.97)	-1.43	(4.45)	4.52	(14.90)	0.76	(7.24)	1.65	(4.32)	2.26	(4.51)	1.52	(5.45)
	Average					-1.11	(5.79)	1.09	(10.79)					1.77	(5.18)	1.65	(5.35)
Non-IT	Argentina			-0.10	(0.38)	0.22	(1.68)	0.08	(1.28)			0.14	(0.69)	0.31	(1.48)	0.23	(1.19)
	China	3.01	(7.36)	2.50	(7.72)	-4.20	(8.47)	-0.21	(8.60)	1.11	(1.62)	2.27	(2.45)	9.38	(5.61)	5.04	(5.44)
	Euro Area			-1.32	(11.20)	1.37	(6.57)	0.97	(7.35)			-0.26	(0.78)	0.33	(1.71)	0.25	(1.61)
	Hong Kong			-3.18	(21.37)	-2.65	(7.63)	-2.80	(12.88)			5.82	(17.88)	7.70	(14.23)	7.16	(15.21)
	India			0.39	(2.00)	-0.88	(4.38)	-0.49	(3.85)			1.15	(1.95)	3.07	(4.66)	2.48	(4.11)
	Japan					-12.81	(451.62)	-12.81	(451.62)					13.58	(447.55)	13.58	(447.55)
	Malaysia					-4.34	(10.73)	-4.34	(10.73)					4.76	(11.18)	4.76	(11.18)
	Singapore	-6.90	(7.96)	-6.64	(10.46)	-7.95	(11.50)	-7.16	(10.01)	8.35	(8.36)	7.36	(10.98)	8.85	(11.48	8.14	(10.26)
	Average	-4.07	(8.95)	-1.46	(10.34)	-3.76	(150.05)	-3.12	(116.18)	6.28	(7.82)	3.29	(8.57)	5.90	(148.74)	5.17	(115.01)

Notes: 1. All figures are quarterly average changes. The average in country group is the simple arithmetic mean of all countries included.

2. The numbers in ( ) indicate standard deviation of quarterly average changes.

3. A large standard deviations of NDA/GDP and NFA/GDP in Japan is due to valuation effects of the assets in 2007, 2008 and 2009.

Appendix 5.4 Time-series based ADF unit root test

	UK (1990-2010)		Korea (1981-2010)		Australia (1990-2010)		Peru (1990-2010)		Canada (1999-2010)		Switzerland (2002-2010)		New Zealand (2000-2010)	
	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value
ΔNFA	-12.892	0.000	-9.369	0.000	-12.216	0.000	-6.401	0.000	-5.858	0.000	-3.971	0.002	-8.835	0.000
ΔNDA	-11.297	0.000	-9.959	0.000	-8.214	0.000	-6.208	0.003	-6.589	0.000	-8.139	0.000	-9.559	0.000
FXDIF	-9.607	0.000	-6.811	0.000	-8.887	0.000	-8.222	0.000	-8.838	0.000	-8.865	0.000	-6.446	0.000
Δp	-9.734	0.000	-4.241	0.000	-3.390	0.012	-3.548	0.009	-4.003	0.002	-2.687	0.079	-3.536	0.008
Y_c	-3.660	0.006	-5.156	0.000	-4.638	0.000	-3.455	0.012	-5.162	0.002	-4.395	0.007	-3.476	0.011
ΔG^1	-1.401 -7.989 0.165	0.560 0.000	-5.041	0.000	-1.840 -11.025 0.217	0.359 0.000	-11.477	0.000	-1.738 -2.817 0.855***	0.409 0.006	-2.023 -1.572 0.225	0.276 0.493	-1.508 -2.575 0.254	0.523 0.102
CA	-2.612	0.093	-3.568	0.008	-4.555	0.000	-2.452	0.081	-2.729	0.072	-2.135 -3.325 0.145	0.232 0.019	-2.604 -7.352 0.374*	0.096 0.000
$\Delta(r_f+ES)$	-8.714	0.000	-8.103	0.000	-8.106	0.000	-5.512	0.000	-8.010	0.000	-8.379	0.000	-7.332	0.000
$(d_1-1)\sigma_r$	-10.574	0.000	-7.056	0.000	-5.428	0.000	-11.200	0.000	-27.123	0.000	-10.873	0.000	-7.949	0.000
$(d_2-1)\sigma_s$	-9.123	0.000	-7.085	0.000	-14.734	0.000	-9.781	0.000	-4.678	0.000	-3.424	0.012	-9.054	0.000
r_d	-0.873	0.793	-1.541	0.509	-1.757	0.400	-2.519	0.114	-2.197	0.208	-2.734	0.007	-4.704	0.000
Δm	-11.396	0.000	-20.693	0.000	-10.447	0.000	-4.440	0.000	-4.882	0.000	-4.475	0.000	-11.141	0.000
r_f^*	-5.671	0.000	-5.869	0.000	-5.262	0.000	-5.377	0.000	-4.127	0.001	-6.158	0.004	-4.997	0.000
Δy_t	-6.125	0.000	-9.758	0.000	-9.245	0.001	-6.976	0.000	-5.925	0.000	-3.893	0.000	-8.848	0.000

Notes: 1. When ADF and PP tests provide conflicting results (e.g. ΔG, CA), we additionally conduct KPSS unit root test. In the cell having three figures, the 1st, 2nd and 3rd row indicate the test statistics of ADF, PP and KPSS, respectively. For example, as for the series ΔG of the UK, the null of I(1) cannot be rejected according to ADF but can be rejected according to PP. KPPS test suggests that the null of I(0) cannot be rejected because test statistics (0.165) is smaller than critical value(0.347) at 10% level. Thus, ΔG is assumed stationary.

2. Only intercept is included in the test forms except for the series r_d and r_f^* which are tested with intercept and trend in test forms.

3. In KPSS test, ***, ** and * indicate that the null of stationarity is rejected at 1%, 5% and 10% significant level, respectively

(Continued) Appendix 5.4 Time-series based ADF unit root test

	Indonesia (1990-2010)		Thailand (1981-2010)		Japan (1990-2010)		China (1990-2010)		India (1999-2010)		Israel (2002-2010)	
	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value
ΔNFA	-7.779	0.000	-6.081	0.000	-5.901	0.000	-2.628	0.091	-5.568	0.000	-10.342	0.000
ΔNDA	-9.313	0.000	-5.811	0.000	-5.935	0.000	-9.221	0.000	-7.748	0.000	-6.301	0.000
$FXDIF$	-4.806	0.000	-3.486	0.013	-5.169	0.000	-4.926	0.000	-3.202	0.027	-6.908	0.000
Δp	-5.684	0.000	-6.017	0.000	-3.050	0.003	-3.902	0.003	-5.572	0.000	-9.036	0.000
Y_c	-5.066	0.006	-3.398	0.017	-5.446	0.000	-5.634	0.000	-5.066	0.002	-5.024	0.007
ΔG[1]	-2.494 -6.403 0.424*	0.125 0.000	-2.006 -8.576 0.500**	0.283 0.000	-2.631	0.089	-1.025 -2.541 0.630**	0.738 0.110	-2.494 -6.403 0.424*	0.125 0.000	-4.037	0.002
CA	-3.503	0.012	-4.626	0.000	-3.559	0.008	-3.056	0.033	-3.503	0.013	-2.648	0.086
$\Delta(r_f+ES)$	-6.417	0.000	-3.962	0.004	-4.526	0.000	-9.546	0.000	-6.417	0.000	-6.421	0.000
$(d_1-1)\sigma_r$	-8.776	0.000	-3.770	0.006	-6.295	0.000	-4.669	0.000	-8.776	0.000	-15.000	0.000
$(d_2-1)\sigma_s$	-6.216	0.000	-5.350	0.000	-5.139	0.000	-4.309	0.000	-6.216	0.000	-7.152	0.000
r_d	-2.605	0.100	-3.670	0.008	-1.511	0.525	-2.520	0.114	-2.605	0.100	-3.916	0.003
Δm	-11.419	0.000	-9.273	0.000	-2.775	0.073	-4.361	0.000	-11.419	0.000	-4.605	0.000
r_f^*	-5.669	0.000	-2.713	0.080	-3.571	0.008	-6.544	0.000	-5.669	0.000	-5.466	0.004
Δy_t	-7.313	0.000	-4.572	0.000	-8.998	0.000	-9.758	0.000	-7.313	0.000	-12.431	0.000

