CONVERGENCE, PRODUCTIVITY AND INDUSTRIAL GROWTH IN CHINA DURING THE REFORM ERA

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ABSTRACT

China has made great progress in many areas since 1978. The impressive economic development witnessed during the post-reform period provides a good illustration of growth empirics. This thesis examines the Chinese economy by focusing on three issues: convergence, total factor productivity (TFP) and industrial growth.

The study of convergence was undertaken using a panel of China's 28 provinces, municipalities and autonomous regions (henceforth, 'provinces') over the period 1979-2004. The analysis found that besides the investment rate, population growth and initial income level, which are preserved in the basic neoclassical growth paradigm, human capital, openness, transport infrastructure and the industrialization level contributed to the provincial economic development. The share of physical capital in China's output was estimated to be 0.23 and the provinces were found to converge at a rate of 5.6 per cent per annum.

To calculate the growth of TFP for China's 29 provinces in this period, the non-parametric Malmquist index approach was employed in the analysis. Human capital, in addition to physical capital stock and the labour force, was included in the frontier production function. It was found that TFP growth in the Eastern and Central Zones was accomplished mainly through technical progress (i.e. innovation) rather than efficiency improvement, while the pattern was completely different in the least developed Western Zone. With respect to TFP level, the Eastern Zone had higher levels of productivity than the Central and Western Zones and the gap of productivity between the Eastern and the other two has widened over time. For China as a whole, TFP grew at a rate of 2.75 per cent per annum, which accounted for 30.02 per cent of its real GDP growth. Given the impressive role that TFP played in the whole Chinese

economy and regional economies, it can be concluded that China's fast economic growth is sustainable in the long run.

The aim of the study of industrial growth here was to examine the correlates of growth of 26 industries in 9 provinces of the Eastern Zone of China over the period 2001 to 2005. Based on a three-way error component model, the analysis found that the dynamic externalities which arise from technological spillovers, such as industrial specialization, competition and industrial spillovers across provinces, played an important role in province-industrial growth. Province-specific externalities, which include exports, education, local market size and transport infrastructure, spurred industrial growth. The analysis also discovered an evident trend in the period under study of conditional convergence within the 26 industries in the Eastern Zone.

Dedicated to

My dear father Wenyu Chen and my mother Yingjin Zheng

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ABBREVIATIONS

COEs	collective-owned enterprises
CRS	constant returns to scale
DEA	data envelopment analysis
EC	efficiency change
ETDZs	Economic and Technological Development Zones
FCADs	first-class administrative divisions
FDI	foreign direct investment
FGLS	feasible generalized least squares
GDP	gross domestic products
GMM	generalized method of moments
LSDV	least squares dummy variables
NIRS	non-increasing returns to scale
OLS	ordinary least squares
PEC	pure efficiency change
PIM	perpetual inventory method
PRC	People’s Republic of China
SEC	scale efficiency change
SEZs	Special Economic Zones
SFA	stochastic frontier analysis
SOEs	state-owned enterprises
TC	technical change
TFP	total factor productivity
VRS	variable returns to scale

CHAPTER 1: INTRODUCTION

Remarkable progress has taken place in the Chinese economy since the introduction of economic reforms and open-door policies in the late 1970s.[1] Many studies have documented the rapid economic development of China. This thesis adds to the literature by exclusively focusing on three issues: the convergence of per capita GDP, total factor productivity (TFP) and industrial growth. In this introductory chapter, I will first present a brief review of the Chinese economy in the post-reform period and then raise the research questions and methodological methods. Following these is an outline of the ensuing chapters.

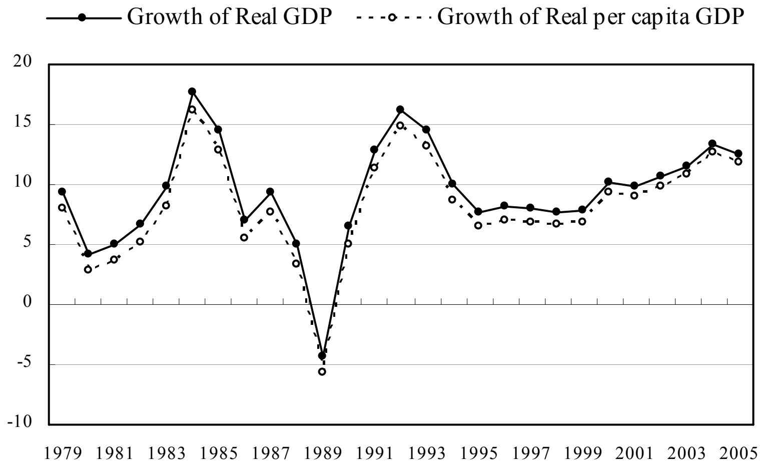
1.1 THE CHINESE ECONOMY AFTER 1978

Chinese economic growth since 1978 has been impressive. Real GDP in constant 1978 prices increased from 364.5 billion Yuan in 1978 to 3943.3 billion Yuan in 2005, rising more than 10-fold. Real per capita GDP in constant 1978 prices increased from 381 Yuan in 1978 to 3024 Yuan in 2005, rising around 8-fold. Real GDP and real per capita GDP grew at an annual average rate of 9.31 and 8.06 per cent, respectively, with the fluctuation of rates over time illustrated given in Figure 1-1. Associated with this rapid GDP growth are remarkable increases in exports and investments (including domestic capital formation and the inflows of FDI). Taking the expenditure approach, real capital formation in constant 1978 prices increased from a level of 137.8 billion Yuan in 1978 to 1713.6 billion Yuan in 2005, rising more than

[1] Unless otherwise stated, the geographical scope of China in this thesis covers only mainland China. The statistical data used in this thesis come from the *China Statistical Yearbook* (various issues) published annually by the State Statistical Bureau of China, various issues of statistical yearbooks published by local statistical bureaus and the *Comprehensive Statistical Data and Materials on 50 Years of New China*.

10-fold. In 2005, capital formation accounted for 42.6 per cent of total GDP.

Figure 1-1 Growth of real GDP and real per capita GDP at national level (1979-2005, %)



The rapid Chinese economic growth has been accompanied by changes in many areas. First of all, it is linked in absolute terms with increased income dispersion between the Chinese provinces. The gap between rich provinces and poor provinces increased over time in the post-reform period. According to the United Nations Human Development Report (2004), China's Gini coefficient,[2] which is an internationally accepted measurement of income equality, was calculated to be over the 'alarm level' of 0.4. In 2004 the Gini coefficient was 0.447 and in 2005 it exceeded 0.45.[3]

Second, China's impressive economic performance is linked with rapid growth in

[2] The Gini coefficient is used as a measure of inequality of income distribution at a moment in time. The coefficient varies between 0 (reflecting complete equality) and 1 (reflecting complete inequality). Comparing Gini coefficients across time gives an indication of the way in which the distribution of income has changed within a country over a certain period, making it possible to see if inequality is increasing or decreasing.

[3] Data source: China Daily (19 June, 2005) and People's Daily (3 August, 2007).

productivity, in particular total factor productivity (TFP). TFP measures the component of economic growth that is not explained by a weighted average of growth in factor inputs and provides an indication of whether the growth of an economy is sustainable in the long run. The role of TFP in the Chinese economy is still under debate. For example, Krugman (1994) argues that China's rapid economic growth is unsustainable, since its productivity growth is very low. However, most studies show that TFP is important to China's recent growth. For example, Maddison (1998) claims that Chinese growth acceleration has mainly been due to increased efficiency.

Finally, rapid Chinese growth has also been accompanied by the transformation from a command economy to a market-oriented economy and from an agrarian economy to an industrial one. Such a transition can be evaluated in many aspects, such as changes in the economic structure, expansion of the private sector and urbanization. Specifically, China's economy has become less agricultural in the post-reform period. 'State investments in agriculture as a share of total investments have declined sharply since economic reforms' (Yao 2000, p.47); the agricultural sector's share of total employment declined from 70.5 per cent to 44.8 per cent; and its share of total GDP reduced from 27.9 per cent in 1978 to 12.6 per cent in 2005. At the same time, secondary industry or the manufacturing sector (including the industrial sector and construction) and tertiary industry or the services sector have become more and more prominent in the Chinese economy.

Second, the private sector[4] has become the dominant force in the Chinese economy. Before China's economic reform (henceforth, 'Reform'), the state sector was almost the only player in the economy in terms of allocating sources and producing products. However, its role has continued to decline in the post-reform era. In 2005, the state sector's shares in industrial output, employment and total investment in fixed assets were 10.6 per cent, 8.6 per cent and 33.4 per cent, respectively. In contrast, the private sector has been developing over time and its role in the Chinese economy has overtaken that of the state sector over the period. The private sector's share in industrial output was 59.2 per cent in 2004 and its shares in employment and total investment in fixed assets were 76.8 per cent and 57.1 per cent respectively in 2005.

Third, urbanization[5] has made immense progress during the post-reform period, especially since the 1990s, when the stringent internal migration policies were to some extent relaxed. The urban area's share of total population increased from 17.9 per cent in 1978 to 43.0 per cent in 2005. 'It can be anticipated that urbanization will increase dramatically in the coming years as new policies and regulations at both the national and local levels have been implemented to encourage rural out-migration' (Wu 2006, p.5).

1.2 RESEARCH QUESTIONS AND METHODOLOTY

This thesis empirically examines the following three issues in China: convergence, total factor productivity and industrial growth. The first issue involves the following

[4] The private sector includes collectively-owned units, individuals' economy, joint ownership units, share holding units and other areas, excluding state-owned units and foreign funded units. Source: *China Statistical Yearbook 2006*, Table 6.3.

[5] Urbanization refers to a process in which an increasing proportion of an entire population lives in cities and the suburbs of cities (Fairfield University [online]).

questions: what factors determine the regional economic growth of China's provinces, municipalities and autonomous regions (henceforth, 'provinces') during the post-reform period? Is China's growth consistent with the neoclassical growth theory? Are Chinese provinces converging in terms of per capita GDP, or equivalently, are initially poorer provinces growing faster than initially richer provinces? And what is the speed of convergence if there is a convergence trend?

The second issue concerns the part of Chinese economic growth which is not explained by factor inputs. It asks: what are the rates of productivity growth for Chinese provinces and China as a whole in the post-reform period? Is China's rapid economic growth sustainable, or equivalently, is China's economic growth mainly due to increases in factor inputs or improvements in productivity? And what is the main cause of China's productivity growth: enhancements in productive efficiency or improvements in technology?

The third issue investigates the correlates of industrial growth in the Eastern Zone of China. The study aims to answer the following questions: how shall we estimate a model with linked province-industry data? What externalities spur industrial growth? And does there exist a trend of convergence within the industrial sector in the Eastern Zone of China?

Regarding methodology, the studies on the above-stated three issues use panel data (i.e. pooled cross-sectional time-series data) analyses. For the convergence and industrial growth studies, econometric regression approaches are employed. Given that provinces have larger populations than municipalities and that regional population consequently gives more weight to the provinces than to the municipalities, weighting observations by regional population reduces the influence of the municipalities in the empirical results. To produce more reliable results, heteroskedasticity across provinces is controlled in the regressions. Moreover, time and province dummy variables are included in the convergence study; and time, province and industry dummy variables are included in the industrial growth study given the linked industry-province data.

For the TFP study, the non-parametric Malmquist index approach is employed. This approach is based on the data envelopment analysis (DEA) of a frontier production function. The Malmquist index approach 'takes the whole deviation of observations from the frontier function as the result of inefficiency, thereby completely neglecting measurement error and making the results more sensitive to outliers' (Krüger 2003, p.267). Its advantages over the traditional growth accounting approach can be seen in the following ways. For example, no pre-determined values of capital share and labour share are required, thereby avoiding the assumption that factors are paid their marginal product; second, to estimate productivity level does not require prior ordering of members of the sample; third, with the Malmquist index approach, the growth of TFP can be further decomposed into improvement in efficiency and the growth of technical progress. Its advantages over the panel regression approach come from its not imposing a specific production function, thereby avoiding the problems of choosing a conditioning set of variables and estimating parameters.

1.3 OUTLINE OF THE CHAPTERS

This thesis is composed of 6 chapters. The rest of the thesis is organized as follows:

Chapter 2 describes the general background concerning China's rapid economic development in the post-reform period. It first introduces the spatial divisions of mainland China, from both an administrative and economic standpoint. It then outlines the distribution of the economic resources which have aided the country's remarkable economic performance, including natural resource endowments, population and employment, physical capital accumulation, education, transportation and the telecommunication infrastructure. This is followed by a brief introduction to the transitional economy, which is examined from three standpoints: changes in economic structure, market liberalization and decentralization in the industrial sector. Finally, China's progress in globalization comes into focus, looking at the evolution of foreign trade, FDI and opening-up policies.

Chapter 3 investigates the trend of convergence within China's 28 provinces during the post-reform period, 1979-2004. This chapter first looks at the trend of sigma-convergence by examining cross-sectional standard deviation in real per capita GDP. It then focuses on the issue of beta-convergence within the 28 provinces. A by-product of the exploration of the two types of convergence is the additional test proposed by Barro and Sala-i-Martin (1990), that beta-convergence is a necessary but not sufficient condition for sigma-convergence. The underlying idea of beta-convergence is to test for the significance of the growth-initial level relation. The derivation of the growth-convergence equation is presented in this context. In addition to identifying the trend of convergence, this study also serves to identify an appropriate growth model for China by looking at the correlation between growth and controlling factors such as investment rate, population growth, human capital, openness, transport infrastructure and economic structure.

In Chapter 4, total factor productivity between provinces is compared, using annual data on China's 29 provinces over the period 1979-2004. The purpose of this study is to find whether China's rapid economic growth in the post-reform period is mainly due to increases in factor inputs or improvements in productivity. The non-parametric Malmquist index approach is employed to calculate the TFP growth rate and its two components: growth of technical efficiency and growth of technological progress. The construction of the Malmquist index is fully described in Chapter 4. This is followed by the construction of physical capital stock using the perpetual inventory method (PIM). Productivity growth is calculated in two versions: one takes human capital into account as the third factor input, in addition to physical capital and labour; the other does not. The comparison of the two versions provides an intuition of the extent to which human capital contributes to productivity growth. The analysis produces not only productivity growth and its components, but also the productivity level, efficiency level and technology level. It also provides comparisons of productivity growth and productivity level between the three zones of China.

Chapter 5 deals with the industrial sector, which is especially important to the export-oriented economies in the Eastern Zone. Based on a three-way error component model given the linked industry-province time-series data, the analysis in this chapter investigates the correlates of industrial growth in 9 provinces of the Eastern Zone of China during the period 2001-2005. Dynamic externalities, which arise from knowledge spillovers and static externalities, which are mainly province-specific factors for the current study, are discussed to build a framework for the industrial growth analysis and the effects of these externalities are formally tested via regression analysis. Furthermore, sensitivity tests are carried out to check the robustness of the externalities.

Chapter 6 concludes by summarizing the most important findings in the thesis, discusses its main limitations and proposes new areas for research.

CHAPTER 2: GENERAL BACKGROUND OF CHINA

Since its foundation, the People's Republic of China (PRC) has experienced a series of economic transformations. The Chinese economy recovered slowly from being nearly bankrupted at the end of the Civil War in the late 1940s but was seriously damaged in the Great Leap Forward (1958-60) and Great Cultural Revolution (1966-76). However, since the late 1970s, when the Chinese government began the gradual transformation of its centrally planned system, the Chinese economy has grown with exceptional rapidity: the average growth rates of nominal gross domestic product (GDP) and per capita GDP at current prices during 1978-2005 were 15.8 per cent and 14.5 per cent respectively. GDP and per capita GDP at the national level at current prices increased respectively from 364.5 billion Yuan and 381.2 Yuan in 1978 to 18308.5 billion Yuan and 14,040 Yuan in 2005.[6]

This remarkable performance has been facilitated by many factors such as natural resource endowments, human capital level, physical capital investment, geographic location, economic reforms and globalization. In this chapter, I seek to provide a comprehensive, though maybe not complete review, of the factors relevant to China's economic development since the Reform. The chapter is organized as follows: section 2.1 presents the spatial division of the Chinese economy; section 2.2 briefly

[6] Data source: *China Statistical Yearbook* (2006).

demonstrates its economic resource base in terms of natural resources, population and labour force, physical capital investment, human capital level and transportation and telecommunication; section 2.3 describes the Reform in terms of changes in economic structure, market liberalization and decentralization of the industrial sector; section 2.4 presents the Chinese government's foreign policies in the area of foreign trade and foreign direct investment (FDI) during the post-reform era and also shows that such foreign policies are biased towards the Coastal Area of China; section 2.5 concludes the analysis.

2.1 THE SPATIAL DIVISION OF MAINLAND CHINA

As shown in Figure 2-1, there are 31 first-class administrative divisions[7] (FCADs) in mainland China including twenty-two provinces, five autonomous regions and four municipalities directly under the central government. Among the 31 FCADs, Hainan Island was part of Guangdong province until it became a separate province in 1988 and Chongqing municipality was part of Sichuan province until 1997. Autonomous regions are established only in regions where the ethnic minorities

[7] 'China is administratively divided into 23 provinces, 5 autonomous regions, 4 centrally administrative municipalities and 2 special administrative regions. Municipalities are directly under the administration of central government. A municipality has the same political, economic and jurisdictional rights as a province.' (*People's Daily* [online]). Mainland China does not include Hong Kong Special Administrative Region, Macao Special Administrative Region or Taiwan Province.

The 31 FCADs in mainland China include Anhui Province, Beijing Municipality, Chongqing Municipality, Fujian Province, Gansu Province, Guangdong Province, Guangxi Zhuang Autonomous Region, Guizhou Province, Hainan Province, Hebei Province, Heilongjiang Province, Henan Province, Hubei Province, Hunan Province, Inner Mongolia Autonomous Region, Jiangsu Province, Jiangxi Province, Jilin Province, Liaoning Province, Ningxia Hui Autonomous Region, Qinghai Province, Shaanxi Province, Shandong Province, Shanghai Municipality, Shanxi Province, Sichuan Province, Tianjin Municipality, Tibet Autonomous Region, Xinjiang Uygur Autonomous Region, Yunnan Province and Zhejiang Province.

constitute the major portion of the population; as a result of the cultural differences between the non-Han ethnic minorities and the Han majority, the autonomous region is the most politically and socially autonomous among the three kinds of FCAD (that is, provinces, autonomous regions and municipalities). FCADs are independent from each other in designing local policies and economic development plans.

According to the levels of economic development and geographic location, the 31 FCADs are usually split into different geographical units for the purpose of economic studies. The two most common divisions are either to divide the whole of mainland China into the Eastern, Central and Western Zones; or to divide the whole of mainland China into the Coastal Area and the Inland Area.

The concept of the Eastern, Central and Western Zones first appeared in the proposal for national economic and social development in the 7^{th} Five-year Plan (1986-1990), which was adopted in April 1986 by the National People's Congress. Generally speaking, the Eastern Zone is more developed than the Central and Western Zones, as a result of its proximity to the Pacific Ocean. The Eastern Zone was the first area in China to introduce the economic reforms and open up to the outside world, with the Western Zone possessing a less developed social and economic infrastructure than the Central Zone.

Figure 2-1 The map of mainland China

Note: In the present study, Chogqing municipality is included in Sichuan province and thus categorized into the Western Zone.

Table 2-1 Spatial division of mainland China

Area	Belt	Land (%)[1]	Geographical Scope (FCADs)
Coastal	Eastern	8.67	(9 FCADs) Liaoning, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong
Inland	Central	31.76	(11 FCADs) Hainan, Hebei, Shanxi, Jilin, Heilongjiang, Anhui, Henan, Hubei, Hunan, Jiangxi and Inner Mongolia
	Western	59.57	(10 FCADs) Guangxi, Sichuan (including Chongqing), Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Tibet, Ningxia, and Xinjiang

1. Data source: Author's calculation based on data from *China Statistical Yearbook* (2006).

In this study, the Eastern, Central, Western Zones are geographically defined as those in Table 2-1.[8] The Eastern Zone includes nine most industrialized provinces and municipalities (Liaoning, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian and Guangdong). Based on the principle of economic similarity, the coastal provinces Hebei and Hainan, which were defined as eastern provinces in Démurger *et al*. (2002) and Ao and Fulginiti (2003), are included in the Central Zone in the current study. Following Gu (1995), Démurger *et al*. (2002) and Chen (2003), Guangxi province, which is along the Gulf of Tonkin in the south, is included in the Western Zone in this study. Figure 2-1 provides a graphic idea of China's FCADs and the three zones defined as above.

The other frequently used categorization of mainland China's 31 FCADs is to divide the whole of China into the Coastal Area and the Inland Area.[9] In the present study, the Coastal Area is exactly the Eastern Zone, while the Inland Area consists of the Central and Western Zones.[10] The Coastal and Inland Areas can be differently defined. For example, according to Guo (1999), Démurger *et al*. (2002) and Ao and Fulginiti (2003), the Coastal Area is composed of 12 FCADs (including Hebei, Hainan and Guangxi provinces, in addition to the nine Eastern FCADs shown in

[8] The same definition can also be seen in papers such as Wu and Hou (1990) and Hsueh (1994). Different definitions of the belts can be seen in Guo (1999) and Ao and Fulginiti (2003).

[9] In the current study, the Coastal Area consists of the better developed FCADs along the east coastline of China and the Inland Area consists of the less developed FCADs in the interior area of China and such three coastal FCADs as Hebei, Hainan and Guangxi. The component provinces of the two Areas are listed in Table 2-1.

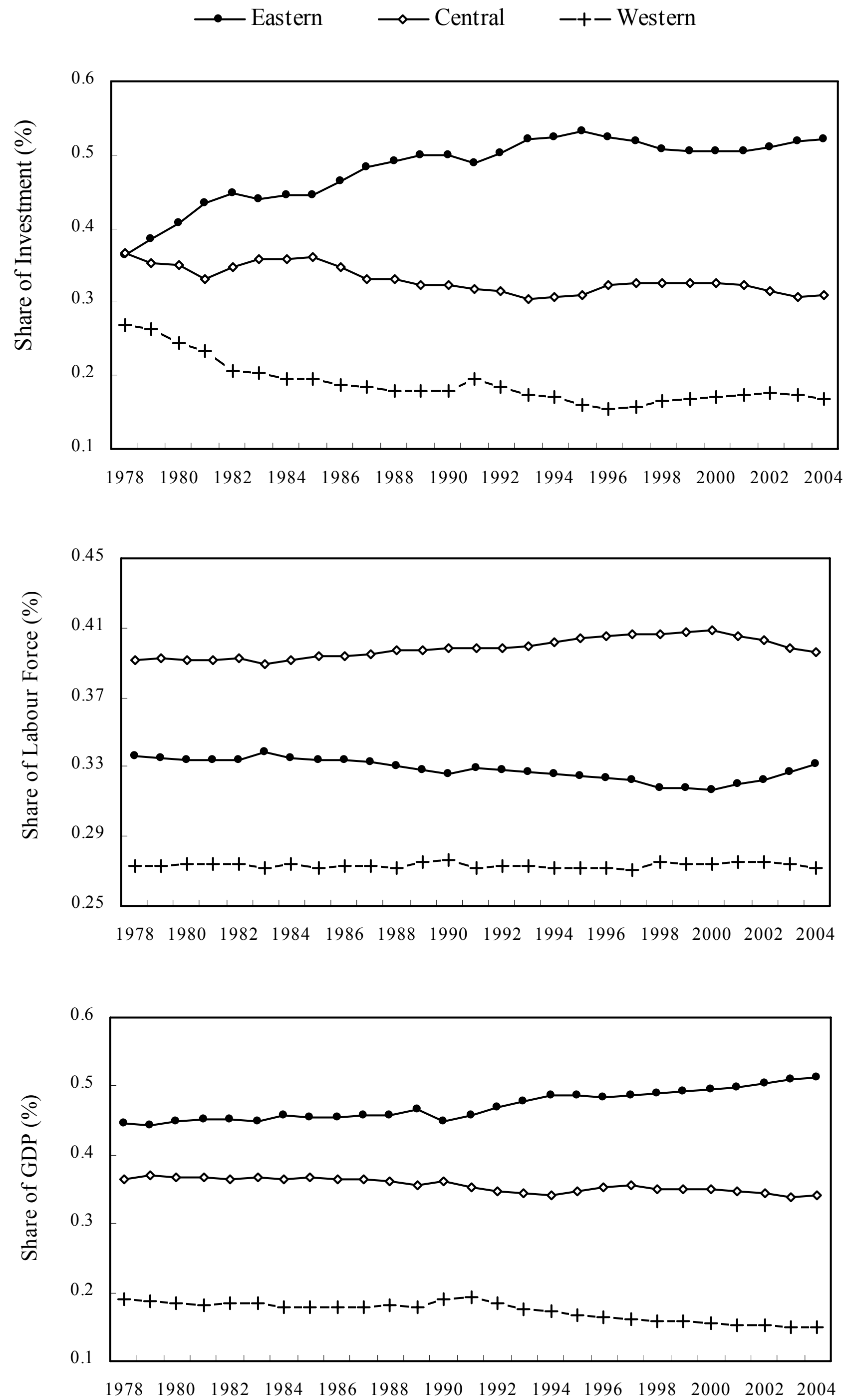
[10] This categorization is the same as that in the State Council (1993), which also classifies two coastal FCADs of Guangxi and Hainan as part of the Inland Area according to the principle of economic similarity to the inland FCADs.

Table 2-1), while the remaining 19 FCADs comprise the Inland Area.

It is obvious that relative to the Inland Area (or equivalently, the Central and Western Zones), the Coastal Area (or equivalently, the Eastern Zone) benefits from a higher percentage of arable land, better conditions for developing infrastructure and easy access to the sea (Guo 1998). Moreover, in the post-reform period, the Eastern Zone (i.e. the Coastal Area) developed faster than the other two zones (i.e. the Inland Area) as a result of its advantages in terms of geographical location and preferential reform and opening-up policies. The diagrams in Figure 2-2 present the distributions of physical capital investment, labour force and GDP between the three zones during 1978-2004.

It is clear that the Eastern Zone's share of national investment capital continued to increase while that of the other two zones did the reverse (the top diagram of Figure 2-2). The second diagram exhibits the distribution of labour force among the three zones. The Central Zone had the highest share of the labour force, which could be expected, given that the inland economies are more agriculture-based. The last diagram shows the contribution of the three zones to national GDP, where we see the Eastern Zone becoming increasingly important to the whole of the Chinese economy.

Figure 2-2 Distribution of national investment, labour force and GDP by zones (1978-2004, %)



2.2 THE DISTRIBUTION OF ECONOMIC RESOURCES

A major reason for the acceleration of Chinese growth since 1979 has been the massive increase in inputs of capital, fuller use of the labour potential and improvements in their education and skills (Maddison 1998, p.61). In this section, the distribution of Chinese economic resources is presented, including the distribution of natural resources, population and employment, physical capital accumulation, education and infrastructure.

2.2.1 Natural Resources

With its vast land area, China possesses an abundance of natural resources. However, if population size is taken into account, China's ownership of natural resources is not greater than other countries. Natural resources, such as land, water, minerals and energy, are the basic components among the factors which influence social and economic activities, especially for less-developed economies lacking capital and technology. Theoretically, in an area where manufacturing and other high-tech industries are not internationally competitive, one of the most feasible ways to eradicate poverty and backwardness is to develop the natural resource-based sectors (Guo 1999, p.19). Chinese economic development followed this path during recent decades. To this day, the natural resource-based sectors still play the most important role in the less-developed interior area of China.

The Chinese economy is characterized by heterogeneous and diversified natural conditions: the climate ranges from the tropical zone in the south to the frigid zone in the north and from the arid and semi-arid zones in the northwest to the humid and semi-humid zones in the southeast. As a result, in China the regional distribution of natural resources is extremely unequal. In general, the agricultural and biological resources diminish from the south to the north and from the east to the west.

Energy resources are disproportionally distributed in China. For example, about 70 per cent of hydropower reserves are concentrated in the southwest area, while the north, northeast and east areas as a whole can only share less than 10 per cent; more than 60 per cent of coal reserves are distributed in the north area, with only a small portion, sparsely distributed, in the northeast, east and central southern areas; the northeastern area accounts for nearly half of the nation's petroleum and natural gas reserves, while the central south and southwest have only a meagre 5 per cent between them. The northwest is the only area which is modestly rich in coal, hydropower and petroleum and natural gas (Guo 1999, p.23).

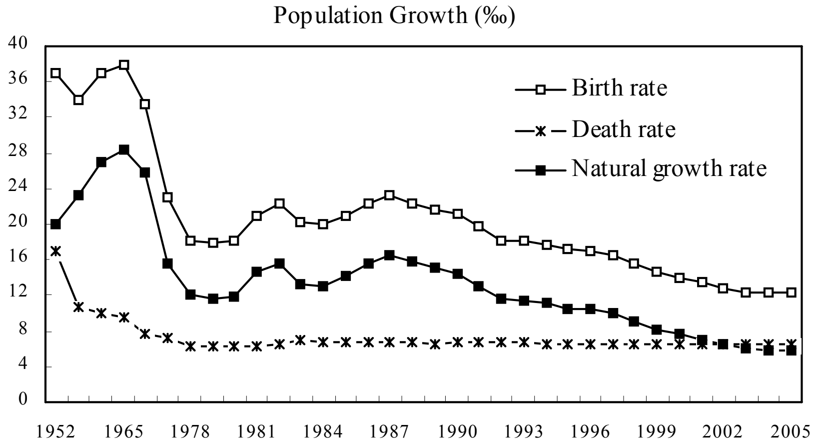
2.2.2 Population and Employment

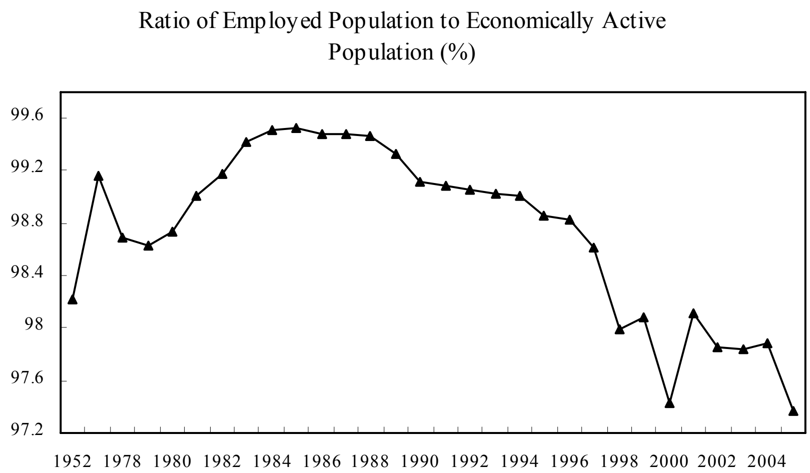
The population of mainland China grew rapidly before the adoption of the birth control policies in the late 1970s. We can clearly see from the first diagram of Figure 2-3 that the birth rate, death rate and natural population growth rate were higher in the pre-reform period than afterwards. The highest value for the birth rate was seen in 1963, 4.34%; the highest death rate was seen in 1960, 2.54%; and the highest natural growth rate was seen in 1963, 3.33%.[11] Over the post-reform period, with the effective birth control policies, the rates of birth and natural growth of the population decreased. In 2005, the population of mainland China surpassed 1.3 billion, accounting for more than one-fifth of the world's total population.

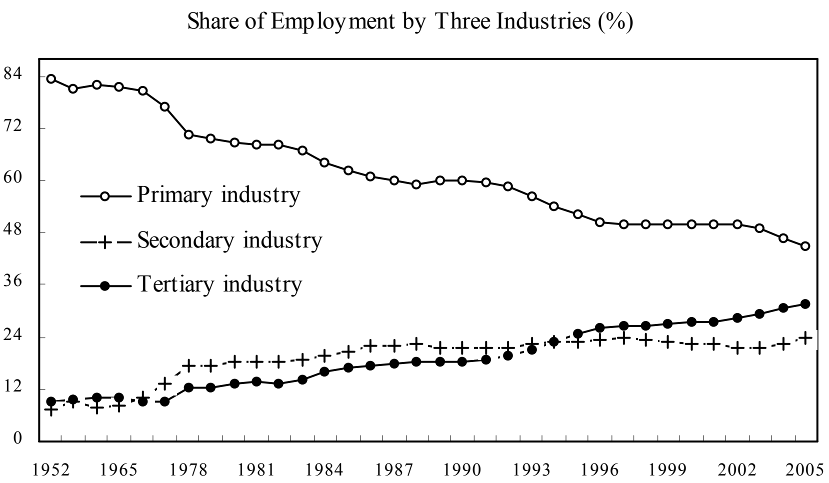
The population is unevenly distributed in mainland China as a result of the diverse regional natural and geographic conditions. Generally, the population density is higher in the Eastern Zone than in the Central Zone, while the Central Zone has a higher population density than the Western Zone. The most populous FCADs are Shanghai, Tianjin, Beijing, Jiangsu and Shandong, while Tibet, Qinghai, Xinjiang and Inner Mongolia are least populous.

[11] Data source: *Comprehensive Statistical Data and Materials on 50 Years of New China*.

Figure 2-3 Population growth, employment rate and employment composition by industries (selected years between 1952 and1978, 1978-2005)







Chinese provinces have dissimilar population growth rates for two reasons. First of all, in China has large regional economic inequalities (which will be discussed in Chapter 3) and as a result, the better developed Eastern Zone has a lower birth rate while the less developed Inland Area has a higher birth rate. Second, the birth control policies are more flexible for the minority groups, which mainly reside in the Inland Area, than for the Han majority, which has resulted in higher birth rates in the minority-based provinces than the Han-based provinces.

Turning to employment, the ratio of employed population to economically active population remained greater than 97 per cent over the period 1952-2005 (the second diagram of Figure 2-3). The average growth rate of labour input over 1978-2005 was 2.42% a year, much higher than population growth rate of 1.14%. The reason for this can be seen from the fall in birth rates, which in turn led to changes in the age structure and the proportion of working-age population. As a result, an increasing number of women joined the labour force, which caused the Chinese labour input to rise faster than population.

As we see from the last diagram of Figure 2-3, there was in a broad sense virtually no net change in the pattern of the composition of employment by the three levels of industry between 1952 and 2005. Primary industry had the highest share of employment during the period 1952-2005 and tertiary industry's share of employment was greater than that of the secondary industry over the whole period of 1952-2005 except in the sub-period 1970-1993. Despite its dominating role in providing job chances, primary industry's share of employment continued to decline over time, from 83.5 per cent in 1952 to 44.8 per cent in 2005, while the secondary and tertiary industries' share of employment continued to increase over time, from 7.4 and 9.1 per cent in 1952 to 23.8 and 31.4 per cent in 2005, respectively. Therefore, as we can see, the Chinese economic structure changed profoundly, not only in terms of output (as presented in section 2.3.1) but also in terms of employment.

The changes in the pattern of employment composition in the levels of industry were facilitated by the relaxed household registration system. In the pre-reform period, 'China made inefficient use of its workers because of the inflexible way in which the labour market was segmented into rural and urban sectors. Rural residents 'were not allowed to migrate to urban areas' (Maddison 1998, p.62). In the post-reform period, although 'there are still important restrictions on rural-urban migration ... allocation of labour improved, particularly in rural areas, where the boom in small scale industry and service employment absorbed surplus labour from farming' (Maddison 1998, p.62).

2.2.3 Investment[12]

After three years (1950-52) of recovery, the government of the People's Republic of China (PRC) began to develop its economy through a centrally planned approach and the investment rate relative to GDP has remained fairly high since then. According to the statistical data published by the National Bureau of Statistics of China, the rate of capital formation relative to GDP during 1978-2005 ranged between 31.9 and 43.2 per cent (see Figure 2-4), which is much higher than the world's average investment rate was in 2003 (20 per cent, according to the World Bank's *World Development Report 2005)*.[13] The consumption rate in China is consequently much lower than the world's average level.

The regional distribution of investment is also uneven in China. In the early years after the foundation of PRC, the government shifted investment from the coastal area[14] to the interior area to overcome the unequal industrial distribution between the two. During the period 1953-1978, total capital formation in the coastal area accounted for only 34.7 per cent of nationwide capital formation while the interior area had 65.3 per cent of nationwide capital formation. In consequence, industrial production grew unevenly between the coastal area and the interior area. The interior

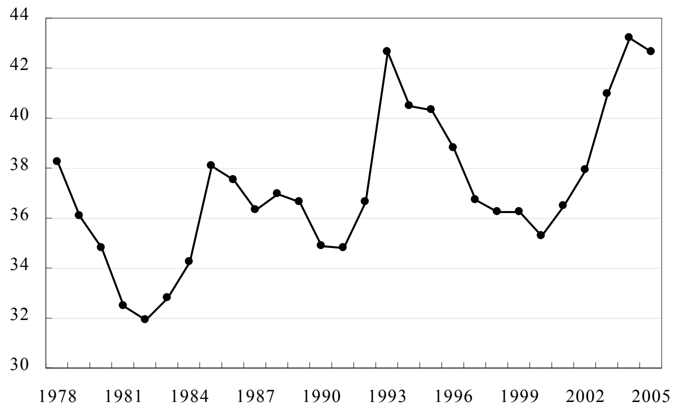
[12] In the present study I use gross fixed capital formation in national account to represent the accumulation of capital (i.e. investment).

[13] Source: *China Statistical Yearbook* (2006) and Ministry of Commerce of the PRC (http://qyscyxs.mofcom.gov.cn/espc/mme/_news/2005/10/1130309416813.html).

[14] The description of the coastal area which appears here is in contrast with the interior area. It includes all coastal FCADs along the coastline and therefore includes Hebei, Hainan and Guangxi, in addition to the nine member provinces of the Coastal Area defined in Table 2-1.

area's share of gross value of the industrial output increased from 31.8 per cent in 1952 to 40.2 per cent in 1978, while the coastal area share of gross value of industrial output decreased accordingly from 68.2 per cent in 1952 to 59.8 per cent in 1978.[15] Since 1978, when the Chinese government realized the importance of reforming its centrally planned economy and paying more attention to efficiency than to regional equality, capital investment was concentrated in the coastal area. During 1979-2005, the Coastal Area (including 9 FCADs, as defined in Table 2-1) accounted for 52.9 per cent of the nation's capital investment, while the share of the Inland Area (including 22 FCADs as defined in Table 2-1) decreased accordingly to 47.1 per cent. As a result, the Coastal Area became the industrial centre of the country. In 2004, the Coastal Area's share of gross value of the industrial output was 67.6 per cent of China's total industrial output.

Figure 2-4 Ratio of gross fixed capital formation to Chinese GDP over 1978-2005 (%)



Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

[15] Data source: Guo (1999, p.61).

Since the early 1980s, there has been a fundamental change in the investment system, mainly characterized by decentralization and regional autonomy. The responsibilities are shared proportionally between the central and local governments: (1) projects which are closely related to the overall structure of the national economy are still financially controlled by the central government. These include key energy, raw material industry bases, trans-provincial communication and transportation networks, key mechanical, electronic and other high-tech development projects, key agricultural bases and the national defence industry; (2) primary industrial and local projects are mainly invested and managed by local governments. These include agriculture, forestry and wood, local energy, raw material industries, regional communication and transportation networks, mechanical and light industries, science and technology, education, culture, public health and urban public infrastructure and services (Guo 1999, p.62).

2.2.4 Education

Since Confucianism began to influence Chinese society about 2,500 years ago, people in China have placed a high value on education. However, education has not been successfully established in China in some eras, including the last century. Education in China has experienced drastic changes since the foundation of the PRC. According to the second national population census, which was conducted in 1964, as much as 33.58 per cent of the total population aged 13 and over were illiterate.

Thereafter, the ratio of illiterate and semi-literate population to the total population age 15 and over decreased considerably to 6.72 per cent in the fifth national population census, which was conducted in 2000.[16]

The most praiseworthy achievement in the Chinese education system since the implementation of *the Nine-Year Free Compulsory Education Policy* in 1986 is that primary education and junior secondary education have achieved much progress with an increase in the percentage of school-age children enrolled from 61.7 per cent in 1957 to 99.2 per cent in 2005 and an increase in the percentage of graduates of primary schools entering junior secondary schools from 44.2 per cent in 1957 to 98.4 per cent in 2005. The percentage of graduates of junior secondary schools entering senior secondary schools increased from 39.7 per cent in 1957 to 69.7 per cent in 2005, while the percentage of graduates of senior secondary schools entering higher education institutes increased from 27.3 per cent in 1990 to 76.3 per cent in 2005. See Table 2-2.

[16] Data source: *China Statistical Yearbook* (2006).

Table 2-2 Percentage of school-aged children enrolled, and graduates of primary, junior middle, senior secondary schools entering higher level schools (selected years, %)

Year	School-aged children enrolled	Primary to junior middle schools	Junior middle to senior secondary	Senior secondary to higher education
1957	61.7	44.2	39.7	
1978	95.5	87.7	40.9	
1985	96.0	68.4	41.7	
1990	97.8	74.6	40.6	27.3
1995	98.5	90.8	50.3	49.9
2000	99.1	94.9	51.2	73.2
2005	99.2	98.4	69.7	76.3

Source: *China Statistical Yearbook* (1996, 2006).

One debate in China's education is whether it lags behind its economic growth. The level of China's investment in education is much lower than the global level in terms of per capita expenditure on education and share of national income invested in it. For instance, the ratio of educational expenditure to gross national income in China increased from 3.22 per cent in 1992 to 4.53 per cent in 2004,[17] but this is still lower than the global ratio which was 5.5 per cent in 1999, according to the *1999 World Technology and Development Report*.

Nonetheless, education has achieved impressive progress in China as a whole, though it is still unevenly provided among the Chinese FCADs. Generally speaking, in terms of average schooling years per student enrolled, the Coastal Area has a higher level than the Inland Area does. For example, in 2005, the top five FCADs for average schooling years per student were Beijing, Shanghai, Tianjin, Jiangsu and

[17] Data Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

Liaoning, while eight out of the ten FCADs at the bottom of the list were those in the Western Zone (column 1 of Table 2-3). However, when the schooling is conflated with regional population, the pattern of distribution of education becomes completely different, with the inland FCADs becoming the higher panel of the list while the coastal FCADs occupy the lower panel (column 2 of Table 2-3). This is because the Inland Area has a higher ratio of students to population (18.2 per cent in 2005), while the Coastal Area has a lower ratio of students to population (15.2 per cent in 2005). Columns 3-6 report the enrolment rates of students in education institutes at each level relative to regional population. In general, the Inland Area has higher primary school and junior middle school enrolment rates than the Coastal Area does, consequent on the achievement of the Chinese government's efforts to popularize the *Nine-Years Compulsory Education* policy. The senior secondary school enrolment rate shows no clear pattern. With respect to higher education, the Coastal Area has a higher level of education than the Inland Area. As we see, the three municipalities rank top of the list (column 6 in Table 2-3).

Next, we turn to the categories within the education system in China. Apart from informal education and postgraduate education, the Chinese education system has four education levels: (1) primary education, which requires 6 years to complete, (2) junior secondary education, which includes regular junior secondary schools and vocational junior secondary schools, to complete which requires 9 years altogether (i.e. another 3 years in addition to primary education), (3) 3 years of senior secondary education including specialized secondary schools, vocational senior secondary schools and regular senior secondary schools, taking 12 years in total to complete, (4) higher education (referred to as undergraduate education in the present study), which includes specialized courses and university courses, requiring 15 to 16 academic years altogether. Figure 2-5 provides a visual summary of the above four education levels.

However, for most FCADs there are no separate data on junior secondary education and specialized education. Instead, published data pertaining to secondary education include both junior and senior secondary levels and published data pertaining to higher education include both specialized courses and undergraduate courses. Therefore, in the following chapters whereas education level is concerned, we follow the three broad categories, that is, primary education, secondary education and higher education.

Table 2-3 Education level by province in year 2005

	Average Schooling Years		Student Enrollment Rate[c] (%)			
	per student[a]	per person[b]	Primary	Junior secon.	Senior secon.	Higher edu.[d]
Beijing	10.991	1.323	0.032	0.021	0.032	0.036
Tianjin	10.040	1.517	0.051	0.034	0.034	0.032
Hebei	8.708	1.487	0.073	0.054	0.032	0.011
Shanxi	8.328	1.715	0.104	0.057	0.032	0.012
Inner Mongolia	8.694	1.325	0.067	0.046	0.030	0.010
Liaoning	8.988	1.293	0.063	0.037	0.028	0.016
Jilin	8.971	1.254	0.060	0.040	0.025	0.015
Heilongjiang	8.908	1.234	0.058	0.045	0.022	0.014
Shanghai	10.451	1.157	0.030	0.026	0.029	0.025
Jiangsu	9.048	1.452	0.065	0.046	0.034	0.016
Zhejiang	8.850	1.340	0.070	0.035	0.033	0.013
Anhui	8.298	1.601	0.095	0.058	0.029	0.010
Fujian	8.670	1.494	0.077	0.050	0.033	0.012
Jiangxi	8.593	1.573	0.089	0.047	0.032	0.015
Shandong	8.884	1.378	0.067	0.043	0.033	0.013
Henan	8.215	1.698	0.105	0.061	0.032	0.009
Hubei	8.946	1.630	0.075	0.056	0.033	0.018
Hunan	8.837	1.390	0.066	0.047	0.032	0.012
Guangdong	7.926	1.584	0.116	0.050	0.024	0.010
Guangxi	8.008	1.422	0.097	0.050	0.023	0.007
Hainan	7.764	1.659	0.128	0.056	0.021	0.008
Chongqing	8.348	1.488	0.093	0.045	0.028	0.012
Sichuan	8.276	1.367	0.087	0.042	0.026	0.009
Guizhou	7.608	1.577	0.127	0.056	0.019	0.006
Yunnan	7.748	1.283	0.099	0.043	0.017	0.006
Tibet	7.553	1.385	0.118	0.044	0.015	0.007
Shaanxi	8.758	1.776	0.091	0.058	0.036	0.018
Gansu	8.018	1.671	0.117	0.053	0.029	0.009
Qinghai	7.959	1.308	0.093	0.042	0.023	0.006
Ningxia	8.004	1.626	0.116	0.048	0.031	0.008
Xinjiang	8.077	1.619	0.107	0.060	0.025	0.009
National	**8.501**	**1.455**	**0.083**	**0.048**	**0.029**	**0.012**

Note:

[a] Average schooling years per student = (primary·6+junior·9+senior·12+higher1·15+higher2·16)/ total number of students enrolled in all education institutes;

[b] Average schooling years per capita = (primary·6+junior·9+senior·12+higher1·15+higher2·16)/ total number of the population;

[c] Student enrolment rates are calculated by dividing the number of students enrolled at education institutes of corresponding level by regional population;

[d] Higher education includes the education levels of higher1 and higher2, where

‘primary’: the number of students enrolled at primary schools;

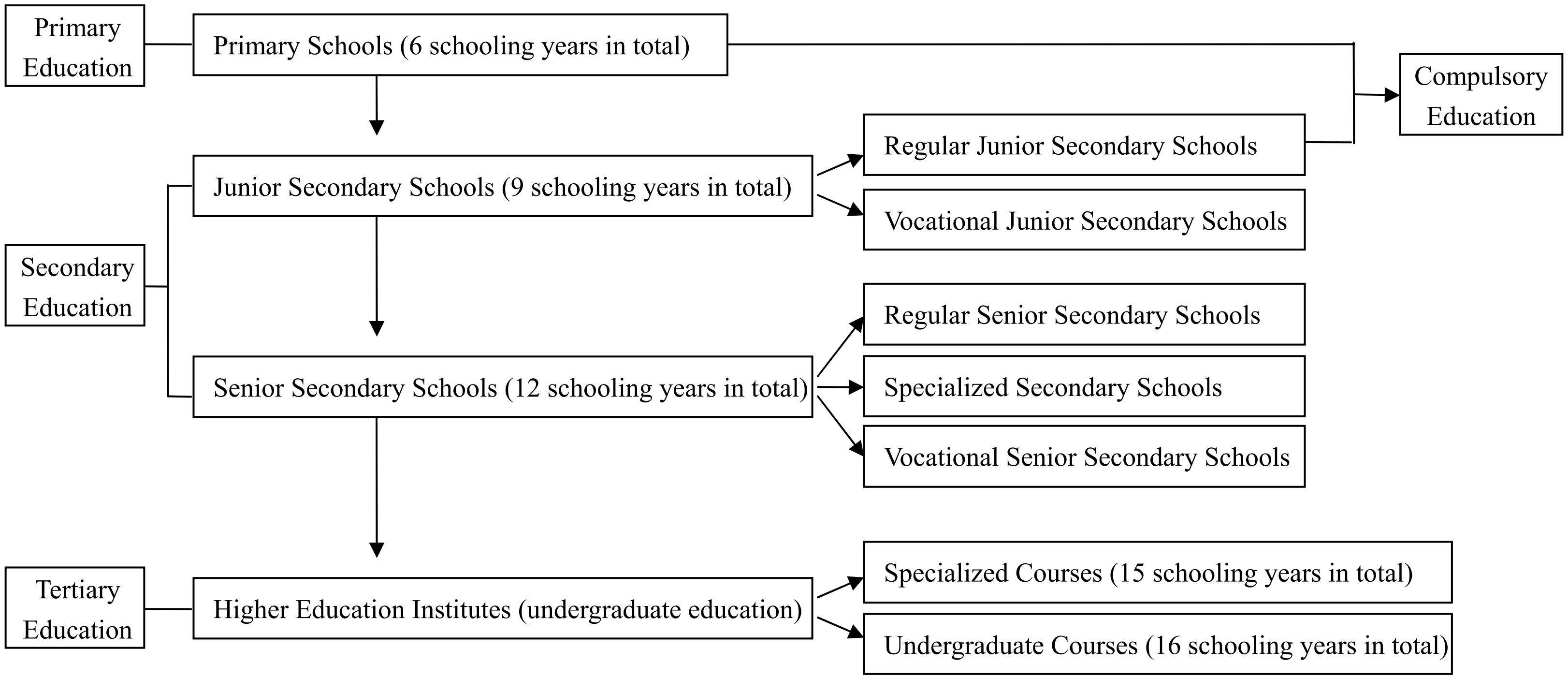
‘junior’: the number of students enrolled at junior secondary schools;

‘senior’: the number of students enrolled at senior secondary schools;

‘higher1’: the number of students enrolled for specialized courses which require three years in higher education institutes;

‘higher2’: the number of students enrolled for undergraduate courses which require three years in higher education institutes.

Figure 2-5 Categories within the educational system in China



Note: 1. Schooling years in the brackets refer to the accumulated schooling years to complete the corresponding degree.

2. Informal education and postgraduate education are not included in this figure.

2.2.5 Public Transport and Telecommunications

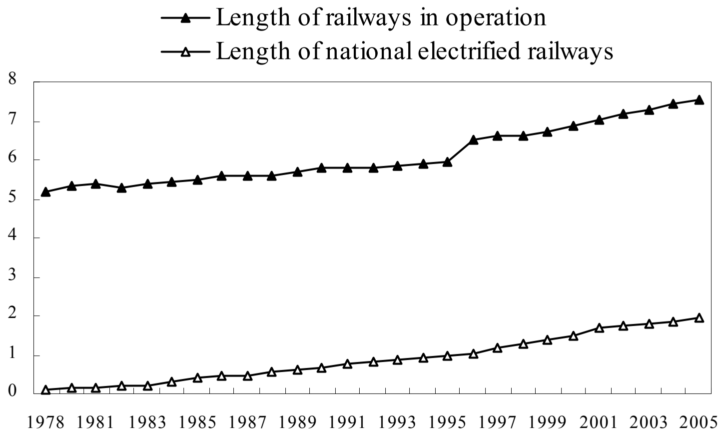
Public transport and telecommunications are important to an economy in providing infrastructure support and therefore facilitating economic development. China has achieved remarkable progress in the areas of transport and telecommunications in the last three decades.

Figure 2-6 depicts the development of major types of transport infrastructure in mainland China. As we see, during the period 1981-2005 the waterway system (the third diagram) was least developed, with the length of navigable inland waterways growing at 0.56 per cent per annum; the railway system (the first diagram) was moderately developed, with the length of railways growing at 1.43 per cent per annum; and the highway system (the second diagram), petroleum and gas pipelines (the fifth diagram) and civil aviation routes (the fourth diagram) were the quickest to develop, with lengths of highways, pipelines and total aviation routes growing at 3.31 per cent, 6.61 per cent and 10.2 per cent per annum, respectively.

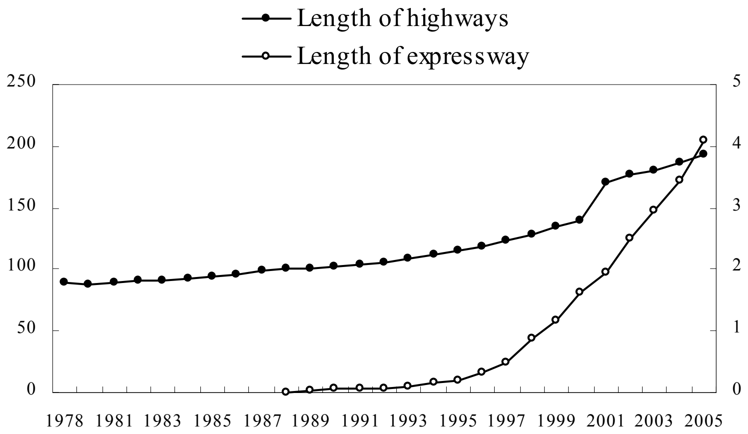
The most significant achievement is the fast development of the expressway system. As we can see from the second diagram of Figure 2-6, there was no expressway at all before 1988; however, it grew at an amazing rate of 46.9 per cent per annum and, by 2005, mainland China had developed a powerful expressway network with a total length of 41,000 kilometres.

Figure 2-6 Lengths of transportation routes, 1978-2005 (10,000 km)

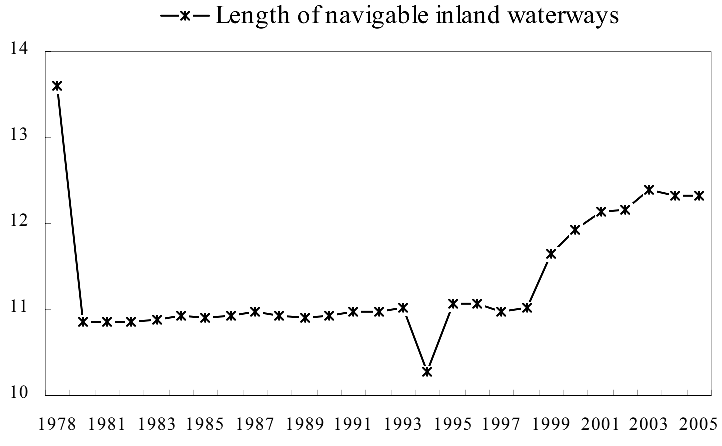
(1)



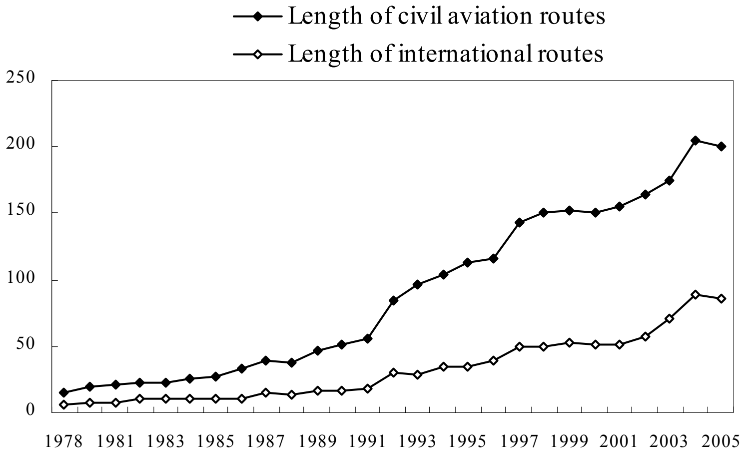
(2)



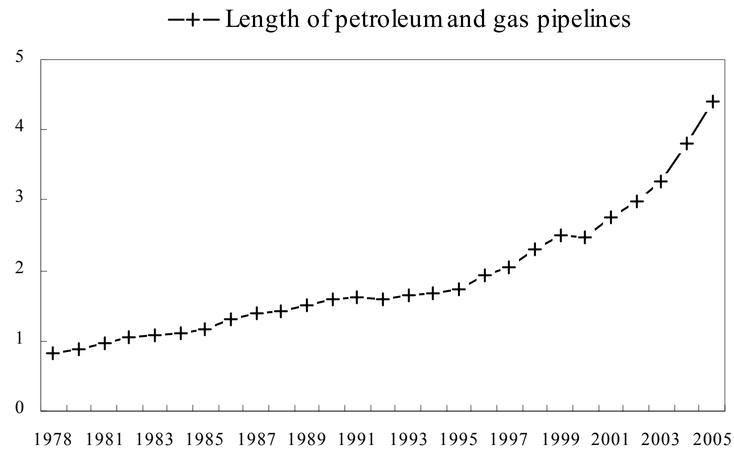
(3)



(4)



(5)



Note: 1. Length of railways in operation includes length of national electrified railways; length of highways includes length of expressway; and length of civil aviation routes includes length of international routes.
2. Length of expressway in the second diagram follows the scale on the right hand side, while the other series follow the scale on the left hand side.

Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

Turning to the Chinese telecommunication sector, Table 2-4 provides a summary of its evolution. As we see, it has greatly developed since the beginning of the 1990s, corresponding to China's rapid economic growth. For instance, the business volume of post and telecommunication services increased from 3.41 billion Yuan in 1978 to an astonishing 1,203 billion Yuan in 2005 (column 1 of Table 2-4); the number of long-distance telephone calls, mobile phone subscribers and local telephone subscribers increased from 1.73 billion calls, 0.05 million subscribers and 8.45 million subscribers in 1991 to 25.92 billion calls, 393.41 million subscribers and 350.45 subscribers in 2005, (columns 3, 4 and 6); and, indexed by the number of internet users which increased fivefold from 2000-2005 (column 5), the information technology infrastructure significantly boosted China's capacity in technological and personal connectivity and therefore accelerated the progress of globalization in China.[18] Remarkable achievements have also been made gained in terms of express mail services and the capacity of the long-distance telephone exchange (columns 2 and 7).

[18] Causality may occur, that is, the progress of globalization may accelerate the construction of the information technology infrastructure.

Table 2-4 Development of telecommunication infrastructure in China (selected years from 1978 to 2005)

	Business volume of post and telecomm services (billion Yuan)	Pieces of express mail services (million pieces)	Long-distance telephone calls (billion times)	Mobile phone subscribers at year-end (million subscribes)	Internet users (million persons)	Subscribers of local telephone at year-end (million)	Capacity of long-distance telephone exchange (million circuits)	Capacity of office telephone exchange (million lines)	Capacity of mobile phone exchange (million subscribers)	Length of long-distance optical cable lines (1000 km)
1978	3.41		0.19			1.93	0.19	4.06		
1980	3.90		0.21			2.14	0.20	4.43		
1985	6.22		0.38			3.12	1.15	6.13		
1989	12.35	2.47	0.78	0.01		5.68	10.33	10.35	0.04	1.85
1990	15.55	3.43	1.16	0.02		6.85	16.14	12.32	0.05	3.33
1991	20.44	5.67	1.73	0.05		8.45	28.63	14.92	0.10	6.49
1992	29.09	9.59	2.87	0.18		11.47	52.19	19.15	0.45	14.39
1993	46.27	21.56	5.07	0.64		17.33	120.61	30.41	1.56	38.67
1994	68.82	40.20	7.58	1.57		27.30	241.63	49.26	3.72	73.29
1995	98.89	55.63	10.14	3.63		40.71	351.88	72.04	7.97	106.88
1996	134.20	70.97	12.74	6.85		54.95	416.20	92.91	15.36	130.16
1997	177.33	68.79	15.54	13.23		70.31	436.83	112.69	25.86	150.75
1998	243.12	76.68	18.26	23.86		87.42	449.16	138.24	47.07	194.10
1999	333.08	90.91	17.83	43.32		108.72	503.20	153.46	81.36	239.74
2000	479.27	110.31	21.08	84.53	22.50	144.83	563.55	178.26	139.86	286.64
2001	455.63	126.53	22.00	145.22	33.70	180.37	703.58	255.66	219.26	399.08
2002	569.58	140.36	19.28	206.01	59.10	214.22	773.01	286.57	274.00	487.68
2003	701.98	172.38	19.60	269.95	79.50	262.75	869.40	350.83	336.98	594.30
2004	971.23	197.72	22.62	334.82	94.00	311.76	1,263.00	423.47	396.84	695.27
2005	1,202.85	228.80	25.92	393.41	111.00	350.45	1,371.63	471.96	482.42	723.04

Source: *China Statistical Yearbook* (2006).

2.3 THE ECONOMY IN TRANSITION

The Reform was started in late 1978 to improve productivity and people's living standards and to achieve social and economic development. Since then great strides toward the market economic system have been made. In general, the Chinese economy experienced six phases of institutional evolution after the foundation of the PRC:[19]

1. Centrally planned economy (before 1978);
2. Economy regulated mainly by planning and supplemented by the market (1979-84);
3. Commodity economy with a central plan (1985-87);
4. Socialist commodity economy (1988-89);
5. Combination of a planned and a market economy (1989-91); and
6. Socialist market economy (since 1992).[20]

The gradual reform has brought rapid economic growth, which in turn has transformed the Chinese economy from a command economy to a market-oriented economic entity and from an agricultural country to an industrial country in terms of output (Maddison 1998, p.79). The processes of reform within China are wide-ranging and challenging. This section provides a brief description of the Reform by looking at the changes in the Chinese economic structure, market liberalization and the decentralization of the industrial sector.

2.3.1 Changes in Economic Structure

China had been an agricultural country for a long time. Primary industry, which refers to agriculture, forestry, animal husbandry and fishery in China, used to be the

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[19] Guo (1999, p.41).

[20] In a socialist market economy 'the public ownership economy plays the leading role and co-exists and shares opportunities with the economy in various other ownerships' (*People's Daily*, 13 July 2005 [online, accessed 05/07/2008].

fundamental level in China.[21] However, massive structural changes have taken place since the foundation of the PRC. The output share of primary industry over the total national output fell from 50 per cent in 1952 to 31.0 per cent in 1979 and 12.6 per cent in 2005; the share of secondary industry, which includes mining and quarrying, manufacturing, the production and supply of electricity, water and gas and the construction industry in China, increased from 20 per cent in 1952 to 47 per cent in 1979 and 47.5 per cent in 2005; and the output share of tertiary industry, or equivalently, service industries, which includes all other economic activities not categorized in the other two, increased from 30 per cent in 1952 to 39.9 per cent in 2005.

With respect to employment in the three industries, the distribution of the labour force has also changed remarkably in consequence of the Reform and the resulting great economic prosperity. The agricultural policies implemented in the early stage of the Reform greatly stimulated peasants' production incentives and hence improved labour productivity; at the same time, with the modernization of agriculture, primary industry began to use more capital-intensive technology than before and therefore needs less labour; both processes freed a great many rural workers. The main part of the surplus was absorbed by secondary industry, which boomed as a consequence of the industrial reforms following the agricultural reforms. Regarding tertiary industry, its employment share grew substantially in response to the released official constraints on private service activities after 1978 and the fact that 'the barriers to entry (in rural and street market activity) are small' since 'not much capital or formal

[21] The definitions of primary industry, secondary industry and tertiary industry are cited from *China Statistical Yearbook* (2006).

education is required to start a new business' (Maddison 1998, p.84). As a result, primary industry's share of employment decreased from 68.7 per cent in 1979 to 44.8 per cent in 2005, secondary industry's share of employment increased from 18.2 per cent to 23.8 per cent and tertiary industry's share of employment increased 13.1 per cent to 31.4 per cent.[22]

Turning to the contribution of the three broad industries to the growth of the country's GDP, the average annual rate of primary industry's contribution was 6.64 per cent during the period 1991-2005; secondary industry contributed most to GDP growth, with an average rate of 59.27 per cent; and tertiary industry contributed 34.10 per cent. See Table 2-5 for the year-by-year contribution rates of the three industries.

One important consequence of the changes in economic structure has been urbanization. The progress of urbanization in China was slow in the early years of the Reform, due to stringent internal migration policies but progress increased after 1990 in consequence of a policy shift. As a result, the percentage of urban dwellers in China increased from 17.92 per cent in 1978 to 42.99 per cent in 2005.[23]

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[22] Data source: *China Statistical Yearbook* (2006) and *Comprehensive Statistical Data and Materials on 50 Years of New China*.

[23] Data source: *China Statistical Yearbook* (2006).

Table 2-5 Contributions of the three industries to the increase of GDP[a] (1991-2005, %)

Year	Primary Industry[b]	Secondary Industry[c]	Tertiary Industry[d]
1991	7.07	62.80	30.13
1992	8.37	64.45	27.07
1993	7.83	65.46	26.71
1994	6.53	67.93	25.64
1995	8.99	64.34	26.67
1996	9.48	62.91	27.62
1997	6.69	59.73	33.58
1998	7.52	60.94	31.56
1999	5.93	57.77	36.30
2000	4.39	60.80	34.81
2001	5.00	46.70	48.30
2002	4.50	49.76	45.75
2003	3.31	58.51	38.18
2004	7.73	52.24	40.14
2005	6.25	54.70	39.00

Note:
a) Contribution of the three industries refers to the proportion of the increment of corresponding industrial value added to the increment of GDP.
b) Primary industry refers to agriculture, forestry, animal husbandry and fishery in China.
c) Secondary industry refers to mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction in China.
d) Tertiary industry includes all other economic activities not included in primary or secondary industry.
Source: *China Statistical Yearbook* (2006).

2.3.2 Market Liberalization

Market liberalization is another prominent feature of China's transitional economy. During 1949-1978, all economic activities including pricing were under the control of the central and local governments and Chinese enterprises were not allowed to purchase inputs and sell outputs freely in the market. Since the start of the Reform, 'along with the expansion of the commodity market scale and the change of the relations between commodity supply and demand, the state has carried out price reform step by step and according to plans.'[24]

[24] Source: Asianinfo.org [online].

In the beginning of the Reform the Chinese government carried out a double-track system, which is also known as the dual pricing system. Under it, a free market developed, where prices were regulated mainly through the relations between market supply and market demand, in parallel with a controlled market, where the prices were kept almost unchanged at an officially fixed level. Because the price of a commodity in the market-regulated track was usually higher than the price of the same commodity in the government-controlled track,[25] the supply in the free market grew rapidly so that its share of total output rose steadily and the share of production subject to government declined correspondingly. In consequence, to narrow the gap between the supply and the demand in the government-controlled market, the artificially low prices in the government-controlled market were revised step by step until they approached the market regulatory prices.

The double-track (or dual pricing) system was first applied to agricultural products and spread slowly to consumption goods and intermediate goods.[26] However, the revision of market prices adjusted before 1984 was insufficient to bring them close to market clearing prices. Prices were further liberalized after 1985. By 1992, both prices and the transactions in consumption goods, except for major grains, were almost completely liberalized (Otsuka *et al*. 1998, p.42).

The double-track system enabled resources to be more efficiently allocated as competitive market prices under the system grew closer to marginal prices for

[25] According to the estimates of the State Statistical Bureau (*China Price Statistical Yearbook* 1992, 1995), free market retail prices were, on average, 70 per cent higher than prices at state-owned stores in 1978. The difference had declined to less than 5 per cent by the early 1990s (Otsuka *et al*. 1998, p.42).

[26] The proportion of consumption goods freely traded through markets increased from a negligible level in 1978 to about one-half in 1985 (Otsuka *et al*. 1998, p.42).

enterprises. However, it also enabled people who had access to state-controlled goods and materials to make large profits by buying at an officially-fixed low price and reselling at a market-based price, which often led to unequal competition and also official corruption. Therefore, the dual pricing system created various distortions in addition to speculative transactions. Still, as Guo (1999, p.63) argues, it was at least better than taking no action at all during the process of rationalizing prices.

The double-track system extended through almost every sphere of the economy during China's period of transition (i.e. 1979-1991) from a centrally planned to a market-oriented system. In 1992 Deng Xiaoping made his famous tour of South China and since then the Chinese government has been endeavouring to establish a socialist market economy. So far, 'China has basically completed the transition to the socialist market economy from a highly centralized planning economy' (People's Daily, 13 July 2005).

2.3.3 Decentralization of the Industrial Sector

In much of the pre-reform period in which the Chinese economy was centrally regulated,[27] the Chinese industrial sector[28] developed rapidly in terms of output. However, the quantitative accompanied low efficiency, slow technological progress and sectoral disproportion (Guo 1999). To change the situation, the Chinese government started to reform the industrial sector by gradually decentralizing the

[27] Before 1978, the Chinese government controlled all the major sectors of the Chinese economy. State-owned enterprises, which accounted for the lion's share of industrial production in the pre-reform period (Otsuka *et al*. 1998, p.11), were directly under the control of the government. The central government decided what should be produced and at what prices the products should be sold. It also made the decisions about how the national income should be distributed.

[28] The industrial sector in the present study refers to industries which are classified as secondary industry and stand in contrast to the agricultural sector.

industrial organization.

Reforms in the industrial sector sought to improve enterprise incentive systems, use indirect economic levers [29] to regulate industrial production, diversify the entrepreneurship structure, endow the state-owned enterprises (SOEs) with greater decision-making autonomy and, above all, to compel enterprises to operate according to market regulations.

A major consequence of the industrial reform is the explosive growth of the non-state sector, which has acted increasingly as the engine of industrial development. There now exists a variety of types of enterprise in China, such as SOEs, collectively-owned enterprises (COEs), private enterprises, cooperative enterprises, joint ownership enterprises, limited liability corporations, share-holding corporations and limited and foreign funded enterprises. SOEs are used by the Chinese government as a means of managing aggregate demand to enable it to operate its counter-cyclical policy. Another important role of SOEs in the Chinese economy is to help the central government to pursue its regional policy by shifting investment to the poor western side of the country (Guo 1999). COEs are under the supervision of local governments which are responsible for the provision of inputs to COEs in their jurisdiction and have first claim on COEs' output and revenues. Private enterprises, which develop quickly in the post-reform era, follow market regulations of supply

[29] 'Chinese economic plans and policies were implemented by a variety of direct of indirect control mechanisms. Direct control was exercised by designating specific physical output quotas and supply allocations for some goods and services. Indirect instruments – also called "economic levers" – operated by affecting market incentives. These included levying taxes, setting prices, allocating investment funds, monitoring and controlling financial transactions through the banking system and controlling the allocation of scarce key resources' (countrystudies.us [online]).

and demand and are free to decide on investment, employment, output and pricing. The other types of enterprise, which mainly comprise joint-ventures and wholly-foreign-owned enterprises, have grown rapidly in consequence of the huge inflows of foreign capital into China.

2.4 GLOBALIZATION

Prompted by the decline in its people's living standards and the economic prosperity in its neighbouring countries, the Chinese government gave up the policy of international isolation[30] in favour of globalization by introducing a series of open-up policies. Foreign policies concerning foreign trade and foreign investment have been implemented gradually in the country since the late 1970s.

2.4.1 Foreign Trade

Before 1978, foreign trade was under the control of the central planning authority.[31] Since the late 1970s, China has gradually globalized by reducing tariff rates[32] and non-tariff barriers, relaxing foreign exchange control, devaluing its currency and increasing the number of foreign trade companies and their mutual competition, which makes China an open economy.[33]

As a consequence of the Chinese government's efforts to globalize, the total volume

[30] In pre-reform era, China employed a policy of international isolation in the name of protecting the interests of the people of China.

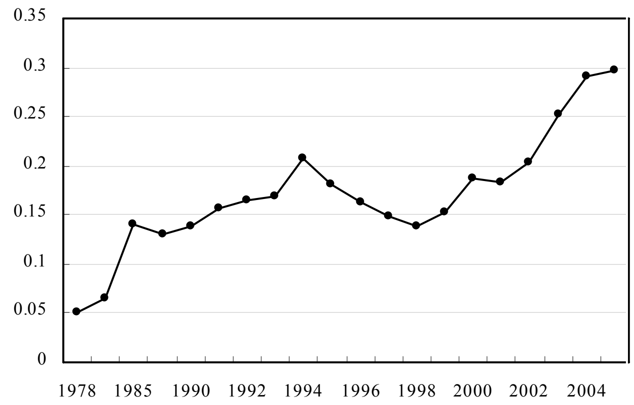
[31] The central government controlled more than 90 percent of trade by monopolizing the imports and exports of over 3,000 kinds of commodity before 1979 (Wan *et al*. 2007).

[32] For example, China's weighted mean tariff rate fell from 32.1 per cent in 1992 to 6.0 per cent in 2004 (Siddique 2006, p.219).

[33] By 1994, almost all planning on imports and exports was abolished, with a few exceptions where extremely important goods were traded by specially appointed trading companies (Wan *et al*. 2007).

of exports and imports in China rose from US$20.64 billion in 1978 to US$ 1421.91 billion in 2005, up by 69 times. Specifically, the values of China's imports and exports increased from US$10.89 billion and US$9.75 billion in 1978 to US$659.95 billion and US$761.95 billion in 2005, respectively. And, as we see in Figure 2-7, with the ratio of exports to total GDP rising from 5.14 per cent in 1978 to 29.64 per cent in 2005, China has become an export-oriented economy.

Figure 2-7 Proportion of exports in national GDP (1978 to 2005)



Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

Foreign trade influences the Chinese economy in the following ways. On the one hand, imports bring advanced foreign technologies and equipment, management expertise and advanced means of production; on the other, exports create a great number of jobs, improve labour productivity, stimulate the Chinese economy via external demand and help to allocate resources more efficiently. Therefore, it is widely believed that there should be a positive correlation between foreign trade and economic growth. For example, Dutta and Ahmed (2001), using the framework of an endogenous growth model, find that exports are one of significant determinants of industrial value added function in Pakistan. Yao (2006), who adopts Pedroni's panel unit root test and Arellano and Bond's dynamic panel data estimating technique, finds that exports had a strong and positive effect on economic growth in 28 Chinese provinces over the period 1978 to 2000.

However, certain researchers disagree about the impact of exports on the Chinese economy. Bao *et al*. (2003), who study the relation between exports and economic growth in China's 29 FCADs over 1990-1999, find a negative relation between the export share of regional GDP and economic growth. Lai and Yang (2002) also arrive at similar conclusions.[34] The negative effects which exports may have on the Chinese economy are also perceived by the Chinese policy makers. *China Trade Remedy Information* reports that '... the impact of net exports on manufacturing industries has turned negative' (China Trade Remedy Information, 10/12/2004).

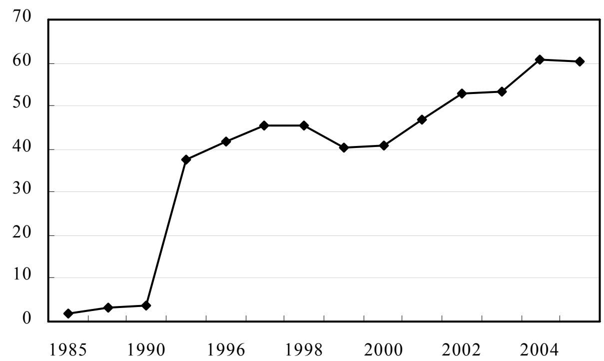
2.4.2 Foreign Direct Investment

Another indicator of global integration is the level of inflows and outflows of FDI, an amalgamation of capital, technology, marketing and management. However, it is a challenging task for a government to attract FDI. For the Chinese government, the main impediment was the presence of the huge state sector running the SOEs, as the SOEs directly competed with the foreign investors in terms of attracting resources for producing and marketing the products under the direct patronage of the government (Siddique 2006).

[34] With respect to the reasons for the negative impacts of exports on the Chinese economy, Lai and Yang (2002) and Bao *et al*. (2003) attribute it to the violation between the structure of Chinese export goods, which was more labour-intensive and the structure of domestic manufacturing goods, which in recent years has become more capital- and/or technology-intensive.

Nevertheless, China has a number of attractions for foreign investors, for example, the abundant supply of labour and the huge domestic market, and it has successfully attracted huge amounts of FDI in response to the Chinese government's continuous efforts. China has become host to the greatest FDI in all the developing economies and sometimes the world's largest recipient in the years since 1996 (Wu 2006). Figure 2-8 summarizes the actual inward FDI in China. With respect to the outflows of capital, China has also become an important source of FDI to other countries in recent years.