Appendix 5.5 Sterilisation and offset coefficient: System GMM with time series

	Australia						UK					
	Whole (1981Q1-2010Q3)		Pre-IT (1981Q1-1992Q4)		Post-IT (1993Q1-2010Q3)		Whole (1981Q1-2010Q4		Pre-IT (1981Q1-1992Q2)		Post-IT (1992Q3-2010Q3)	
	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA
Intercept	0.0102***	0.0012	0.0206***	0.0200***	0.0226**	0.0089*	-8.32E-05	-0.0004	0.0012	0.0053***	0.0045	0.0028
	(0.0057)	(0.7202)	(0.0025)	(0.0002)	(0.0299)	(0.0562)	(0.9867)	(0.9256)	(0.2706)	(0.0000)	(0.4547)	(0.2453)
ΔNFA (sterilisation)	-0.6563***	-	-0.6736***	-	-0.7739***	-	-0.7412***	-	-0.8114***	-	-0.4241	-
	(0.0000)		(0.0000)		(0.0007)		(0.0000)		(0.0000)		(0.1331)	
ΔNDA (offset)	-	-0.5061***	-	-0.8909***	-	-0.3840***	-	-0.3918***	-	-0.6543***	-	-0.2400***
		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)		(0.0000)
CA	0.1845**	0.0011	0.3097**	0.3062***	0.5639***	0.1996*	-0.2786***	-0.0021	0.1187***	0.0939	-0.1798	-0.1065
	(0.0336)	(0.9861)	(0.0497)	(0.0008)	(0.0005)	(0.0594)	(0.0067)	(0.9717)	(0.0074)	(0.1899)	(0.5127)	(0.2158)
$\Delta(r_f+ES)$	0.0773***	0.0365	0.0933**	0.0292	0.0397	-0.1104**	0.1609	-0.1166	-0.0631*	-0.0669***	-0.1690	0.1382**
	(0.0017)	(0.2095)	(0.0240)	(0.3793)	(0.6636)	(0.0187)	(0.3195)	(0.2249)	(0.0730)	(0.0059)	(0.5641)	(0.0278)
$(S_{t-1}-\overline{S_t})$	-0.1196***	-0.0292	0.0384	0.0744***	-0.1218*	-0.1126***	0.1096	-0.0069	-0.0522***	-0.0236**	0.1234	-0.0345
	(0.0000)	(0.1057)	(0.1633)	(0.0020)	(0.0713)	(0.0049)	(0.1667)	(0.8681)	(0.0000)	(0.0134)	(0.3543)	(0.2945)
Δp_{t-1}	-0.0610	0.1864**	-0.3604***	-0.2009*	0.3238	0.2738	-0.8128**	-0.0172	-0.1069**	-0.2041***	-1.4761**	-0.6826***
	(0.5627)	(0.0106)	(0.0003)	(0.0767)	(0.6709)	(0.2690)	(0.0314)	(0.9565)	(0.0500)	(0.0096)	(0.0201)	(0.0072)
Y_c	0.0938	-0.0306)	0.2610***	0.2025***	0.6747***	0.0468	-0.0301	0.0906	0.4514***	0.1838	0.1664	-0.1184
	(0.2017)	(0.6192)	(0.0038)	(0.0001)	(0.0067)	(0.8199)	(0.8639)	(0.3034)	(0.0000)	(0.1284)	(0.2207)	(0.2524)
Fiscal deficit	-8.45E-05	-0.0600**	-0.0872***	-0.0583***	0.2370*	0.1643**	-0.1812***	-0.1101	-0.1492***	-0.0138	-0.1564**	-0.1227***
	(0.9972)	(0.0163)	(0.0000)	(0.0004)	(0.0602)	(0.0371)	(0.0004)	(0.1101)	(0.0000)	(0.5294)	(0.0189)	(0.0000)
$(d_1-1)\sigma_r$	-0.4997	-	-0.3558	-	-5.8433***	-	-3.2163***	-	-0.8879***	-	-5.6567***	-
	(0.1227)		(0.1425)		(0.0000)		(0.0017)		(0.0000)		(0.0001)	
$(d_2-1)\sigma_s$	-	-0.4893***	-	-0.1762***	-	-0.4189***	-	-0.6048***	-	-0.2062***	-	-0.8072***
		(0.0000)		(0.0298)		(0.0000		(0.0000)		(0.0002)		(0.0000)
Observation	115	115	45	45	71	71	116	116	43	43	73	73
J-statistics	20.263	(0.3182)	9.883	(0.3601)	11.649	(0.2339)	12.187	(0.203)	10.209	(0.3601)	9.858	(0.3621)

Notes: 1.The numbers in parenthesis are p-values.

2. ***, ** and * denote the rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.
3. A constant, ΔCIC, ΔFDI, standard deviation of FX rate return and up to 2 lags of variables are used as instruments.
4. J-statistics is the diagnostic test for the validity of over-identifying restriction. Null is that the specification has a valid over-identifying restriction.
5. Newey & West (1987)'s HAC standard-errors are used.

(Continued) Appendix 5.5 Sterilisation and offset coefficient: System GMM with time series

	Korea						Peru					
	Whole (1981Q1-2010Q3)		Pre-IT (1981Q1-1998Q4)		Post-IT (1999Q1-2010Q4)		Whole (1991Q3-2010Q2)		Pre-IT (1991Q3-2001Q4)		Post-IT (2002Q1-2010Q2)	
	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA
Intercept	-0.0115***	-0.0073	0.0015	-0.0017	0.0186***	0.0252***	0.0072	0.0116***	-0.0422***	0.0116	0.0107***	0.0169***
	(0.0098)	(0.1161)	(0.6083)	(0.4552)	(0.0000)	(0.0000)	(0.1180)	(0.0001)	(0.0000)	(0.3563)	(0.0000)	(0.0000)
ΔNFA(sterilisation)	-1.0175***	-	-0.1925*	-	-1.0194***	-	-1.0128***	-	-0.2282***	-	-0.9352***	-
	(0.0000)		(0.0709)		(0.0000)		(0.0000)		(0.0000)		(0.0000)	
ΔNDA (offset)	-	-0.7378***	-	-0.2033**	-	-0.8786***	-	-0.7508***	-	-0.1077	-	-0.9318***
		(0.0000)		(0.0423)		(0.0000		(0.0000)		(0.4742)		(0.0000)
CA	0.3446***	0.2625***	0.1921***	0.0465	0.0942	-0.0989	0.2910*	0.1587**	-0.4723***	0.0576	0.1700**	0.0496
	(0.0000)	(0.0001)	(0.0000)	(0.4539)	(0.4296)	(0.3888)	(0.0559)	(0.0463)	(0.0000)	(0.8023)	(0.0125)	(0.5568)
$\Delta(r_f+ES)$	0.2098*	-0.0726	0.5661***	-0.5577***	0.2097***	0.1558	0.8230***	0.1767	-0.6819***	-0.1418**	1.1923***	0.8778***
	(0.0994)	(0.4892)	(0.0004)	(0.0000)	(0.0001)	(0.1267)	(0.0001)	(0.1004)	(0.0000)	(0.0494)	(0.0000)	(0.0000)
$(S_{t-1}-\overline{S_t})$	-0.0328	-0.1204***	0.0349	-0.0746***	0.0232	0.0596**	-0.3692*	-0.3427**	0.7850***	-0.3347	0.3187***	0.1725***
	(0.3520)	(0.0006)	(0.2393)	(0.0025)	(0.3519)	(0.0218)	(0.0771)	(0.0163)	(0.0000)	(0.1200)	(0.0000)	(0.0455)
Δp_{t-1}	-1.3126***	-1.4145***	-0.2634	0.8733***	-1.9684***	-1.9807***	1.0820***	0.4780***	0.5680***	0.2831***	1.2581***	0.5706***
	(0.0004)	(0.0003)	(0.2852)	(0.0000)	(0.0000)	(0.0035)	(0.0095)	(0.0001)	(0.0002)	(0.0022)	(0.0000)	(0.0279)
Y_c	-0.4410***	-0.2324	-0.3460***	0.3099**	-0.4115**	-0.1574*	0.5299***	0.4644***	-0.0947***	0.5172**	0.9462***	0.8918***
	(0.0014)	(0.1198)	(0.0041)	(0.0122)	(0.0179)	(0.0648)	(0.0074)	(0.0000)	(0.0077)	(0.0173)	(0.0000)	(0.0000)
Fiscal deficit	-0.0205	0.0062	-0.2555***	-0.0500	0.0884***	-0.0211	0.0472	0.1056	-0.9790***	0.1165	-0.0414	-0.0205
	(0.8089)	(0.9241)	(0.0000)	(0.3591)	(0.0079)	(0.5020)	(0.6322)	(0.2276)	(0.0000)	(0.2472)	(0.4807)	(0.7610)
$(d_1\text{-}1)\sigma_r$	-3.2106***	-	-3.4660***	-	-2.3589***	-	0.2476	-	-0.5116***	-	- 0.1441*	-
	(0.0000)		(0.0000)		(0.0009)		(0.1634)		(0.0000)		(0.0612)	
$(d_2\text{-}1)\sigma_s$	-	0.5994***	-	-0.3621	-	-0.2966**	-	0.3495	-	-0.8231	-	0.3589***
		(0.0025)		(0.0767)		(0.0287)		(0.5637)		(0.2993)		(0.0862)
Observation	116	116	69	69	47	47	76	76	42	42	34	34
J-statistics	14.580	(0.1032)	14.373	(0.1097)	9.791	(0.3677)	12.302	(0.2030)	9.175	(0.2185)	8.647	(0.4704)

(Continued) Appendix 5.5 Sterilisation and offset coefficient: System GMM with time series

	Canada				Switzerland		New Zealand		Israel	
	Whole (1985Q4- 2010Q3)		Post-IT (1991Q1- 2010Q3)		(2002Q1-2010Q2)		(1997Q2-2010Q1)		(1997Q2-2010Q1)	
	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA
Intercept	-0.0001	0.0005*	0.0002***	0.0006**	0.1155***	0.0662***	-0.0273***	-0.0249***	-0.0164***	0.0013
	(0.5695)	(0.0579)	(0.2586)	(0.0127)	(0.0000)	(0.0078)	(0.0000)	(0.0004)	(0.0000)	(0.7974)
ΔNFA (sterilisation)	-0.0621	-	0.1708	-	-0.2269***	-	-0.8625***	-	-0.2242***	-
	(0.5439)		(0.1515)		(0.0000)		(0.0000)		(0.0013)	
ΔNDA (offset)	-	-0.2545***	-	-0.2135**	-	-0.4602***	-	-0.8175***	-	-0.4588***
		(0.0025)		(0.0429)		(0.0000)		(0.0000)		(0.0044)
CA	-0.0684	-0.0046	0.0067	0.0312	-0.9023***	-0.3188*	-0.2405***	-0.1830***	0.0028	-0.0149
	(0.2040)	(0.9133)	(0.8978)	(0.5931)	(0.0000)	(0.0791)	(0.0074)	(0.0022)	(0.9839)	(0.8764)
$\Delta(r_f+ES)$	-0.0012	-0.0036	-0.0082	0.0047	-0.0994	0.9803***	0.0678	0.0140	-0.1698	0.0647
	(0.8933)	(0.7398)	(0.2156)	(0.6701)	(0.3512)	(0.0000)	(0.4772)	(0.8966)	(0.2532)	(0.5262)
$(S_{t-1}-\overline{S_t})$	0.0037	-0.0048	-0.0032	0.0042	0.0320	0.5454***	-0.0481**	-0.0256	0.0766	0.1740***
	(0.5704)	(0.4347)	(0.5323)	(0.4176)	(0.8341)	(0.0002)	(0.0141)	(0.4815)	(0.1137)	(0.0014)
Δp_{t-1}	0.0807*	-0.0756*	-0.0616	-0.1030*	-1.9245***	-4.0840***	2.3498**	2.7950***	0.0885	-0.0148
	(0.0765)	(0.0847)	(0.3242)	(0.0736)	(0.0012)	(0.0001)	(0.0010)	(0.0040)	(0.6851)	(0.9590)
Y_c	-0.0169*	0.0144	-0.0255**	-0.0081	-1.5430***	2.1933***	-0.6772***	-0.4887*	0.5321***	0.3258*
	(0.0944)	(0.1715)	(0.0335)	(0.5835)	(0.0000)	(0.0000)	(0.0003)	(0.0542)	(0.0007)	(0.0909)
Fiscal deficit	0.1039**	-0.0496**	0.0764*	-0.0272*	-3.7264***	-2.3017***	0.1401	0.0780	-0.5964***	-0.5019***
	(0.0364)	(0.0137)	(0.0846)	(0.0716)	(0.0000)	(0.0029)	(0.1171)	(0.3912)	(0.0000)	(0.0039)
$(d_1-1)\sigma_r$	-0.4569***	-	-1.0155***	-	-0.3699*	-	-3.1943**	-	-7.7020***	-
	(0.0001)		(0.0000)		(0.0773)		(0.0286)		(0.0000)	
$(d_2-1)\sigma_s$	-	-0.0013	-	-0.0020	-	-1.3477***	-	-0.3299	-	-1.1772***
		(0.9707)		(0.9659)		(0.0001)		(0.1570)		(0.0006)
Observation	100	100	79	79	42	42	80	80	52	52
J-statistics	15.348	(0.0818)	13.980	(0.1230)	9.229	(0.4164)	7.656	(0.5691)	9.937	(0.3556)

(Continued) Appendix 5.5 Sterilisation and offset coefficient: System GMM with time series

	Indonesia (2000Q3-2010Q3)		Thailand (2000Q2-2010Q3)		Japan (2002Q3- 2010Q3)		China (1995Q4 2010Q3)		India (1997Q3 2010Q1)	
	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA	ΔNDA	ΔNFA
Intercept	-0.0034	0.0193***	0.0006	-0.0022	0.1101*	0.1528***	0.0393*	0.0313**	-0.0160**	0.0328***
	(0.7825)	(0.0046)	(0.9028)	(0.7638)	(0.0567)	(0.0055)	(0.0689)	(0.0231)	(0.0332)	(0.0014)
ΔNFA (sterilisation)	-1.1714***	-	-0.9884***	-	-1.0102***	-	-1.1055***	-	-0.3768***	-
	(0.0000)		(0.0000)		(0.0000)		(0.0043)		(0.0057)	
ΔNDA (offset)	-	-0.5155***	-	-0.7258***	-	-0.9898***	-	-0.1380*	-	0.1001
		(0.0000)		(0.0000)		(0.0000)		(0.0836)		(0.3854)
CA	0.0422	-0.0032	0.0453	0.2366*	-11.0921*	-15.5806***	-0.8052	-0.2555	-0.5709**	1.0759***
	(0.8192)	(0.9857)	(0.7255)	(0.0689)	(0.0549)	(0.0044)	(0.1628)	(0.5673)	(0.0456)	(0.0000)
$\Delta(r_f+ES)$	0.0851	0.2656***	-0.5592***	-0.3661*	0.6558**	0.0799	0.3467	-1.9199	-0.0226	0.0938
	(0.1841)	(0.0000)	(0.0008)	(0.0512)	(0.0136)	(0.7472)	(0.8745)	(0.1273)	(0.8505)	(0.6861)
$(S_{t-1}-\overline{S_t})$	-0.1924***	-0.1021**	0.1382**	-0.0998	-0.8122**	-0.6972**	-17.3943	-0.0515	-0.2378	-0.8353***
	(0.0000)	(0.0130)	(0.0193)	(0.3018)	(0.0230)	(0.0481)	(0.1159)	(0.9934)	(0.1925)	(0.0000)
Δp_{t-1}	0.2405	-0.5484**	0.7495***	0.8841***	11.1046***	5.9769	-0.1013	-0.2819	0.2771	-0.0489
	(0.4626)	(0.0170)	(0.0038)	(0.0000)	(0.0012)	(0.1033)	(0.9098)	(0.7355)	(0.1642)	(0.8429)
Y_c	-2.2606**	1.2393**	0.0917	0.3160***	-1.8932***	-1.3965***	0.0591	0.0668	0.1484	-0.1508
	(0.0110)	(0.0436)	(0.3260)	(0.0059)	(0.0005)	(0.0040)	(0.4593)	(0.1350)	(0.1033)	(0.3871)
Fiscal deficit	-0.7289*	-0.3745*	-0.2607**	-0.9241**	-0.3164	0.3121	-1.5571***	-0.3663**	-0.2635***	0.2832*
	(0.0920)	(0.0706)	(0.0178)	(0.0218)	(0.5770)	(0.6281)	(0.0000)	(0.0492)	(0.0068)	(0.0872)
$(d_1-1)\sigma_r$	-6.6498***	-	-6.0931***	-	-12.8042***	-	-15.3305***	-	-0.4297*	-
	(0.0000)		(0.0019)		(0.0002)		(0.0000)		(0.0568)	
$(d_2-1)\sigma_s$	-	-0.4249	-	-0.1362	-	2.0454**	-	-9.1046	-	-4.3367***
		(0.3238)		(0.3338)		(0.0236)		(0.6560)		(0.0000)
Observation	41	41	42	42	33	33	78	78	51	51
J-statistics	15.051*	(0.0895)	10.442	(0.3159)	7.237	(0.6124)	14.236	(0.1142)	11.423	(0.2478)