Figure 2-8 Values of inflows of FDI (selected years, US$ billion)



Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

The distribution of FDI is uneven in China. In general, the Coastal Area (i.e. the Eastern Zone) absorbs most of the total foreign capital in China per year. More specifically, for example, in 1994, Guangdong province received the largest share (28.42 per cent) of total foreign capital, followed by Jiangsu (11.30 per cent), Fujian (11.15 per cent), Shandong (7.67 per cent), Shanghai (7.43 per cent), Liaoning (4.32 per cent), Beijing (4.12 per cent), Zhejiang (3.45 per cent) and Tianjin (3.05 per cent). The five FCADs which received the least foreign capital were Tibet (none), Qinghai (0.007 per cent), Ningxia (0.02 per cent), Shanxi (0.10 per cent) and Inner Mongolia

(0.12 per cent).[35]

Foreign capital has been playing an increasingly important role in the Chinese economy. The shares of foreign trade for foreign-funded enterprises'[36], gross value of industrial output and employees increased dramatically from 17.4 per cent, 2.1 per cent and 1.4 per cent in 1990 to 57.4 per cent, 19.2 per cent and 10.2 per cent in 2005, respectively, up by 3.32, 9.14 and 7.29 times respectively.[37]

Despite the great progress of globalization in China, however, the country is not yet fully globalized.

2.4.3 Opening-Up Policies

The opening-up policies were from the outset implemented so as to favour the better developed coastal FCADs.[38] In general, the policies were first applied to the coastal area at the beginning of the Reform and then spread to the interior after the early 1990s when they had proved successful.

Specifically, four Special Economic Zones (SEZs) were setup in four coastal cities between 1979 and 1982,[39] and the whole Hainan province, which was part of Guangdong province until 1988, was set up as the fifth SEZ in 1988; in 1984,

[35] Source: Author's calculation based on data from *China Statistical Yearbook* (1996).

[36] Foreign-funded enterprises include joint ventures, cooperation enterprises, enterprises with sole foreign funds and share-holding corporations ltd. with foreign investment.

[37] Source: Author's calculation using data from *China Statistical Yearbook* (2006).

[38] Deng Xiaoping advocated that 'let some segments of society get rich first and let some regions flourish first' (Chen 2003).

[39] Three SEZs (Shenzhen, Zhuhai and Shantou) were in Guangdong province and one (Xiamen City) in Fujian province.

another 14 coastal cities were opened to overseas investors and 10 Economic and Technological Development Zones (ETDZs) were established in the coastal provinces. Between 1985 and 1990, the Chinese government expanded the open coastal areas by setting up three Coastal Open Economic Zones in the Pearl River delta, Yangtze River delta and the Xiamen-Zhangzhou-Quanzhou Triangle in south Fujian province, another four ETDZs in Fujian and Shanghai, one Open Coastal Zone covering Liaoning, Shandong, Hebei and Guangxi and Pudong New Area in Shanghai.

Having perceived the success of the open-door policies in the coastal area, since 1992, the Chinese government has extended the policies westwards. A number of border cities and all the capital cities of inland FCADs were opened to foreign investors and 15 free trade zones, 32 ETDZs and 53 new and high-tech industrial development zones were established in large- and medium-sized cities, [40] until today, when it can be said that 'China has formed a multi-level, multi-channel, all-directional pattern of opening and integrating coastal areas, border and interior areas' (China-detective.com [online]).

[40] Sources: Démurger *et al*. (2002).

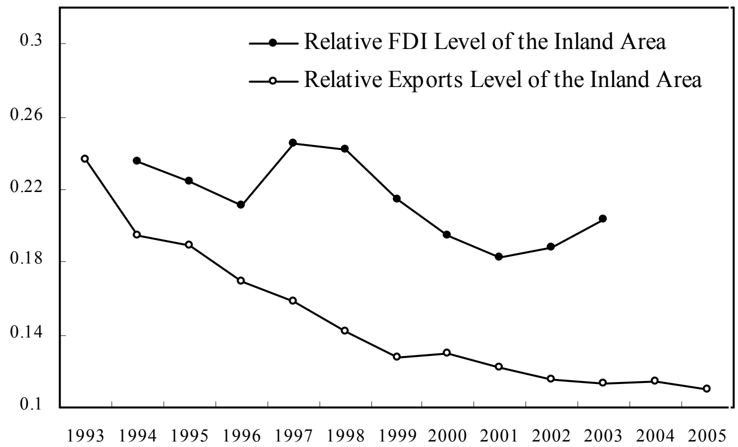
Table 2-6 Preferential policy indices by province (1978-1998)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Average
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Tianjin	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.43
Liaoning	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1.24
Shanghai	0	0	0	0	0	0	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	1.76
Jiangsu	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.43
Zhejiang	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.43
Fujian	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2.71
Shandong	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.43
Guangdong	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2.86
Coastal	**0.00**	**0.00**	**0.67**	**0.67**	**0.67**	**0.67**	**1.78**	**1.78**	**1.89**	**1.89**	**2.00**	**2.00**	**2.11**	**2.11**	**2.33**	**2.33**	**2.33**	**2.33**	**2.33**	**2.33**	**2.33**	**1.65**
Hebei	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1.24
Shanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Inner Mongolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Jilin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Heilongjiang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Anhui	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	0.62
Jiangxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Henan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Hubei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	0.62
Hunan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Guangxi	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1.24
Hainan	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	3	1.57
Sichuan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	0.62
Guizhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Yunnan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Tibet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Shaanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Gansu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Qinghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Ningxia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.33
Xinjiang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0.67
Inland	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.10**	**0.10**	**0.10**	**0.10**	**0.33**	**0.33**	**0.33**	**0.33**	**1.43**	**1.57**	**1.57**	**1.57**	**1.57**	**1.57**	**1.57**	**0.60**

Source: Démurger *et al*. (2002).

Different open areas adopt different preferential policies, which to a great extent reflect the degree of openness of the area. Based on the number of designated open economic zones and the extent of the preferential treatment, Démurger *et al*. (2002) have constructed a preferential policy index for each FCAD in mainland China, which is included in Table 2-6. It is obvious that the Coastal Area has a much higher degree of openness than the Inland Area.

Figure 2-9 Relative levels of exports and FDI of the Inland Area relative to the Coastal Area (1993-2005)



Note: Relative FDI = FDI in the Inland Area / FDI in the Coastal Area
Relative exports = Exports by the Inland Area / Exports by the Coastal Area
See Table 2-1 for the members of the Coastal Area and the Inland Area.
Source: Author's calculation based on data from *China Statistical Yearbook* (2006).

The biased regional development strategy, together with other factors such as geographic location, has led to uneven economic performance among Chinese FCADs. Figure 2-9 summarizes the trends of relative levels of exports and FDI of the Inland Area relative to the Coastal Area. We can clearly see that there are great differences between the Inland Area and the Coastal Area in terms of exports and FDI levels and the differences have been widening over time.

2.5 CONCLUSION

To summarize, the economic reform and open-door policies started in the late 1970s have transformed China from a virtually closed economy into an important trading nation in the world. The economic reform, in the form of decentralization of the central government's powers, has had an enormous effect in changing the Chinese economic structure, market liberalization and decentralization of the industrial sector; and the opening-up policies, implemented gradually in time and space, have successfully led China on the path to globalization. Both the Reform and foreign policies have provided the nation with unprecedented opportunities for achieving economic prosperity. China has achieved remarkable progress in almost every aspect of the social and economic sphere, for example, physical capital accumulation, human resources, transportation and telecommunications infrastructure, foreign trade and inflows of FDI, which has laid the foundation for further economic progress in the future.

CHAPTER 3: CONVERGENCE IN CHINA DURING 1979-2004

Income inequality within mainland China is pronounced. Consider the gap in terms of income per person between the poorest province, Guizhou, and the richest municipality Shanghai. In 1979, the real per capita GDP of Shanghai was 12.8 times that of Guizhou (Figure 3-1).[41] The ratio of the two regions' income levels declined over time until 1991, in response to the successful agricultural reform in the first stage of the Reform which greatly improved efficiency in the agricultural sector,[42] and it has again increased steadily since 1992, in response to the cumulative effects of unbalanced industrial policies and open-door policies implemented in a way which favoured the eastern Coastal Area.

Let's firstly look at income inequality between Chinese provinces. The trends in inequality in terms of per capita GDP within the whole of mainland China and sub-groups of the country are summarized in Figure 3-2. The curve for the Coastal Area illustrates the trend in inequality in terms of the standard deviation[43] in real per

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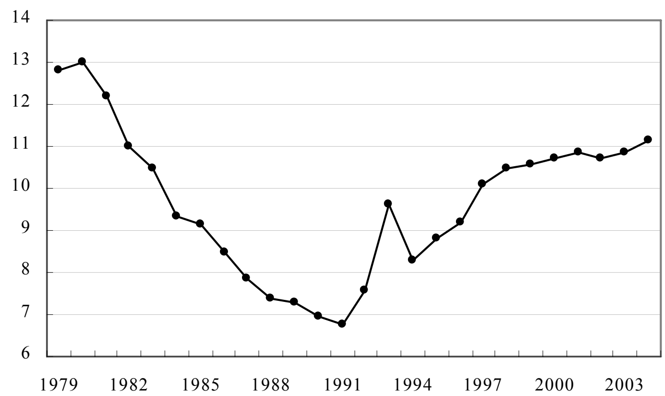
[41] In this chapter, GDP is deflated by 1978 prices. If not stated, the source of the data appeared in this chapter comes from author's calculation based on data from *China Statistical Yearbooks* of various editions.

[42] Otsuka *et al*. (1998, p.8) argue that 'Agriculture is the first sector that has achieved successful outcomes as a result of economic reform. The major reform was the establishment of individual household farming systems known as the "household responsibility system". This replaced collective farming by a production team consisting of 20-30 households, which was managed under the guidance and supervision of the people's commune ... The problem of the large size was exacerbated by collective farming, which reduces work incentives to individual members under an egalitarian system of output-sharing. In contrast, individual farm households paying tax to the government under the new household responsibility system is similar to and as efficient as tenant households paying rents to landowners'. Yao (2000, p.33) claims that 'Prior to economic reforms before 1978, agriculture was heavily taxed by the state to subsidize urban and industrial development. Economic reforms since 1978 have reduced the burden on agriculture, but lack of state investments still remains a constraint on its development'.

[43] A variety of measurements of regional inequalities has been employed in the literature, such as standard deviation or alternatively standard error (see, for example, Yang 1989; Liu *et al*. 1994), the Gini coefficient (see, for example, Wan 2001; Zheng 2004), the coefficient of variation (see, for example, Wang and Hu 2006; Liu 2006) and weighed mean error (see, for example, Guo 1998).

capita GDP across provinces within the Coastal Area (see Table 2-1 in Chapter 2 for the spatial division of mainland China); the curve for the Inland Area illustrates the trend in inequality within the Inland Area; the curve for the 30 Chinese provinces illustrates the trend in income inequality in the whole of mainland China; and the curve for the 27 Chinese provinces demonstrates the trend in income inequality in Mainland China, without taking into account the three municipalities of Beijing, Tianjin and Shanghai.

Figure 3-1 Shanghai's real per capita GDP relative to Guizhou's (1979-2004)

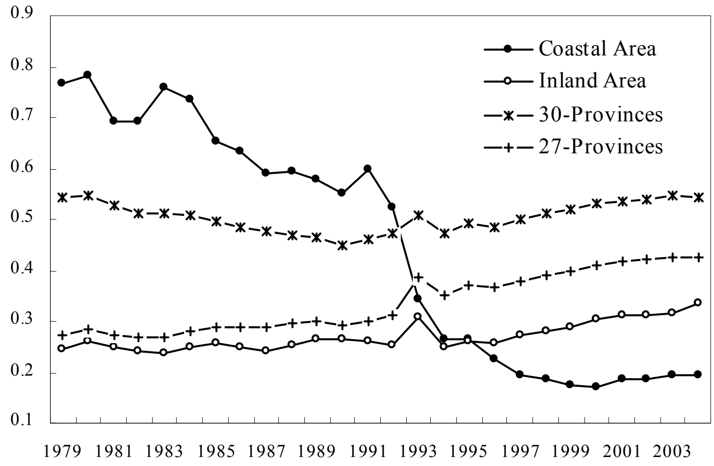


As we see from Figure 3-2, the Coastal Area exhibits a clear downward trend in inequality during 1979-2004. This indicates that the income dispersion among the nine coastal provinces and municipalities of China decreased dramatically after the Reform, with the coefficient on standard deviation in real per capita GDP reducing from as high as 0.77 in 1979 to as low as 0.19 in 2004. This is taken as evidence of sigma-convergence within the Coastal Area.[44] Income dispersion within the Inland Area, however, widened steadily during the period, with the coefficient on standard

[44] Sigma-convergence refers to decreases of the dispersion of real per capita GDP between economies. Another type of convergence which is widely studied is beta-convergence. Beta-convergence refers to the situation where poor economies grow faster than rich economies and will eventually catch up with them. The concepts of sigma- and beta-convergence were first introduced by Xavier Sala-i-Martin.

deviation rising from 0.25 in 1979 to 0.34 in 2004, which indicates sigma-divergence within the Inland Area.

Figure 3-2 Cross-sectional standard deviation in real per capita GDP (1979-2004)



Note: The Coastal Area includes 9 eastern and coastal provinces, among which 3 are municipalities; the Inland Area includes 21 provinces and autonomies; the 30-Provinces curve depicts income inequality within the whole of mainland China; and the 27-Provinces curve depicts income inequality within China, excluding the coastal three municipalities.

Turning to the whole country, when the three coastal municipalities are excluded from the analysis, the upward-sloping 27-Provinces line indicates that income inequality among China's 27 provinces increased steadily in the post-reform era, with the coefficient on standard deviation rising from 0.27 in 1979 to 0.43 in 2004. Therefore, clear evidence of sigma-divergence can be identified within mainland China's 27 provinces during the period 1979-2004. For the whole of mainland China, the situation is more complex. The first part of the 30-Provinces line shows that income inequality declined during 1979-1990 in response to the drastically declined dispersion within the Coastal Area. The second part of the 30-Provinces line exhibits a steady and modest upward trend in 1991-2004, in response to the obvious fact that the effect of widened income inequality within the Inland Area outweighed the effect of decreased income inequality within the Coastal Area. Moreover, as we see that the 30-Provinces line remains throughout above the 27-Provinces line, we can conclude that the inclusion of the three municipalities increases the regional income dispersion to a higher degree.

After the issue of sigma-convergence, that is, whether the provinces converge in terms of income distribution, we turn to examine beta-convergence, namely, whether poor provinces grow faster than rich provinces. The relation between the two types of convergence is defined by Barro and Sala-i-Martin (1990): beta-convergence is a necessary but not sufficient condition for sigma-convergence. In other words, the presence of sigma-divergence does not necessarily imply the absence of beta-convergence and beta-convergence 'need not imply a reduction in the dispersion of income levels ... if each country's level of income is continually subject to random disturbances' (Barro 1991, p.407).

The rest of this chapter deals with beta-convergence in mainland China. Section 3.1 presents the derivation of the growth-convergence equation. Section 3.2 briefly reviews the literature of convergence. Section 3.3 describes the model and data. Section 3.4 reports the empirical results and section 3.5 draws some conclusions.

3.1 THE GROWTH-CONVERGENCE EQUATION

The growth-convergence equation originates from the neoclassical growth model and its framework is built up on the basis of work by many researchers. Solow's 1956 paper formed a landmark in neoclassical growth theory and, along with his 1957 growth-accounting paper, it

> "transformed growth theory from arguably obscure debates about stability and gloomy knife-edge properties into a fully fledged, flexible framework for analysing key growth questions: e.g. the impact of changes in savings, population, depreciation and technical progress on the level and growth of output; the nature of transition to steady states; the possibility of convergence and catch-up between countries, etc." (McAdam and Allsopp 2007).

The development of the convergence literature has reached a high level of sophistication, thanks to the efforts of Mankiw, Romer and Weil (1992), Barro and Sala-i-Martin (2004) and Islam (2003a, 2003b).

To derive the growth-convergence equation, first of all, let us assume a simple Cobb-Douglas production function which exhibits neutral technology:

(3.1) $Y = F(K, L) = AK^{\alpha} L^{1-\alpha}$,

which is homogeneous of degree one with the marginal product of capital[45] $F_K > 0$ and marginal product of labour $F_L > 0$.

Income per person y is simply a function of the capital-labour ratio k :

(3.2) $y = f(k) = Ak^{\alpha}$ and $f'(k) = F_K > 0$,

where $y = Y / L$ and $k = K / L$. Thus all conclusions about the evolution of y can be reached through analysis of the evolution of k .

In turn, if investment $\dot{K}$ is a proportion of Y and population growth $\dot{L} / L = n$, the equation of motion for the capital stock per person, k , is

(3.3) $\dot{k} = s \cdot f(k) - (n + g + \delta) \cdot k$,

where $\dot{k}$ is the time derivative of k , s is the rate of investment, g measures

[45] The marginal product of capital, assuming all other factors are fixed, refers to the additional output resulting from the use of an additional unit of capital.

technical progress and δ is the depreciation rate of physical capital.

Hence k is governed by an autonomous differential equation, which can be represented graphically in the $(k,\dot{k})$ space (see Figure 1 in Solow 1956, p.70). Simply knowing the outlook of $f(k)$ and the parameters s and n enables us immediately to form conclusions on the evolution of k and y.

Let $\dot{k}=0$ at the steady state, that is,

$$s\cdot f(k^*)=(n+g+\delta)\cdot k^* \text{ with } f(k^*)=A\cdot k^*,$$

then we have the steady state value of capital stock per worker,

$$(3.4) \qquad k^*=(A\cdot\frac{s}{n+g+\delta})^{1/(1-\alpha)}.$$

Substituting k^* back into the production function (3.1) and taking logarithms, we have steady-state output per unit of labour,

$$(3.5) \qquad \ln(y^*)=\frac{2-\alpha}{1-\alpha}\ln(A)+\frac{\alpha}{1-\alpha}\ln(s)-\frac{\alpha}{1-\alpha}\ln(n+g+\delta),$$

where y^* is the steady state value of output per worker. $\frac{2-\alpha}{1-\alpha}\ln(A)$ is a constant term and thus (3.5) is identical to

$$(3.6) \qquad \ln(y^*)=\ln(A)+\frac{\alpha}{1-\alpha}\ln(s)-\frac{\alpha}{1-\alpha}\ln(n+g+\delta).$$

Thus the Solow model shows that income level per worker is positively determined by saving and negatively determined by population growth. Given the assumption that inputs are paid their marginal products, the basic Solow model is capable of predicting the magnitude of both the saving rate and population growth. Under such circumstances, the output share of physical capital is represented by $(F_k \cdot k)/y$, where F_k is the marginal product of capital.

The next step is to see how the concept of convergence emerged and where its specification comes from. The process of deriving the growth-convergence equation exactly follows Barro and Sala-i-Martin (2004, p.621) and Islam (2003a, p.319).

First order Taylor expansion of $f(k)$ around the steady state gives[46]

$$f(k) \cong f(k^*) + f'(k^*) \cdot (k - k^*) .$$

Substituting the above equation into (3.3) gives the dynamic function of capital stock around the steady state:

$$\text{(3.7)} \qquad \dot{k} = s[f(k^*) + f'(k^*)(k - k^*)] - (n + g + \delta) \cdot k .$$

At the steady state, $\dot{k} = sf(k^*) - (n + g + \delta) \cdot k^* = 0$, thus $s = \dfrac{(n + g + \delta) \cdot k^*}{f(k^*)}$.

Substituting s into (3.7) gives

$$\text{(3.8)} \qquad \dot{k} = [f'(k^*) \cdot k^* / f(k^*) - 1] \cdot (n + g + \delta) \cdot (k - k^*) .$$

---

[46] The Taylor theorem gives a sequence of approximations of the differentiable function $f(k)$ near k^* by polynomials whose coefficients depend only on the derivatives of the function at k^*: $f(k) = f(k^*) + f'(k^*) \cdot (k - k^*) + f''(k^*) \cdot (k - k^*)^2 + \cdots + \dfrac{f^n(k^*)}{n!}(k - k^*)^n + R_n(k)$, where $R_n(k)$ is an error term. It is obvious that $f''(k^*) \cdot (k - k^*)^2 + \cdots + \dfrac{f^n(k^*)}{n!}(k - k^*)^n + R_n(k) \approx 0$. Therefore $f(k) \cong f(k^*) + f'(k^*) \cdot (k - k^*)$, which is the first order Taylor expansion of $f(k)$.

Under the assumption that inputs are paid their marginal products, the steady state capital's share of income $\alpha = f'(k^*) \cdot k^* / f(k^*)$. 'In the Cobb-Douglas case, this will also be the exponent of capital in the production function' (Islam 2003a, p.319). Therefore (3.8) becomes

$$\text{(3.9)} \qquad \dot{k} = (1-\alpha) \cdot (n+g+\delta) \cdot (k^* - k).$$

The term $(1-\alpha) \cdot (n+g+\delta)$, which is denoted as the rate of convergence λ, measures the speed at which the gap between the steady state level of capital and its current level is closed. The same rate holds for convergence in terms of income per labour. This is because $y = f(k)$, which, upon expansion at k^* and differentiation with respect to time, gives

$$\text{(3.10)} \qquad \dot{y} = f'(k^*) \cdot \dot{k}.$$

Substituting $\dot{y} = \frac{dy}{dt} = \frac{y^* - y}{dt}$ and $\dot{k} = \frac{dk}{dt} = \frac{k^* - k}{dt}$ into (3.10) gives

$$\text{(3.11)} \qquad y^* - y = f'(k^*) \cdot (k^* - k).$$

From (3.10) we have $f'(k^*) = \dot{y} / \dot{k}$. Substituting it into (3.11) gives

$$y^* - y = \dot{y} \cdot (k^* - k) / \dot{k}.$$

Replacing $\dot{k}$ in the above equation with (3.9) gives

$$\text{(3.12)} \qquad \dot{y} = \lambda \cdot (y^* - y),$$

where $\lambda = (1-\alpha) \cdot (n+g+\delta)$, which is again the speed at which an economy reaches its steady state level of income.

Having discovered the convergence rate, we now turn to deriving the equation for testing convergence. In practice, it is omnipresent in log-transform data, since the log-transform does the best job of making the data appear normal. Thus, 'switching to logarithms' (Islam 2003a, p.320), we get straightaway from (3.12):

(3.13) $\dot{\ln(y_t)} = \lambda \cdot [\ln(y^*) - \ln(y_t)]$.

Moving $\ln(y_t)$ from the right-hand side of the equation to the left-hand side gives

(3.13.1) $\dot{\ln(y_t)} + \lambda \cdot \ln(y_t) = \lambda \cdot \ln(y^*)$.

Multiply both sides of (3.13.1) by the integrating factor $e^{\lambda t}$ and the left-hand side becomes time derivative of $e^{\lambda t} \cdot \ln(y_t)$:

$$e^{\lambda t}[\dot{\ln(y_t)} + \lambda \cdot \ln(y_t)] = \frac{d(e^{\lambda t}\ln(y_t) + \psi_1)}{dt},$$ [47]

where ψ_1 is an arbitrary constant.

After multiplying both sides of (3.13.1) by $e^{\lambda t}$, integrate

(3.13.2) $\int e^{\lambda t}[\dot{\ln(y_t)} + \lambda \ln(y_t)]dt = \int e^{\lambda t}[\lambda \ln(y^*)]dt$. [48]

The integral on the left-hand side of (3.13.2) becomes $e^{\lambda t} \cdot \ln(y_t) + \psi_1$ and the integral on the right-hand side of (3.13.2) equals $e^{\lambda t} \cdot \ln(y^*) + \psi_2$, where ψ_2 is also an arbitrary constant of integration. Therefore (3.13.2) is equivalent to

(3.14) $\ln(y_t) = \ln(y^*) - \psi_1 \cdot e^{-\lambda t} + \psi_2 \cdot e^{-\lambda t}$.

From Equation (3.2) $y = f(k) = Ak^{\alpha}$ we have $\ln(y) = \ln(A) + \alpha \cdot \ln(k)$. Therefore, the time path for $\ln(k)$ is given by

(3.15) $\ln(k_t) = \ln(k^*) - \psi_1 \cdot e^{-\lambda t} + \psi_2 \cdot e^{-\lambda t}$.

---

47 Expansion of the right-hand side gives:

$$\frac{d(e^{\lambda t}\ln(y_t) + c_0)}{dt} = e^{\lambda t} \cdot \lambda \cdot \ln(y_t) + e^{\lambda t} \cdot \dot{\ln(y_t)} = e^{\lambda t}[\dot{\ln(y_t)} + \lambda \cdot \ln(y_t)].$$

48 Expansion of the right-hand side gives:

$$\int e^{\lambda t}[\lambda \ln(y^*)]dt = \ln(y^*) \cdot \int e^{\lambda t} \cdot \lambda \cdot dt = \ln(y^*) \cdot e^{\lambda t} + c_1.$$

In Equation (3.15), Barro and Sala-i-Martin (2004) claim that

> "$\psi_1 = 0$ must hold for $\ln(k_t)$ to tend asymptotically to $\ln(k^*)$. ($\psi_1 > 0$ violates the transversality condiation and $\psi_1 < 0$ leads to $k \to 0$, which corresponds to cases in which the system hits the vertical axis in figure 2.1.[49]) The other constant, ψ_2, is determined from the initial condition, $\psi_2 = \ln(y_0) - \ln(y^*)$" (Barro and Sala-i-Martin 2004, pp.133-134).

Thus, (3.15) becomes $\ln(k_t) = \ln(k^*) + [\ln(k_0) - \ln(k^*)] \cdot e^{-\lambda t}$. Multiplying both sides by $e^{\lambda t}$ and re-arranging produces

(3.16) $$e^{\lambda t} \cdot \ln(k_t) = (e^{\lambda t} - 1) \cdot \ln(k^*) + \ln(k_0).$$

Similarly, Equation (3.14) evolves to

(3.17) $$e^{\lambda t} \cdot \ln(y_t) = (e^{\lambda t} - 1) \cdot \ln(y^*) + \ln(y_0).$$

Multiply both sides of (3.17) by $e^{-\lambda t}$ and re-arrange,

(3.18) $$\ln(y_t) = (1 - e^{-\lambda t}) \ln(y^*) + e^{-\lambda t} \ln(y_0).$$

Subtracting $\ln(y_0)$ from both sides of (3.18) leads to a dynamic equation, that is, the growth-initial level equation,

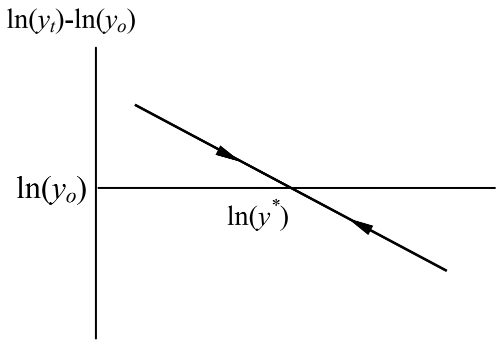
(3.19) $$\ln(y_t) - \ln(y_0) = (1 - e^{-\lambda t}) \cdot \ln(y^*) - (1 - e^{-\lambda t}) \cdot \ln(y_0).$$

Equation (3.19) explicitly exhibits a clear relationship between growth and initial income level. A negative value of the estimated coefficient on $\ln(y_0)$, i.e. $-(1 - e^{-\lambda t}) < 0$, makes the slope downward and convergence possible: to the left of the steady-state income level (see Figure 3-3), $\ln(y^*) > \ln(y_0)$, then (3.19) suggests that $\ln(y_t) - \ln(y_0) > 0$, which indicates a positive growth rate and $\ln(y_t)$ increases over time; to the right of the steady-state income level, $\ln(y^*) < \ln(y_0)$.

[49] Figure 2.1 is on page 100 in Barro and Sala-i-Martin (2004).

Then (3.19) suggests that $\ln(y_t) - \ln(y_0) < 0$, which indicates a negative growth rate of per capita output and $\ln(y_t)$ decreases over time. Hence we see that as long as $-(1-e^{-\lambda t}) < 0$, no matter where the initial position of an economy is, above or below its steady-state per capita income level, the economy will eventually reach a stable equilibrium. This is the case when convergence happens within an economy. Moreover, a positive value of the estimated coefficient on $\ln(y_0)$ makes convergence impossible, as can be seen by applying the same logic to analyze an unstable equilibrium.

Figure 3-3 Unique and stable equilibrium



Furthermore, substituting $\ln(y^*)$ from Equation (3.6) into the growth-initial level equation (3.19) gives

$$\text{(3.20)} \quad \begin{aligned} \ln(y_t) - \ln(y_0) = (1-e^{-\lambda t})\ln(A) + (1-e^{-\lambda t})\frac{\alpha}{1-\alpha}[\ln(s) - \ln(n+g+\delta)] \\ -(1-e^{-\lambda t})\ln(y_0) \end{aligned}.$$

A negative value of the coefficient on $\ln(y_0)$, i.e. $-(1-e^{-\lambda t}) < 0$ is evidence of an economy converging to its steady-state level of income; a positive value of the coefficient on $\ln(y_0)$, i.e. $-(1-e^{-\lambda t}) > 0$, is evidence of beta-divergence.

3.2 THE LITERATURE

The issue of convergence is more often applied to study convergence across a sample of economies than to a single economy. Studies have proceeded through several stages and different definitions of convergence and approaches to studying convergence have emerged in the literature.

Different definitions of convergence have emerged only with time. The first type of convergence is absolute convergence, that is, poor countries and rich countries will converge to the same or similar steady state levels of income per capita in the long run, as the neoclassical growth theory implies. The best known initial study of absolute convergence is by Baumol (1986), who identified strong evidence of absolute convergence within a sample of 16 OECD countries.[50] However, when the sample was extended to 72 countries, Baumol found no evidence of absolute convergence. The hypothesis of absolute convergence is rejected in most empirical studies which employ large samples of countries (see, for example, De Long (1988), Barro and Sala-i-Martin (1992), Sala-i-Martin (1996b) and Evans and Karras (1996b)).

The failure to find evidence of absolute convergence provides an important point of departure for the further discussion of convergence. Researchers find that it is more realistic to assume that countries have different steady states contingent on differences in their technological and behavioural parameters. Notice that (3.17) includes the term $\ln(y^*)$ as an explanatory variable. That is, the growth rate of an

[50] De Long (1988), however, shows that Baumol's finding of absolute convergence suffers from selection bias.

economy not only 'depends on its initial level of income, but it also depends on the steady-state level of income. This is why we use the concept of conditional rather than absolute convergence: the growth rate of an economy depends negatively on its initial level of income, after we "condition" on the steady state' (Barro and Sala-i-Martin 2004, p.466). See, for example, Barro and Sala-i-Martin (1990, 1992 and 2004), Mankiw, Romer and Weil (1992), Holtz-Eakin (1993), Durlauf and Johnson (1995) and Islam (1995), for practical examples of conditional convergence.

To distinguish between convergence with respect to income growth and convergence with respect to income level, Barro and Sala-i-Martin raise the concepts of beta-convergence and sigma-convergence, correspondingly (see, for example, Barro and Sala-i-Martin (1990 and 1992)). Furthermore, researchers, such as De Long and Summers (1991), Dowrick and Nguyen (1989) and Wolff (1991), noticed that 'income-convergence can be the joint outcome of the twin process of capital deepening[51] and technological catch-up' (Islam 2003a, p.315) and when they intended to separate the technological progress effect from the capital accumulation effect they raised the concept of TFP-convergence. At the same time, researchers noticed that conditional convergence in most cases took place within a group of countries, i.e. club-convergence and little evidence has been found for global convergence (see, for example, Barro and Sala-i-Martin (1992 and 1995), Mankiw, Romer and Weil (1992), Den Haan (1995), Durlauf and Johnson (1995) and Islam (1995)). The notions of deterministic convergence and stochastic convergence arose when the time series econometric method was applied to study convergence across countries, which, in testing for unit root in the deviation series, allowed a

[51] Capital deepening refers to an increase in the amount of capital per unit of labour input.

deterministic or stochastic trend in the tails (see, for example, Binder and Pesaran (1999) and Li and Papell (1999)).

The literature has also witnessed the evolution of various approaches to study this issue. The most frequently used one in the early studies is the cross-section approach, because a large part of the literature concerns this issue across economies. The cross-section approach evolved from an informal stage to a formal stage. The informal cross-section approach was based on an equation which was not formally derived from the growth model (see, for example, Baumol (1986), Kormendi and Meguire (1985) and Barro (1991)), while the formal cross-section approach, initiated by Mankiw, Romer and Weil (1992) and Barro and Sala-i-Martin (1992), was based on an equation which was formally derived from the neoclassical growth model. The time-series approach was introduced to study convergence both within an economy and across economies (see, for example, Carlino and Mills (1993), Evans and Karras (1996b), Lee *et al*. (1997) and Binder and Pearan (1999)). Later, the panel regression method was introduced to allow differences in the aggregate production function for different economies (see, for example, Islam (1995, 2003a) and Yao and Zhang (2001)).

It is obvious that there is some correspondence between the types of convergence and the approaches to studying the issue; such correspondence is, however, not unique. For instance, the informal and formal cross-section approaches, the panel approach and the time-series approach have been applied to study both conditional and absolute beta-convergence (see, for example, Durlauf and Johnson (1995)); the formal cross-section approach and the panel approach have been used to study club-convergence and TFP-convergence (see, for example, Islam (2003b)); the cross-section approach has also been applied to both sigma-convergence and beta-convergence (for example, Barro and Sala-i-Martin (1991), Sala-i-Martin (1996b) and Andrés *et al*. (2003)).

Among all the various types of convergence, it is obvious that conditional beta-convergence is the most frequently studied in the literature. The conditioning variables reflect various economic and social aspects, including investment rate, population growth, education, life expectancy, fertility rate, government consumption ratio, inflation, openness, transportation, law and democracy. See Mankiw, Romer and Weil (1992) and Barro (1997) for good examples of conditional beta-convergence studies.

Previous studies indicate that the estimated speed of convergence is sensitive to the sample of member observations and periods as is the approach which the analysis has adopted. For instance, for within the U.S., the rate of convergence is found to be 2 per cent over 1880-1990 in Sala-i-Martin (1996b) and 4.5 per cent over 1973-1986 in Holtz-Eakin (1993). For the OECD countries over 1960-1985, Mankiw, Romer and Weil (1992) and Barro and Sala-i-Martin (1992) who use the cross-section regression approach, find a convergence rate of around 2 per cent per year,[52] while Islam (1995), who uses the panel regression approach, finds the rate as high as 9.26 per cent per year.[53]

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[52] Caseli *et al.* (1996) argue that 'the existing empirical literature on cross-country growth relies on inconsistent estimation procedures. Consequently, the convergence rate and the other growth coefficients as obtained in existing contributions are unreliable.' They find instead a 'consistent estimate of the rate of convergence which is approximately 10 per cent.' (p.1)

[53] The samples in Mankiw, Romer and Weil (1992) and Islam (1995) include 22 OECD countries; in Barro and

Based on the regression results, structural parameters can be estimated. Like the rate of convergence, the estimated values of structural parameters are sensitive to the choice of sample and approach. Take output share of physical capital as an example. For 22 OECD countries over 1960-85, Mankiw, Romer and Weil (1992), using the cross-section regression approach, find the output share of physical capital to be 0.21, while Islam (1995), using the panel approach, estimates the value as 0.38.

3.3 THE MODEL AND DATA

3.3.1 The Growth-Initial Level Model with Human Capital

The present study employs the panel approach, which starts with the following framework,

$$
\begin{aligned}
\ln(y_{i,t}) - \ln(y_{i,0}) &= -(1-e^{-\lambda\tau})\ln(y_{i,0}) \\
&\quad + (1-e^{-\lambda\tau}) \cdot \frac{\alpha}{1-\alpha} \cdot [\ln(s_i) - \ln(n_i + g + \delta)] \\
&\quad + (1-e^{-\lambda\tau}) \cdot \ln A_{i,0} + g \cdot (t - e^{-\lambda\tau} \cdot 0) + \varepsilon_{i,t}
\end{aligned} \tag{3.21}
$$

where the subscript *i* denotes provinces, *0* denotes the start year of each time span, t is the end year of each time span;

τ is the difference between time points *0* and t;

the explanatory variables s_i and n_i are averages over corresponding time spans ;

$(1-e^{-\lambda\tau})\ln A_{i,0}$ is to capture time-invariant individual effect u_i;

$g \cdot (t_2 - e^{-\lambda\tau} t_1)$ is to capture individual-invariant period effect η_t; and

$\varepsilon_{i,t}$ is the error term.

Sala-i-Martin (1992) the sample includes 20 OECD countries.

This model should be modified when it is applied to real data. Most of all, human capital is as important as physical capital and labour in an economy, which attracts special attention when the empirical value of output share of physical capital is found to be much higher than it is expected to be and when the evidence of convergence (conditional convergence, in particular) is absent in a large sample. For the former case, researchers add a variable representing human capital into the growth-convergence equation and expect to find evidence which could explain the unexpectedly high value of the output share of physical capital. For the latter case, some researchers take it as a signal of the failure of the neoclassical growth theory and therefore try to relax the constraint of diminishing returns and to set up new growth models (see, for example, Barro (1991)).

There is no consensus yet about the precise way in which human capital should enter the aggregate production function. Different ways of modelling human capital have different implications for the productivity term. For example, natural logarithmic transformation of $Y = K^{\alpha}(AL)^{1-\alpha}$ yields

(3.22) $\ln Y - \alpha \ln K - (1-\alpha)\ln L = (1-\alpha)\ln A^{Solow}$,

where subscripts i and t are omitted, A^{Solow} indicates that this productivity term comes from the original Solow-type production function given by $Y = K^{\alpha}(AL)^{1-\alpha}$. Hence any contribution made by human capital to production has to occur through its impact on A^{Solow}.

Mankiw, Romer and Weil (1992) include human capital in the production function multiplicatively and symmetrically (relative to physical capital):

(3.23) $Y = K^{\alpha} H^{\varphi} (A^{MRW} L)^{1-\alpha-\varphi}$,

where H represents human capital and φ ranges between 0 and 1. As we see, Mankiw, Romer and Weil (1992) assume that workers are technically augmented.

A natural logarithmic transformation of (3.23) yields

$$\text{(3.24)} \quad \begin{aligned} \ln Y - \alpha \ln K - (1-\alpha)\ln L &= (1-\alpha-\varphi)\ln A^{MRW} + \varphi \cdot (\ln H - \ln L) \\ &= (1-\alpha)\ln A^{MRW} + \varphi \cdot (\ln h - \ln A^{MRW}) \end{aligned}$$

where h is human capital per unit of labour.

Comparing (3.24) with (3.22), we find that A^{MRW} differs from A^{Solow} in the following way:

$$\text{(3.25)} \quad \ln A^{Solow} = \frac{1-\alpha-\varphi}{1-\alpha} \ln A^{MRW} + \frac{\varphi}{1-\alpha} \ln h .$$

Equation (3.25) indicates that productivity A^{Solow}, which is computed using $Y = AK^{\alpha} L^{1-\alpha}$, contains a human capital component which is left out of A^{MRW}.

Hall and Jones (1999) propose a third way of including human capital in the aggregate production function: as

(3.26) $Y = K^{\alpha} (A^{HJ} H)^{1-\alpha}$,

where $H = e^{\phi(E)} L$, with E being years of education. Hall and Jones (1999) argue that H 'reflects the efficiency of a unit of labour with E years of schooling relative to one with no schooling ($\phi(0) = 0$). The derivative $\phi'(E)$ is the return to schooling: an additional year of schooling raises a worker's efficiency proportionally by $\phi'(E)$' (pp.87-88).

Natural logarithmic transformation of (3.26) yields

(3.27) $\ln Y - \alpha \ln K - (1-\alpha)\ln L = (1-\alpha)\ln A^{HJ} + (1-\alpha)\cdot\phi(E)$.

Comparing (3.27) with (3.22), we find the relationship between A^{Solow} and A^{HJ} is simply as

$$(3.28) \quad \ln A^{Solow} = \ln A^{HJ} + \phi(E).$$

From (3.25) and (3.28), we see that in the basic neoclassical model, the productivity term implicitly contains the information on human capital, no matter how the latter enters the growth model.

In the present analysis, Mankiw, Romer and Weil's method is adopted, that is, human capital enters the model multiplicatively and symmetrically, i.e.

$$(3.29) \quad Y = F(K, L) = AK^{\alpha}H^{\varphi}L^{1-\alpha-\varphi}.$$

Let s_k be the fraction of income invested in physical capital and s_h be the fraction of income invested in human capital. 'The evolution of the economy is determined' (Mankiw, Romer and Weil 1992, p.416) by:

$$(3.30) \quad \dot{k} = s_k \cdot y - (n + g + \delta) \cdot k \text{ and } \dot{h} = s_h \cdot y - (n + g + \delta) \cdot h,$$

where $h = H / L$. The two equations in (3.30) indicate that an economy converges to its steady state subject to

$$(3.31) \quad k^* = (A \cdot \frac{s_k^{1-\varphi} s_h^{\varphi}}{n + g + \delta})^{1/(1-\alpha-\varphi)} \text{ and } h^* = (A \cdot \frac{s_k^{\alpha} s_h^{1-\alpha}}{n + g + \delta})^{1/(1-\alpha-\varphi)}.$$

Substituting k^* and h^* into the production function (3.29) and taking logarithms, we have the steady-state output per unit of labour,[54]

[54] If human capital enters the model in the form of the level of human capital (*h*), the way to express the role of human capital ought to be different from (3.32). See Mankiw, Romer and Weil (1992) for more information.

$$\ln(y^*) = \ln(A) - \frac{\alpha+\varphi}{1-\alpha-\varphi}\cdot\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\varphi}\cdot\ln(s_k) + \frac{\varphi}{1-\alpha-\varphi}\cdot\ln(s_h) \quad . \tag{3.32}$$

Following steps (3.7)-(3.18), one can easily arrive at the growth-initial level equation with human capital included in the production function:

$$\begin{aligned}
\ln(y_{i,t}) - \ln(y_{i,0}) &= -(1-e^{-\lambda\tau})\ln(y_{i,0}) - (1-e^{-\lambda\tau})\cdot\frac{\alpha+\varphi}{1-\alpha-\varphi}\cdot\ln(n_i+g+\delta) \\
&\quad + (1-e^{-\lambda\tau})\cdot\frac{\alpha}{1-\alpha-\varphi}\cdot\ln(s_{k,i}) + (1-e^{-\lambda\tau})\cdot\frac{\varphi}{1-\alpha-\varphi}\cdot\ln(s_{h,i}) \\
&\quad + (1-e^{-\lambda\tau})\cdot\ln A_{i,0} + g\cdot(t-e^{-\lambda\tau}\cdot 0) + \varepsilon_{i,t} \\
&\textit{i.e.} \\
\ln(y_{i,t}) - \ln(y_{i,0}) &= -(1-e^{-\lambda\tau})\ln(y_{i,0}) \\
&\quad + (1-e^{-\lambda\tau})\cdot\frac{\alpha}{1-\alpha-\varphi}\cdot[\ln(s_{k,i}) - \ln(n_i+g+\delta)] \\
&\quad + (1-e^{-\lambda\tau})\cdot\frac{\varphi}{1-\alpha-\varphi}\cdot[\ln(s_{h,i}) - \ln(n_i+g+\delta)] \\
&\quad + (1-e^{-\lambda\tau})\cdot\ln A_{i,0} + g\cdot(t-e^{-\lambda\tau}\cdot 0) + \varepsilon_{i,t}
\end{aligned} \tag{3.33}$$

where '0' represents the start of each time span and 't' the end of each time span.

The difference between (3.33) and (3.18) is that the model presented by (3.33) not only considers the correlation between the growth of per capita income and physical capital investment and labour, but also investigates the correlation between the growth of per capita income and investment in human capital. The difference between (3.33), (3.24) and (3.27) comes from the fact that (3.33) corresponds to neutral technology, while (3.24) and (3.27) correspond to labour-augmented technology.

As an important input in the production function, human capital can be measured in several ways, such as average schooling years per capita or per worker (see, for example, Hall and Jones (1996 and 1997)), school enrolment rate(s) (see, for example, Barro (1991), Mankiw *et al*. (1992) and Yao and Wei (2007)) and the expenditure on education, science, health care and cultural activities (see, for example, Yao and Zhang (2001)). Even with the same measure, the form in which the human capital variable enters the regression varies. For example, Barro (1991) uses the start of the period of human capital level, Mankiw *et al*. (1992) use the averages over corresponding time spans and Islam (1995) uses the end of the period human capital level. For the present analysis, human capital is indexed by the student enrolment rate at the secondary school level, which measures the rate of human capital accumulation.[55]

Besides human capital, some other factors also play essential roles in an economy. For example, Hall and Jones (1996) argue that a good infrastructure in a broad sense provides an environment which supports productive activities, thereby encouraging capital accumulation, skill acquisition, invention and technology transfer. To study convergence within China, the human capital augmented Solow model (3.33) should also be further modified, since industrialization level, transportation level and the degree of openness are important to the Chinese economy. By taking into account these additional factors, the model becomes

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[55] The student enrolment rate proxy is measured by the number of students enrolled in schools relative to the total provincial population. Student enrolment rate at the primary school level is found to inappropriately reflect the education level of a Chinese province. This is due to different age structures across Chinese provinces. Student enrolment rate at the higher education level is found to have an insignificant impact on the Chinese economy. Therefore, student enrolment rates at the levels of primary school and higher education institutes are not used in the present study to measure the rate of human capital accumulation.

Another measure of human capital which has been tried for the present study is the logarithmic share of government expenditure for the operating expenses of cultural activities, education, scientific activities and public health; this, however, produced poor results. Furthermore, because the data on the number of students enrolled in junior secondary schools have been available only lately, the use of figures for average years of schooling is not feasible for the current study.

$$
\begin{aligned}
\ln(y_{i,t}) - \ln(y_{i,0}) = &-(1-e^{-\lambda\tau})\ln(y_{i,0}) + \\
&(1-e^{-\lambda\tau})\cdot\frac{\alpha}{1-\alpha-\varphi}\cdot[\ln(s_{k,i}) - \ln(n_i + g + \delta)] \\
&+(1-e^{-\lambda\tau})\cdot\frac{\varphi}{1-\alpha-\varphi}\cdot[\ln(s_{h,i}) - \ln(n_i + g + \delta)] + \gamma\cdot X_i \\
&+(1-e^{-\lambda\tau})\cdot\ln A_{i,0} + g\cdot(t - e^{-\lambda\tau}\cdot 0) + \varepsilon_{i,t}
\end{aligned} \tag{3.34}
$$

where the subscripts denotes province *i*;

'0' represents the start of each time span and '*t*' the end of each time span;

$y_{i,t}$ is real per capita GDP at the end of each time span;

$y_{i,0}$ is real per capita GDP at the start of each time span;

s_k is the share of the sum of fixed capital formation and FDI in regional GDP;

n is the growth rate of total population and $(g+\delta) = 0.05$;[56]

s_h is the rate of human capital accumulation. It is represented by student enrolment rate at the secondary school level; and

X is a variable matrix including industrialization level, transport infrastructure and openness. Industrialization, i.e., agricultural decline, is indexed by the ratio of primary industry output to GDP. Transportation is represented by the volume of freight traffic in logarithm. Openness is represented by the preferential policy index which is constructed by Démurger *et al.* (2002) who construct preferential policy indices for all the provinces in mainland China (see Table 2-6 in Chapter 2).

In equation (3.34), it can be interpreted as the signal of convergence that the coefficient on initial per capita income is less than 0, i.e. $-(1-e^{-\lambda\tau}) < 0$. The rate

[56] Most previous studies assume ($g+\delta$) to be the same for all countries/regions and the most frequently used value is 0.05 (see, for example, Mankiw, Romer and Weil (1992), Islam (1995) and Yao and Zhang (2001)), but this may not be true for every country or province in China. Therefore, the use of $\ln(n+g+\delta)$ is actually based on the strong assumption that all cross-sections under study have the same rate of technical progress and capital depreciation rate.

of convergence λ can be obtained from the estimated coefficient. Furthermore, by making the restriction that the coefficients on $\ln(s_k)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the neoclassical growth model and an additional restriction that the coefficients on $\ln(s_h)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the human-capital augmented Solow model, one is able to obtain such structural parameters as the output share of physical capital α and output share of human capital φ.

3.3.2 Data

The present study employs annual 1979-2004 data at the province level on China's 28 FCADs. Among the 28 FCADs, 21 are provinces[57], 4 are autonomous regions[58] and 3 are municipalities. The whole time period is divided into 5 five-year sub-periods: 1979-1984, 1984-1989, 1989-1994, 1994-1999 and 1999-2004. This is because yearly time spans are too short to be appropriate for studying growth convergence; as Islam (1995, p.1139) puts it 'short-term disturbances may loom large in such brief time spans'.

Data between 1979 and 1998 come from *Comprehensive Statistical Data and Materials on 50 Years of New China*. Data after 1998 come from various editions of the *China Statistical Yearbooks* and various editions of the statistical yearbooks at province level. Given that data are from different sources, one should plot the data of various series to check their consistency. Figure 3-4 gives an example of the consistency check by plotting the GDP data for the 28 provinces under study. Table 3-1

[57] Sichuan province is excluded from the analysis because its data on government expenditure on education, scientific activities, cultural activities and public health for some early years are missing.

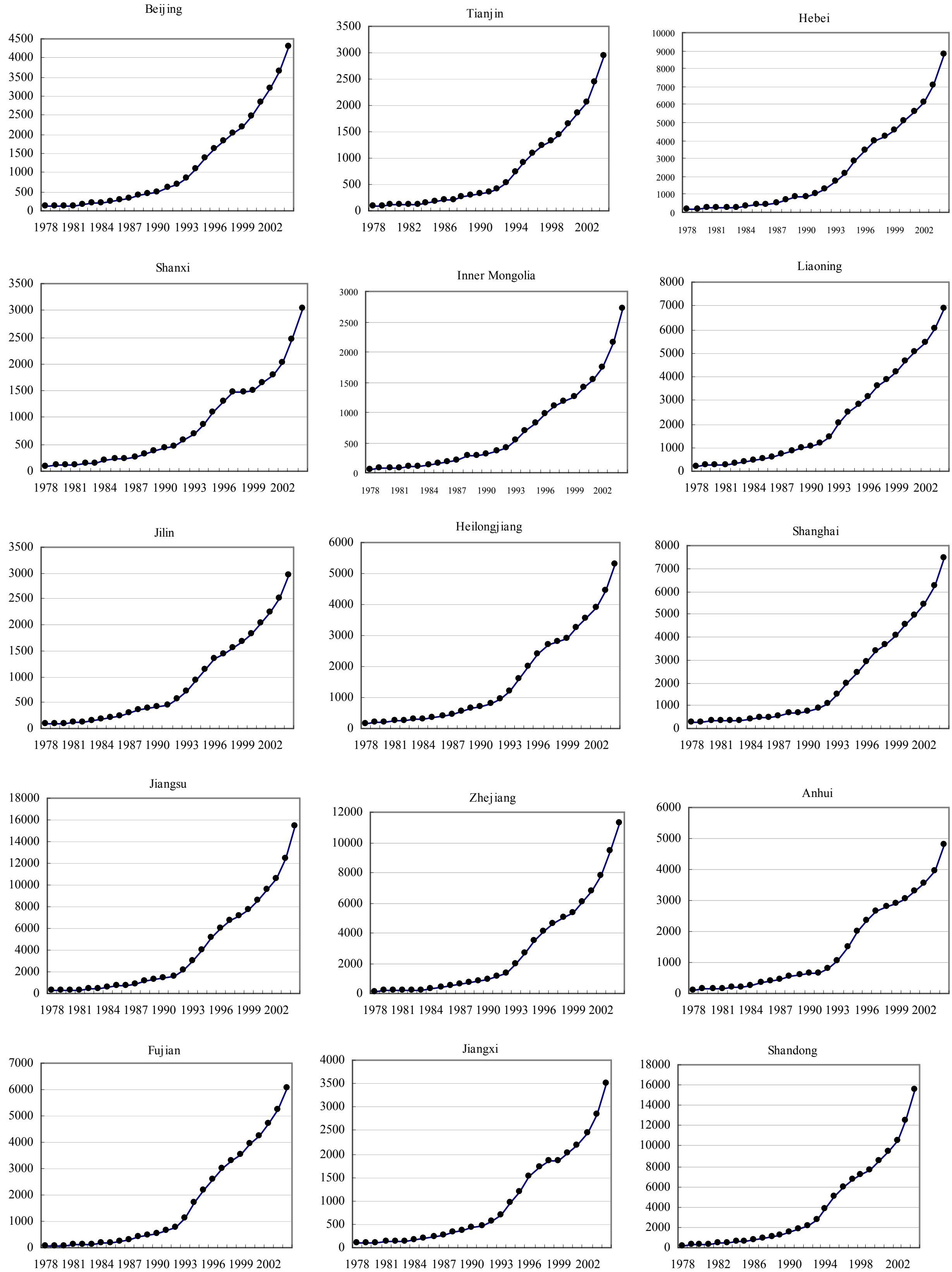
[58] Tibet, an autonomous region, is excluded because its data on price indices for early years are missing.

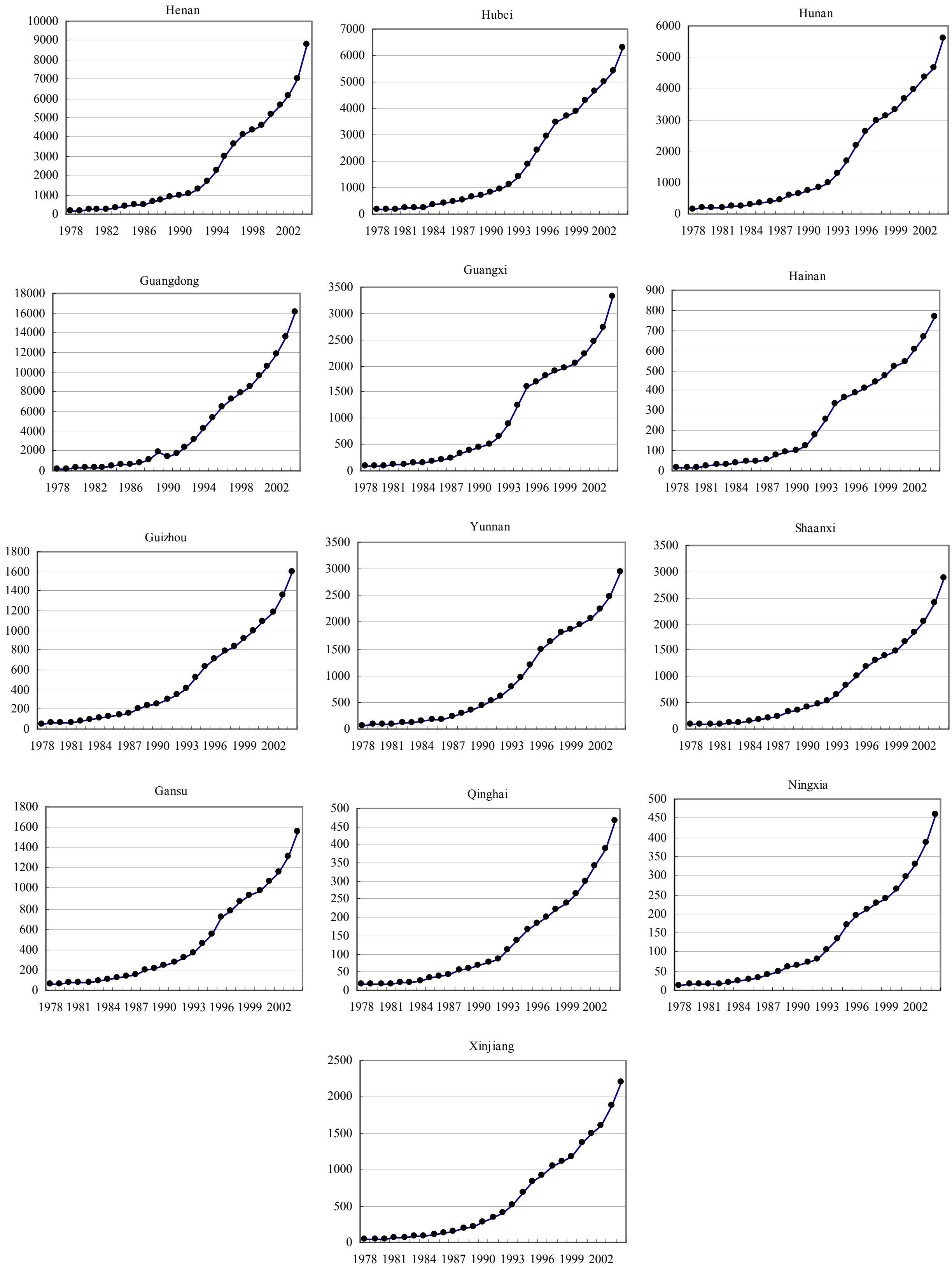
presents the basic description of the essential variables employed in the current analysis.

Table 3-1 Basic description of essential variables, 1979-2004

Variable	Mean	Standard Deviation	Min. Value	Max. Value
Growth of real per capita GDP over 5 years, $\ln(y_t\text{-}y_0)$	0.358	0.161	-0.090	0.767
Start of time span real per capita GDP, $\ln(y_0)$	6.666	0.670	5.292	8.661
Investment rate, s_k	0.341	0.112	0.153	0.693
Population growth rate, n	0.013	0.005	0.002	0.031
Student enrolment rate at the secondary school level	0.057	0.012	0.030	0.085
Preferential policy index	1.198	0.997	0.000	3.000
ln(volumes of freight traffic)	9.993	0.966	6.912	11.558
Share of provincial GDP by the primary industry	0.244	0.114	0.016	0.572

Figure 3-4 Plotting the nominal GDP data by province (1979-2004)





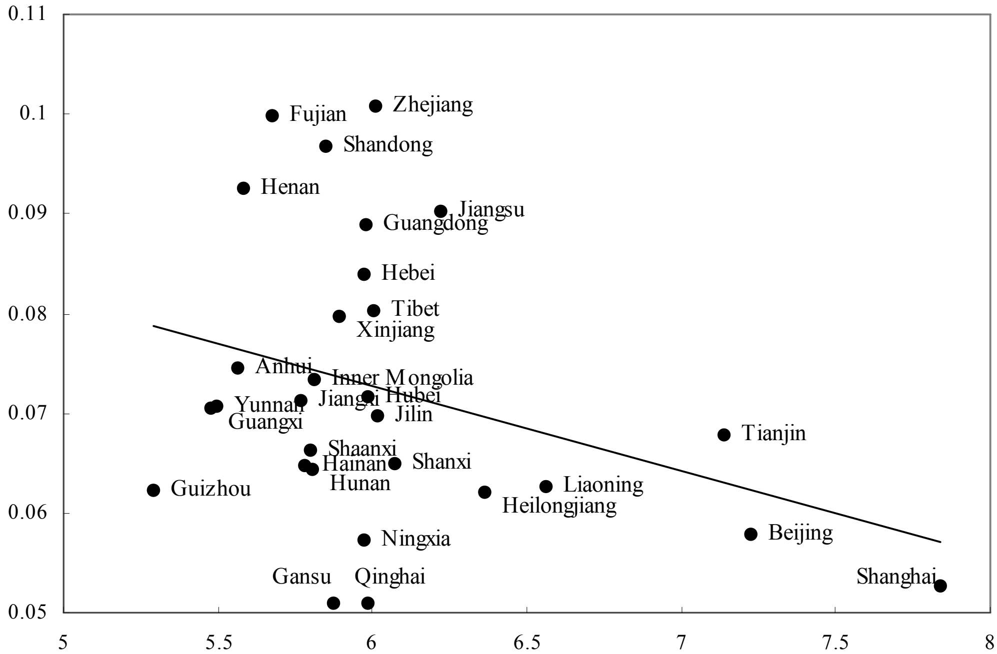
Note: Published data on GDP before 1987 were estimated on the basis of data on national income, which, as can be seen, does not affect the consistency of the GDP data.

3.4 EMPIRICAL RESULTS

First of all, by scatter plotting the average annual growth rate of per capita GDP against the logarithmic per capita GDP in 1979 in Figure 3-5, we see, at the beginning of the Reform, that many provinces were at a similar level in terms of real per capita GDP. However, due to the imbalance of economic reform policies and open-up policies across different provinces in China, these provinces had unequal chances to develop their economies. As a result, most provinces in the east Coastal Area grew particularly fast, which explains the impressive narrowing of the gap of income level in the Coastal Area during 1979-2004 (see the Coastal Area line in Figure 3-2); while inland provinces, especially those in the Western Zone, such as Gansu, Qinghai and Ningxia, show least development. Furthermore, economic development within the Inland Area varied greatly from province to province. For example, Hebei and Ningxia had the same income level of RMB392 in 1979, but they turned out very differently, with Hebei's income level being twice that of Ningxia in 2004. The varying performance of the inland provinces explains why a slight upward trend of divergence appears can in terms of absolute income level within the Inland Area during the post-reform era (see the Inland Area line in Figure 3-2).

From Figure 3-5 we can see some trace of beta-convergence, since some initially rich provinces, such as Shanghai, Beijing, Tianjin and Liaoning, grew relatively more slowly, while some initially poor provinces, such as Henan, Fujian and Shandong, grew relatively faster. However, the evidence of such 'catch-up' is not convincing, since quite a few observations lie far away from the trend line; for example, Gansu and Qinghai in the lower panel of the figure and Zhejiang and Fujian in the upper panel of the figure.

Figure 3-5 ln(real per capita GDP in 1979) vs. growth



Note: The x-axis presents ln(real per capita GDP in 1979) and the y-axis presents average annual growth rate of real per capita GDP over 1979-2004.

To formally test for beta-convergence, regressions of $\ln(y_{i,t} / y_{i,0})$ on $\ln(y_{i,0})$ are run either solely or together with other controlling factors and the coefficient on $\ln(y_{i,0})$ indicates whether any evidence of beta-convergence emerges. Specifically, when the initial income level is the only explanatory variable, if the coefficient on it is less than 0 absolute beta-convergence is present; and when the explanatory variables include more than the initial income level, if the coefficient on the initial income level is less than 0, conditional beta-convergence is present. Furthermore, by making the restriction that the coefficients on $\ln(s_k)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the neoclassical growth model and an additional restriction that the coefficients on $\ln(s_h)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the human-capital augmented Solow model, one is able to obtain such structural parameters as the output share of physical capital α and output share of human capital φ.

Turning to the empirical results, we first look at the absolute beta-convergence. Regressing $\ln(y_{i,t}) - \ln(y_{i,0})$ on the sole explanatory variable $\ln(y_{i,0})$ produces a highly significant coefficient on initial income level, which is greater than 0 (first column of Table 3-2). This provides strong evidence of absolute beta-divergence within mainland China between 1979 and 2004.

The regressions in columns (2)-(6) of Table 3-2 test for conditional beta-divergence and the importance of relevant factors, such as the physical capital investment rate, population growth, rate of human capital accumulation, industrialization level, transport infrastructure and openness level. Given the presence of heteroskedasticity across panel members, the regressions in columns (2)-(4) use the generalized least squares (GLS) estimator. In regressions (5) and (6), given the problems of endogeneity among the freight traffic and openness variables, the generalized method of moments (GMM) estimator has been used to simultaneously control for the problems of endogeneity and heteroskedasticity. In the GLS regressions, fixed effects for panels and time dummies are included in the regressions. In the GMM regressions, zone dummies and time dummies are included in the regressions.

Table 3-2 Regressions on $\ln(y_t)$-$\ln(y_0)$ to test for beta-convergence in China (1979-2004)

	(1)	(2)	(3)	(4)	(5)	(6)
ESTIMATION METHOD	OLS	GLS	GLS	GLS	GMM	GMM
VARIABLE	COEF. (S.E.)	COEF. (S.E.)	COEF. (S.E.)	COEF. (S.E.)	COEF. (S.E.)	COEF. (S.E.)
Constant	0.092 (0.135)	2.443 (0.481)***	4.066 (0.556)***	3.278 (0.565)***	1.494 (0.577)***	1.587 (0.551)***
$\ln(y_0)$	0.039 (0.020) *	-0.319 (0.042)***	-0.420 (0.044)***	-0.419 (0.042)***	-0.234 (0.034)***	-0.250 (0.033)***
$\ln(s_k)$		0.138 (0.044)***	0.106 (0.043)**	0.108 (0.041)***	0.147 (0.077)***	0.113 (0.059)**
$\ln(n+g+\delta)$		-0.151 (0.108)***	-0.076 (0.102)	-0.208 (0.101)***	-0.051 (0.140)***	-0.147 (0.088)*
$\ln(s_h)$			0.245 (0.049)***	0.183 (0.051)***	0.070 (0.077)***	0.161 (0.077)**
ln(primary industry ratio)				-0.087 (0.023)***	-0.057 (0.024)***	-0.091 (0.023)***
ln(freight traffic)					0.035 (0.016)***	0.033 (0.016)**
Openness						0.073 (0.026)***
Adjusted/uncentred R-squared	0.020	---	---	---	0.940	0.944
Wald chi2 (*Prob>chi2*)	---	770.33 (0.00)	935.67 (0.00)	1006.79 (0.00)	---	---
Constant		2.485 (0.310)***	3.075 (0.328)***	2.962 (0.303)***	0.991 (0.303)***	1.211 (0.316)***
$\ln(y_0)$		-0.320 (0.040)***	-0.381 (0.041)***	-0.408 (0.038)***	-0.223 (0.034)***	-0.243 (0.034)***
$\ln(s_k)$-$\ln(n+g+\delta)$		0.141 (0.041)***	0.076 (0.042)*	0.102 (0.040)***	0.148 (0.077)***	0.113 (0.060)**
$\ln(s_h)$-$\ln(n+g+\delta)$			0.198 (0.044)***	0.166 (0.043)***	0.029 (0.065)***	0.134 (0.065)**
ln(primary industry ratio)				-0.094 (0.021)***	-0.061 (0.023)***	-0.096 (0.024)***
ln(freight traffic)					0.032 (0.015)***	0.030 (0.014)**
Openness						0.076 (0.026)***
Wald test (*pvalue*): $\ln(s_k)=-\ln(n+g+\delta)$		0.01 (0.907)	0.07 (0.787)	0.86 (0.355)	0.48 (0.489)	0.07 (0.787)
Wald test (*pvalue*): $\ln(s_h)=-\ln(n+g+\delta)$			1.98 (0.159)	0.04 (0.840)	0.01 (0.912)	0.01 (0.932)
Implied λ		0.077	0.096	0.105	0.050	0.056
Implied $\alpha^{\text{physical capital}}$		0.31	0.12	0.15	0.37	0.23
Implied $\varphi^{\text{human capital}}$			0.30	0.25	0.07	0.27

To be continued...

Notes:

1. The samples for the LSDV and GLS regressions in columns (1)-(4) include 5 time spans and 28 cross-sections. The samples for the GMM regression in columns (5) and (6) include 4 time spans and 28 cross-sections.
2. In the GLS regressions, the problem of heteroskedasticity has been controlled for. In the GMM regressions, the problems of endogeneity of the openness and freight traffic variables and heteroskedasticity have been simultaneously controlled for.
3. The LSDV and GLS regressions include region dummies and time dummies. The GMM regressions include zone dummies and time dummies.
4. Adjusted R-squared statistic is reported for the OLS regression in column (1). Uncentred R-squared statistic is reported for the GMM regressions in columns (5) and (6). The R-squared statistic is less useful as a diagnostic tool for GLS regressions. Instead, Wald chi-square is reported for the GLS regressions in columns (2)-(4).
5. y_t is end of time span per capita GDP at 1978 prices;
   y_0 is start of time span per capita GDP at 1978 prices. Evidence of beta-convergence is captured by its coefficient less than 0;
   s_k is investment rate and is measured by averages over corresponding time spans;
   n is population growth rate. It is measured by averages over corresponding time spans;
   s_h measures the rate of human capital accumulation. It is indexed by student enrolment rate at the secondary school level.
   Openness is measured by preferential policy index which is constructed by Démurger *et al*. (2002);
   Freight traffic measures regional transportation level; and
   Primary industry ratio represents a region's industrialization level, the higher value of this index, the less industrialized of the region.
6. Standard errors are in the parentheses (robust standard errors for the GMM regressions).
7. * Significant at 10% significance level.
   ** Significant at 5% significance level.
   *** Significant at 1% significance level.

3.4.1 Testing for the Growth Model Hypotheses

The neoclassical growth theory suggests that economic growth is positively related to saving but negatively related to population growth and predicts identical magnitudes but different signs of coefficients on the two variables. In addition, the human-capital augmented Solow model also predicts identical magnitudes but different signs of coefficients on the human capital variable and the population growth variable. Acceptance of these two hypotheses, together with the presence of beta-convergence, enables us to recover the underlying structural parameters.

Columns (2)-(6) in Table 3-2 show that the saving rate $\ln(s_k)$ and population growth $\ln(n+g+\delta)$, two basic explanatory variables in the neoclassical growth model, are important factors in the Chinese economy. Columns (3)-(6) in Table 3-2 show that in the human-capital augmented Solow model, the role of human capital in the Chinese economy is as important as that of physical capital. The two hypotheses stated above are not rejected in any of the regressions.

A third hypothesis of the neoclassical growth model and the human-capital augmented Solow model is the prediction of conditional beta-convergence. This is realized in China through all the regressions in columns (2)-(6) which test for conditional beta-convergence within the whole of mainland China.[59]

3.4.2 Speed of Convergence & Output Share of Physical Capital

The estimated speed of convergence λ and structural parameters – such as output

[59] This can be seen from the fact that the coefficients on $\ln(y_0)$, that is, $-(1-e^{-\lambda\tau})$ are less than 0 for all the conditional beta-convergence regressions.

share of physical capital α and output share of human capital φ – which allow researchers to compare the results across different regressions, make it possible to compare the results across different regressions in Table 3-2 and to compare the empirical findings of the current study with those of previous studies in the literature.

Values of less than 0 for the coefficients on the initial income variable in columns (2)-(6) of Table 3-2, that is, $-(1-e^{-\lambda\tau})<0$, provide strong evidence of conditional beta-convergence within China.

The estimated values for the convergence speed λ and structural parameters, output share of physical capital α and output share of human capital φ, vary across different regressions. In the neoclassical growth model in column (2) of Table 3-2, where convergence is conditional only on the saving rate and population growth variables, the estimated λ is 7.7 per cent per annum and the estimated α is 0.31, which is close to the national account figure of 1/3.

As we shall see, when the model is further modified to better explain China's growth empirics, the results, including the estimated convergence speed and structural parameters, become different. The regression in column (3) presents the human-capital augmented Solow model. A value of -0.420 for the coefficient on the initial income variable serves as evidence of beta-convergence within China. In this regression, the human capital variable, which is indexed by the student enrolment rate at the secondary school level, is highly significant. This means that convergence is not only conditional on the saving rate and population growth variables, but also conditional on the human capital variable. The estimated λ is 9.6 per cent per annum, the estimated output share of physical capital α, is 0.12 and the estimated output share of human capital φ is 0.30.

To further examine the growth empirics of China, the industrialization, transportation and openness variables are included in the human-capital augmented neoclassical growth model. The results are presented in columns (4)-(6). The regression in column (6) serves as the final model for the current convergence study. In this regression, the GMM estimator is employed to control for the problem of endogeneity in the openness and transportation variables. The implied λ in column (6) of Table 3-2 suggests that Chinese provinces converged at a rate of 5.6 per cent per annum between 1979 and 2004, indicating a 'half-life' of convergence of around 25 years.[60] In other words, poor provinces of China grow faster than rich provinces and, given unchanged conditions, the poor provinces would eventually catch up with the rich in approximately 13 years.

3.4.3 The Effect of Human Capital

Human capital is as important as physical capital in an economy; without taking account of it, one is likely to obtain biased coefficients and thus biased structural parameters. In the current study, two measures of human capital have been tried:[61] a

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[60] The approximate half-life is computed as $\ln(2)/\ln(1+\lambda)$, where λ is the speed of convergence.

[61] Average schooling has not been tried as a method of measuring the level of human capital. This is because in early years, there were no separate data on junior secondary education from most provinces. Instead, published data pertaining to secondary education included both junior and senior secondary levels. Therefore, it is not possible for these early years to calculate the average schooling years in most provinces.

set of three variables representing school enrolment rates at three school levels[62] and government expenditure on education, scientific activities, cultural activities and public health. The empirical results show that the performance of government expenditure varies greatly across samples and depend too much on the technique employed.[63] In general, among the three proxies of school enrolment rate, only the secondary school enrolment rate significantly and positively affected the Chinese economy. The impact of the higher education institute enrolment rate was ambiguous, while the impact of the primary school enrolment rate was significantly negative. The negative relationship between primary school education and economic growth is, however, not unrealistic. As we recall from the regional distribution of education presented in Chapter 2, on average, the poor provinces in the less developed Inland Area had higher primary school enrolment rates than the rich provinces in the more developed Coastal Area. But, because the less developed provinces in China generally have a larger proportion of population aged 0-14 years, it cannot be concluded that the poor provinces in China are more educated at the primary level than are the rich provinces. This is because student enrolment rate in the current analysis is defined as the number of students enrolled in schools relative to the total provincial population. In the current study, consequently, the student enrolment rate at secondary school level is used to measure human capital.

In the human-capital augmented growth models in regression (3)-(6) of Table 3-2, the human capital variable turns out to have an important impact on the growth of the

[62] They are measured by the ratio of the number of students enrolled in institutes of corresponding to the total regional population.

[63] The results when using government expenditure as the human capital variable are not reported here, due to limited space, but are available from the author upon request.

Chinese economy, an impact which is both statistically and quantitatively significant. The magnitude of the coefficient on this variable of 0.134 in the final regression in column (6) suggests that a ten per cent increase in human capital increases Chinese economic growth by around 1.34 percentage points. With the acceptance of the two hypotheses that the coefficients on $\ln(s_k)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the neoclassical growth model and that the coefficients on $\ln(s_h)$ and $\ln(n+g+\delta)$ have identical magnitudes but different signs in the human-capital augmented growth model, the final regression recovers a value of 0.27 for the exponent of the human capital variable for the whole of China. This value, by comparison with the exponent of physical capital of 0.23, indicates that in the Chinese economy human capital had a greater impact than physical capital on magnitude.

3.4.4 The Effect of Industrialization

As we saw in Chapter 2, the Reform has successfully changed the structure of the economy from agriculture-dominated to industry-dominated. China's secondary industry, or the industry sector in a broad sense, which includes mining and quarrying, manufacturing, the production and supply of electricity, water and gas and construction, dominates the economy not only in terms of the volume of output, but also in its contribution to the economic growth in the country.

Hence, the economic structure should be considered in studying the Chinese growth empirics. In this study, the output share of primary industry (or equivalently, the agriculture industry in a broad sense, which includes the agriculture, forestry, hunting and fishing industries in China), is employed to measure the role of the agriculture industry in the Chinese economy. The results in columns (4)-(6) of Table 3-2 show that this variable is highly significant in the Chinese growth models. The final regression in column (6) recovers a negative coefficient of -0.091 on this variable, which suggests that a 10 per cent increase in the share of primary industry reduces Chinese GDP growth by 0.91 percentage points.[64]

As we note, a lower value of this variable indeed implies a higher share for non-agriculture industry, which includes the industry sector in a broad sense and tertiary industry in China. Therefore, the results can be interpreted in another way: that a Chinese province develops faster if it is more non-agriculturalized.[65]

3.4.5 The Effect of Transport Infrastructure

The rapid Chinese economic development has benefited from the speedy development of the Chinese transportation systems. However, the transportation systems of China have developed unevenly in the post-reform era. On the one hand, impressive development has been seen in the highway system and the civil aviation system. The length of highways and civil aviation routes in operation increased from 0.89 and 0.15 million kilometres in 1978 to 1.87 and 2.05 million kilometres in 2004 respectively. On the other hand, the railway system, which was the major transportation tool in China in former years, has hardly developed. The length of railways in operation increased very little, from 0.05 million kilometres in 1978 to

[64] It could be the other way around; that is, when China's GDP grows, the share of agriculture in China's GDP is reduced.