Appendix 5.6 Sterilisation effect on domestic interest rate: Single equation GMM

Regression equation: $\Delta r_{d,t} = c_0 + c_1 r^*_{f,t} + c_2 \Delta NDA_t + c_3 m_{t-1} + c_4 \Delta p^e_{t+1} + c_5 y_t + \varepsilon_t$

	Australia			UK			Canada			Korea			Peru	
	Whole	Pre-IT	Post-IT	Whole	Pre-IT	Post-IT	Whole	Pre-IT	Post-IT	Whole	Pre-IT	Post-IT	Whole	Post-IT
	1981Q3 -2010Q3	1981Q4 -1992Q4	1993Q1 -2010Q3	1981Q3 -2010Q2	1981Q3 -1992Q3	1992Q4 -2010Q2	1981Q4 - 2010Q3	1981Q4 -1990Q4	1991Q1 -2010Q3	1982Q1 -2010Q3	1982Q1 -1996Q4	1999Q1 -2010Q3	1995Q4 -2010Q3	2002Q1 -2010Q3
Intercept	0.0239	0.0721***	0.0546***	0.0325**	0.0968***	0.0372***	0.0216***	0.0842***	0.0306***	-0.0538	0.0268	0.0335***	0.0283*	0.0366***
	(0.1576)	(0.0002)	(0.0000)	(0.0399)	(0.0000)	(0.0000)	(0.0014)	(0.0000)	(0.0000)	(0.1549)	(0.5179)	(0.0027)	(0.0932)	(0.0000)
r^*_f (+)	0.2654**	0.1056	0.1179**	0.5780***	-0.0961	0.2991***	0.6613***	0.4640***	0.4107***	0.9392*	0.3837***	0.2857***	1.6736***	0.3265***
	(0.0246)	(0.4085)	(0.0114)	(0.0001)	(0.5665)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0848)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ΔNDA	-0.3502	-0.6031*	-0.0702	-0.2297	0.7060**	-0.0153	-1.5858	-3.6615	-1.9019	-0.4279*	0.0826	-0.0124*	0.1124	-0.0140
	(0.2160)	(0.0660)	(0.4934)	(0.5660)	(0.0371)	(0.9539)	(0.5452)	(0.1551)	(0.2302)	(0.0973)	(0.5525)	(0.0709)	(0.6475)	(0.6911)
Δm_{t-1} (-)	-0.0383	-0.2747	0.1463	-0.2863**	-0.1245	-0.1493**	-0.5009	-1.7915	-0.5688	-0.3855	-0.5261	0.0634	-0.2987	0.1531***
	(0.9194)	(0.7051)	(0.2876)	(0.0156)	(0.8425)	(0.0208)	(0.7059)	(0.2829)	(0.5234)	(0.4361)	(0.1844)	(0.6209)	(0.1939)	(0.0014)
p^e_{t+1}	5.1072***	3.3637***	-0.0041	1.0104	2.4948**	-0.2136	2.0697**	-0.4079	0.4127	1.6878	5.0047***	-0.7696	-0.9793	-0.1170
	(0.0001)	(0.0000)	(0.9906)	(0.3132)	(0.0143)	(0.7691)	(0.0331)	(0.6091)	(0.6578)	(0.7653)	(0.0043)	(0.4302)	(0.1970)	(0.6595)
Δy (+)	-0.1337	0.1180	-0.4758	-0.5006	-1.8282**	0.8377	-1.2104***	-1.7506***	-1.0716***	4.3975*	0.3520	0.4883	-0.2334	-0.3505**
	(0.8970)	(0.9139)	(0.2290)	(0.8725)	(0.0200)	(0.1099)	(0.0067)	(0.0001)	(0.0705)	(0.0943)	(0.7930)	(0.2175)	(0.8003)	(0.0366)
Observation after adjustment	116	45	71	116	45	71	116	37	79	117	62	47	60	35
J-statistics	7.6918	3.2699	3.8202	7.6338*	3.5686	5.8577	7.6476	3.7027	6.6877	1.3505	3.7507	4.6539	9.0329	7.8978
	(0.1740)	(0.6584)	(0.5755)	(0.0542)	(0.3119)	(0.1187)	(0.1768)	(0.5930)	(0.2449)	(0.7171)	(0.2896)	(0.1989)	(0.5290)	(0.6388)

Notes: 1. The numbers in ( ) are p-values.

2. ***, ** and * denote the rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

3. The signs in ( ) indicated the priori expected signs according to model.

4. A constant and up to two lags of explanatory variables are used as instruments together with CIC/GDP, FDI/GDP and standard deviation of FX rate return.

5. Newey-West HAC standard errors & covariance is used.

(Continued) Appendix 5.6 Sterilisation effect on domestic interest rate: Single equation GMM

	Switzerland		Israel			New Zealand	Thailand	Indonesia	China			Japan	India
	Pre-IT	Post-IT	Whole	Pre-IT	Post-IT	Post-IT	Post-IT						
	1984Q3 -1999Q4	2000Q1 -2010Q3	1983Q4 -2010Q1	1983Q4 -1997Q1	1997Q2 -2010Q1	1990Q1 -2010Q3	2000Q2 - 2010Q3	1998Q1 - 2010Q3	1990Q2 -2010Q3	2000Q1 -2010Q3	1990Q2 -1999Q4	2002Q4 -2010Q3	1997Q4 -2010Q3
Intercept	0.0341***	0.0073**	0.2527	-0.7610	0.0595***	-0.0086***	0.0334**	-0.0050	0.0255*	0.0227***	0.0262	-0.0013	0.0869***
	(0.0003)	(0.0183)	(0.3604)	(0.1166)	(0.0004)	(0.0271)	(0.0135)	(0.5912)	(0.0605)	(0.0000)	(0.5474)	(0.3853)	(0.0000)
r^*_f (+)	-0.4656**	0.3038***	-6.6590	4.7475	0.1287	0.0070	0.1558	0.1658**	0.4819	0.1159*	0.7255	0.0968***	0.8292***
	(0.0122)	(0.0004)	(0.1806)	(0.4418)	(0.7266)	(0.8482)	(0.1584)	(0.0453)	(0.1953)	(0.0865)	(0.1679)	(0.0043)	(0.0001)
ΔNDA	0.4698**	-0.0468	0.3553	-6.6167*	0.6192**	0.1138*	0.0343	0.0203	0.3803**	-0.1328*	0.1682	0.0018**	-0.1276
	(0.0304)	(0.1893)	(0.9148)	(0.0726)	(0.0461)	(0.0523)	(0.8347)	(0.6427)	(0.0381)	(0.0693)	(0.5772)	(0.0316)	(0.4674)
Δm_{t-1} (-)	-0.3708***	-0.0509	0.4679	-1.7239	0.2694	-0.0729	0.4721**	-0.0071	0.0160	-0.1076	0.6861*	0.3687	-0.0318
	(0.0077)	(0.1473)	(0.7770)	(0.5963)	(0.1868)	(0.2010)	(0.0256)	(0.8341)	(0.9544)	(0.1736)	(0.0773)	(0.1628)	(0.8323)
p^e_{t+1}	7.1747***	-0.4357	16.6773***	13.7387***	0.1386	1.0017**	-1.6462**	-0.5809	-1.2690**	-0.4486	-1.3312*	-0.7410**	-1.0748***
	(0.0000)	(0.1947)	(0.0029)	(0.0060)	(0.8568)	(0.0461)	(0.0465)	(0.1465)	(0.0332)	(0.1143)	(0.0727)	(0.0227)	(0.0002)
Δy (+)	-2.0825*	-0.3874	-10.8153	2.5884	0.1375	0.3204	-0.6109	0.9661*	0.9339	0.1480	-0.4716	0.0569	0.4320
	(0.0746)	(0.4842)	(0.1600)	(0.7836)	(0.8337)	(0.3490)	(0.1013)	(0.0728)	(0.4937)	(0.5398)	(0.7098)	(0.7345)	(0.3916)
Observation after adjustment	62	43	106	54	52	83	40	38	82	43	39	32	51
J-statistics	1.5604	4.3038	2.0866	1.2741	5.7109	14.5665	2.4444	8.1404	1.4526	2.0569	1.2338	5.2870	5.5875
	(0.9060)	(0.5066)	(0.8370)	(0.9376)	(0.3354)	(0.1487)	(0.7848)	(0.6151)	(0.4836)	(0.3575)	(0.5396)	(0.3818)	(0.8485)

Appendix 5.7 Panel unit root test

	IT Advanced						IT Asia				IT-Latin		IT-Europe		Non-IT	
	1981-1990		1991-2000		2001-2010		1991-2000		2001-2010		2001-2010		2001-2010		2001-2010	
	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value	Statistics	P-value
ΔNFA	79.2690	0.0000	124.956	0.0000	125.712	0.0000	30.8629	0.0000	45.1185	0.0000	60.1000	0.0000	47.1967	0.0000	118.597	0.0000
	-6.92801	0.0000	-9.71996	0.0000	-9.26242	0.0000	-4.06035	0.0000	-5.12619	0.0000	-6.19032	0.0000	-4.86630	0.0000	-8.51552	0.0000
ΔNDA	74.9097	0.0000	127.918	0.0000	119.097	0.0000	29.4376	0.0001	52.8847	0.0000	49.4330	0.0000	62.4255	0.0000	168.763	0.0000
	-6.72971	0.0000	-9.81048	0.0000	-8.98435	0.0000	-3.95014	0.0000	-5.90368	0.0000	-5.23945	0.0000	-6.04194	0.0000	-11.0906	0.0000
$FXDIF$	87.2929	0.0000	144.785	0.0000	157.928	0.0000	60.2692	0.0000	66.2119	0.0000	117.314	0.0000	127.045	0.0000	357.484	0.0000
	-7.30455	0.0000	-10.2235	0.0000	-10.8908	0.0000	-6.43468	0.0000	-6.91771	0.0000	-9.63599	0.0000	-9.86291	0.0000	-17.4124	0.0000
Δp	70.4677	0.0000	80.3941	0.0000	120.801	0.0000	31.1717	0.0001	69.9809	0.0000	103.512	0.0000	78.0581	0.0000	201.589	0.0000
	-6.20330	0.0000	-6.73795	0.0000	-8.64380	0.0000	-3.96785	0.0000	-7.12320	0.0000	-8.44621	0.0000	-6.57921	0.0000	-11.5210	0.0000
Y_c	25.2330	0.0323	32.6821	0.0081	60.4942	0.0000	15.3419	0.0528	26.7996	0.0008	35.9246	0.0001	31.2270	0.0018	79.6499	0.0000
	-2.30075	0.0107	-2.97025	0.0015	-5.10043	0.0000	-2.08398	0.0186	-3.56086	0.0002	-3.94305	0.0000	-3.46177	0.0003	-6.65070	0.0000
ΔG	37.1206	0.0000	42.8924	0.0003	25.0589	0.0688	26.9425	0.0001	62.8673	0.0000	81.6649	0.0000	56.9176	0.0000	220.735	0.0000
	-3.68708	0.0001	-3.45679	0.0003	-1.54549	0.0611	-3.55350	0.0002	-6.00616	0.0000	-6.84851	0.0000	-5.18193	0.0000	-11.4130	0.0000
CA	32.9998	0.0010	53.5596	0.0000	47.5581	0.0001	14.0450	0.0806	28.5464	0.0004	39.6110	0.0000	34.6879	0.0005	49.7079	0.0000
	-3.39531	0.0003	-2.02238	0.0216	-3.99524	0.0000	-0.60671	0.2720	-3.72338	0.0001	-4.39341	0.0000	-3.31573	0.0005	-4.44410	0.0000
$\Delta(r_f+ES)$	83.5697	0.0000	111.422	0.0000	118.728	0.0000	29.1761	0.0003	55.0459	0.0000	73.7124	0.0000	86.2570	0.0000	242.077	0.0000
	-7.07828	0.0000	-8.57797	0.0000	-8.98923	0.0000	-3.75529	0.0001	-6.12976	0.0000	-7.17211	0.0000	-7.61957	0.0000	-13.8223	0.0000
$(d_1-1)\sigma_r$	55.2037	0.0000	136.835	0.0000	143.851	0.0000	36.4696	0.0000	36.7667	0.0000	101.754	0.0000	86.1349	0.0000	153.378	0.0000
	-5.32049	0.0000	-9.88906	0.0000	-9.91608	0.0000	-4.79642	0.0000	-4.38350	0.0000	-8.53622	0.0000	-7.52259	0.0000	-10.6121	0.0000
$(d_2-1)\sigma_s$	86.3033	0.0000	134.988	0.0000	73.9115	0.0000	21.0256	0.0018	47.4948	0.0000	67.4733	0.0000	80.6608	0.0000	188.279	0.0000
	-7.63376	0.0000	-9.91620	0.0000	-6.42605	0.0000	-2.98833	0.0014	-5.39288	0.0000	-6.71686	0.0000	-7.10944	0.0000	-11.4966	0.0000
r_d	21.4794	0.1608	40.4314	0.0007	31.8625	0.0104	19.6075	0.0119	21.5623	0.0058	34.6843	0.0001	31.2636	0.0018	82.4429	0.0000
	-1.13865	0.1274	-3.58673	0.0002	-2.72129	0.0033	-2.09002	0.0183	-1.92594	0.0271	-3.72077	0.0001	-3.32775	0.0004	-5.13042	0.0000
Δm	133.451	0.0000	148.268	0.0000	142.286	0.0000	84.6668	0.0000	116.473	0.0000	73.7270	0.0000	103.760	0.0000	328.235	0.0000
	-10.1667	0.0000	-10.7640	0.0000	-10.0762	0.0000	-8.29376	0.0000	-9.58966	0.0000	-6.72321	0.0000	-8.28287	0.0000	-15.7481	0.0000
r_f^*	63.7845	0.0000	76.9829	0.0000	63.6141	0.0000	27.1962	0.0007	42.9187	0.0000	56.7647	0.0000	70.6784	0.0000	165.372	0.0000
	-5.73265	0.0000	-6.56408	0.0000	-5.70958	0.0000	-3.56044	0.0002	-5.17290	0.0000	-5.94906	0.0000	-6.57771	0.0000	-11.0082	0.0000
Δy_t	90.9124	0.0000	117.545	0.0000	129.201	0.0000	66.7785	0.0000	330.281	0.0000	99.0870	0.0000	119.854	0.0000	200.559	0.0000
	-7.03672	0.0000	-8.39179	0.0000	-8.77175	0.0000	-6.42202	0.0000	-14.2309	0.0000	-8.58532	0.0000	-9.16624	0.0000	-12.3646	0.0000

Notes: 1. H_0: All cross-sections with unit root; H_1: Some cross-section without unit root.