[65] However, Yao (2000) claims that a 'sustainable economic growth has to depend on a balanced development of agriculture and the industrial sector' (p.47) and that China's agriculture is still an important force for the growth of other sectors, even though its share in GDP declined sharply over time (p.33).

0.07 million kilometres in 2004. It is obvious that the development of the railway system, with a growth rate of 1.42 per cent per annum, lagged far behind the growth of the Chinese economy, which grew at an average rate of more than 8 per cent per annum. Comtois (1990) claims that 'railway transport facilities were far from sufficient to meet the demand and traffic confusion and congestion were rampant.' Sun (2006) finds that the Chinese railway system can only meet 35 per cent of freight traffic demand, which prevents many enterprises from sustaining normal production activities. See Lu (2000) and Li (2007) for more details on the relation between the Chinese railway system and Chinese economic development.

For the current analysis, two proxies have been tried to measure a province's transport infrastructure level: one derives from the aspect of supply, which is indexed by a set of two variables, namely the lengths of both highways and railways in operation relative to a province's territory; and the other derives from the aspect of demand, which is indexed by the volume of freight traffic. For the first proxy, the empirical results find a significantly positive coefficient on the highway variable, but a significantly negative coefficient on the railway variable. However, the negative coefficient on the railway variable is unacceptable, even though the development of the railway system lagged far behind the growth of GDP.

The other proxy, the volume of freight traffic, produces more satisfactory results. It is obvious that faster developing economies have a higher demand for a better developed transport infrastructure to meet their growing freight traffic demands. For this reason, the volume of freight traffic reflects well both the transport infrastructure level and economic development of a province. The total volume of freight traffic at the national level increased from a capacity of 2.49 billion tons in 1978 to 17.01 billion tons in 2004, growing at 7.68 per cent per annum, which is quite close to the annual growth rate of 8.47 per cent of Chinese real GDP. Within the total volume of freight traffic, around 74.60 per cent was undertaken by the highway system and 14.64 per cent by the railway system.

The estimate of the Chinese growth model which uses freight traffic as the measure of transport infrastructure shows that this variable is highly significant (see columns (5)-(6) of Table 3-2). The final regression in column (6) finds a value of 0.033 for the elasticity of output with respect to transportation for the whole country, indicating that a 10 per cent increase in the volume of freight traffic would increase Chinese GDP growth by 0.33 percentage points.

3.4.6 The Effect of the Degree of Openness

As we saw in Chapter 2, another significant change brought by the Chinese Reform is to have shifted the Chinese economy from a closed economy to an open one. There are a few proxies in the literature to measure the regional openness level, such as the ratio of imports and/or exports to GDP (see, for example, Edwards (1993), Wang (2005) and Liang (2006)); ratio of FDI to GDP (see, for example, Lv (2003), Yang (2005) and Chanda *et al*. (2006)); ease of access to foreign markets represented by distance to the sea (see, for example, Radelet and Sachs 1998 and Liang (2003)); and foreign policies towards foreign trade and attracting foreign capital (see, for example, Krueger (1997) and Démurger *et al*. (2002)). For the current analysis, two different proxies have been tried to measure the level of openness: the share of FDI in the total investment of a province and the preferential policy index.[66] The former indicator is not used for the current analysis, since it is found that the positive impact on the Chinese economy of FDI is not statistically significant.[67] When the preferential policy index is employed instead, regressions produce robust results.

Column (6) of Table 3-2 reports the performance of the preferential policy index in the Chinese economy. The high significance of this variable suggests that opening up to the outside world greatly enhanced Chinese economic development. The magnitude of the coefficient on the openness variable, 0.073, implies that a 10 per cent increase in the measure of openness increases Chinese GDP growth by 0.73 percentage points.

3.5 CONCLUSIONS

This chapter reports the phenomenon of convergence within China's 28 provinces over the post-reform period, 1979-2004. The analysis shows that income inequality between the rich provinces and poor provinces of China was substantial. The plotting of the standard deviation in the cross-sectional distribution of real per capita GDP illustrates that income inequality in income level terms decreased dramatically within the faster developing Coastal Area of China, but increased more slowly within the whole country and the less developed Inland Area.

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[66] The preferential policy index is constructed by Démurger *et al.* (2002) and is summarized in Table 2-6 in Chapter 2.

[67] A significantly positive impact of FDI on production has been widely identified. For example, Yao and Wei (2007) find that FDI, which contributes about 5 per cent of total investment in China, positively influences output at the national level. Yao (2006) also finds that FDI has a positive impact on the Chinese economy. However, Hu and Jefferson (2002) identify significantly negative spillover effects of FDI on domestic firms (cited from Yao and Wei (2007), p.229).

The focus of the current analysis has been on beta-convergence, that is, whether initially poor provinces grew faster than initially rich provinces. The findings are summarized as follows:

First of all, it is found that human capital, openness, transport infrastructure and economic structure, together with the saving rate, population growth and initial income level variables which are preserved in the basic Solow model, are important in China's economic growth. All the coefficients on the variables appear to have correct signs. Specifically, a province grows faster if it has a higher saving rate, slower population growth, more human capital, a higher degree of openness, better transport infrastructure and is more industrialized.

Second, absolute beta-convergence was not present for China as a whole in the post-reform era. However, conditional beta-convergence was evident there. The current study identified a moderate speed of convergence of 5.6 per cent per year for China between 1979 and 2004. Accepting the hypotheses that the coefficients on investment rate and population growth have identical magnitudes but different signs in the neoclassical growth model and that the coefficients on human capital accumulation and population growth have identical magnitudes but different signs in the human-capital augmented Solow model, we find that output share of physical capital α was 0.23 and output share of human capital φ was 0.27 for China as a whole during the period 1979-2004.

The policy implications of the above empirical results are as follows:

First of all, it can be suggested that the Chinese government should make great efforts to develop education. The current study indicates that a higher rate of human capital accumulation can greatly promote provincial economic growth. In this study, the accumulation of human capital is measured by student enrolment rate at the secondary school level. The importance of education has also been acknowledged in the growth literature and growth experiences of other countries. In the current situation, where the average educational level of Chinese people is far lower than that in developed countries, the Chinese government should develop education as a priority by increasing investment in it in order to improve the accumulation of human capital and thus improve its citizens' contributions to Chinese economic development.

Second, it can be suggested that the Chinese government should increase its support for developing the less developed Inland Area. In 2000, the central government of China launched the Grand Western Development programme to promote social and economic progress in the less developed Central and Western Zones. In order to give a huge push to this project, the Government provides financial aid and offers favourable policies to encourage the inflow of capital and advanced technologies. Yet, huge gaps still exist in the relative degrees of openness, infrastructure construction and industrialization level between the Coastal Area and the Inland Area. A direct result of this is the agglomeration of physical and human capital in the Coastal Area. Therefore, together with the power of the market economy system, the central government should use its power to re-allocate resources more fairly among the different Chinese regions. Through reducing tax and increasing investment on infrastructure construction in the less developed Inland Area, its industrialization can be accelerated. In addition, because opening up to the outside world can attract FDI and foreign advanced technologies, the central government should implement more favourable policies to improve the degree of openness in of the less developed Inland Area.

CHAPTER 4: INTER-PROVINCIAL COMPARSON OF TOTAL FACTOR PRODUCTIVITY IN CHINA OVER 1979-2004

It is widely acknowledged that economic expansion represents the sum of two sources of growth. On the one side are increases in 'inputs': growth in employment, in the education level of workers and in the stock of physical capital. On the other side are increases in the output per unit of input, i.e. productivity.

As a measure of productivity, total factor productivity (TFP) is believed to be superior to labour productivity.[68] The concept of TFP was firstly raised by Solow (1957), who identifies the changes in productivity with shifts in the production function. TFP, which is often referred to as the 'Solow residual' in the literature, addresses any effects in total output not explained by factor inputs and productivity. For instance, Solow (1957) defines TFP as a 'sort of measure of our ignorance,' Abramovitz (1962) defines TFP growth as 'the effect of "costless" advances in applied technology, managerial efficiency and industrial organization' and Denison (1967) regards TFP as 'technological progress in the broadest sense'.[69] Some researchers, such as Caves, Christensen and Diewert (1982b) and Islam (1999) even distinguish TFP from technical advances; and some researchers such as Nishimizu and Page (1982) and Battese and Coelli (1995) further accurately decompose TFP into technological efficiency and technical progress.

[68] Kravis (1976) claims that it is desirable that TFP rather than labour productivity alone should be compared.

[69] Hall and Jones (1996), however, equalize TFP to labour productivity.

There has been a number of TFP studies in the literature and quite a few approaches have been developed to study this issue since its emergence. In the early stage, due to limitations in data availability and reliability, TFP studies focused on the US and its main trading partners, using the growth accounting approach (see, for example, Kendrick (1956), Solow (1957), Denison (1967), Barger (1969), Maddison (1972), Jorgenson and Nishimizu (1978) and Christensen *et al*. (1981)). The international comparison of TFP was extended to a large sample of countries, including both developed and developing countries, when methods of cross-sectioning TFP studies became more sophisticated (see, for example, Hall and Jones (1996) and Islam (1999)). In addition to their interest in TFP studies which employ aggregate output data, researchers also show great interest in the comparison of TFP in the industrial sector. For instance, by means of constructing non-parametric Malmquist indices from a frontier production function, Nishimizu and Page (1982) examine the changes in technical progress and changes in technological efficiency in Yugoslavian industries; and Battese and Coelli (1995) study TFP changes in 14 Indian paddy farms by means of parametric stochastic frontier analysis.[70] Attention has also been drawn to the determinants of TFP growth. For instance, Griliches (1967) argues that changes in applied technology may be associated with the construction of new types of capital equipment. Islam (1999) claims that increases in productivity may result from better management or better economic policy, but in the long run are primarily due to increases in knowledge. Huang and Shi (2005) and Jin *et al*. (2006) find that factors such as investments in R&D, technological diffusion through imports and exports greatly contribute to TFP growth as well.

[70] Other TFP studies focusing on industries include Unel (2003) and Shen (2006).

The issue of TFP also receives considerable attention in China. It is well known that China is competitive in producing labour-intensive products; however, in recent years China has been losing such comparative advantage now that south Asian countries, such as India and Pakistan, have become more competitive in this regard. Many researchers have suggested that China should change its economic structure and produce technology-intensive products.

With respect to technological progress in China, it is well known that the four great Chinese inventions (paper-making, gunpowder, movable-type printing and the compass) have greatly contributed to the progress of civilization. However, in recent centuries China lagged far behind the Western nations. It is often reported that outdated machinery and equipment are still used in many Chinese factories, which results in low labour productivity, high energy consumption and a high probability of producing poor quality products. Despite the Chinese government's efforts to accelerate technological progress,[71] many problems still exist in the Chinese science and technology sector. The main problem is low investment in this sector. Although the R&D/GDP ratio has improved in recent years from a rate of 0.6 per cent in 1996 to 1.3 per cent in 2003,[72] Guo (1998, p.110) shows that the R&D/GNP ratio of China is much lower than that of many advanced countries, such as the USA (2.9 per cent in 1988), Japan (3.0 per cent in 1991), France (2.4 per cent in 1991) and the UK (2.1 per cent in 1991).

[71] For example, since the mid-1980s, China has implemented a package of plans for the development of new technology, high-technology and traditional technology.

[72] Figures are cited from Jian and Jefferson (2005).

The estimated rate of China's TFP growth varies greatly in previous studies. A number of researchers find that China's TFP growth rate was low and made little contribution to China's economic growth. Such opinions are found in much of the literature. For example, Krugman (1994) claims that China's economic growth is unsustainable because, like the other East Asian countries, China's economic development mainly depends on increased capital and labour inputs instead of improvements in productivity. Kalirajan *et al*. (1996) report that TFP growth in the Chinese agriculture sector was negative in 20 out of 28 provinces in the pre-reform period of 1970-1978; it turned positive in almost all provinces in the 1979-1983 reform period, but reverted to negative in 16 out of 28 provinces between 1984 and 1987. Sachs and Woo (1997) point out that China's growth experience is similar to the experience of other East Asian economies and is attributable mainly to factor accumulations. Young (2003) estimates the TFP growth rate of the Chinese non-agricultural sector to be 1.4 per cent per between 1978 and 1998, which accounts for only 9 per cent of China's GDP growth.

Other researchers, such as Ezaki and Sun (1999), Ao and Fulginiti (2003) and Hu (2003), find modest rates of TFP growth in China and claim that productivity improvements account for a significant proportion of the dramatic increase of China's GDP over the past 20 years. Ezaki and Sun (1999), by means of the traditional growth accounting approach, find that the growth rate of TFP in China was as high as 3 to 4 per cent between 1981 and 1995. Ao and Fulginiti (2003), on the basis of stochastic frontier analysis, obtain the average national TFP growth rate over 1978-1998 as 3.3 per cent. However, Maddison (1998), who uses the growth accounting method, finds that China's TFP increased at a rate of 2.23 per cent per year between 1978 and 1995. Given China's real GDP growth at 8.93 per cent per year over the corresponding period, Maddison's finding implies that TFP accounted for 25 per cent of Chinese real GDP growth between 1978 and 1995.[73]

Table 4-1 Summary of the literature on TFP growth rate of China and rate of the TFP contribution to Chinese GDP growth over 1978-1998 (%)

Source	Approach	Rate of TFP Growth	Rate of TFP's Contribution
The present study	Malmquist index	1.46	17.25
Ezaki and Sun (1999)	Growth accounting	3~4	40
Young (2003)	Growth accounting	1.4	9
Zhang and Shi (2003)	Growth accounting	2.8	28.9
Ao and Fulginiti (2003)	Stochastic frontier	3.3	38.7

Note:
1. No human capital is taken into account in the production function in these studies.
2. The whole period sample for the present study covers 1979-2004. To make the results of the current study comparable with the literature, the data covering the sub-sample 1979-1998 are used to calculate the values shown in the first row.

This study re-examines the TFP progress in China. To do so, non-parametric Malmquist indices are constructed to search for the sources of China's economic growth and annual data on the Chinese 29 provinces over 1979-2004 are employed.

This chapter is organized as follows. Section 4.1 gives a brief review of different approaches to TFP studies in the literature. Section 4.2 presents the construction of the Malmquist index through which the TFP growth rate is calculated. Section 4.3 describes the data. Section 4.4 presents the empirical results for TFP growth and its components and section 4.5 draws some conclusions.

[73] The TFP growth rate of 2.23 per cent comes from Maddison (1998), where the contribution rate of TFP is 58 per cent. The value of 25 per cent for the contribution rate of TFP stated in the above is based on the author's calculation, which is obtained from dividing the TFP growth rate, 2.23 per cent, by the growth rate of China's real GDP, 8.92 per cent.

4.1 APPROCHES TO TFP STUDIES IN THE LITERATURE

Several approaches to TFP studies have been found in the literature since the emergence of this issue. Some researchers use a non-parametric time-series growth accounting approach to study TFP trends within a country (e.g. Kendrick (1956), Solow (1957), Denison (1967) and Jorgenson (1988)), some use a non-parametric cross-section growth accounting approach to give an international comparison of the TFP trend (e.g. Hall and Jones (1996, 1997, 1999) and Abramovitz (1993)), some use the panel regression method (e.g. Islam (1999)) and certain researchers, by estimating frontier production functions, decompose TFP into technological efficiency and technical progress (e.g. Ao and Fulginiti (2003), Krüger (2003); and Maudos *et al*. (2003)). Those approaches which are unable to decompose TFP are categorized in the current study as traditional approaches and those able to decompose TFP are categorized as frontier approaches.

4.1.1 Traditional Approaches

The traditional approaches include the time-series growth accounting approach, the cross-section growth accounting approach and Islam's panel regression approach.

The time-series growth accounting approach relies on accounting for the contribution of the increase in the input factors to the growth of output and the residual part of the output growth rate which cannot be accounted for is then labelled TFP growth. This approach, which is introduced in Solow (1957), provides a 'fully fledged, flexible framework' (McAdam and Allsopp 2007) for analysing the source of economic growth.

Due to data constraints, the application of time-series growth accounting has remained limited to small samples of developed countries. Yet, from the viewpoint of technological diffusion and TFP-convergence, the extent and evolution of TFP differences across wider samples of countries is of particular interest (Islam 1999, p.493). This gave rise to two new approaches to international TFP comparison: the cross-section growth-accounting approach employed by Abramovitz (1993), Krugman (1994), Hall and Jones (1996), Dougherty and Jorgenson (1996), Young (1995, 2000) and Li and Li (2006),[74] and the regression approaches presented in Islam (1999, 2003) and Virmani (2004).

The advantages of non-parametric growth accounting approaches include, first, that these approaches do not impose a specific form on the aggregate production function; second, they do not require the estimation of parameters of the production function; and third, they also allow factor share parameters to vary across countries. However, the growth accounting approaches are not without their shortcomings. First of all, they assume that factors are paid their marginal products, though this occurs only in perfectly competitive markets. Second, the computation of country-specific values of the factor share parameter is made on the basis of an assumed uniform rate of return across countries, which, however, does not hold. Third, the growth accounting approach with cross section data requires the prior ordering of countries to calculate productivity level and therefore TFP indices are sensitive to the ordering chosen and to the inclusion/exclusion of countries. Fourth, the growth accounting approaches assume that the technology is fully utilized, which is not the case, and thus these

[74] With the cross-section growth accounting approach, Diewert (1976) derives the translog multilateral indexes of TFP from the translog production function. The translog quantity indexes have also been employed for international comparison of TFP by Christensen et al. (1981), etc.

approaches produce biased estimates of technical change rates.

The advantages of Islam's panel regression approach over growth accounting approaches arise from their overcoming the first three disadvantages of the growth accounting approaches, while its disadvantages are reflected in its incapacity to deal with the problems which have been overcome by the growth accounting approaches.

4.1.2 Frontier Approaches

Frontier approaches to TFP studies were developed by some researchers, such as Battese, Islam, Färe, Nishimizu and Krüger, who recognized that TFP growth may not be synonymous with technological change. Abramovitz (1956) first brought this to notice and it was also the position taken by many researchers. In his Nobel address, Solow (1987) unpacks 'technological progress in the broadest sense' into 'technological progress in the narrow sense' and several other constituents such as improved allocation of resources and economies of scale. Nishimizu and Page (1982) claim that the distinction between technological progress and efficiency improvement is particularly important. Islam (1999), in a study of long-run growth, claims that advanced nations' sustained growth in per capita income results from the fact that technological advances have led to a continual increase in TFP.

In practice, TFP growth can be measured by estimating frontier production functions and then deriving productivity changes from both the changes in the inputs and output of the economies and the shifts of the frontier function. The frontier approaches allow the change in TFP (henceforth, 'TFP-change')[75] to be decomposed into two elements, efficiency improvement and technical change.

The basic building block of the frontier approaches is the estimation of a frontier production function and the measurement of the distances of an observation to this frontier function, which is then interpreted as technological inefficiency (Krüger 2003, p.266). Here again, two conceptually different approaches can be taken. On the one hand, quite a number of economists, such as Battese and Coelli (1995), Wu (2000, 2003), Ao and Fulginiti (2003) and Liu and Gu (2006), employ the parametric stochastic frontier analysis (henceforth 'SFA') to estimate the frontier function. This approach has the advantage of being able to deal with measurement error; however, it imposes a specific production functional form and certain distributional assumptions for the separation from measurement error of the distance between the technology frontier and the level of current productivity (Krüger 2003, p.267).

On the other hand, with the application of the data envelopment analysis (DEA), the non-parametric Malmquist index[76] approach takes the whole deviation of observations from the frontier functions to be the result of inefficiency, thereby completely neglecting measurement error and making the results more sensitive to outliers (Krüger 2003, p.267).[77] TFP growth is subsequently quantified by this

[75] Coelli (1996) interprets the Malmquist index as TFP-change, which is equivalent to the concept of TFP in other papers such as Maddison (1998) and Ao and Fulginiti (2003). He interprets growth in the Malmquist index as growth in TFP-change, which is equivalent to the notion of TFP growth in Maddison (1998) and Ao and Fulginiti (2003). In the current productivity analysis, we follow Coelli's interpretations of productivity measures.

[76] The concept of the Malmquist index was introduced by Malmquist (1953) in a consumption context and it is applied by Caves et al. (1982b) as a productivity index.

[77] The production function of the fully efficient province is not known in practice and thus must be estimated from observations of a sample of provinces in the country concerned. In this paper we use DEA to estimate this frontier. DEA involves the use of linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data, so as to be able to calculate efficiencies relative to this surface (Coelli 1996). Krüger

index.

The great advantage of the DEA in contrast to the SFA is that using linear programming methods, the frontier function is determined without the need for any functional or distributional assumptions. The DEA has two further essential advantages. First, unlike the growth accounting approach, this one does not need the assumption that factors are paid their marginal product. It instead requires a balanced panel of quantity data on inputs and the output, which is easy to obtain and is more reliable than information on factor shares. Second, TFP-change can be decomposed into two elements and hence one can tell whether TFP-change is mainly due to efficiency improvement or technical progress. However, the Malmquist index approach is not without shortcomings. Its main disadvantage is that the estimation of inefficiency may show an upward bias, capturing the influence of other factors (e.g. errors in data measurements) as inefficiency (Maudos *et al*. 2003, p.423). Examples of writer who apply the DEA method and construct the Malmquist indices include Nishimizu and Page (1982), Caves *et al*. (1982b), Färe *et al*. (1994), Coelli *et al*. (1998), Krüger (2003), Maudos *et al*. (2003), Zheng and Hu (2004) and Shen (2006).

Another of its shortcomings is, as Krüger (2003) claims, that the decomposition of TFP-change into technical change and efficiency change is likely to be quite fragile. By calculating posterior standard errors, Koop *et al*. (1999, p.473) provide an impression of the uncertainty involved in the decomposition of TFP-change. For many countries, the standard errors of efficiency change and technical change are

(2003) defines DEA as a local method in that it calculates the distance to the frontier function through a direct comparison with only those observations in the sample that are most similar to the observation for which the inefficiency is to be determined (p.267).

substantially higher than the standard errors of TFP-change. ‘Thus, the results of the decomposition should be regarded with some caution, especially the result of widespread technological regress. This result is the outcome of the mechanics of the Malmquist index in that it captures only changes of the best-practice technology and in such a concept it is possible that if all countries which determine parts of the frontier function experience a deterioration of their actual technological performance the consequence is a backward shift of certain parts of the frontier function’ (Krüger 2003, p.273).

Weighing all the advantages and disadvantages against each other, the frontier analysis, rather than the growth accounting approaches or Islam’s panel regression approach, has been chosen to calculate the TFP-change index. And, to quantify the distances to the production frontier, the DEA method is employed rather than the SFA.

4.2 CONSTRUCTION OF THE MALMQUIST INDEX

The construction of the Malmquist index is based on the non-parametric DEA of the frontier production function, which was first introduced by Caves *et al*. (1982b) as a productivity index and has since been well developed and used by Färe *et al*. (1994), Krüger (2003), Maudos *et al*. (2003) and Zheng and Hu (2004).

4.2.1 The Malmquist Index

We follow Färe *et al*. (1994) and construct the output-based Malmquist index of TFP change. We assume that for each time period $t = 1,...,T$, the production technology

F^t models the transformation of inputs, $x^t \in R_+^N$, into outputs, $y^t \in R_+^M$ (that is, the technology consists of the set of all feasible input/output vectors),

(4.1) $F^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\}$.

F^t is assumed to satisfy certain axioms which suffice to define meaningful output distance functions (see Shephard (1970) or Färe (1988) for such axioms).

Following Shephard (1970) and Färe (1988), the output distance functions are defined as

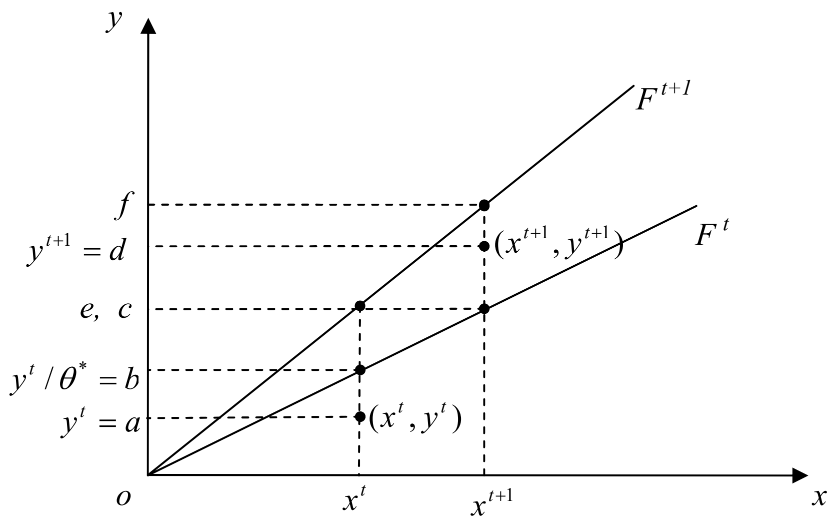
(4.2) $D_o^t(x^t, y^t) = \inf\{\theta : (x^t, y^t / \theta) \in F^t\} = (\sup\{\theta : (x^t, \theta\, y^t) \in F^t\})^{-1}$,

where θ measures technical efficiency. Thus the distance functions are the reciprocal of the 'maximum' proportional expansion of the output vector y^t, given inputs x^t. They completely characterize the technology. In particular, note that $D_o^t(x^t, y^t) \le 1$ if and only if $(x^t, y^t) \in F^t$. In addition, $D_o^t(x^t, y^t) = 1$ if and only if (x^t, y^t) is on the boundary or frontier of technology. In the terminology of Farrell (1957), $D_o^t(x^t, y^t) = 1$ occurs when production is technically efficient. A similar definition is given by $D_o^{t+1}(x^{t+1}, y^{t+1})$, the distance at period $t+1$ relative to the CRS technology at $t+1$.

In Figure 4-1, a scalar input is used to produce a scalar output. In the figure, observed production at t is interior to the boundary of technology at t; that is, we say that (x^t, y^t) is not technically efficient. The distance function seeks the reciprocal of the greatest proportional increase in the output, given the inputs, such that output is still feasible. In the diagram, maximum feasible production, given x^t, is at (y^t / θ^*).

The value of the distance function for our observation in terms of the distances along the y-axis is oa/ob, which is less than 1. More generally, one may write the value of the distance function for observation (x^t, y^t) as $\|y^t\|/\|y^t/\theta^*\|$.

Figure 4-1 The Malmquist output-based index and output distance functions



Source: Färe *et al.* (1994), p70.

Note that under the CRS technology, the maximum feasible output is achieved when average productivity, y/x, is maximized. In the simple single-output, single-input example, this is also the maximum observed TFP-change. In the following empirical work in section 4.4, this maximum is the 'best practice' or highest productivity observed in our sample of the Chinese provinces and is determined with the use of programming techniques.

In order to define the Malmquist index, one needs to define distance functions with respect to two different time periods, such as

(4.3) $$D_o^p(x^q, y^q) = \inf\{\theta : (x^q, y^q/\theta) \in F^t\} = (\sup\{\theta : (x^q, \theta y^q) \in F^t\})^{-1},$$

for all $(p,q) \in \{(t,t+1),(t+1,t)\}$.

The distance function (4.3) captures the distance at period q relative to the CRS frontier at period p. In other words, it measures the maximal proportional change in outputs required to make (x^q, y^q) feasible in relation to the technology at period p. This is illustrated in Figure 4-1. Note that production (x^{t+1}, y^{t+1}) occurs above the set of feasible production in period t and the distance function evaluating (x^{t+1}, y^{t+1}) relative to the CRS technology in period t (i.e. $D_o^t(x^{t+1}, y^{t+1})$) in terms of the y-axis in Figure 4-1 is $0d/0e$, which is greater than 1; the values of the other three distance functions under the CRS technology (i.e. $D_o^t(x^t, y^t)$, $D_o^{t+1}(x^t, y^t)$ and $D_o^{t+1}(x^{t+1}, y^{t+1})$) are less than 1.

Caves, Christensen and Diewert (1982b) (henceforth 'CCD-type') define the Malmquist productivity index as:

$$(4.4) \qquad \frac{y^{t+1}}{y^t} = M_{CCD}^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}.$$

In this formulation, the technology in period t is the reference technology. Similarly, one could define the CCD-type Malmquist productivity index at period $t+1$ as:

$$(4.5) \qquad M_{CCD}^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}.$$

In order to avoid choosing an arbitrary benchmark, Färe *et al*. (1994) specify the output-based Malmquist productivity change index as the geometric mean of two CCD-type Malmquist productivity indices:

$$(4.6)\qquad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2}.$$

An equivalent way of writing (4.6) is

$$(4.7)\qquad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \cdot \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2}$$

The ratio outside the brackets measures the change in relative efficiency (that is, the change in the distance of observed production from maximum potential production) between t and $t+1$ and therefore captures the 'catching-up' progress to the frontier,

$$(4.8)\qquad EC = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)},$$

where *EC* represents the efficiency change.

The geometric mean of the two ratios inside the brackets captures the shift in technology between the two periods evaluated at x^t and x^{t+1} and therefore quantifies 'innovation' or technical change,

$$(4.9)\qquad TC = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2},$$

where *TC* represents technical change.

Hence, as we have seen, TFP-change is represented by the Malmquist index and it is the product of efficiency change and technical change.

Note that if $x^t = x^{t+1}$ and $y^t = y^{t+1}$ (that is, if there has been no change in inputs and output between the periods), the productivity index (equation 4.7) signals no change at all: $M_o(\cdot) = 1$. In this case, the component measures of efficiency improvement and technical progress are reciprocals, but not necessarily equal to 1.

The decomposition of TFP-change is illustrated in Figure 4-1 for the CRS technology case, where we provide an illustration in which technical advances have occurred, in the sense that $F^t \subset F^{t+1}$. Note that $(x^t, y^t) \in F^t$ and $(x^{t+1}, y^{t+1}) \in F^{t+1}$, but (x^{t+1}, y^{t+1}) does not belong to F^t since technical progress has occurred in the example shown in Figure 4-1. In terms of the distances along the y-axis, the Malmquist index (4.7) is

$$(4.10) \quad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{od}{of}\right) \Big/ \left(\frac{oa}{ob}\right) \cdot \left[\left(\frac{od/oe}{od/of}\right)\left(\frac{oa/ob}{oa/oc}\right)\right]^{1/2},$$

which is equivalent to

$$(4.11) \quad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{od}{of}\right)\left(\frac{ob}{oa}\right) \cdot \left[\left(\frac{of}{oe}\right)\left(\frac{oc}{ob}\right)\right]^{1/2}.$$

In Equation (4.10), od/of represents the distance at period $t+1$ relative to the same period CRS DEA frontier, i.e. technical efficiency rate at $t+1$; oa/ob represents the distance at period t relative to the same period CRS DEA frontier, i.e. technical efficiency rate at t. The ratio of the two efficiency rates captures the change in technical efficiency, i.e. whether production is getting closer to or farther from the frontier. It is used by Färe *et al*. (1994), Benhabib and Spiegel (2002) and Maudos *et al* (2000, 2003) to capture 'technology diffusion' between countries.[78]

For the other two ratios appearing in (4.10), od/oe in the brackets represents the

[78] Applied to the diffusion of technology between countries, with the country leading in total factor productivity representing the technology frontier, this is a formalization of the catch-up hypothesis which was originally proposed by Gerschenkron (1962) (cited from Benhabib and Spiegel (2002)).

distance at period $t+1$ relative to the previous period CRS DEA frontier and oa/oc represents the distance at period t relative to the next period CRS DEA frontier.

The first ratio inside the brackets in Equation (4.11), of/oe, represents the shift in technology at input level x^{t+1}; and the second ratio, oc/ob, the shift in technology at input level x^t. The geometric mean of those two shifts measures technical change.

Turning to the interpretation of the Malmquist index and its two components, a Malmquist index greater than 1 represents improvements in TFP, while a Malmquist index of less than 1 signals deterioration in TFP performance. Improvements in any of the components are also associated with component indices greater than 1 and deterioration is associated with component indices of less than 1. Note that by definition, the product of the efficiency and technical-progress components must equal the Malmquist index and the two components may be moving in opposite directions. For example, the value of a Malmquist index 1.2 could be the product of an efficiency change of 0.8 (or 1.5) and technical progress of 1.5 (or 0.8).

4.2.2 Relating the Malmquist Index to the Solow Residual

Färe *et al*. (1994) also provide some intuition concerning the relation between the Malmquist productivity index and the traditional measures of productivity growth. Suppose that technology can be represented by a Cobb-Douglas production function

$$(4.12) \quad y^t = A^t \prod_{n=1}^{N} (x_n^t)^{\alpha_n} \qquad \alpha_n > 0\,.$$

In this case the output distance function at t becomes

$$
\begin{aligned}
D_o^t(x^t, y^t) &= \inf\left\{\theta : y^t/\theta \le A^t \prod_{n=1}^{N} (x_n^t)^{\alpha_n}\right\} \\
&= \inf\left\{\theta : y^t \middle/ \left(A^t \prod_{n=1}^{N} (x_n^t)^{\alpha_n}\right) \le \theta\right\} \qquad (4.13) \\
&= y^t \middle/ \left(A^t \prod_{n=1}^{N} (x_n^t)^{\alpha_n}\right).
\end{aligned}
$$

Inserting (4.13) and the other three Cobb-Douglas distance functions (i.e. $D_o^t(x^t, y^t)$, $D_o^{t+1}(x^t, y^t)$ and $D_o^{t+1}(x^{t+1}, y^{t+1})$) into the Malmquist index in (4.6) yields

$$
(4.14) \quad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{y^{t+1}}{\prod_{n=1}^{N} (x_n^{t+1})^{\alpha_n}}\right)\left(\frac{\prod_{n=1}^{N} (x_n^t)^{\alpha_n}}{y^t}\right).
$$

From (4.12) we find that the above index (4.14) can be written as the ratio of the technology parameters of the Cobb-Douglas production function:

$$
(4.15) \quad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = A^{t+1}/A^t
$$

The formulation in (4.15) is actually equivalent to the more general formulation by Solow (1957), which is the basis for the growth-accounting approach to measuring TFP-change. In this approach, A^{t+1}/A^t is calculated by taking the time derivative of (4.12), dividing through by y and using observed factor shares as proxies for the α_n; that is,

$$
(4.16) \quad \dot{A}/A = \dot{y}/y - \sum_{n=1}^{N} \alpha_n \dot{x}_n / x_n
$$

where the dots refer to time derivatives and y and x would be in natural logs for the Cobb-Douglas case.

In the growth accounting approach, observed output is assumed to be equivalent to frontier output and its index of TFP-change would be interpreted as capturing shifts in the technology (that is, technical change). However, in the presence of technical inefficiency, the growth accounting approach would give a biased estimate of technical change.

In terms of Figure 4-1, ignoring technical inefficiency means that the frontier of technology is assumed to go through the observed points (x^t, y^t) and (x^{t+1}, y^{t+1}) in periods t and $t+1$, respectively. Productivity would then be assumed to be synonymous with technical change and technical change would be measured as the change in observed performance, adjusting for changes in input use (Färe *et al*. 1994, p.73).

4.2.3 Calculation of the Indices

There are several ways in the literature to calculate the Malmquist index. Caves *et al*. (1982) compute (4.6) as the quotient of Törnqvist indices, in which the distance functions are of translog form with identical second-order terms. Balk (1993) generalizes the conditions under which the Malmquist index may be calculated as a quotient of Fisher ideal indices. One could also calculate the component distance functions using the Aigner and Chu (1968) parametric linear-programming approach as well as frontier econometric approaches (Färe *et al*. 1994, p.73).

In empirical work, the Malmquist productivity index is calculated by applying the linear-parameteric programming techniques outlined by Färe *et al*. (1994) and Battese and Coelli (1995).

We assume that there are $k = 1,...,K$ provinces using $n = 1,...,N$ inputs $x_n^{k,t}$ at each time period $t = 1,...,T$. These inputs are used to produce $m = 1,...,M$ outputs $y_m^{k,t}$. The frontier technology in period t is thereby constructed as

$$(4.17) \quad F^t = \{(x^t, y^t) : y_m^t \le \sum_{k=1}^{K} z^{k,t} y_m^{k,t} \quad \text{subject to} \quad \sum_{k=1}^{K} z^{k,t} x_n^{k,t} \le x_n^t \quad m = 1,...,M; \quad z^{k,t} \ge 0 \quad n = 1,...,N; \quad k = 1,...,K\}$$

which exhibits the CRS technology. $z^{k,t}$ is 'an intensity variable indicating at what intensity a particular activity (in our case, each province is an activity) may be employed in production' (Färe *et al*. 1994, p.73).

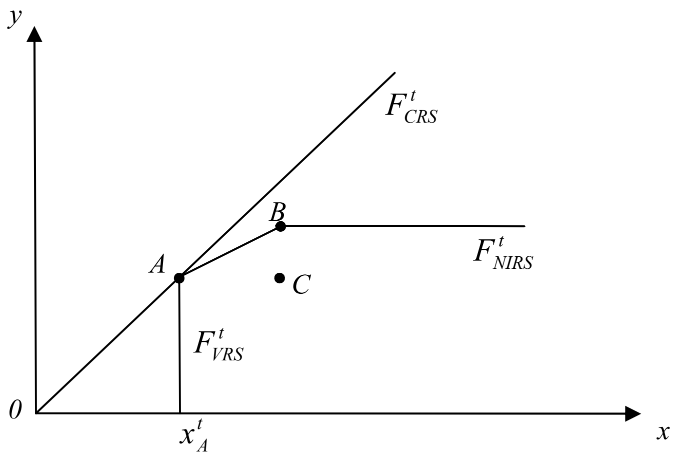
Furthermore, Afriat (1972) suggests that the assumption of CRS may be relaxed to allow non-increasing returns to scale (henceforth 'NIRS', i.e. constant or decreasing returns to scale) by adding the following restriction:

$$(4.18) \quad \sum_{k=1}^{K} z^{k,t} \le 1 \ .$$

Again, one may also allow for variable returns to scale (henceforth 'VRS', i.e. increasing, constant or decreasing returns to scale) by changing the inequality in (4.18) to equality (Färe *et al*. 1994, p.73).