2. Upper values indicate the ADF χ^2 statistics (Maddala and Wu 1999) while lower ones indicate the ADF Z-statistics(Choi 2001).

3. P-values are the probabilities for ADF Fisher tests computed using an asymptotic Chi-square and asymptotic normal distribution, respectively.

4. The number of lags of each cross-section determined by SIC.

5. The "demean" option to ***xtunitroot*** in STATA are used

Appendix 5.8 GMM and diagnostic tests

In this appendix, GMM estimation and relevant diagnostic tests used in Chapter 5 are summarized based on Baum (2006)'s Chapter 8 and Baum et al. (2003, 2007).

I. GMM estimation

Consider the following linear regression.

(A.1) $Y = X\beta + u$, $E[uu' \mid X] = \Omega$ with typical row $Y_i = X_i\beta + u_i$

where *Y* is *(N×1)* matrix of dependent variables; *X* is *(N×k)* matrix of regressors when *N(k)* is the number of observations (coefficients); β is *(k×1)* vector of parameters; u is *(N×1)* matrix of error term with mean zero; Ω is *(N×N)* covariance matrix. We assume that the k_1 regressors X_1 are endogenous and the $(k\text{-}k_1)$ remaining regressors X_2 are exogenous: i.e., $E(X_1u)\neq 0$ and $E(X_2u)=0$. $(N\times\ell)$ matrix *Z* indicates instrument variables which are assumed to satisfy orthogonality condition $E(Zu)=0$. Instrument *Z* is partitioned into $[Z_1\ Z_2]$ where the ℓ_1 instrument Z_1 are instruments excluded from regressions, while the remaining $(\ell\text{-}\ell_1)$ instruments Z_2 are included in the regression and equal to the exogenous regressors ($Z_2 \equiv X_2$).

GMM is based on the moment function(*g*) which depends on the observable random variable *Y* and *X* (or *Z*), and unknown parameters (*β*) and which has zero expectation in the population when evaluated at the true parameters. Thus, in case of a linear model, GMM is to choose an estimator $\widehat{\beta}_{GMM}$ that solves:

(A.2) $E[g[Z_i', u(\beta_{GMM})] = E[Z_i'(Y_i - X_i\widehat{\beta}_{GMM})] = 0$.

where *g* is the moment function expressed as $g[Z_i', u(\beta)] = Z_i'u(\beta) = Z_i'(Y_i - X_i\beta)$.In equation (A.2), if the model is exactly identified (*ℓ*=*k*), we can find a unique $\widehat{\beta}_{GMM}$ because we solve *ℓ* moment conditions for k coefficients in $\widehat{\beta}_{GMM}$. However, if the model is overidentified (*ℓ*>*k*) and thus we have more equations than unknown coefficients, we cannot find *k*-vector $\widehat{\beta}_{GMM}$ that satisfies *ℓ* moment condition $E[g[Z_i', u(\beta_{GMM})] = 0$. Thus, the natural solution is to choose

$\hat{\beta}_{GMM}$ for $E[Z_i'(Y_i - X_i\hat{\beta}_{GMM})]$to be close to zero as possible. For this, Hansen (1982) proposes to minimize the following quadratic form $J(\hat{\beta}_{GMM})$:

(A.3) $\min_{\beta_{GMM}} J(\hat{\beta}_{GMM}) = \min_{\beta_{GMM}}[\bar{g}(\hat{\beta}_{GMM})]' \cdot W \cdot [\bar{g}(\hat{\beta}_{GMM})]$

where $\bar{g}(\hat{\beta}_{GMM}) = E[g[Z_i', u(\beta_{GMM})]] = E[Z_i'(Y_i - X_i\hat{\beta}_{GMM})]$; W is a positive definite *(ℓ×ℓ)* weighting matrix that accounts for the correlation among the $\bar{g}(\hat{\beta}_{GMM})$ when the errors are not *i.i.d*. It can be shown that this process provides a consistent estimator. Deriving and solving *k* first under order condition $\frac{\partial J(\hat{\beta}_{GMM})}{\partial \hat{\beta}_{GMM}} = 0$, we can obtain the following GMM estimator with overidentifying restrictions.

(A.4) $\hat{\beta}_{GMM} = (X'ZWZ'X)^{-1} X'ZWZ'Y$

The above GMM estimator has several features. First, if *ℓ=k* (exactly identified), then $X'Z$ is a square matrix, and so $(X'ZWZ'X)^{-1} = (Z'X)^{-1} W^{-1} (X'Z)^{-1}$. Then, GMM estimator (A.4) coincides with IV estimator. $\hat{\beta}_{GMM} = (Z'X)^{-1} Z'Y = \hat{\beta}_{IV}$. Second, if all regressors are exogenous (i.e., *Z=X*), then $\hat{\beta}_{GMM} = \hat{\beta}_{IV} = \hat{\beta}_{OLS} = (X'X)^{-1} X'Y$. Note that the weighting matrix (*W*) does not play any role in the case of IV and OLS. Third, if *ℓ>k* (overidentified), there are as many GMM estimators as there are choices of W. Among all possible candidates for *W*, the optimal one (which provides the most efficient estimate) is the inverse of the covariance matrix of the moment condition *g*. That is, $W=S^{-1}$ where *S* is the (*ℓ×ℓ*) covariance matrix of the moment *g* measured as:

(A.5) $S = E(Z'uu'Z) = E(Z'\Omega Z)$

Substituting (A.5) into (A.4) yields the efficient GMM estimator

(A.6) $\hat{\beta}_{EGMM} = (X'ZS^{-1}Z'X)^{-1} X'ZS^{-1}Z'Y$

Note that there is not any assumption about the covariance matrix of error terms (Ω) to derive (A.6). Because *S* is unknown, the efficient estimator based on the *S* is not feasible. Thus, we need to estimate S by making some assumptions about $\mathbf{\Omega}$. To obtain a consistent and asymptotically efficient GMM estimator, a two-step procedure is, in general, used. In the first step, the 2SLS estimator is used to obtain a preliminary estimation of parameter β (denoted $\widetilde{\beta}$) and residual $\widetilde{u}_i = Y_i - X_i'\widetilde{\beta}$. Then, we can obtain S by the assumption about the structure of $\mathbf{\Omega}$ from the residual $\widetilde{u}_i$. In the second step, using S^{-1} (obtained from the first stage) as W, we re-estimate the model to obtain a feasible efficient GMM estimator $(\hat{\beta}_{FEGMM})$.

$$\text{(A.7)}\ \hat{\beta}_{FEGMM} = (X'Z\hat{S}^{-1}Z'X)^{-1}X'Z\hat{S}^{-1}Z'Y$$

II. Diagnostic test for GMM estimator

When using IV estimations like GMM, we need to conduct tests for exogeneity and validity of the overidentifying restriction.

(1) Test for overidentifying restriction: Sargan test or Hansen's J-statistics

The null hypothesis of the valid overidentifying restriction is tested by using Hansen's (1982) J-statistics. The statistic is the value of the GMM objective function (A.3), evaluated at the efficient GMM estimator $\hat{\beta}_{EGMM}$:

$$\text{(A.8)}\ J(\hat{\beta}_{EGMM}) = N[\bar{g}(\hat{\beta}_{GMM})]' \cdot \hat{S}^{-1} \cdot [\bar{g}(\hat{\beta}_{GMM})] \overset{A}{\sim} \chi^2_{l-k}$$

If the null is rejected, the instruments do not satisfy the required orthogonality conditions and thus GMM specification is considered inappropriate, either because the instruments are correlated with the disturbances or because they are inappropriately excluded from the regression.