The above-stated technologies can be illustrated in Figure 4-2, which illustrates the construction of technology for scalar input and output for one period t. Suppose there are three observations, A, B and C. If we restrict the intensity variables to sum to less than or equal to 1 (i.e. we allow for NIRS), technology will be bounded by $0AB$ and the horizontal extension from B. If we impose constant returns by allowing the elements of z to take any non-negative values, technology becomes a cone. Finally, in the VRS case, technology is bounded by x_A^t, A, B and the horizontal extension from B (Färe *et al*. 1994, p.74).

Figure 4-2 Construction of frontier technology



Source: Färe *et al*. (1994), p74.

In principle, one may calculate the Malmquist productivity index relative to any type of technology (i.e. satisfying any type of returns to scale). Here we choose to calculate the Malmquist index relative to the CRS technology and use an enhanced decomposition of the Malmquist index:

$$(4.19) \quad M_o(x^{t+1}, y^{t+1}, x^t, y^t) = TFPC = PEC \cdot SEC \cdot TC,$$

where *PEC* represents pure efficiency change calculated under VRS and *SEC* represents scale efficiency change; this captures the deviation between the VRS technology and CRS technology. In Figure 4-2, scale efficiency for observation C

is the vertical distance between F_{VRS}^{t} and F_{CRS}^{t} evaluated at the corresponding input for observation C. And *PEC* is calculated on the basis of the ratio of distance functions under the VRS technology at periods t and $t+1$,

$$(4.20) \qquad PEC = \frac{D_{VRS}^{t+1}(x^{t+1}, y^{t+1})}{D_{VRS}^{t}(x^{t}, y^{t})}.$$

In order to apply this theoretical device to real data for inputs and output and to calculate TFP-change and its two components, we need to quantify the four distance functions under the CRS technology for each province in each year: $D_o^t(x^{t+1}, y^{t+1})$, $D_o^t(x^t, y^t)$, $D_o^{t+1}(x^t, y^t)$ and $D_o^{t+1}(x^{t+1}, y^{t+1})$. Furthermore, if one is interested in recovering changes in pure efficiency, one also needs to calculate two additional distance functions under VRS (i.e. $D_o^t(x^t, y^t)$ and $D_o^{t+1}(x^{t+1}, y^{t+1})$ under the VRS technology) by adding the restriction (4.18).

The calculations are performed by solving the linear programming problems of the following output-oriented DEA:

$$(4.21) \qquad \begin{aligned} \max \theta^{k'} \quad s.t. \quad & \theta^{k'} y_m^{k',q} \le \sum_{k=1}^{K} z^{k,p} y_m^{k,p} && m = 1,\dots,M \\ & \sum_{k=1}^{K} z^{k,p} x^{k,p} \le x_n^{k',q} && n = 1,\dots,N \\ & z^{k,p} \ge 0 && k = 1,\dots,K. \end{aligned}$$

where $(p,q) \in \{(t,t),(t,t+1),(t+1,t),(t+1,t+1)\}$. We also make use of the fact that the output distance function is reciprocal to the output-based measure of technical efficiency, that is, $D_o^p(x^q, y^q) = \theta^{-1}$.

On the basis of (4.7), (4.8), (4.9), (4.19) and (4.20), all the indices of TFP-change and its elementary components can be obtained: *EC*, *TC*, *PEC*, *SEC* and *TFPC*. The calculation of these elements is done in Coelli's DEAP package.[79]

4.3 DATA

The data needed to calculate TFP-change and its components using the method described in section 4.2 are taken from various editions of the *China Statistics Yearbook* and *Comprehensive Statistical Data and Materials on 50 Years of New China*. The data are at the province level for Chinese 29 provinces over the period 1979-2004. In the current empirical analysis, Tibet is excluded from the analysis due to the limited of data available. Our sample ends with the year 2004 due to the fact that the National Bureau of Statistics of China revised production-side GDP in 2005, largely as a result of better coverage of the service sector.[80]

For the output variable, real GDP for each province is used;[81] for the labour input, the number of workers is used;[82] and for the capital input, since the official publications do not provide the data on capital stock, the capital input can only be calculated using the data which are available. For the current study, we use the data on fixed capital formation as the investment data and the price index of investment in fixed assets as the deflator for each province in each year.[83]

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[79] Full information can be seen in Coelli (1996).

[80] In 2004 GDP was revised up by almost 17 percent. However, the World Bank (2006) shows that the revised GDP data do not really change the pattern of sources of China's economic growth.

[81] The consumer price index for each province is used as the deflator for each province in each year.

[82] Due to the limited data available, we are unable to adjust labour input by quality or measure labour input by number of hours.

[83] The price index of investment in fixed assets is set to unity for the years 1952-1977 where the price information is not available. This is feasible as Zhang *et al*. (2004) find that price indices of fixed capital investment before 1978 showed little fluctuation in most provinces.

Capital stock is calculated by the perpetual inventory method using the following equation:

(4.22) $K_t = (1-\delta)K_{t-1} + I_{t-1}$,[84]

and hence the capital stock in year T:

(4.23) $K_T = (1-\delta)^T K_0 + \sum_{j=0}^{T-1} I_{t+j}(1-\delta)^{T-j-1}$,

where K_0 is the capital stock in the initial year, δ is the depreciation rate of the capital stock and I is investment. Therefore, to obtain the capital stock for each province in each year, we need to know the initial capital stock level and the rate of depreciation.

The initial capital stock level can be estimated in many ways. For instance, Hall and Jones (1999) set the initial value of capital stock as $I_0/(g_I + \delta)$, where I_0 is the amount of investment in the first period for which data are available and g_I is the average geometric growth rate of the investment series over the ten subsequent years. Krüger (2003) sets K_0 as $I_0 \cdot (1+g_I)/(g_I+\delta)$, where g_I is the average growth rate of investment over the five subsequent years. Zhang *et al*. (2004) derive K_0 by dividing I_0 by 10 per cent; the initial capital stock levels which they obtain are close to those of Young (2000). Yao and Wei (2007) set K_0 as twice the level of real GDP in the initial year of the sample period. Despite the different methods to

[84] The equation is widely used in the literature to calculate the capital stock. See Meinen *et al*. (1998) for more information on the perpetual inventory method. One of the other ways to calculate the capital stock can be seen on Yao and Wei (2007), who employ the equation: $K_t = (1-\delta)K_{t-1} + \lambda I_{t-1}$, where delta is the depreciation rate of the capital stock and lamda is the rate of capital formation from investment in fixed assets.

measure K_0, there is little discussion in the literature on which method is better. This is because the value of the benchmark capital stock becomes less important to the capital stock in year T as long as the time length is long enough.

In this study, the capital stock at year 1952 is used as the benchmark capital stock K_0, which is set at $I_0 \times 10$ and our sample starts with 1978. Therefore, as $(1-\delta)^T$ decreases over time due to the value of δ being between 0 and 1, the contribution of the benchmark capital stock, $(1-\delta)^{26} K_{1952} \approx 0$, becomes negligible in determining the level of capital stock in 1978,

$$K_{1978} = (1-\delta)^{26} K_{1952} + \sum_{j=0}^{25} I_{1952+j} (1-\delta)^{25-j} .$$

The value of the depreciation rate, δ, is more difficult to determine than the level of initial capital stock. The officially published national depreciation rate in China is only 0.036, which, however, is much lower than those in advanced countries (e.g. 0.133 in Britain) and the empirical value is 0.072, which is found in many studies of international comparison of TFP-change. The value of the depreciation rate varies case-by-case in the literature. For example, the depreciation rate is set as 0.06 in Hall and Jones (1999) and 0.10 in Krüger (2003) for international comparisons of the trend in TFP-change. For the depreciation rate of fixed assets of China, it is set at 0.06 in Young (2000) and Deng and Li (2004), 0.042 in Ao and Fulginiti (2003) and 0.10 in Gong and Xie (2004). Wang (2001), who believes that δ varies over time in China, sets the depreciation rate during 1973-1977 at 0.03, 0.05 between 1978 and 1990 and 0.055 since 1990. Song *et al*. (2003) and Meng and Li (2005), set the depreciation rate as the sum of the published national depreciation rate and provincial economic growth rate, which will be greater than 0.10 for most provinces and years.

Table 4-2 Depreciation rates of capital stock employed in the literature

Source	Sample	Depreciation rate
Mankiw, Romer, and Weil (1992)	98 countries	0.030
Hall and Jones (1999)	127 countries	0.060
Krüger (2003)	87 countries	0.100
McQuinn and Whelan (2007)	96 countries	0.060
Jorgenson and Stiroh (2000)	U.S.	0.100
National Bureau of Stat.	China	0.036
Young (2000)	China	0.060
Wang (2001)	China	0.030~0.055
Ao and Fulginiti (2003)	China	0.042
Song *et al*. (2003)	China	$\delta_{national} + g_{province}$
Meng and Li (2005)	China	$\delta_{national} + g_{province}$
Deng and Li (2004)	China	0.060
Gong and Xie (2004)	China	0.100
Zhang *et al*. (2004)	China	0.096

Note: $\delta_{national}$ is the officially published depreciation rate of capital stock at the national level, and $g_{province}$ is GDP growth rate at the provincial level.

For the current study, I tried different values for the depreciation rates, including a set of values which vary with period and area, such that it is 0.042 for all provinces in each year between 1952 and 1977, 0.072 for coastal provinces and 0.060 for inland provinces between 1978-1990, 0.096 for coastal provinces and 0.072 for inland provinces between 1991-2004. The results were different from those of another trial with δ=0.096 only in terms of the calculated values of productivity growth and its components, but were very similar in terms of the pattern of distribution of productivity across the provinces under study. Assuming that some provinces would probably have low rates of productivity growth and levels in the early years of the

Reform, I finally chose for this study a value of 0.096 for the depreciation rate of capital stock.[85]

Table 4-3 presents the basic description of essential variables employed in the current analysis.

Table 4-3 Basic description of essential variables, 1979-2004

Variable	Mean	Standard Deviation	Min. Value	Max. Value
GDP at 1978 prices (0.1 billion Yuan)	378.22	434.27	10.69	3,337.88
Capital stock at 1978 prices (0.1 billion Yuan)	971.78	1,341.52	17.28	9,778.50
Labour force (10,000 persons)	1,913.93	1,377.36	135.64	6,316.11
Ratio of primary school students to labour force (%)	0.72	0.85	0.10	6.77
Ratio of secondary school students to labour force (%)	12.19	3.67	5.64	32.40
Ratio of higher education students to labour force (%)	25.12	7.89	5.77	53.14

With all the data at hand we can solve the linear programmes described in (4.21) and quantify the Malmquist index and its components using Coelli's DEAP package.

4.4 RESULTS

In this section we look at the trends of TFP at provincial, zone[86] and national levels in terms of both the growth of TFP and the relative TFP level and we also compare the results of the DEA model including human capital with those of the DEA model without the inclusion of human capital.

[85] Zhang *et al*. (2004) have a valuable discussion about the derivation of this value.

[86] China as a whole is divided into three belts according geographic location and levels of economic development. The Eastern belt (or the Coastal Area) is most industrialized and the Central and Western (or the Inland Area) is more agriculture-based. Refer to Table 2-1 in Chapter 2 for the definition of these three belts.

The average percentage growth rates of the Malmquist index and its components between two time points are calculated according to the following formulas for each province:

$$(4.24)\quad Growth \text{ of } TFP-change = \left[\left(\prod_{t=t_1}^{t_2} TFPC_r^t \right)^{1/(t_2-t_1+1)} - 1 \right] \cdot 100 \,;$$

$$(4.25)\quad GEC = \left[\left(\prod_{t=t_1}^{t_2} EC_r^t \right)^{1/(t_2-t_1+1)} - 1 \right] \cdot 100 \,;$$

$$(4.26)\quad GTC = \left[\left(\prod_{t=t_1}^{t_2} TC_r^t \right)^{1/(t_2-t_1+1)} - 1 \right] \cdot 100 \,;$$

$$(4.27)\quad GPEC = \left[\left(\prod_{t=t_1}^{t_2} PEC_r^t \right)^{1/(t_2-t_1+1)} - 1 \right] \cdot 100 \,;$$

$$(4.28)\quad GSEC = \left[\left(\prod_{t=t_1}^{t_2} SEC_r^t \right)^{1/(t_2-t_1+1)} - 1 \right] \cdot 100 \,;$$

$$(4.29)\quad GGDP = \left[\left(\frac{GDP^{t_2}}{GDP^{t_1}} \right)^{1/(t_2-t_1)} - 1 \right] \cdot 100 \,,$$

where *GEC* represents the growth of efficiency change; *GTC* the growth of technical change; *GPEC* the growth of pure efficiency change; *GSEC* the growth of scale change; and *GGDP* the growth of real GDP.[87]

4.4.1 Productivity Changes over the Whole Period 1979-2004

[87] The concept of 'growth of TFP-change' in the current analysis is equivalent to 'growth of TFP' in previous studies using other approaches, such as Nadiri (1972), Hall and Jones (1996) and Islam (1999). This is due to that 'TFP-change' in the current analysis is measured by the Malmquist index and the Malmquist index is equivalent to the concept of 'TFP' in previous studies. Similarly, 'growth of efficiency change' and 'growth of technical change' in the current study are equivalent to 'growth of efficiency' and 'technical progress' in previous studies.

Instead of presenting the disaggregated results for each province and year, we make a summary description of the average performance of each province and zone over the entire 1979-2004 time period. These overall averages are geometric means, since the Malmquist index is multiplicative. To look at the differences between the three Chinese zones in terms of productivity trends, we also calculate the growth rates of productivity changes for the three Chinese zones; the measures for zones are the arithmetic means of the province-specific measures.

Looking first at the growth of productivity changes at the national level (last row of Table 4-4), we see that on average, TFP grew at a rate of 1.98 per cent over the period 1979-2004 and this accounts for 21.66 per cent (the last cell in the table) of China's real GDP growth. The average growth rate of efficiency change at the national level was 1.00 per cent and the average growth rate of technical change at the national level was 0.98 per cent, which indicates that the two components contributed almost equally to China's TFP growth on average over the whole period. Furthermore, efficiency improvements were more associated with changes in pure efficiency than with changes in scale efficiency.[88]

Compared with the estimated rates of growth of TFP-change over 1978-2004 in the literature, our finding on the average annual rate of growth of TFP-change at the national level is higher than those in Sun and Zhong (2006) and Wang and Liu (2006), who use the growth accounting approach. Compared with the rate of growth of TFP-change of 3.8 per cent and contribution rate of 40 per cent over 1978-93 from

[88] The growth rates of pure efficiency change and scale change for each province in each year are not reported here but are available from the author upon request.

the World Bank (2006), using the growth accounting approach, our calculated rate of growth of TFP-change, 1.51 per cent and contribution rate, 17.90 per cent over the same period is quite low; however, our finding on the growth of TFP-change rate, 2.76 per cent and contribution rate, 27.39 per cent over 1993-2004 is close to the rate of growth of TFP-change of 2.7 per cent and contribution rate of 30 per cent over 1993-2005 from the World Bank (2006) using unrevised data.[89] See Table 4-5 for the summary of rates of growth of TFP-change found in the current study and some previous studies.

Turning to the zone-by-zone results, we observe that over 1979-2004, the Eastern Zone had the highest average annual rate of real GDP growth of 9.47 per cent, the Central Zone 8.51 per cent and the Western Zone 8.06 per cent (Table 4-4). The pattern remains the same with respect to the growth of TFP-change: the Eastern Zone had the highest annual rate of growth of TFP-change of 2.97 per cent and a contribution rate of 30.69 per cent, the Central Zone 1.58 per cent and 18.21 per cent respectively and the Western Zone 1.53 per cent and 19.31 per cent respectively.

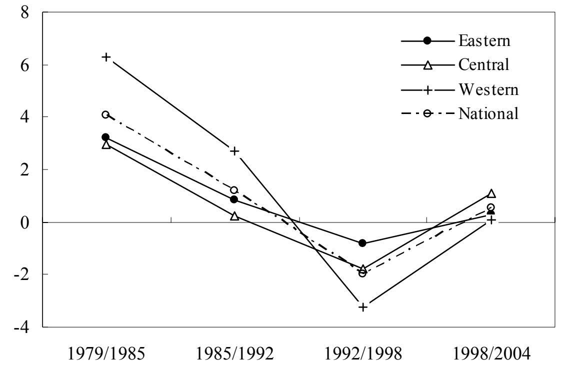
[89] With revised data the growth accounting in World Bank (2006) finds that TFP in China grew at 3.0 per cent and contribution rate was 32 per cent over 1993-2005.

Table 4-4 Decomposition of growth of TFP-change and TFP's contribution (without human capital, %)

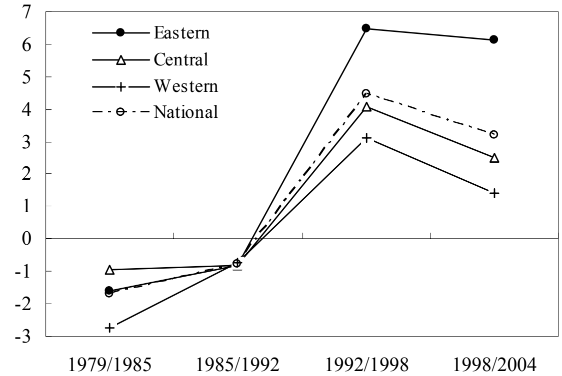
	I. Growth of EC (*GEC*)					II. Growth of TC (*GTC*)					III. Growth of TFP-change					IV. Growth of GDP					V. TFP's Contribution				
	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**
BeiJing	2.33	-2.56	-4.86	-2.91	-1.25	-6.00	0.19	11.42	9.85	2.71	-3.79	-2.37	6.01	6.68	1.44	8.39	3.82	5.15	12.21	7.20	-45.18	-61.93	116.5	54.72	20.01
TianJin	3.87	1.21	2.30	0.73	2.19	-3.40	-4.18	2.27	7.15	0.00	0.36	-3.04	4.61	7.95	2.19	7.30	2.76	9.55	13.51	7.99	4.96	-109.9	48.24	58.85	27.37
LiaoNing	3.16	0.00	-2.39	2.02	0.24	-1.45	-0.36	7.81	5.70	2.59	1.67	-0.36	5.24	7.82	2.83	8.54	5.90	6.20	9.53	7.47	19.52	-6.14	84.45	82.03	37.90
ShangHai	0.00	0.00	0.00	0.00	0.00	-2.76	-1.51	6.25	7.38	1.46	-2.76	-1.51	6.25	7.38	1.46	4.23	2.08	8.90	11.18	6.36	-65.14	-72.41	70.27	66.02	22.90
JiangSu	0.26	-0.55	1.30	1.06	0.11	0.95	-0.02	4.97	6.04	2.81	1.21	-0.56	6.37	7.16	2.93	10.12	7.88	10.38	12.80	10.18	11.93	-7.04	61.34	55.96	28.76
ZheJiang	5.23	0.87	-1.29	0.36	1.25	0.63	-0.67	7.94	5.98	3.02	5.92	0.21	6.49	6.37	4.31	12.28	7.82	11.24	13.67	11.10	48.20	2.63	57.77	46.62	38.87
FuJian	3.41	4.24	0.00	0.00	1.95	0.16	-0.12	4.61	1.22	1.18	3.63	4.12	4.61	1.22	3.16	13.18	10.88	15.16	9.96	12.22	27.53	37.85	30.41	12.26	25.86
Shandong	7.28	1.56	-1.22	0.68	2.19	-1.90	-0.09	6.18	6.00	2.31	5.22	1.49	4.90	6.71	4.55	14.21	8.50	10.09	12.74	11.25	36.73	17.56	48.53	52.69	40.46
Guangdong	3.36	2.63	-1.25	0.64	1.31	-0.63	-0.50	6.65	5.98	2.56	2.73	2.09	5.32	6.65	3.90	11.48	10.69	11.40	12.29	11.43	23.81	19.58	46.68	54.10	34.12
Eastern	**3.21**	**0.82**	**-0.82**	**0.29**	**0.89**	**-1.60**	**-0.81**	**6.46**	**6.15**	**2.07**	**1.58**	**0.01**	**5.53**	**6.44**	**2.97**	**9.97**	**6.70**	**9.79**	**11.99**	**9.47**	**6.93**	**-19.98**	**62.69**	**53.69**	**30.69**
HeBei	3.94	3.17	-2.51	2.16	1.79	-1.54	-0.57	8.96	5.94	2.76	2.37	2.58	6.20	8.22	4.60	8.01	9.01	11.28	12.12	10.05	29.55	28.61	54.96	67.85	45.76
ShanXi	8.02	-0.66	-3.79	-0.45	1.00	-3.45	-0.50	6.62	5.98	1.87	4.29	-1.14	2.56	5.48	2.88	9.02	4.74	5.90	11.30	7.59	47.61	-24.13	43.42	48.52	37.93
Inner M	4.74	-1.43	-2.63	2.09	0.36	-2.10	-0.17	5.80	6.00	2.17	2.52	-1.62	3.01	8.22	2.53	12.30	3.27	7.43	13.36	8.78	20.52	-49.51	40.54	61.53	28.83
JiLin	3.45	-1.79	-1.54	3.00	0.74	-2.50	-0.13	8.11	5.93	2.50	0.89	-1.91	6.45	9.12	3.27	8.70	5.25	8.35	10.80	8.14	10.22	-36.45	77.19	84.44	40.14
HeiLJ	-0.55	-0.29	-1.67	2.31	0.45	-3.98	-0.86	5.76	5.91	1.50	-4.49	-1.17	3.96	8.35	1.95	5.84	4.86	8.06	11.28	7.38	-76.78	-24.10	49.21	74.00	26.48
AnHui	0.00	-1.33	0.65	0.14	0.00	0.74	-3.59	-1.76	-2.97	-2.23	0.74	-4.88	-1.11	-2.80	-2.23	13.87	3.23	11.12	8.67	8.91	5.32	-150.8	-10.0	-32.32	-25.03
JiangXi	1.42	1.78	-0.54	-0.72	0.57	1.12	-1.03	-1.31	-3.12	-1.40	2.57	0.74	-1.85	-3.83	-0.83	7.62	5.75	9.71	10.67	8.31	33.66	12.95	-19.08	-35.94	-10.00
HeNan	6.54	1.74	-0.98	2.13	2.18	-0.59	-0.43	3.76	-3.08	-0.23	5.91	1.31	2.74	-1.02	1.93	13.01	7.34	11.25	11.77	10.68	45.39	17.81	24.31	-8.65	18.05
HuBei	2.53	0.60	-4.56	0.67	-0.13	0.99	-0.14	4.27	4.15	2.03	3.53	0.43	-0.51	4.86	1.88	9.21	5.56	9.47	8.62	8.10	38.30	7.76	-5.35	56.34	23.20
HuNan	1.52	1.24	-0.13	-0.22	0.85	0.28	-0.79	-1.29	-2.98	-1.46	1.78	0.45	-1.41	-3.22	-0.63	5.94	5.26	8.35	8.86	7.02	29.98	8.63	-16.92	-36.32	-8.92
HaiNan	1.05	-0.49	-2.14	0.68	-0.56	0.66	-0.79	5.96	5.91	2.63	1.71	-1.28	3.73	6.63	2.06	10.22	9.91	4.89	9.48	8.66	16.70	-12.94	76.27	69.93	23.82
Central	**2.97**	**0.23**	**-1.80**	**1.07**	**0.66**	**-0.94**	**-0.82**	**4.08**	**2.52**	**0.92**	**1.98**	**-0.59**	**2.16**	**3.64**	**1.58**	**9.43**	**5.83**	**8.71**	**10.63**	**8.51**	**18.22**	**-20.20**	**28.60**	**31.76**	**18.21**
GuangXi	3.03	7.56	-4.71	-0.72	1.53	0.73	-2.39	-2.44	-3.00	-2.22	3.79	5.00	-7.03	-3.68	-0.71	7.53	9.86	7.61	9.27	8.61	50.36	50.71	-92.35	-39.68	-8.28
SiChuan	4.29	2.19	-1.49	-0.79	1.14	-1.65	-0.01	0.98	-3.08	-1.10	2.55	2.19	-0.54	-3.83	0.03	8.04	5.94	8.05	9.45	7.78	31.76	36.87	-6.73	-40.48	0.35
GuiZhou	5.31	1.69	-0.85	-0.85	1.76	-0.33	-1.06	-1.62	-2.97	-1.76	4.92	0.57	-2.47	-3.78	-0.05	10.31	5.93	4.04	10.35	7.56	47.71	9.70	-61.22	-36.50	-0.62
YunNan	3.62	4.45	-3.76	0.21	1.49	-0.96	-0.23	1.30	-3.10	-0.91	2.61	4.21	-2.48	-2.88	0.58	10.16	10.52	6.19	8.07	8.79	25.70	40.02	-40.08	-35.74	6.56
ShaanXi	5.69	0.97	-4.11	2.86	1.31	-3.66	-0.41	6.62	5.35	1.73	1.86	0.56	2.24	8.38	3.07	7.54	6.46	4.87	12.70	7.79	24.66	8.65	46.00	65.96	39.44
GanSu	8.47	1.57	-2.70	-0.56	1.38	-5.12	-0.81	6.04	5.94	1.22	2.96	0.75	3.16	5.35	2.63	7.21	4.69	6.09	9.42	6.75	41.12	15.94	51.89	56.83	38.94
QingHai	5.98	1.22	-4.77	0.27	0.39	-4.60	-0.59	7.25	5.91	1.69	1.10	0.66	2.15	6.21	2.10	9.42	4.40	4.77	11.62	7.38	11.64	14.90	45.09	53.40	28.46
NingXia	12.07	0.79	-4.64	0.48	2.11	-4.74	-0.64	6.97	1.78	0.58	6.73	0.16	1.99	2.27	2.70	8.57	5.24	6.97	11.62	7.96	78.47	3.10	28.59	19.58	33.90
XinJiang	8.26	4.09	-2.08	0.05	2.50	-4.14	-0.40	3.11	6.01	0.95	3.77	3.67	0.98	6.05	3.47	12.97	9.53	5.90	11.38	9.90	29.09	38.51	16.53	53.16	35.03
Western	**6.30**	**2.73**	**-3.24**	**0.11**	**1.51**	**-2.72**	**-0.73**	**3.13**	**1.43**	**0.02**	**3.37**	**1.97**	**-0.22**	**1.57**	**1.53**	**9.08**	**6.95**	**6.05**	**10.43**	**8.06**	**37.83**	**24.27**	**-1.36**	**10.73**	**19.31**
National	**4.06**	**1.18**	**-1.98**	**0.52**	**1.00**	**-1.71**	**-0.79**	**4.45**	**3.20**	**0.98**	**2.25**	**0.36**	**2.41**	**3.76**	**1.98**	**9.59**	**6.79**	**9.38**	**11.34**	**9.16**	**23.51**	**5.32**	**25.72**	**33.18**	**21.66**

Note: Columns in block I-III are average percentage growth rates according to Equations (4.24)-(4.26) with t_1 and t_2 are start and end years of each sub-period respectively.

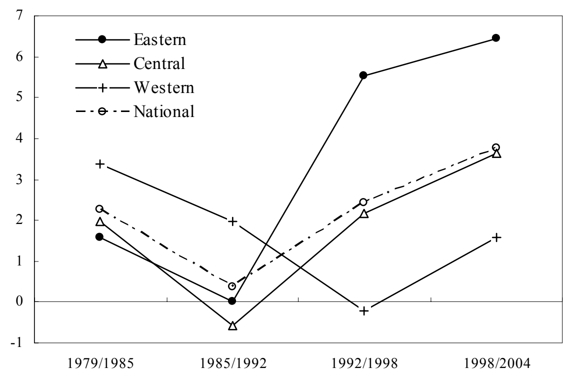
Figure 4-3 Rates of Growth of TFP-change and its components without human capital (%)



Growth of Efficiency Changes by Belt (without Human Capital)



Growth of Technical Change by Belt (without Human Capital)



Growth of TFP-change by Belt (without Human Capital)

Table 4-5 Comparison of Rates of Growth of TFP-change in China (without human capital)

Period	Source	Rates of Growth of TFP-change (%)	TFP's Contribution (%)
1979-2004 or 1978-2003	The present study	1.98	21.66
	Deng and Li (2004)	3.81	39.67
	Li *et al*. (2005)	2.40	26.20
	Sun and Zhong (2006)	1.29	13.74
	Wang and Liu (2006)	0.31	3.31
	Wu (2007)	2.28	36.19
1978/79-1992/93	The present study	1.51	17.90
	Sun and Zhong (2006)	2.10	22.30
	World Bank (2006)	3.80	40.00
1993-2004	The present study	2.76	27.39
	World Bank (2006)	2.70	30.00

The decomposition of the growth of TFP-change into growth of efficiency change and growth of technical change is given in the columns *GEC* and GTC in Table 4-4. We see that on average, innovation (i.e. improvements in technical progress *GTC*) was the main reason for the growth of TFP-change in the Eastern Zone and the Central Zone with contribution rates of 69.60 per cent and 58.29 per cent, respectively; while improvements in efficiency (*GEC*) accounted for 98.54 per cent of the growth of TFP-change in the Western Zone, which in turn indicates that almost no technical progress was made in this least developed zone after the Reform.

Turning to the province-by-province results over the whole period, we observe the following findings. First, all provinces saw positive productivity progress except for five inland provinces (Anhui, Jiangxi, Hunan, Guangxi and Guizhou).[90] Second,

[90] Recall that if the value of the Malmquist index (i.e. TFP-change) or any of its components is less than 1 (or equivalently if growth of TFP-change and any of its components are less than 0) regress or deterioration is signified in the performance of the relevant element, whereas values greater than 1 (or equivalently, if the growth of TFP-change and any of its components is greater than 0) denote improvements in the relevant performance.

technical progress occurred in 20 out of 29 provinces, while technical regress occurred in 9 provinces, of which 8 are in the Inland Area. Third, improvements in efficiency can be recognized in most provinces by positive values of *GEC* except in Beijing, Hubei and Hainan. The five provinces, namely, Xinjiang, Tianjin, Shandong, Henan and Ningxia, show especially fast movement towards their respective frontier parts (see Table 4-4).

4.4.2 Productivity Changes in Sub-periods

We now turn to examine the evolution of productivity changes over different stages of the Reform. To this end, we divide the whole time period into four sub-samples (1979-1985, 1985-1992, 1992-1998 and 1998-2004). Table 4-4 and the diagrams in Figure 4-3 provide an illustration of the appearance of improvements in productivity in mainland China.

Growth of TFP-changes

For the growth of TFP-change measures (the third block of columns in Table 4-4 and the third diagram in Figure 4-3), in the first sub-period 1979-1985, the TFP-change of the Western Zone grew at the highest rate of 3.37 per cent per annum while the Eastern Zone's TFP-change grew at the lowest rate of 1.58 per cent; in the second sub-period 1985-1992, the East showed almost no TFP-change progress, the Central suffered from a negative TFP-change progress and TFP-change in the West continued to grow but at a much lower rate than in the first sub-period. Recall from Chapter 2 that the economies in the Inland Area were mainly agriculture-based and therefore the growth pattern of TFP-change in China during the first two sub-periods reflects the success of the Chinese government's policies applied in the agricultural sector in the early stage of the Reform.

In the last two sub-periods, 1992-1998 and 1998-2004, as a consequence of implementing comprehensive and successful reform policies in the industrial sector and cities in the Coastal Area, the Eastern Zone experienced a substantial TFP-change process, with rates of growth of TFP-change at 5.53 per cent in the third sub-period and 6.44 per cent in the fourth sub-period. The Central Zone had growth of TFP-change rates of 2.16 per cent and 3.64 per cent respectively in the last two sub-periods. However, the growth of TFP-change in the Western Zone declined substantially during the third sub-period when the Chinese government switched its reform focus from the agricultural sector to the industrial sector;[91] and the Western Zone started to experience positive growth of TFP-change when reforms in the industrial sector were extended to the Inland Area.[92]

Growth of Efficiency Changes

To get further insights into the evolution of productivity changes over different reform stages, we now look at the way in which the components of the Malmquist index evolved. The positive signs and large magnitudes of *GEC* (i.e. growth of efficiency change, the first block of columns in Table 4-4 and the first diagram in Figure 4-3) in the first sub-period, 1979-1985, show that the Chinese government's agricultural policies in the first stage of the Reform were successful and had the immediate effect of bringing initiative on the part of the farmers into full play, thus improving productive efficiency in China's rural areas. This in turn enabled the

[91] Refer to Chapter 2 for the policies implemented in different stages of the reform.

[92] Our finding regarding the first three sub-periods is generally in accordance with that in Wang and Li (2006) who studied TFP growth in China over 1978-1998 taking the growth accounting approach.

redundant rural labour force to move to urban areas and contribute to efficiency improvements in the whole country.

In the second sub-period, 1985-1992, efficiency improvements slowed down as a consequence of the low state investment and absence of new agricultural policies being implemented during this sub-period to further stimulate the agricultural economy. Moreover, the effects of industrial reforms that were carried out during this sub-period had not yet made themselves felt.

In the third sub-period, 1992-98, a substantial reverse in efficiency occurred in most Chinese provinces, as a result of the long-term effect of the chaos caused by various reform policies since the late 1980s (e.g. the dual pricing system adopted in the second stage of the Reform). Since 1998, efficiency improvements had been made as a consequence of the deepened reforms (especially reforms in state-owned enterprises) and the thorough implementation of the open-door policy throughout the country.

There are a few studies (e.g. Gao (1998); Otsuka *et al*. (1998); and Preston and Xing (2002)) which explain the reasons for the reverse in efficiency during the 1990s in China. The reasons can be summarized as follows: (1) Productive efficiency in the agricultural sector had reached its highest point as a result of the agricultural policies implemented in the first reform stage. Efficiency declined in consequence of reduced investment in the agriculture sector, as well as worsened conditions for trading agricultural products to industrial buyers; (2) Since the early 1980s the focus of the Reform had switched from the agricultural sector to the industrial sector. Reforms during this period were complicated and the effects of reform policies took time to become apparent. (3) The dual pricing system, which was put into practice in the 1980s, on the one hand, was more efficient in allocating resources than the centrally planned market had been; on the other hand, it encouraged corruption because investment decisions could be distorted by distorted dual prices (Tidrick 1987); (4) As a result of reforms on the financial market and state-owned enterprises (SOEs) during the 1990s, the SOEs and the newly developed Township and Village enterprises suffered from fund insufficiency and thus lost efficiency for the system.

Growth of Technical Changes

With respect to technical change, as we see from the second block of columns of Table 4-4 and the second diagram in Figure 4-3, in the first sub-period, 1979-1985, severe technical regress took place in most provinces as a result of the closed-door policy before the late 1970s. In the second sub-period 1985-1992, technical regress became less severe as a consequence of the successful agricultural policies. However, the negative sign of the parameter on *GTC* (i.e. growth of technical change) indicates that the agricultural reform had hardly introduced new technologies during this sub-period.

Substantial technical progress occurred after 1992 when the positive effects of industrial reform policies and the open-door policy began to be felt. The number of improvements in technical progress outweighed the reverse in efficiency and led to TFP improvements in most Chinese provinces in the period 1992-1998. As we see, the Eastern Zone, which benefited the most from industrial reform policies and the open-door policy, had the highest positive rates of technical change in the last two sub-periods.

To sum up, the pattern of growth of TFP-change varied over time during the whole period 1979-2004. Specifically, the first two sub-periods (1979-1985 and 1985-1992) saw gains in efficiency in most Chinese provinces with the Western Zone having the highest efficiency growth rates; most provinces had negative growth rates of technical progress in the first two sub-periods and the Western Zone suffered the most from severe technical regress. Efficiency improvements outweighed the amount of technical regress and led to TFP progress in most provinces. In the third sub-period, 1992-1998, the pattern of growth of TFP-change became completely different. Most provinces suffered from a loss of efficiency, on the one hand, but gained substantial technical progress, on the other. During this period, the number of positive technical changes exceeded the number of negative efficiency changes and led to positive rates of growth of TFP-change in most provinces. In the last sub-period, 1998-2004, technical progress slowed down but still remained with positive growth rates, while efficiency improvements were achieved by most provinces, both of which led to high rates of growth of TFP-change. In general, growth of TFP-change in China was mainly due to the improvements in technological efficiency in the first two sub-periods and is associated more with technical progress in the last two sub-periods.

The literature shows great differences in terms of the estimated rate of growth of TFP-change and rate of the TFP's contribution to China's GDP growth. The majority of previous studies on China's TFP cover the period 1978-1998. Therefore, to make the current study comparable with previous studies, the rate of growth of

TFP-change for China and the rate of the TFP's contribution at the national level over 1979-1998 have also been calculated. Table 4-5 summarizes these comparisons.

4.4.3 The Inclusion of Human Capital

The results presented above are based on a production function which does not include human capital as an input. However, as we found in Chapter 3, human capital is an important factor in the Chinese economy. Thus, human capital is taken into account in this section to examine its impact on the growth of TFP-change and its components at both the national and provincial levels. Human capital in this section is represented by student enrolment rates in schools at three education levels, namely, primary schools, secondary schools and higher education institutes.

Table 4-6 reports growth rates of TFP progress and its components with human capital included in the production function. Comparing the columns in block III in Table 4-6 (*Growth of TFPC*, i.e. the growth of TFP-change) with those in Table 4-4, we see that the inclusion of human capital in the DEA analysis in most years changes the values of growth rates in the progress of TFP-change and its two components for a majority of Chinese provinces.

We first look at the overall influence of human capital on the growth of efficiency over 1979-2004. Comparing the columns in block I of Table 4-6 with those in block I of Table 4-4, we see that except for Tianjin, Shanghai, Fujian, Jilin, Hainan, Qinghai and Ningxia provinces, where the inclusion of human capital has no impact on the progress of efficiency, human capital reduces the growth rates of the efficiency component in most provinces. This, however, does not necessarily imply that the efficiency level is lower when human capital is taken into account. The relationship between human capital and efficiency level will be examined in section 4.4.4, below.

To examine the changes in technical progress when human capital is included, we compare the columns in block II of Table 4-6 with those in block II of Table 4-4. As can be seen, except for Hainan, Qinghai and Ningxia, where the inclusion of human capital input shows no influence on growth rates of technical progress,[93] human capital accelerates technical progress in most provinces, except for Tianjin, Liaoning, Hebei and Hubei, which have lower growth rates of technical progress when human capital is included in the production function. In section 4.4.4 we examine the effects of human capital on the level of technology.

As a consequence of the above changes due to the inclusion of human capital, growth rates of TFP progress become higher in most provinces when human capital is taken into account in the DEA. However, Hainan, Qinghai and Ningxia provinces show indifference to human capital in terms of the growth of TFP progress; while Tianjin, Liaoning, Zhejiang, Hebei, Henan, Shaanxi and Gansu provinces exhibit lower rates of growth of TFP-change when human capital is taken into account. The overall rate of growth of TFP-change at the national level over the whole period, 1979-2004, increases from 1.98 per cent per annum without human capital to 2.75 per cent with human capital included in the analysis and the contribution rate increases from 21.66 to 30.03 per cent accordingly.

[93] Human capital had no effect on the growth rate of technical progress in Beijing during the first two sub-periods or on Tianjin during the first three sub-periods (see block II of Table 4-6 and block II of Table 4-4).

The diagrams in Figure 4-4 provide a graphic summary of the pattern of growth of TFP-change over time and across the three zones of China when human capital is included in the analysis. Comparing the diagrams in Figure 4-4 with those in Figure 4-3, we see that if we do not take account the differences in terms of the magnitudes of the indices, the patterns of growth of TFP-change obtained from the model with human capital are generally in accordance with that without human capital, with the following exceptions,

- With respect to the growth of technical progress, during the first sub-period, the Eastern Zone had the highest rate of growth of technical change (*GTC*) while the Western Zone had the lowest growth rate in the model with the inclusion of human capital, which was completely unlike the model without it. During the second sub-period, the differences in terms of growth of technical change between the three zones were significant in the model with human capital, while the differences were negligible in the model without. During the last sub-period, the Eastern Zone had a higher rate of growth of technical change relative to the third sub-period; however, in the model without human capital, technical progress in the Eastern Zone slowed down in the last sub-period;

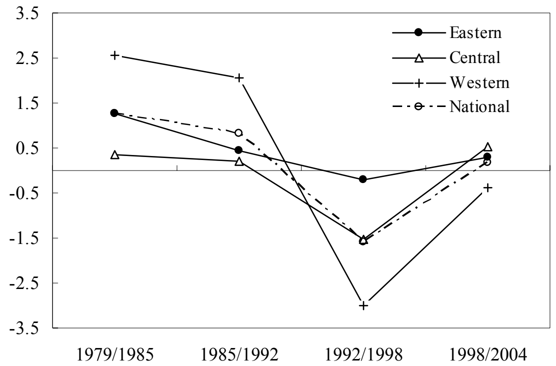
- With respect to the growth of TFP-change, during the first-sub-period the rate of growth of TFP-change in the Eastern Zone was greater than that in the Western Zone, whereas in the model without human capital, the growth of TFP-change of the Eastern Zone was lowest.

Table 4-6 Decomposition of growth of TFP-change and TFP's contribution (including human capital, %)

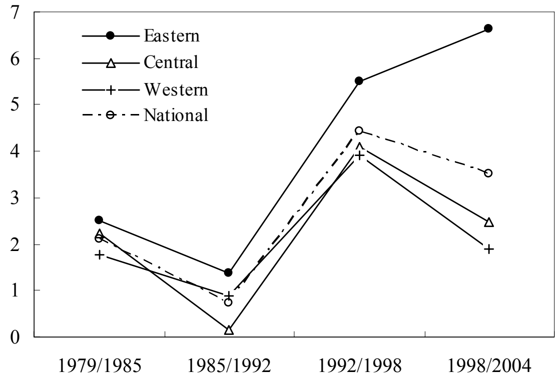
	I. Growth of EC (*GEC*)					II. Growth of TC (*GTC*)					III. Growth of TFP-change					IV. Growth of GDP					V. TFP's Contribution				
	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**	79-85	85-92	92-98	98-04	**79-04**
BeiJing	2.33	-2.56	-4.31	0.49	-0.33	-6.00	0.19	9.79	14.07	3.59	-3.79	-2.37	5.02	14.61	3.25	8.39	3.82	5.15	12.21	7.20	-45.18	-61.93	97.39	119.68	45.10
TianJin	3.87	1.21	2.30	0.73	2.19	-3.40	-4.18	2.27	6.76	-0.10	0.36	-3.04	4.61	7.56	2.09	7.30	2.76	9.55	13.51	7.99	4.96	-110.0	48.24	55.97	26.13
LiaoNing	1.96	0.00	-1.32	0.49	0.13	0.66	0.59	4.65	5.13	2.53	2.65	0.58	3.29	5.65	2.67	8.54	5.90	6.20	9.53	7.47	31.00	9.87	52.98	59.30	35.71
ShangHai	0.00	0.00	0.00	0.00	0.00	2.32	-1.31	6.89	11.38	4.22	2.32	-1.31	6.89	11.38	4.22	4.23	2.08	8.90	11.18	6.36	54.75	-62.91	77.43	101.85	66.43
JiangSu	0.00	-0.34	1.94	0.00	0.00	7.52	6.99	7.59	7.76	7.35	7.52	6.61	9.68	7.76	7.35	10.12	7.88	10.38	12.80	10.18	74.34	83.85	93.26	60.63	72.16
ZheJiang	1.34	0.00	0.00	0.00	0.36	5.06	2.22	3.67	5.50	3.85	6.48	2.22	3.67	5.50	4.22	12.28	7.82	11.24	13.67	11.10	52.73	28.44	32.60	40.20	38.07
FuJian	3.41	4.24	0.00	0.00	1.94	0.78	-0.11	4.98	1.49	1.50	4.25	4.13	4.98	1.49	3.48	13.18	10.88	15.16	9.96	12.22	32.27	37.96	32.84	14.95	28.50
Shandong	0.00	0.00	0.00	0.00	0.00	9.10	4.89	4.30	4.25	5.99	9.10	4.89	4.30	4.25	5.99	14.21	8.50	10.09	12.74	11.25	64.01	57.51	42.58	33.34	53.23
Guangdong	-1.56	1.30	-0.37	0.80	0.09	6.52	2.98	5.45	3.39	4.51	4.88	4.31	5.05	4.21	4.60	11.48	10.69	11.40	12.29	11.43	42.48	40.33	44.31	34.24	40.23
Eastern	**1.26**	**0.43**	**-0.20**	**0.28**	**0.49**	**2.51**	**1.36**	**5.51**	**6.64**	**3.71**	**3.75**	**1.78**	**5.28**	**6.93**	**4.21**	**9.97**	**6.70**	**9.79**	**11.99**	**9.47**	**34.59**	**26.57**	**53.90**	**57.84**	**45.06**
HeBei	-3.10	1.94	-0.95	0.55	-0.21	6.78	1.70	0.98	0.38	2.29	3.45	3.69	0.03	0.95	2.09	8.01	9.01	11.28	12.12	10.05	43.12	40.91	0.28	7.86	20.81
ShanXi	2.40	-1.73	-3.55	-0.26	-0.61	1.93	2.00	7.89	5.81	4.22	4.37	0.20	4.08	5.53	3.57	9.02	4.74	5.90	11.30	7.59	48.49	4.29	69.06	48.93	47.10
Inner M	3.58	-1.17	-2.55	2.43	0.27	-0.69	1.19	7.22	5.72	3.19	2.85	0.01	4.51	8.30	3.47	12.30	3.27	7.43	13.36	8.78	23.20	0.43	60.72	62.13	39.50
JiLin	3.45	-1.79	-1.62	3.00	0.74	-2.50	-0.10	8.24	5.93	2.52	0.89	-1.89	6.49	9.12	3.28	8.70	5.25	8.35	10.80	8.14	10.22	-35.98	77.72	84.44	40.33
HeiLJ	-1.62	-1.23	-2.00	1.99	-0.23	1.24	1.51	6.84	6.03	3.81	-0.38	0.26	4.68	8.10	3.57	5.84	4.86	8.06	11.28	7.38	-6.55	5.43	58.10	71.80	48.34
AnHui	0.00	0.00	0.00	0.00	0.00	3.40	-2.86	1.57	-2.46	-0.34	3.40	-2.86	1.57	-2.46	-0.34	13.87	3.23	11.12	8.67	8.91	24.50	-88.56	14.16	-28.39	-3.83
JiangXi	-0.01	2.18	-0.75	-0.72	0.18	2.76	-1.19	-0.14	-3.12	-0.68	2.77	0.97	-0.87	-3.83	-0.49	7.62	5.75	9.71	10.67	8.31	36.33	16.95	-9.00	-35.94	-5.90
HeNan	0.13	1.12	0.00	0.00	0.03	2.78	0.70	2.71	-2.51	1.10	2.91	1.82	2.71	-2.51	1.13	13.01	7.34	11.25	11.77	10.68	22.38	24.82	24.13	-21.34	10.60
HuBei	1.33	1.73	-2.61	-2.08	-0.26	3.09	-0.40	2.24	3.85	1.93	4.48	1.32	-0.42	1.70	1.67	9.21	5.56	9.47	8.62	8.10	48.68	23.66	-4.41	19.74	20.67
HuNan	-3.20	1.81	-0.58	0.33	-0.14	5.21	0.05	1.48	1.57	1.96	1.83	1.87	0.93	1.93	1.82	5.94	5.26	8.35	8.86	7.02	30.86	35.66	11.13	21.83	25.91
HaiNan	1.05	-0.49	-2.14	0.68	-0.56	0.66	-0.79	5.96	5.91	2.63	1.71	-1.28	3.73	6.63	2.06	10.22	9.91	4.89	9.48	8.66	16.70	-12.94	76.27	69.93	23.82
Central	**0.36**	**0.22**	**-1.52**	**0.54**	**-0.07**	**2.24**	**0.16**	**4.09**	**2.46**	**2.06**	**2.57**	**0.37**	**2.49**	**3.04**	**1.98**	**9.43**	**5.83**	**8.71**	**10.63**	**8.51**	**27.08**	**6.42**	**28.65**	**28.62**	**24.30**
GuangXi	-0.98	6.03	-4.66	-0.10	0.46	5.25	-1.93	-0.77	-4.14	-0.75	4.21	4.00	-5.41	-4.22	-0.29	7.53	9.86	7.61	9.27	8.61	55.91	40.62	-71.03	-45.53	-3.36
SiChuan	0.00	0.00	0.00	-3.04	-0.83	7.61	7.19	5.24	2.34	5.65	7.61	7.19	5.24	-0.77	4.78	8.04	5.94	8.05	9.45	7.78	94.68	121.00	65.04	-8.15	61.38
GuiZhou	1.16	1.48	-1.60	-0.90	0.50	4.72	-0.24	-0.75	-3.03	-0.15	5.92	1.22	-2.36	-3.91	0.33	10.31	5.93	4.04	10.35	7.56	57.39	20.55	-58.47	-37.74	4.38
YunNan	-1.19	3.75	-2.06	-1.51	0.25	6.79	0.74	1.48	-0.87	1.71	5.53	4.51	-0.58	-2.36	1.97	10.16	10.52	6.19	8.07	8.79	54.42	42.85	-9.32	-29.24	22.41
ShaanXi	1.02	1.22	-3.95	1.31	-0.03	0.30	1.08	5.12	4.16	2.59	1.31	2.34	0.99	5.51	2.56	7.54	6.46	4.87	12.70	7.79	17.44	36.20	20.41	43.39	32.87
GanSu	-2.82	-0.02	-3.34	-0.55	-2.01	3.66	2.38	7.34	5.48	4.61	0.74	2.34	3.71	4.91	2.51	7.21	4.69	6.09	9.42	6.75	10.31	50.02	60.95	52.11	37.15
QingHai	5.98	1.22	-4.77	0.27	0.39	-4.60	-0.59	7.25	5.91	1.69	1.10	0.66	2.15	6.21	2.10	9.42	4.40	4.77	11.62	7.38	11.64	14.90	45.09	53.40	28.46
NingXia	12.07	0.79	-4.64	0.48	2.11	-4.74	-0.64	6.97	1.78	0.58	6.73	0.16	1.99	2.27	2.70	8.57	5.24	6.97	11.62	7.96	78.47	3.10	28.59	19.58	33.90
XinJiang	7.77	4.09	-2.08	0.53	2.51	-3.04	-0.13	3.44	5.55	1.29	4.49	3.95	1.31	6.14	3.84	12.97	9.53	5.90	11.38	9.90	34.61	41.47	22.12	53.99	38.75
Western	**2.56**	**2.06**	**-3.01**	**-0.39**	**0.37**	**1.77**	**0.87**	**3.93**	**1.91**	**1.91**	**4.18**	**2.93**	**0.78**	**1.53**	**2.28**	**9.08**	**6.95**	**6.05**	**10.43**	**8.06**	**46.10**	**42.15**	**12.92**	**14.68**	**28.44**
National	**1.27**	**0.83**	**-1.59**	**0.17**	**0.23**	**2.10**	**0.72**	**4.44**	**3.51**	**2.51**	**3.41**	**1.57**	**2.78**	**3.67**	**2.75**	**9.59**	**6.79**	**9.38**	**11.34**	**9.16**	**35.59**	**23.10**	**29.69**	**32.33**	**30.02**

Note: Columns in block I-III are average percentage growth rates according to Equations (4.24)-(4.26) with t_1 and t_2 are start and end years of each sub-period respectively.

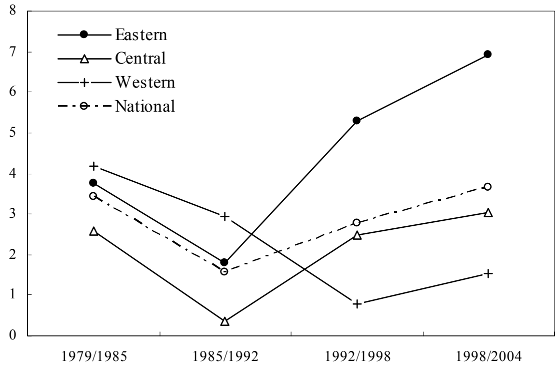
Figure 4-4 Rates of Growth of TFP-change and its components with human capital included (%)



Growth of Efficiency Changes by Belt (including Human Capital)



Growth of Technical Change by Belt (including Human Capital)



Growth of TFP-change by Belt (including Human Capital)

4.4.4 Cumulated TFP Levels

In this section we look at the relation between human capital and the level of productivity. We follow Krüger (2003) and construct three measures of relative productivity levels corresponding to the rates of change in Equations (4.24) to (4.26). To obtain our measures of relative TFP level, relative efficiency level and relative technology level in $t+N$ we cumulate the TFP change, efficiency change and technical change with respect to each province, starting from the distance towards the frontier function in 1979:

$$TFP_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} TFPC_k^{t+N} \quad (4.30)$$

$$EFF_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} EC_k^{t+N} \quad (4.31)$$

$$TECH_k^{t+N} = D_k^t(x_k^t, y_k^t) \cdot \prod_{t+1}^{t+N} TC_k^{t+N} \quad (4.32)$$

To give a clear idea of the impact of human capital on productivity, we compare the three measures obtained from the model including human capital and the model excluding human capital. Table 4-7 presents the three measures for each province over the whole time period, 1979-2004, and the diagrams in Figure 4-5 summarize these three measures at both the zone and national levels in each year.

Looking first at the cumulated efficiency levels (referred to as EFFICIENCY in the first block of columns of Table 4-7), the impact of human capital on this measure varies across provinces. First of all, the endowment of human capital was associated with a higher efficiency level in 15 out of 29 provinces; human capital had no impact on the efficiency level of 8 provinces, where cumulated efficiency levels remain the same, whether or not human capital is included; and the remaining 7 provinces had lower cumulated efficiency levels when human capital was included in the production function.

Recall from section 4.2 that if the index of efficiency change is greater than 1 it indicates an improvement in efficiency; the higher the index, the greater the improvement. We clearly see from the first column of Table 4-7 that Tianjin, Zhejiang and Xinjiang provinces, which had the highest values in the EFFICIENCY index, made the most progress in improving technological efficiency during the whole sample period. Shanghai, Shandong and Anhui, which had the value of the index as unity for each year in the model with human capital,[94] were fully efficient throughout the whole period.

With respect to the cumulated relative technical progress (referred to as TECHNOLOGY in the second block of columns of Table 4-7), we see that human capital improved technical progress in 24 out of 29 provinces, where the values of this index obtained from the model including human capital are higher than those excluding human capital; in Hainan, Qinghai and Ningxia, technology is indifferent to human capital as the values of this index remain the same whether or not human capital is included; and in Tianjin and Hebei, lower technology levels were found when human capital is included. Furthermore, as identified by values higher than 1 from the model including human capital, we find that 18 out of 29 provinces made technological progress between 1979 and 2004 and the greatest progress was achieved in Jiangsu (6.326), Shandong (4.534) and Sichuan (4.178).

[94] Yearly values are not reported here due to limited space but can be obtained from the author on request.

The distribution of the cumulated TFP levels (the third block of columns of Table 4-6) is largely consistent with the distribution of TECHNOLOGY. As we can see, human capital enhanced productivity levels in 23 out of 29 provinces, the values of this measure being higher in the model including human capital than those in the model excluding human capital; in 3 provinces, namely, Hainan, Qinghai and Ningxia, human capital had no impact on the cumulated TFP level; and in the remaining 3 provinces, Tianjin, Hebei and Hubei, lower TFP levels were found in the model including human capital. Moreover, as indicated by the values greater than unity from the model including human capital, we find that two-thirds of Chinese provinces made progress in TFP over the whole period, the greatest progress being achieved in Jiangsu (6.322), Shandong (4.534) and Sichuan (3.366).

Turning to the zone results, from Table 4-7, Figure 4-5 and Figure 4-6, we see that human capital had a positive impact on China's three zones in terms of improving technical efficiency, technological progress and productivity. In general, the Eastern Zone had the highest values in all three indices, while the Western had the lowest values. This finding is consistent with prior expectation.

With regard to productivity at the national level, China made evident TFP progress with the cumulated TFP level over 1979-2004 at 1.464 and evident technical progress, with the cumulated technology level at 1.376.[95] However, the value of cumulated efficiency level fluctuated between 0.7 and 0.8 over the whole sample period,

[95] However, Zheng and Hu (2004) claim that the technical progress is mainly the result of transferring foreign technologies into domestic use and these provinces had little innovation of their own.

indicating that China needs to make more effort to improve its efficiency and capacity to use the existing technology before it introduces new technologies.

Furthermore, as is clear from the diagrams in Figure 4-6, the differences between the Coastal Area and the Inland Area (equivalently, the Central and Western Zones) in terms of TFP indices and TECHNOLOGY indices have been increasing over time. We take this as evidence of the 'diverging trend' of productivity level between the Coastal Area and the Inland Area.

So far, the current findings on the effects of human capital in productivity are in accordance with most previous studies which include human capital. For example, the World Bank (1997) identifies that human capital has had a positive effect on China's TFP growth. Mayer (2001) suggests that in both developed and developing countries human capital facilitates the adoption of technology from abroad. Maudos *et al*. (2003) also claim that human capital fostered both technical change and efficiency change in the OECD countries over the period 1975-1990.

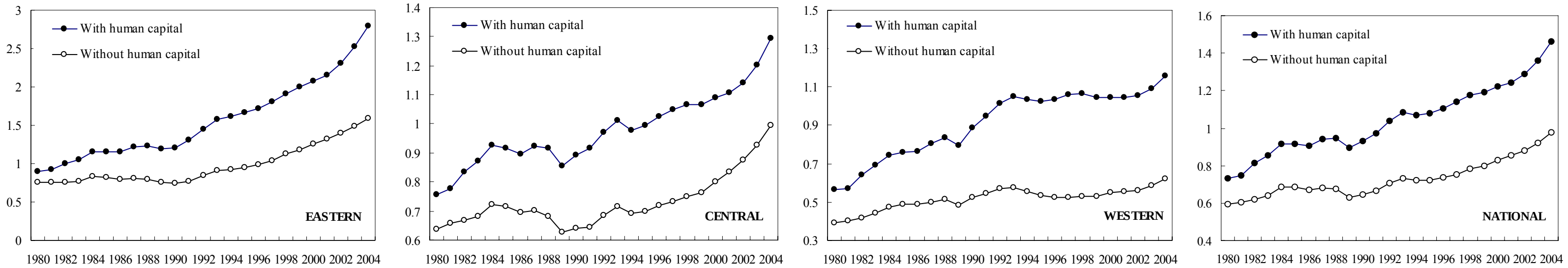
Table 4-7 Comparison of cumulated productivity levels with and without human capital (cumulated over 1979-2004, %)

	Cumulated *EFFICIENCY*		Cumulated *TECHNOLOGY*		Cumulated *TFP*	
	1	0	1	0	1	0
BeiJing	0.586	0.461	1.599	1.280	1.467	0.927
TianJin	1.075	1.075	0.596	0.611	1.047	1.074
LiaoNing	0.948	0.901	1.756	1.647	1.818	1.750
ShangHai	1.000	1.000	2.930	1.456	2.930	1.456
JiangSu	1.000	0.982	6.326	1.959	6.322	2.021
ZheJiang	1.038	1.110	2.523	1.745	2.771	2.410
FuJian	1.007	1.007	0.898	0.827	1.485	1.370
ShanDong	1.000	0.933	4.534	0.963	4.534	1.692
GuangDong	0.892	0.843	2.736	1.161	2.801	1.628
Eastern	**0.949**	**0.924**	**2.655**	**1.294**	**2.797**	**1.592**
HeBei	0.946	0.893	1.803	1.145	1.713	1.815
ShanXi	0.624	0.634	2.140	0.794	1.821	1.025
Inner M	0.463	0.453	0.977	0.719	1.048	0.789
JiLin	0.696	0.696	1.098	1.093	1.331	1.326
HeiLJ	0.770	0.766	2.162	1.004	2.032	1.126
AnHui	1.000	0.999	0.915	0.556	0.915	0.556
JiangXi	0.672	0.724	0.537	0.433	0.564	0.502
HeNan	1.009	0.924	1.328	0.497	1.340	0.867
HuBei	0.757	0.762	1.333	1.331	1.247	1.280
HuNan	0.590	0.576	1.015	0.315	0.979	0.392
HaiNan	0.640	0.640	1.457	1.457	1.260	1.260
Central	**0.743**	**0.733**	**1.342**	**0.849**	**1.295**	**0.994**
GuangXi	0.703	0.725	0.513	0.272	0.579	0.405
SiChuan	0.806	0.540	4.178	0.301	3.366	0.405
GuiZhou	0.382	0.432	0.323	0.172	0.366	0.271
YunNan	0.613	0.580	0.893	0.312	0.955	0.459
ShaanXi	0.521	0.521	1.019	0.581	1.012	0.817
GanSu	0.342	0.348	1.870	0.335	1.102	0.479
QingHai	0.570	0.570	0.796	0.796	0.884	0.884
NingXia	0.511	0.511	0.345	0.345	0.593	0.593
XinJiang	1.104	1.006	0.809	0.677	1.543	1.286
Western	**0.617**	**0.582**	**1.194**	**0.421**	**1.156**	**0.622**
National	**0.768**	**0.758**	**1.376**	**0.755**	**1.464**	**0.977**

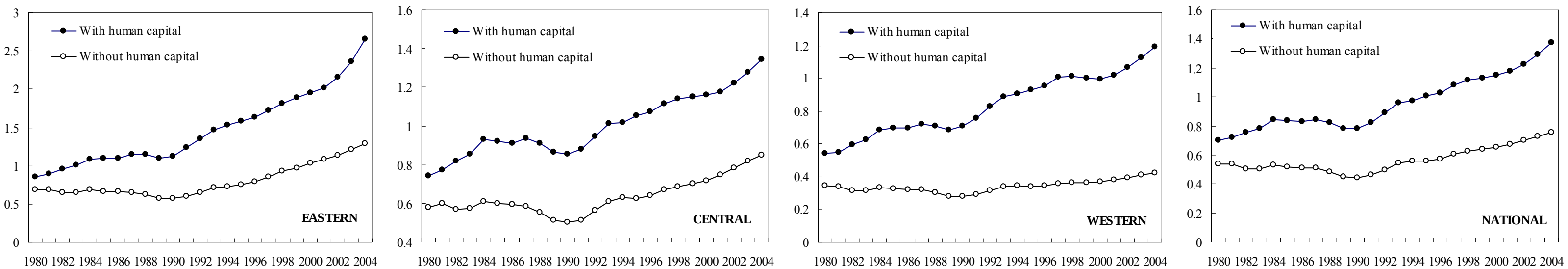
Note:

1. '0' represents results from the model without human capital, while '1' with human capital.
2. The relationship TFPP=EP*TP does not hold for the *cumulated* productivity level.

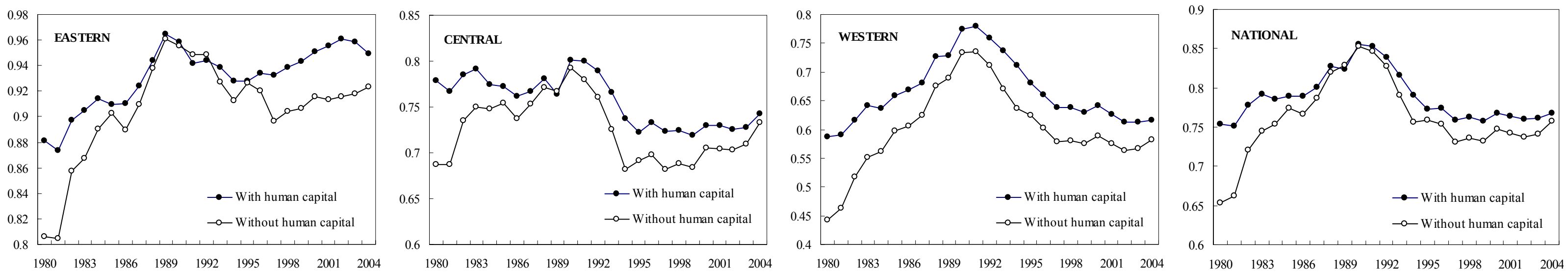
Figure 4-5 Evolutions of cumulated levels of TFP, efficiency, and technology



Cumulated TFP Level Index

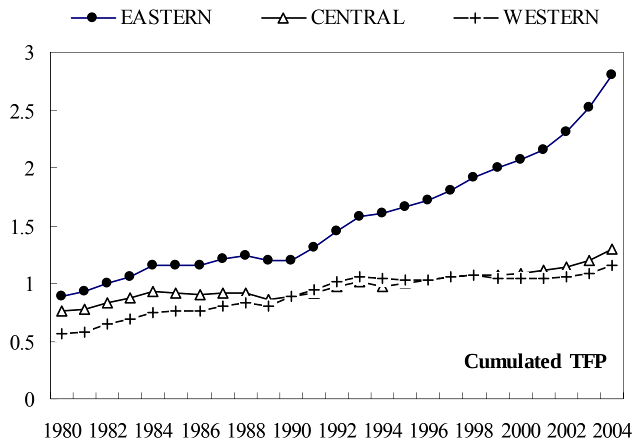


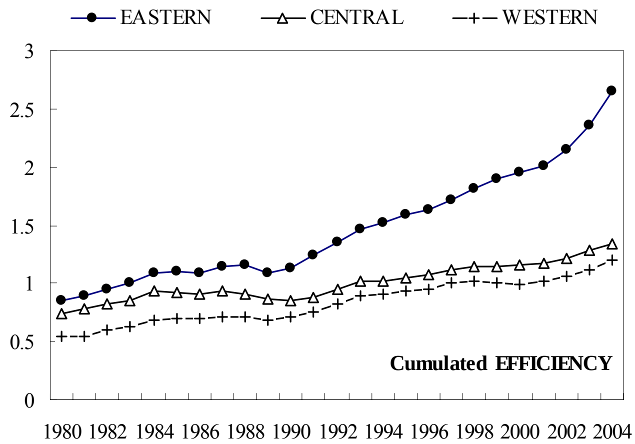
Cumulated Technical Progress

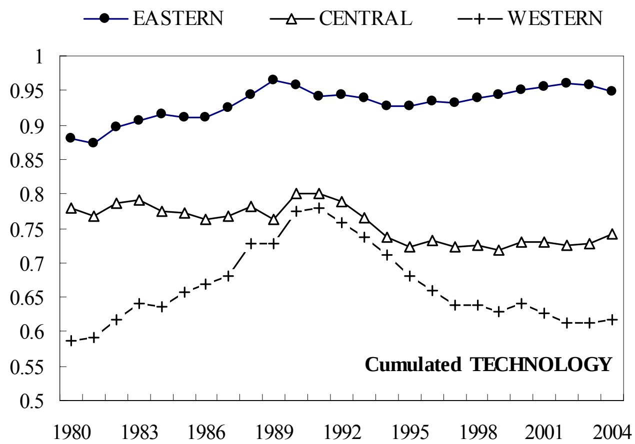


Cumulated Technological Efficiency

Figure 4-6 Evolutions of levels of TFP, efficiency, and technology by zone (including human capital)







4.4.5 Identifying the Frontier

Given the information on TFP-change and its components, we can identify the provinces which are on the technology frontier. Following Färe (1994), we define that a province has contributed to a shift in the frontier between period t and $t+1$ only if it satisfies the following three conditions: (1) the value of technological progress (i.e. TC^k) of the province is greater than 1; (2) the distance at $t+1$ relative to the previous period CRS frontier ($D_o^{k,t}(x^{k,t+1}, y^{k,t+1})$) is greater than 1; and (3) the distance at $t+1$ relative to the same period CRS frontier ($D_o^{k,t+1}(x^{k,t+1}, y^{k,t+1})$) equals 1.

Provinces which satisfy the above conditions are summarized in Table 4-8. In most years during the period 1979-2004, the national production frontier was jointly determined by several provinces (most of them in the Eastern Zone).

Table 4-8 Provinces shifting the frontier

Year	Provinces
1978-79	Jiangsu, Hebei, Shandong, Sichuan, Anhui, Henan
1979-80	Shanghai, Shandong, Sichuan, Anhui
1980-81	Anhui, Shandong, Jiangsu, Shanghai
1981-82	Sichuan, Shandong, Jiangsu, Zhejiang, Anhui, Shanghai
1982-83	Shandong, Sichuan, Jiangsu, Liaoning, Shanghai, Anhui
1983-84	Shandong, Zhejiang, Jiangsu, Sichuan, Liaoning, Anhui, Shanghai
1984-85	Jiangsu, Sichuan, Zhejiang
1985-86	Jiangsu, Liaoning, Zhejiang, Shandong
1986-87	Jiangsu, Henan, Shandong, Sichuan, Zhejiang, Liaoning
1987-88	Sichuan, Jiangsu, Shandong
1988-89	Guangdong
1989-90	Sichuan, Shandong, Xinjiang, Henan, Shanghai, Anhui, Zhejiang
1990-91	Shandong, Sichuan, Zhejiang, Xinjiang, Fujian, Henan, Shanghai, Liaoning, Guangxi
1991-92	Sichuan, Fujian, Liaoning, Shanghai, Guangxi, Zhejiang, Anhui, Henan, Shandong, Xinjiang
1992-93	Fujian, Jiangsu, Liaoning, Sichuan, Shanghai, Henan, Anhui, Zhejiang, Shandong, Xinjiang
1993-94	Jiangsu, Shandong, Fujian, Sichuan, Zhejiang, Shanghai
1994-95	Henan, Jiangsu, Anhui, Shandong, Zhejiang, Sichuan, Shanghai
1995-96	Jiangsu, Shanghai, Sichuan, Shandong, Henan, Fujian, Zhejiang
1996-97	Shanghai, Jiangsu, Sichuan, Fujian, Shandong, Zhejiang, Anhui, Henan
1997-98	Shanghai, Jiangsu, Shandong, Zhejiang, Fujian
1998-99	Shanghai, Jiangsu, Shandong, Tianjin, Zhejiang, Fujian
1999-00	Tianjin, Shanghai, Jiangsu, Zhejiang
2000-01	Shanghai, Jiangsu, Tianjin, Zhejiang, Fujian
2001-02	Shanghai, Jiangsu, Zhejiang, Tianjin, Shandong, Fujian
2002-03	Shanghai, Jiangsu, Zhejiang, Tianjin, Shandong, Fujian, Henan
2003-04	Shanghai, Jiangsu, Shandong, Tianjin, Zhejiang, Henan, Fujian, Anhui

Note: The findings are based on the production function with human capital included as an input.

4.5 CONCLUSIONS

4.5.1 Conclusions

This chapter examines the trends of total factor productivity and its components in terms of both growth and level in the 29 Chinese provinces over the period 1979-2004. Data envelopment analysis was employed to calculate the Malmquist index which was constructed for each province in each year. The Malmquist index for China's three zones was calculated to examine the pattern of distribution of productivity throughout China as a whole.

The current study has made three major contributions to the existing literature. First of all, the decomposition of TFP growth into technical progress and efficiency improvement has important policy implications, because the distinction is fundamental for policy actions. In China's case, equating TFP progress to technical progress, which some researchers acquiesce in, can miss the fact that technical efficiency is an important component of TFP. Therefore, the introduction of new technologies before realizing the full potential of the existing ones may be pointless. As we have seen from the above discussion, considerable productivity growth was found in China in most years and it was accomplished mainly through technical progress rather than efficiency improvements. This serves well as an indication that Chinese firms should make best use of existing technologies at the same time as they are introducing new ones.

Second, human capital has been taken into account in the production function in addition to physical capital stock and labour input. Human capital has proved to be essential in improving Chinese TFP level, accelerating technical progress and enhancing technological efficiency.

Third, by cumulating the Malmquist indices and its components, this study has identified the ‘divergencing trend’ among the Chinese provinces in terms of TFP level and technology level, given the widening differences with respect to productivity levels between the rich and poor provinces.

The findings of this study can be summarized as follows:

(1) On average, the TFP of China grew at a rate of 2.75 per cent per annum when human capital is included in the analysis (1.98 per cent without the inclusion of human capital) during the last 25 years. TFP proved to be important in the Chinese economy with the average contribution rate of 30.02 per cent when human capital was included (21.66 per cent when it was not included).

In terms of the productivity of the three Chinese zones, the average rate of TFP growth and its contribution to GDP growth were 4.21 per cent and 45.06 per cent respectively in the Eastern Zone when human capital is included and 1.98 per cent and 24.30 per cent respectively in the Central Zone and 2.28 per cent and 28.44 per cent respectively in the Western Zone.

Given the importance of TFP in the Chinese economy, we may claim that the pattern of China’s economic growth is consistent with its comparative advantages in producing labour- and capital-intensive products and is sustainable in the long run.

(2) Technical progress and efficiency improvement contributed almost evenly to TFP growth in the Chinese economy during the period under study. However, the roles of the two elements in the Malmquist index differed province by province and period by period. In general, innovation (i.e. technical progress) was the main reason for the TFP growth of the Eastern Zone and the Central Zone, while efficiency improvement accounted for almost all the TFP growth of the Western Zone.

(3) The evolution of productivity change and its components in terms of both growth and cumulated level across different reform stages generally reflected the Chinese people's efforts in terms of improving the country's productivity and technology. However, the analysis also suggests that they should make greater efforts to improve the nation's productive efficiency.

4.5.2 Policy Implications

The above findings give rise to the following policy suggestions:

First of all, the Chinese government should make greater efforts to improve the growth rate of TFP. According to the growth experiences of most countries, an economy should change its growth model from mainly depending on the increments of factor inputs to focusing on improvement in TFP. In China's current situation, the engine of the Chinese economy consists of the increments of factor inputs. This has resulted in low marginal productivity and low efficiency in the use of capital. Therefore, to maintain the country's sustainable economic development, the central government should make more effort to encourage innovation and improve technical efficiency in order to enhance the TFP growth rate. Specifically, the Eastern Zone should increase investment in innovation and re-innovation to enhance the productivity of factor inputs, given that the Eastern Zone has sufficient physical capital and human capital; the Central Zone should develop profit-making mainstay industries and advantageous industries, given that the physical capital investment in this zone has reached a certain level; regarding the Western Zone, the Chinese government should provide more financial aid to improve its investment environment. Meanwhile, some better developed regions in the Western Zone should develop high-tech industries to enhance their capacity to innovate.

Second, China should improve its efficiency in exploiting technologies. The main problem of introducing foreign technologies in China is its low capacity to make use of technologies. Li and Xu (2008) argue that the ratio of technology use to the cost of introducing technology in large and medium-sized Chinese industrial enterprises is lower than 10 per cent, which is much lower than the more than the 300 per cent in most developed countries. Therefore, when introducing advanced technologies, Chinese industrial enterprises should make sure that they have made the best of existing technologies. At the same time, the Chinese government should encourage the activity of re-innovation in addition to introducing advanced foreign techniques. Only in this way will China's sustainable economic development expand to the fullest.

Third, China should pay more attention to the relation between the accumulation of human capital and productivity progress. Its technical progress of China is in a situation where many scientific achievements cannot be used to benefit productivity. According to the statistical data, the number of Science Citation Index (SCI) papers of China ranks 5th in the world. However, the average rate of indexing of each paper ranks 120th. Tao Zhang, a member of the standing committee of the National Committee of the Chinese People's Political Consultative Conference, pointed out that there is a huge bubble made up of the scientific achievements in China, most of which have no practical value (Jiefang Daily, 7th September 2006). Therefore, the Chinese government should, on the one hand, strengthen regulations on the marketing transformation of Chinese independent intellectual property rights; on the other, the Government should increase investment on education in order to enhance the potential of Chinese employers in terms of using technologies.

CHAPTER 5: INDUSTRIAL GROWTH IN THE EASTERN ZONE OF CHINA DURING 2001-2005

The industrial sector[96] is essential to the Chinese industrialized economy and is the main component of its secondary industry (the other component is construction). The industrial sector's share of Chinese GDP was 40 per cent between 1978 and 2005 and real industrial output rose more than 10-fold in the post-reform period. With industrial output growing by 9 per cent a year, China's industrial sector enjoyed a super-growth.[97]

This chapter focuses on the industrial growth of 26 industries in six provinces and three municipalities (henceforth 'provinces') within the Eastern Zone (or equivalently, the Coastal Area)[98] of China between 2001 and 2005,[99] and aims to examine the correlates of industrial growth. Certain distinguishing features of the current analysis are worth noting. First, most of the studies on the growth of a developing country focus on aggregate GDP at the national or provincial level and the current 'focus on individual industrial sectors is likely to yield more reliable estimates' (Mody and Wang 1997, p.295). This is because province-specific variables, such as education, exports and transport infrastructure, are likely to be influenced by

[96] The industrial sector in the current study refers to the material production sector. The term 'industry' in the context refers to an individual industry in the industrial sector.