(2) Instrument orthogonality test: Eichenbaum, Hansen and Singleton test

The instrument orthogonality test or *C-test* is used to test whether orthogonality conditions are satisfied by a *subset* of instrument Z_1 but not satisfied by the remaining instrument Z_2: i.e., to test $E(Z_1u) = 0$ and $E(Z_2u) \neq 0$. This test is used when we doubt that a subset of instruments is endogenous. In this context, the *C-test* is different from the Hansen-Sargan J-test, which evaluates the *entire* set of overidentifying restrictions. The *C-statistics* are calculated by the difference between two J-statistics: one is computed from the regression using the *entire* set of instruments (*Z*) and the other is obtained from the model using a *smaller* set of instruments (Z_1), in which a set of specified instruments is removed from the instruments. Under the null that the specified variables are proper instruments (and thus exogenous), the C-statistic is distributed with χ^2 with degree of freedom equal to the number of suspected instruments.

(A.9) $C_T = J(Z) - J(Z_1) \sim \chi^2$

If the null is rejected, the suspected instruments are not exogenous. Note that this test requests that the researcher believe the non-suspect instruments to be valid (Baum 2006, p 202).

(3) Regressor endogeneity test: Durbin-Wu-Hausman test

The endogenous regressors are the ones explained by the listed instrument in the model, while the exogenous variables are not explained by the listed instruments. If we use IV or GMM when endogeneity is, in fact, not a problem, the estimators will be consistent but inefficient. In this case, asymptotic variance of the IV estimator is larger than that of OLS. The regressor endogeneity test can be used when we suspect that the variables (that are specified in the regressor list but not included in the instrument list) are exogenous. This test basically compares two J-statistics:

(A.10) $H_T = J(V_2) - J(V_1) \sim \chi^2$

where $J(V_1)$ is the J-statistic obtained from the original IV estimation like GMM; $J(V_2)$ is the J-statistic obtained from the estimation which augments the original estimation by the variables which are being tested for endogeneity like OLS estimation. As a result, this test involves fitting the model by both OLS and GMM and comparing the resulting coefficient vectors. Under the null that candidate variables are exogenous and thus the OLS estimator is consistent and fully efficient, using IV may result in the loss of efficiency (Baum 2006, p 211). Thus, if the null is rejected, IV or GMM estimation is appropriate.

(4) Weak instrument diagnostic

Weak instrument problems occur when the correlations between the endogenous variables and the excluded instruments are non-zero but very small (Baum et al. 2007, p 23). The weak instruments cause a variance of the IV estimator to be higher than the OLS estimator and exacerbate the bias caused by invalid instruments even as the sample size goes to infinity. Even if the instrument is not correlated with disturbance (i.e., $E(Z_i u_i)=0$) in the population, IV estimation using weak instruments yields biased estimator and biased standard errors in a small sample. To see how highly an instrument and endogenous variable are correlated, we first examine the fit of the first-stage regression like R^2. Note that at the first stage we regress the endogenous regressors X_1 on the full set of instruments Z. Thus, low R^2 indicates that the identification used may be wrong.

When there is a single endogenous regressor, Cragg-Donald (1993) statistics are generally used. This statistic is simply the "first-stage *F*-statistic" for testing the hypothesis that the instruments do not enter the first stage regression of 2SLS. When there are multiple endogenous regressors, Stock and Yogo (2005) statistics, a variant of Cragg and Donald statistics, is used. The null hypothesis of the Stock and Yogo test is that the instruments are weak, even though the parameters might be identified, whereas Cragg and Donald tests the null of under-identification. Cragg and Donald statistics are not valid if the errors are heteroskedastic and serially correlated. Note that there appear no established test methods for weak instrument in the presence of non-i.i.d error. In this case, Kleibergen-Paap (2006) Wald rk F statistic can be used to test weak instrument. The statistics should be compared to Stock-Yogo (2005) weak ID test critical value for i.i.d case with caution. Alternatively, if the F-statistics should at least 10, it is unlikely that the model does not have significant problem of weak identification (Baum et al 2007 p 24).

Appendix 6.1 Summary of previous studies on fiscal sustainability

Authors	Sample	Sustainability condition	Main features	Sustainable?
Hamilton & Flavin (1986)	US, annual, 1962-1984	$(T_t - GE_t) \sim I(0)$ *and* $D_t \sim I(0)$	• Nonstochastic model: constant positive (ex post) real interest rate $(r_{t+n} = r > 0)$ • Real interest rate = 1 year T-bill rate - CPI rate • Discounted debt series should be stationary	Yes
Trehan & Walsh (1988)	US, annual, 1890-1986	$(rD_{t-1} + GE_t - T_t) \sim I(0)$ *and* $D_t \sim I(1)$	• Constant positive real interest rate $(E_t r_{t+n} = r > 0)$ • D_t is measured by par value • Inconsistent results between unit root and cointegration due to low power of unit root test and nonstationary interest rate	Yes
Wilcox (1989)	Same as Hamilton & Flavin(1986)	$\theta^n D_t \sim I(0)$ with zero unconditional mean	• N-period compound actual return on Fed debt, i.e., non-constant ex-post real interest rates=rate of return on Fed debt – rate of return on gold • Allow non-stationary discounted debt series • Results are sensitive to the lag length • Hard to apply to the case with negative realised rate	No
Haug(1991)	US, quarterly, 1960-87	$(T_t - GE_t) \sim I(1)$ *and* $D_t \sim I(1)$, *two series are CI(1.1)*	• D_t is measured by market value • Real interest rate =10 yrs TB – GDP deflator	Yes
Trehan & Walsh (1991)	US, annual, 1962-84	$(GE_t - T_t) \sim I(1)$ *and* $D_t \sim I(1)$, *two series are CI(1.1)* (in case of $E_t r_{t+n} = r$) $(r_t D_{t-1} + GE_t - T_t) \sim I(0)$ (in case of $E_t r_{t+n} > 0$)	• $E_t r_{t+n} = r > 0$ • Applied in the sustainability of current account deficits of the US during 1946-87	Yes
Smith & Zin (1991)	Canada, monthly, 1946-84	Same as Trehan and Walsh (1991)'s condition	• Allowing negative expected real rate of return on debt • D_t is measured by market value • Focus on the interpretation of the test results • Fiscal regime change, omitted variable, funding source other than primary surplus are crucial factors for the test	Yes
Hakkio & Rush (1991)	US, quarterly, 1950-88	$(rD_{t-1} + GE_t) \sim I(1)$ and $T_t \sim I(1)$ and two series are cointegrated with cointegrating vector(1,-1): $\beta=1$ for $T_t = \alpha + \beta(rD_{t-1} + GE_t) + \varepsilon_t$ (same as Quintos (1995)'s strong condition)	• All variables relative to GDP • Allow stochastic and *stationary* real interest: $E_t r_{t+n} \sim I(0)$ • Consider (exogenous) breaks(1964, 1976) which signalled sub-periods during which the condition did not hold	No

Note: 1. $D_t = \theta^n E_t(\sum_{n=1}^{\infty} TR_{t+n} - \sum_{n=1}^{\infty} GE_{t+n}) + \theta^n E_t D_{t+n}$ where D=government debts; T=tax revenues; GE=government expenditures (exclusive of interest payment on debts), $\theta = 1/(1+r)$ = discount factor where r is real interest rate; all fiscal variables are real or ratios to GDP growth.

2. CI(1,1) indicates that two series are cointegrated with cointegration vector (1,1)

(Continued) Appendix 6.1

Authors	Sample	Sustainability condition	Main features	Sustainable?
Bohn(1991)	US, annual, 1916-1989	If ρ >0 in $ps_t = a_0 + \rho \cdot d_t + \beta_1 \cdot GVAR + \beta_2 \cdot YVAR + \varepsilon_t$ (where *p*= primary surplus, *d*= debt, *GVAR* and *YVA*=cyclical non-debt determinants of ps), then the debt is sustainable.	• Traditional stationarity-based test assume r>g, which is not consistent with dominant evidence of r<g. • Crucial point in sustainability test is not NPC but $\lim_{n\to\infty} E_t(u_{t,n} \cdot d_{t+n}) = 0$ where $u_{t,n}$ is the marginal rate of substitution between *t* and *t+n*	Yes
Tanner & Lieu (1994)	US, quarterly, 1950-89	Hakkio & Rush(1991)'s condition with structural dummy: $\beta=1$ for $T_t = \alpha + \beta(rD_{t-1} + GE_t) + \gamma Dum_t + \varepsilon_t$ where $Dum=1$ (break period) and zero otherwise	• Determine break date both exogenously and endogenously - dummies for a level shift at 1982Q1 and 1981Q4	Yes
Haug (1995)	US, quarterly, 1950-90	Hakkio & Rush(1991)'s condition and parameter stability test ($\beta=1$) in cointegration	• Impose endogenous break • Deficit policies in the 1980s are not significantly different from those during three earlier decades • Divergent debt-GNP ratio	No
Quintos (1995)	US, quarterly, 1942-1992	(1)"*Strong*": same as Hakkio and Rush(1991) (2) ***"Weak"*** : $(\Delta D_t = rD_{t-1} + GE_t - T_t) \sim I(1)$ and $D_t \sim I(2)$, and revenues and total spending are cointegrated with cointegrating vector $(1,-\beta)$; i.e., $0<\beta<1$ *for* $T_t = \alpha + \beta(rD_{t-1} + GE_t) + \varepsilon_t$	• $\beta \leq 0$: unsustainable: • Newly introduce *weakly* sustainability • Endogenous break at 1975Q2 and 1980Q4	Yes (weakly) until 1980, No afterward
Ahmed & Rogers (1995)	UK: 1692-1992 US: 1792-1992 annual	Same as previous cointegration studies	• Structural break tests • IBC holds despite structural breaks	Mostly yes
Bohn (1995)	Theoretical	Government has to satisfy an IBC even if the safe interest rate is below growth rate in stochastic model.	• Standard tests have limits since they depend on too strong assumptions about future states • The correct discount rate in no-Ponzi condition is (approximately) the interest rate on income-indexed contingent claims, even if the debt itself is safe one	-
Bohn (1998)	US, annual 1916-1995	Coefficient β>0 for the reaction function $(t_t - ge_t) = \beta d_t + AZ_t + \eta_t$ Where A is the vector of coefficient and Z_t is a vector of other variables than debts	• Criticize standard IBC tests depending nonstochastic environment (e.g. a constant real rate) • Focus on fiscal policy reaction function of government • If the primary surplus-to-GDP ratio reacts positively to higher debt ratios, the policy is sustainable	Yes
Martin (2000)	US, quarterly 1947-92	Following Quintos(1995)	• Investigate multiple endogenous breaks by using Markov chain Monte Carlo simulation	Yes(absurdly weakly)

(Continued) Appendix 6.1

Authors	Sample	Sustainability condition and method	Main features	Sustainable?
Bergman (2001)	Theoretical	(i) strong condition: same as Quintos(1995) (ii) weak condition: D_t~*I(m)* and D_t *is not explosive process*	• Assume that individual's rate of time preference is strictly positive	-
Sarno (2001)	Same as Bohn(1998)	Standard stationary tests considering nonlinear mean reversion	• Standard test have low power to reject a false null hypothesis of unit root since debt-GDP ratio has a property of nonlinear mean reversion • Smooth transition autoregressive model to investigate nonlinear stochastic process of debt-GDP ratio	Yes
Bohn (2004)	USA, annual 1792-2003	Use both standard stationarity tests and Bohn test(1998)	• Unit root test on real variables (unscaled by GDP) are distorted by severe heteroskedasticity • Bohn test for debt-GDP ratio is most credible	Yes
Davig (2005)	USA, annual 1960-1999	Testing IBC in a Markov-switching framework	• Two-regimes: periods when the PV of US debt is expanding vs. periods when it is collapsing • Expectation about future regime changes are critical	Yes
Benz & Fetzer (2005)	Germany, annual 2002(base year) - 2040	Forward-looking sustainability test: Future budget and GDP growth should be projected for constructing sustainability indicators	• Sustainability test should combine the General Accounting approach and the OECD-method. • Depend on arbitrary forecast methods for fiscal variable	Yes
Kalyoncu (2005)	5 countries, quarterly, 1970-2003	Quintos(1995)	• Sample periods differ depending individual countries • Weakly sustainable: Korea, Turkey • Unsustainable: Mexico, the Philippines, South Africa	Yes/No
Wyplosz (2007)	Theoretical and descriptive	Basically, test for fiscal sustainability is impossible since it is forward-looking	• Any practical definition of sustainability is arbitrary • Any sustainability indicator will be both arbitrary and too imprecise for policy prescription	-
Makin (2005)	ASEAN 4, quarterly 2003-2004	Sustainable if current primary surplus is greater than benchmark value, $\left(\frac{T-GE}{GDP}\right)_t = \left(\frac{D}{GDP}\right)\left(\frac{r-g}{1+g+\pi}\right)$ where g is a real growth rate and π is inflation rate	• Benchmark value somewhat lacks of objectivity. • Sustainable: Malaysia and Thailand • Unsustainable: Philippines and Indonesia	Yes/No
Bajo-Rubio et al. (2006)	Spain, 1964-2003(annual) 1992-2004(quarter)	If budget deficit shows a mean-reverting after a certain threshold reaches, the debt policy is sustainable	• Consider nonlinearity in expenditures (inclusive of interest payment) and revenues by using threshold cointegration	Yes

(Continued) Appendix 6.1

Authors	Sample	Sustainability condition	Main features	Sustainable?
Greiner et al. (2007)	1960-2003, Quarterly, France, Germany and Portugal	Following Bohn(1998, 2007)	• Two exogenous structural break • Estimating a semi-parametric model with time varying reaction coefficients	Yes
Haber & Neck (2006)	1960-2003, annual, Austria	Following Bohn(1998, 2007)	• Different degree of sustainability before and after the structural break time • Public debt is affected by structural causes and a shift in the fiscal policy paradigm rather than political ideology	Yes
Luiz de Mello (2008)	1995-2004, monthly, Brazil	Following Bohn(1998, 2007)	• Considering consolidated public sector as well as central and regional government, separately • All levels of government respond to changes in debts by adjusting their primary surplus targets.	Yes
Baharumshah & Lau(2007)	1975-2003, Quarterly, 5 Asian countries	Exactly following Quintos(1995)	• Weak sustainable: Philippines and Malaysia • Strong sustainable: Singapore, Thailand and Korea • One-way causation from spending to revenue for Korea, Singapore and Thailand	Yes
Bohn (2007)	Theoretical	If $T_t \sim I(m_T)$, $(rD_{t-1} + GE_t) \sim I(m_{TS})$ for any $m_T \geq 0$, $m_{TS} \geq 0$ then $D_t \sim I(m)$ for any finite $m \geq 0$ where m_{TR} , m_{TS} and m are the order of integration. Once if $MSB_t \sim I(m)$ and MSB_t is not explosive process, the current debt policy may be weakly sustainable	• Stationarity test is not necessary condition for fiscal sustainability • Confirm the importance of the sustainability test based on fiscal policy reaction function • Recommend Bohn (1998) rather than stationary-based test	-
Afonso & Rault (2007)	1970-2006, quarterly, 15 EU members	Following Quintos(1995)	• Panel cointegration techniques developed by Pedroni (1999, 2004)	Yes
Correia et al. (2008)	1852-2004, annul, Portugal	Used all tests and compare them: standard unit root test, cointegration test, and Bohn test	• Breitung's nonparametric tests for stationarity • Multiple structural breaks • Recursive trace test for cointegration between public expenditures and revenues	Yes
Bella (2008)	2009-2014, Dominica	Calculation of the primary balance of the consolidated public sector to achieve the desired debt targets	• Analysis under integrated accounting framework • Estimate country-specific debt threshold • Choosing an appropriate baseline scenario is crucial • No ad-hoc assumptions for the values of the macro variables during the planning horizon	Depend on scenarios