[97] Unless otherwise stated, the figures in this chapter come from the author's calculations based on data from various editions of *China Statistical Yearbooks* and various statistical yearbooks at the province level.

[98] See Table 2-1 in Chapter 2 for the definition of the spatial divisions of China.

[99] Chinese manufacturing industries are mainly located in the more developed Eastern Belt which includes six provinces and three municipalities (hereafter 'nine provinces'). In 2004, the Eastern Belt produced 67.6 per cent of the nation's whole industrial output.

overall provincial growth rather than by province-industrial growth,[100] and therefore the endogeneity of province-specific variables poses a less serious problem. Second, by studying industrial growth within the relatively homogeneous Eastern Zone of China, the current analysis overcomes the concerns in interpreting cross-sectional growth regressions where it is difficult to control for wide heterogeneities in economic and social systems. Third, the econometric technique which is employed in the current study, with regressions controlled for heteroskedasticity across provinces and observations weighted by provincial population, produces more reliable empirical findings. Finally, although covering only a short time period of 2001-2005, this study is able to exploit the panel features of the data and examine the externalities which influence the province-industrial growth.

This chapter is organized as follows: Section 5.1 demonstrates the explosion of pent-up entrepreneurship in China during the post-reform era. Section 5.2 presents a three-way error component model and discusses the econometric methods used to estimate the model. Section 5.3 distinguishes three types of external variable: the industry-specific variables, the inter-provincial industrial spillovers variable and the province-specific variables. The data used for the current analysis are also described briefly in this section. Section 5.4 presents and interprets the empirical findings. In section 5.5, sensitivity tests are carried out to investigate the robustness of the externalities. Section 5.6 concludes the analysis.

[100] Given that the share of industrial output in China's GDP was 40 per cent during the post-reform period, the environmental variables, such as education, exports and transport infrastructure, may be influenced more or less by province-industrial growth.

5.1 EXPLOSION OF PENT-UP ENTREPRENERUSHIP

The development of the industrial sector was outstanding in the post-reform period, in particular since the 1990s, when economic reforms were extended throughout the country. The average annual growth rate of industrial output in the whole industrial sector increased from 8.46 per cent over 1985-1990 to 19.15 per cent over 1999-2004 (see the upper panel of Table 5-1).

Rapid industrial growth during the post-reform period was accompanied by an explosion of constrained entrepreneurship. Generally, a firm in China can either be state-owned or non-state-owned. The state-owned enterprises (SOEs) refer to those created and managed by a government at the state or province level. Non-state-owned enterprises include those funded by domestic private capital or foreign capital, joint enterprises and the collectively-owned enterprises (COEs) which are typically owned by local governments – that is, by governments below the province level. On average, an SOE is larger than a non-SOE in terms of both output and employment.

After three decades of economic reforms, enterprises in the non-state sector have become the star performers in China. As we see from the lower panel of Table 5-1, the industrial output share of the Chinese SOEs diminished over time, while the non-state sector's share of industrial output increased over time. More specifically, from the state sector's perspective, the SOEs' share of the total volume of industrial output fell from 59.05 per cent over 1985-1990 to 42.38 per cent over 1999-2004. In the non-state sector, the share of the COEs went down from 34.61 per cent to 10.42 per cent; the share of private enterprises increased dramatically from 3.80 per cent to

20.45 per cent; and the share of other enterprises, including joint ventures and foreign funded enterprises, increased from 2.54 per cent to 36.76 per cent.

Table 5-1 Growth and shares of Chinese industrial output by entrepreneurship (1985-2004, %)

	Average Exponential Growth of Industrial Output[a] (%)				
	Total	SOE[b]	COE	Private	Rest[c] (foreign[d])
1985-1990	8.46	4.75	10.89	35.51	40.76
1990-1995	14.92	4.48	16.18	38.77	50.41
1999-2004[e]	19.15	11.55	-4.34	54.97	28.12 (23.70)
	Share of Industrial Output (%)				
	Total	SOE	COE	Private	Rest (foreign)
1985-1990	100	59.05	34.61	3.80	2.54
1990-1995	100	46.76	35.33	7.83	10.08
1999-2004	100	42.38	10.42	20.45	36.76 (28.98)

Note:
a. Values of industrial output are deflated by ex-factory industrial output prices.
b. Data on SOEs over 1999-2004 include those controlled by the state.
c. Over 1999-2004, data on 'rest' enterprises include data on 'foreign' enterprises. 'Foreign' enterprises data are in the parenthesis.
d. 'Foreign' refers to enterprises funded by foreign capital.
e. Industrial output after 1999 refers to those produced by SOEs and enterprises above designated size.

Gains in the industrial sector were especially remarkable in the Eastern Zone of China, where the average annual growth rate of industrial value-added during the most recent years surveyed, 2001-2005, was 25.77 per cent. Columns 2-5 of Table 5-2 present the average growth rates in the Eastern Zone of industrial value-added according to ownership. As we can see, the growth of industrial value-added produced by the SOEs during 2001-2005 varied considerably between the nine coastal provinces. Zhejiang province had the largest average growth rate of 44.8 per cent a year and Beijing had on average a negative annual growth rate of -14.4 per cent. Turning to the non-state sector, the COEs' industrial value-added declined rapidly in six provinces during 2001-2005 and grew at a negligible rate in the other three provinces. 'Foreign' enterprises, which are funded by foreign investors including those from Hong Kong, Taiwan, Macao and the rest of the world, performed well during the period with an average growth rate of 24.6 per cent per annum in the three municipalities and 31.9 per cent per annum in the six provinces. In comparison, industrial value-added by 'other' enterprises, which are mainly funded by domestic private capital, grew at 37.6 per cent per year in the three municipalities and 33.7 per cent per year in the six provinces.

Distinguishing the growth rates of the heavy industrial sector from those of the light industrial sector, we can see from Tables 5-2 and 5-3 that heavy industries grew faster than light industries in all provinces in terms of both industrial value-added and the number of firms. The growth of industrial value-added and number of firms by firm size are reported in the last three columns of Tables 5-2 and 5-3. We can clearly see that in terms of both industrial value-added and number of firms, medium-sized firms grew faster than small firms, while large firms had the lowest growth rates of industrial value-added.

The impression presented so far is that the non-state sector grew faster than the state sector, that the heavy industries grew faster than the light industries and that medium-sized firms and small firms performed better than the large firms. This impression is further confirmed by the information given in Tables 5-4 and 5-5, which report the shares of industrial value-added and number of firms by ownership, light and heavy industrial sectors and size.

As a conclusion from the explosion of entrepreneurship in China, Maddison (1998, p.55) claims that 'small scale industrial activities were freed from government controls and their performance greatly outpaced that of the state sector.'

Table 5-2 Average growth rate of industrial value-added by entrepreneurship; whether heavy or light; and size (2001-2005)

	Total Industrial Value-added	SOE	COE	Foreign Funded	Other	Light Industry	Heavy Industry	Large size	Medium size	Small size
Beijing	0.245	-0.144	-0.082	0.248	0.531	0.129	0.277	0.259	1.124	0.248
Tianjin	0.224	0.082	-0.131	0.241	0.355	0.087	0.276	0.135	1.042	0.136
Shanghai	0.217	0.045	-0.056	0.250	0.241	0.107	0.268	0.123	0.794	0.236
Municipalities	**0.228**	**-0.006**	**-0.090**	**0.246**	**0.376**	**0.107**	**0.274**	**0.172**	**0.987**	**0.207**
Fujian	0.270	0.066	-0.030	0.253	0.441	0.230	0.311	0.141	0.897	0.265
Guangdong	0.241	0.323	-0.128	0.248	0.272	0.160	0.317	0.202	0.777	0.164
Jiangsu	0.273	0.121	0.015	0.393	0.275	0.178	0.333	0.258	0.540	0.204
Liaoning	0.233	0.076	0.076	0.267	0.292	0.208	0.240	0.153	1.149	0.237
Shandong	0.326	0.123	0.017	0.373	0.441	0.258	0.377	0.200	0.825	0.351
Zhejiang	0.290	0.448	-0.177	0.381	0.300	0.230	0.359	0.233	0.859	0.230
Provinces	**0.272**	**0.193**	**-0.038**	**0.319**	**0.337**	**0.211**	**0.323**	**0.198**	**0.841**	**0.242**

Note: 1. Values of industrial value-added are deflated by ex-factory industrial output prices. 2. In this section industrial output refers to that of SOE and those with sale income above five million Yuan. 3. Foreign funded enterprises include those funded by investors from Hong Kong, Taiwan, Macao and the rest of the world. 4. 'Other' enterprises include mainly private enterprises, partnerships, individuals, joint ventures with foreigners, and COEs below the township level. 5. Bold figures are averages for municipalities and provinces respectively. Source: *China Statistical Yearbooks* of various editions. *Same to Table 5-3 - Table 5-5*.

Table 5-3 Average growth rate of number of firms by entrepreneurship; whether heavy or light; and size (2001-2005)

	SOE	COE	Foreign-funded	Other	Light	Heavy	Large size	Medium size	Small size
Beijing	-0.092	-0.129	0.072	0.376	0.044	0.173	-0.219	0.130	0.135
Tianjin	-0.077	-0.169	0.053	0.251	-0.022	0.078	-0.226	0.035	0.047
Shanghai	-0.195	-0.088	0.112	0.219	0.053	0.172	-0.099	0.163	0.132
Municipalities	**-0.121**	**-0.128**	**0.079**	**0.282**	**0.025**	**0.141**	**-0.181**	**0.109**	**0.105**
Fujian	-0.154	-0.041	0.144	0.389	0.156	0.208	-0.119	0.211	0.191
Guangdong	-0.141	-0.184	0.161	0.282	0.121	0.199	-0.056	0.332	0.148
Jiangsu	-0.235	-0.127	0.207	0.182	0.094	0.166	-0.073	0.208	0.135
Liaoning	-0.039	0.023	0.145	0.410	0.142	0.232	-0.143	0.210	0.224
Shandong	-0.146	-0.150	0.236	0.373	0.188	0.270	-0.151	0.173	0.265
Zhejiang	-0.110	-0.130	0.297	0.257	0.191	0.294	-0.024	0.542	0.230
Provinces	**-0.137**	**-0.101**	**0.198**	**0.316**	**0.149**	**0.228**	**-0.094**	**0.279**	**0.199**

Note: Firms in this table refer to the SOEs and those above designated size.

Table 5-4 Share of industrial value-added by ownership; whether heavy or light; and size (2001-2005)

	SOE	COE	Foreign Funded	Other	Light Industry	Heavy Industry	Large size	Medium size	Small size
Beiing	0.157	0.033	0.424	0.385	0.212	0.788	0.495	0.211	0.294
Tianjin	0.102	0.080	0.478	0.339	0.263	0.737	0.458	0.228	0.314
Shanghai	0.083	0.035	0.605	0.278	0.297	0.703	0.467	0.210	0.322
Municipalities	**0.114**	**0.050**	**0.502**	**0.334**	**0.257**	**0.743**	**0.473**	**0.217**	**0.310**
Fujian	0.084	0.030	0.612	0.274	0.473	0.527	0.323	0.280	0.398
Guangdong	0.051	0.036	0.633	0.279	0.463	0.537	0.369	0.262	0.369
Jiangsu	0.087	0.078	0.337	0.498	0.371	0.629	0.317	0.274	0.409
Liaoning	0.172	0.045	0.225	0.558	0.175	0.825	0.551	0.182	0.268
Shandong	0.102	0.159	0.162	0.577	0.415	0.585	0.401	0.229	0.370
Zhejiang	0.061	0.049	0.219	0.671	0.508	0.492	0.175	0.279	0.546
Provinces	**0.093**	**0.066**	**0.364**	**0.476**	**0.401**	**0.599**	**0.356**	**0.251**	**0.393**

Table 5-5 Share of number of firms by ownership; whether heavy or light; and size (2001-2005)

	SOE	COE	Foreign-funded	Other	Light Industry	Heavy Industry	Large size	Medium size	Small size
Beijing	0.238	0.131	0.231	0.400	0.446	0.554	0.032	0.082	0.886
Tianjin	0.205	0.191	0.253	0.351	0.448	0.552	0.031	0.081	0.888
Shanghai	0.058	0.121	0.384	0.438	0.482	0.518	0.034	0.088	0.878
Municipalities	**0.167**	**0.148**	**0.289**	**0.396**	**0.459**	**0.541**	**0.032**	**0.083**	**0.884**
Fujian	0.081	0.110	0.421	0.388	0.600	0.400	0.023	0.084	0.893
Guangdong	0.058	0.092	0.440	0.411	0.603	0.397	0.021	0.100	0.879
Jiangsu	0.038	0.092	0.203	0.667	0.467	0.533	0.018	0.088	0.894
Liaoning	0.176	0.140	0.190	0.493	0.337	0.663	0.035	0.083	0.882
Shandong	0.077	0.139	0.173	0.611	0.497	0.503	0.040	0.122	0.837
Zhejiang	0.022	0.044	0.154	0.781	0.565	0.435	0.008	0.064	0.928
Provinces	**0.075**	**0.103**	**0.263**	**0.558**	**0.512**	**0.488**	**0.024**	**0.090**	**0.885**

5.2 THE MODEL AND ESTIMATION METHODS

To study industrial growth in the Eastern Zone of China, a three-way error component model was employed to carry out the analysis and different econometric techniques were used to estimate the model.

5.2.1 Model Specification

The model employed in the current study is based on the following three-way error component model, which was developed by Glaeser *et al*. (1992), Henderson, Kuncoro and Turner (1995), Mody and Wang (1997), Gao (2004) and Andrews *et al*. (2006):

$$(5.1) \qquad G_{ijt} = x_{ijt}\beta + w_{jt}\gamma + u_i\eta + q_j\rho + \alpha_i + \phi_j + \mu_t + \varepsilon_{it},$$

where the subscript $i = 1,...,N$ indexes industries, $t = 1,...,T_i$ time periods and $j = 1,...J$ provinces. Industries are nested within provinces over the period;

G_{ijt} is the growth rate of industrial value-added of industry *i* in province *j* at time period *t*. It is the dependent variable in the model;

x_{ijt} and u_i are the vectors of the observable i-level covariates;

w_{jt} and q_j are the vectors of the observable j-level covariates; and

the error components (or unobserved heterogeneities) comprise α_i for the industry and ϕ_j for the province. The third error component, μ_t, represents the unobserved time effect. α_i, ϕ_j and μ_t may be correlated with each other and also with any of the observable covariates. The last error component, ε_{it}, is assumed to be strictly exogenous.

Note that both α_i and u_i are time-invariant for industries and similarly both ϕ_j and q_j are time-invariant for provinces. However, x_{ijt} varies across i, j and t and w_{jt} varies across j and t. Yet, because the data are recorded at the (i,t) level, province-level covariates also vary at the (i,t) level. Thus we should strictly write $w_{J(i,t)t}$ and $q_{J(i,t)}$, where $J(i,t)$ is the function which maps industry i to province j at time t (Andrews *et al*. 2006, p.3).

Equation (5.1) therefore contains all the possible types of covariates which could be supplied about the industry-province data. For studying industrial growth, x_{ijt} may include a vector of industry-specific variables such as local specialization in a specified industry, local competition within the industry, per capita initial industrial value-added, industrial diversity and inter-provincial industrial spillovers. w_{jt} may include a vector of such province-specific variables as education, exports, imports, FDI, provincial market size, network of highways and the state sector's share of value-added. The time-invariant variable u_i is a dummy variable, which could be an index to distinguish heavy industries from light ones and q_j could be an index which measures the preferential foreign policies of a province.[101] The two variables are only useful when one wants to identify the error components α_i and ϕ_j, as we shall see below. We assume that there are K observed covariates in total.

It is practical to assume that the heterogeneity terms α_i and ϕ_j are correlated with

[101] The preferential policy index for mainland China's provinces is constructed by Démurger *et al*. (2002). Table 2-6 in chapter 2 presents the indices.

the observables. This means that random effects methods are inconsistent and fixed effects methods are appropriate to estimate the parameters of interest. This, in turn, means that η and ρ, the parameter vector associated with the time-invariant variables, u_i and q_j, is not identified. For this, Andrews *et al*. (2006) suggest that rather than dropping $[u_i, q_j]$, it is usual to define

(5.2) $\theta_i \equiv u_i\eta + \alpha_i$, and $\psi_j \equiv q_j\rho + \phi_j$.

Substituting (5.2) into (5.1) gives

(5.3) $G_{it} = x_{ijt}\beta + w_{jt}\gamma + \theta_i + \psi_j + \varepsilon_{it}$.

Furthermore, the unobserved time component μ_t is treated as fixed and hence can be estimated directly by using time dummies; to do this is practical as long as the time dimension of the panel is short (Andrews *et al*. 2006). Therefore, by subsuming time dummies into one of the vectors of observable covariates, the model has successfully dropped the time effect μ_t. This successfully turns a three-way error components model (5.1) into a two-way error components model (5.3), on the basis of which one can investigate the correlates of industrial growth. Moreover, by means of Equation (5.2), one can obtain the parameters of the error components.

5.2.2 Estimation Methods

The methods for the fixed effects estimation of the three-way error components model are not yet standard (Andrews *et al*. 2006, p.1). The present analysis of linked industry-province data follows the methods developed by Andrews *et al*. (2006).

Andrews *et al*. recommend an easy and practical method of 'spell fixed effects' if one is not interested in the estimates of θ_i and ψ_j in Equation (5.2), or equivalently, of estimating the parameters on the time-invariant variables u_i and q_j. Consistent estimates of the parameters β and γ in Equation (5.3) are 'straightforward to obtain by taking differences or by time-demeaning within each unique industry-province combination (or "spell")' (Andrews *et al*. 2006, p.3).

If one wishes to recover estimates of θ_i and ψ_j, one can use an alternative estimator, the Least Squares Dummy Variables (LSDV) estimator. Andrews *et al*. argue that the LSDV estimates of α_i, which is the error component for the lower-level, i.e. industry-level, is found to be inconsistent, although unbiased.[102] The estimates of ψ_j have the same properties as those of $[\beta, \gamma]$ (Andrews *et al*. 2006, p.4).

However, a direct estimation of Equation (5.3) using dummy variables when the dataset is large is not usually feasible, since the model has a high number of parameters, approximately $K + N + J$, to estimate. In a two-way error component model, this problem is avoided by using the within transformation which sweeps out the i-level heterogeneity. Yet Andrews *et al*. argue that for a model which has a high number of observations, for example, linking worker-firm, there is no algebraic transformation of the observables that sweeps away both heterogeneity terms (i-level and j-level) at once and allows them subsequently to be recovered. 'This is

[102] See Wooldridge (2002, ch.10) for the assumptions and properties of panel data models (cited in Andrews *et al*. 2006, p.4).

because of the lack of patterning between workers and the firms they work for ... More precisely, sort the data by industries and the province dummies are un-patterned; sort the data by provinces and the industry dummies are un-patterned' (Andrews *et al*. 2006, p.4). This method, which explicitly includes dummy variables for the higher-level heterogeneity but sweeps out the lower-level heterogeneity algebraically, gives exactly the same solution as the LSDV estimator (Abowd *et al*. 1999). Andrews *et al*. further find that, in linear models, there is no distinction between removing the heterogeneity algebraically and adding two full sets of dummy variables, for higher and lower levels. Therefore, as a solution to the stated problem, according to Andrews *et al*., one must generate a dummy variable for each province:

$$(5.4) \qquad F_{it}^{j} = 1(J(i,t) = j) \quad j = 1,...,J,$$

where 1(.) is the dummy variable indicator function and the function $J(i,t) = j$ maps industry i at time t to province j (Andrews *et al*. 2006, p.5).

Substitute

$$(5.5) \qquad \psi_{J(i,t)} = \sum_{j=1}^{J} \psi_j F_{it}^{j}$$

into (5.3) and then θ_i is removed by time-differencing over i such that:

$$(5.6) \qquad G_{it} - \overline{G}_i = (x_{it} - \overline{x}_i)\beta + (w_{jt} - \overline{w}_j)\gamma + \sum_{j=1}^{J} \psi_j (F_{it}^{j} - \overline{F}_i^{j}) + \varepsilon_{it}.$$

Write (5.6) in a matrix notation,

$$(5.7) \qquad \widetilde{G} = \widetilde{X}\beta + \widetilde{F}\psi + \varepsilon,$$

where $\widetilde{G}$, $\widetilde{X}$ and $\widetilde{F}$ are mean-deviated. This indicates that J demeaned (i.e. differenced) province dummies actually need to be created. This estimator is labelled

FE*i*LSDV*j* to distinguish it from the LSDV estimator. The two estimators are identical in the results which they produce, but differ in the way in which they are computed (Andrews *et al*. 2006, p.5).

There are two potential computational problems with the FE*i*LSDV*j* estimator, as pointed out by Andrews *et al*. The first problem comes from the number of the higher level J. Some datasets linking worker-firm data have tens of thousands of firms, or even hundreds of thousands. It is problematic for a statistical package to invert a matrix of dimension $(K+J)\times(K+J)$. However, for some applications such as the current industry-province case, the number of provinces is sufficiently small to make the FE*i*LSDV*j* estimator computationally feasible.

The second problem deals with the memory capacity of a statistical package. One must create and store J mean-deviations for N^* observations and this indicates a data matrix of $N^*\times(K+J)$, which may be prohibitively large for the software packages which store all data in memory (Andrews *et al*. 2006, p.5). The memory required for the data matrix of the FE*i*LSDV*j* estimator is approximately $(N^*J)+4[N^*(K+1)]$ bytes for the mean-deviated province dummies and the remaining K explanatory variables and dependent variables, which ranges only between 1794~2522 bytes for the current analysis. Therefore, the memory requirement does not impose a problem for the present study.

5.3 EXTERNALITIES AND DATA

The current study focuses on industrial growth rather than on productivity growth in the industrial sector, partly because the labour force data at the industry-province level are not consistently available. However, the data on province-industrial value-added are so rich that

> "considerable insights can be obtained even in the absence of information on labour and capital inputs ... Indeed, if we believe that enterprise-level decisions to acquire or invest in labour or capital inputs are influenced by available knowledge, infrastructure, human capital and industrial organization, then not only productivity but also a considerable amount of output growth can be attributed to these factors" (Mody and Wang 1997, p.299).

5.3.1 Externalities

This study assesses the importance of both dynamic and static externalities in province-industrial growth in the Eastern Zone of China. Because results of this type of analysis are sensitive to the choice of samples and conditioning sets of variables, this study aims at describing the most robust partial correlates rather than testing any specific model of industrial growth for this area

Dynamic externalities, which arise from knowledge spillovers, are 'viewed as the engine of growth in the recent literature on endogenous growth and have implications for long-run industrial growth' (Gao 2004, p.101-2). In the literature, dynamic externalities include regional specialization, competition, industrial diversity and inter-provincial industrial spillovers, which reflect 'technological spillovers among firms within an industry' (Gao 2004, p.104). Static externalities

> "may arise due to the interplay between increasing returns to scale internal to firms and transport costs under product differentiation and imperfect competition. Increasing returns at the firm level imply that an individual firm will concentrate its production in a small number of places to take advantage of scale economies" (Gao 2004, p.105).

In this study, we first consider as many dynamic and static factors as possible, then follow a general-to-specific strategy to identify those which are most influential. Only those factors which are important to the industrial growth of the Eastern Zone of China are presented here. For the static province-specific variables, the following four are included in the analysis: education, exports, local market size and transport infrastructure.[103]

It is sometimes difficult to distinguish strictly the effects of dynamic and static externalities. This is because, for instance, 'regional specialization, which gives rise to some of the dynamic externalities, is usually caused by natural advantage and local market conditions in the first place' (Gao 2004, p.103). Moreover, in some circumstances, certain factors have both static and dynamic effects on growth. For example, FDI, which is very much directed by policies, to a great extent reflects the technological transfer from other countries.

The system showing how industrial growth correlates with externalities is illustrated in Figure 5-1, which presents a simple economy with two provinces (A and B) and two industries (1 and 2). The most proximate influences on the growth of an industry come from industry-specific factors, such as local specialization on a specified industry, local competition between firms within an industry and initial industrial value-added level, which condition the extent of knowledge flows within the specified industry (Mody and Wang 1997). Province-specific factors such as local education level, degree of openness, size of domestic market and transport

[103] To find the region-specific factors that play important roles in the Eastern Belt's regional industrial growth, the estimation starts with a general model which includes a variety of region-specific variables. The empirical analysis turns out that the above-stated four region-specific factors are the most important to the industrial growth in the Eastern Belt of China.

Besides the externalities stated in the context, I have also tested for the correlates between industrial growth and some other factors which are frequently considered in the literature, including industrial diversity, state sector's share of industrial output, per capita FDI and telecommunications. All parameters of these factors turned out to have correct signs but not statistically significant. To keep the context neat, these factors are not fully described.

infrastructure are also found to have an important influence on the development of an industry. Besides, the growth of an industry from one province is also influenced by the growth of the same industry outside the province, which captures knowledge flows within the same industry and is called inter-provincial industrial spillover. Furthermore, the growth of industry 1 may be influenced by the other industries in the same province, that is, through the effects of industrial diversity.[104]

Industry-specific Variables

Three industry-specific variables are found essential in the current industrial growth analysis, namely, the level of local specialization, local competition and initial industrial size. Following Glaeser *et al*. (1992), Mody and Wang (1997) and Gao (2004), the measures of local specialization, S_{ijt} and local competition, C_{ijt}, are calculated as follows:

$$(5.8) \qquad S_{ijt} = \frac{\text{(output in industry } i \text{ / total industrial value - added) for province } j}{\text{(output in industry } i \text{ / total industrial value - added) for all nine provinces}}$$

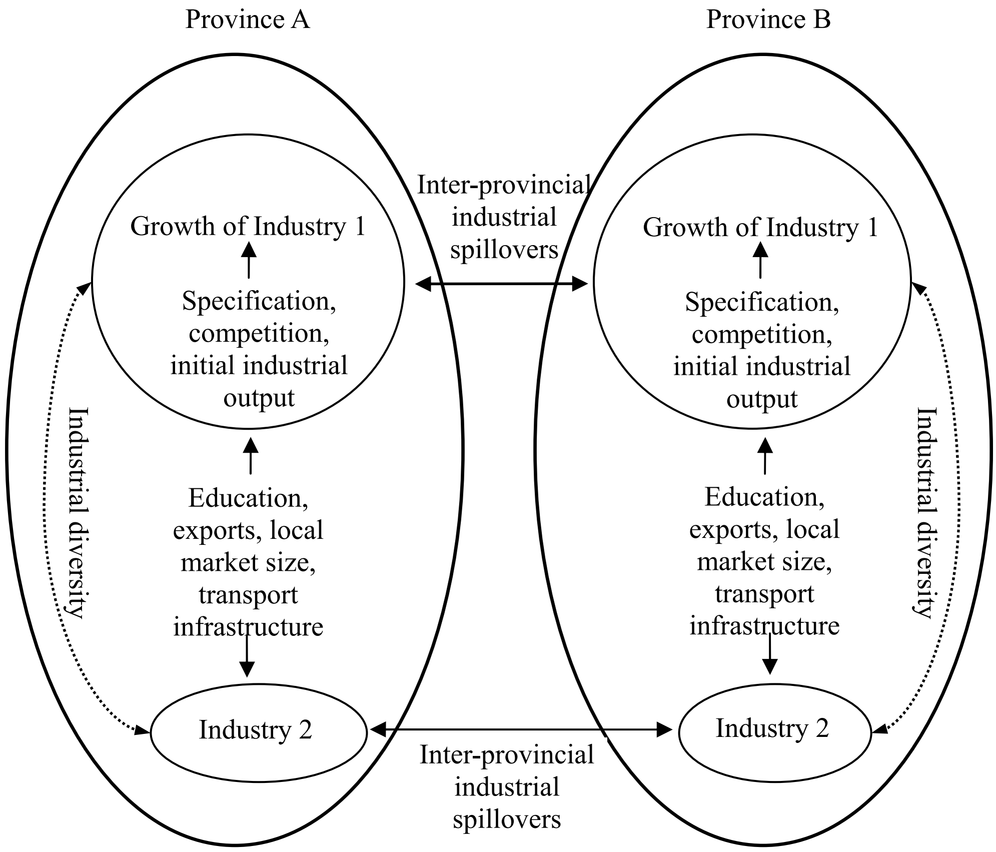
$$(5.9) \qquad C_{ijt} = \frac{\text{(number of firms / industrial value - added) for industry } i \text{ in province } j}{\text{(number of firms / industrial value - added) for industry } i \text{ in all nine provinces}}$$

where i is industry, j is province, y is industrial value-added and the time subscript indicates that these measures are different for each year.

[104] The industrial diversity variable is quantified by the sum of squared output share of industry other than i in region j, $D_{ijt}=\sum_{k\neq i}(y_{kj}/y_{.j})^2$. This variable, on one hand, measures the knowledge spillovers from other industries, on the other hand reflects the alternative choice of consumers. A higher value of this index indicates less industrial diversity in the province. Presumably, 'a higher degree of diversity helps industrial growth, so industrial growth should be negatively related to the measure of D_{ijt}' Gao (2004, p.109).

In the current analysis, this diversity variable turns unimportant to industrial growth in the Eastern Belt of China. To make the context neat, this variable is not fully described. Yet, the performance of this variable in the model will be shown in the sensitivity tests in Table 5-9 in section 5.5.

Figure 5-1 Framework for an industrial growth analysis



As we see, S_{ijt} measures industry i's share of value-added in province j relative to its average for all the nine provinces. S greater than 1 indicates that the industry has a larger share of the province's industrial value-added than this industry has in the nine provinces; a higher measure of S_{ij} indicates that province j is more specialized in industry i. For the impacts of S_{ij} on an industry, Mody and Wang (1997, p.301) note that 'Presumably greater specialization is good for an industry if the relevant knowledge is best acquired within the industry and deleterious when diverse skills and information from other industries are important'.

The role which specialization plays in industrial growth is debated in the literature.

Jacobs (1969), who believes that 'exchanges of information between different sectors are more productive than exchanges within a sector', claims that low-*S* industries grow faster than high-*S* industries.[105] Mody and Wang (1997), who make the same prediction, argue that 'As *S* increases, knowledge flows will be increasingly restricted to sources within that industry. Learning from other industrial sectors is likely to be greater when *S* is low' (p.302). Nonetheless, Porter (1990) argues that more specialized industries grow faster than less specialized industries. In their Chinese case study, Mody and Wang (1997) find a significantly negative relation between specialization and industrial growth, which suggests that in coastal China during the period 1985-1989 'the flow of knowledge across industries was more conductive to growth than was the flow within an industrial sector' (Mody and Wang 1997, p.306, citing Jacobs 1969). However, Gao (2004) finds significantly positive impacts of *S* on the 32 two-digit industrial classification industries in 29 provinces over the period of 1985-1993.

The competition variable C_{ijt} is quantified by firm size in terms of value-added relative to its average in the whole sample. Another commonly used measure of firm size is the number of persons in a firm. In the post-reform period during which the Chinese economy was in transition to a market economy, there was first spectacular downsizing in average firm size in terms of the number of employees, with a decline from 175 persons per firm in 1978 to7 persons per firm in 1994, in response to the boom in small-scale non-state firms. Increases in average firm size have been seen since the mid-1990s as a result of increasing competition among firms and scale

[105] Cited from Mody and Wang (1997, p.302).

economies. In 2004, the average firm size was 67 persons.[106] However, data on the number of employees at province-industry level are not consistently available for the current study, although the records of industrial value-added and number of firms at the industry-province level are abundant. This will explain why value-added, rather than employees, was chosen to define C_{ij}.

Focusing on industry size in terms of value-added, a higher C_{ij} implies that firms in industry i in province j are smaller than the average size in all nine provinces. In the current study, small firms indicate more local competition. Thus, a higher C implies that, relative to all nine provinces, province j has a higher degree of competition. For the effects of competition on industrial growth, an unresolved debate centres around whether more competition or monopoly is more effective in encouraging innovation (Mody and Wang 1997). For industrial growth in China, both Mody and Wang (1997) and Gao (2004) find significantly positive effects of C_{ij} on industrial growth.

Another industry-specific variable taken into account in this study is per capita industrial value-added at 2001 in constant 2000 prices. This variable is time-invariant but province- and industry-variant. It measures the degree of 'backwardness' of a province and thus the inclusion of this variable makes it possible to capture the convergence or divergence trend within the industries. A significantly negative parameter of this variable is taken as strong evidence of a convergence trend.

[106] Data source: Maddison (1998, p.80) and *China Statistical Yearbook 1995 and 2005*.

Inter-provincial Industrial Spillovers

The growth of an industry outside a province variable is included in the specification since an industry within a province is very likely to be influenced by the same industry in other provinces, due to technological synchronization or diffusion within the same industry across provinces. By their construction, the values of this series vary with industry, province and time. However, as this variable captures across-the-board industrial growth, it is close to being a time-varying industry-specific factor with little provincial variation in a given time period.

Province-specific Variables

The current study has identified four province-specific variables (human capital, domestic market size, exports and transport infrastructure) which are important influences on industrial growth in the Eastern Zone of China. For a sample which has a short period of five years, the decision about the appropriate way to measure these industry-invariant province-specific variables should be made with particular caution.

In the current study, the human capital variable is measured by the log of the share of government expenditure on education, the exports variable is represented by the share of industrial value-added that is exported, domestic market size is measured by the log of per capita retail sales at constant 2000 prices and transport infrastructure is represented by the log of the volumes of freight traffic.

Some provincial growth-related factors are not only important in their own right but may have important spillover effects. For instance, Lucas (1988) notes that human capital is twice blessed: first because it is inherently productive and second because interactions among well-educated people further increase efficiency. Shleifer (1990) suggests that good infrastructure provides the focal point for the development of agglomerations, which in turn create the environment for knowledge spillovers.

5.3.2 Data Description

The data which are employed to study industrial growth in this chapter cover 26 industries in nine provinces in the Eastern Zone of China over the period 2001 to 2005. Among the nine provinces, three are municipalities (Beijing, Shanghai and Tianjin) and six are provinces (Fujian, Guangdong, Jiangsu, Liaoning, Shandong and Zhejiang). The data for the current industrial growth analysis include various editions of *China Statistical Yearbooks* and statistical yearbooks at the province level.

Of the 26 industries under study, 14 are light industries and 12 are heavy industries.[107] The definitions of light and heavy industries are different in different countries. In China, a light industry refers to an industry which produces consumer goods and tools. The light industrial sector contains two categories: one which uses farm products as raw materials and the other, which uses non-farm products as raw

[107] The 14 light industries include manufacture of textile wearing apparel, footwear and caps; manufacture of beverages; manufacture of articles for culture, education and sport activity; manufacture of foods; manufacture of furniture; manufacture of leather, fur, feather and related products; manufacture of medicines; processing of food from agricultural products; manufacture of paper and paper products; manufacture of plastics; manufacture of rubber; manufacture of textile; manufacture of tobacco; and processing of timber, manufacture of wood, bamboo, rattan, palm and straw products.

The 12 heavy industries include manufacture of raw chemical materials and chemical products; manufacture of electrical machinery and equipment; manufacture of communication equipment, computers and other electronic equipment; mining and processing of ferrous metal ores; production and supply of gas; manufacture of general purpose machinery; mining and processing of non-ferrous metal ores; manufacture of metal products; mining and processing of non-metal ores; manufacture of non-metallic mineral products; manufacture of special purpose machinery; and manufacture of transport equipment.

materials. A heavy industry is one which provides general products to other manufacturers. According to the purpose of production or use of products, the heavy industrial sector divides into three branches: (1) extracting of petroleum, coal, metal and non-mental ores and timber felling, (2) smelting and processing metals, coke making and coke chemistry, chemical materials and building materials such as cement, plywood and power, petroleum and coal processing and (3) machine building to equip sectors of the national economy, metal structure industry and cement works, producing the means of agricultural production and making chemical fertilizers and pesticides (Guo 1998). Industrial value-added data involve only the SOEs and enterprises with annual sale income of more than five million Yuan. Industrial value-added is deflated by provincial ex-factory industrial product prices.

Table 5-6 presents the basic description of the essential variables employed in the current analysis.

Table 5-6 Basic description of essential variables, 2001-2005

Variable	Mean	Standard Deviation	Min. Value	Max. Value
Growth of industry *i* in province *j*	0.231	0.203	-0.898	1.363
Specialization index, *S*	1.042	0.567	0.001	4.277
Competition index, *C*	1.096	0.523	0.089	6.363
ln(per capita province-industry output in 2001)	9.699	0.410	9.230	10.529
Growth in industry *i* outside province	0.234	0.119	-0.344	0.678
ln(share of government expenditure on education)	-1.870	0.182	-2.206	-1.582
Share of exports in industrial output	0.384	0.282	0.053	1.003
ln(real per capita retail sales) (Yuan)	8.921	0.444	8.051	9.902
ln(volumes of freight traffic) (10,000 tons)	11.089	0.528	10.240	11.882

5.4 EMPIRICAL RESULTS

To estimate the three-dimension error component model, a variety of estimation methods, such as Ordinary Least Square (OLS), Least Square Dummy Variable (LSDV), LSDV*j*FE*i* estimator and Feasible Generalized Least Square (FGLS) estimator, were tried. The OLS generates biased estimates of the coefficients. The LSDV, which is a usual approach to estimating the fixed-effects model, produces exactly the same results as the LSDV*j*FE*i* estimator.[108] Given the presence of heteroskedasticity in the errors, this problem is controlled for by using the FGLS estimator. Furthermore, since the regional populations of provinces are greater than those of municipalities,[109] observations are weighted by regional population in order to reduce the influence of the municipalities in the regression results. For this reason, the regression in column 4 of Table 5-7, which employs the FGLS with the regression controlling for panel heteroskedasticity and observations weighted by regional population, serves as the base regression for the current study.

One feature of the province-specific variables which should be pointed out before the presentation of the empirical results is that, in the current analysis, given that a variable may have more than one proper proxy, the magnitude of the parameter changes with the choice of proxy, while the sign of the parameter remains unchanged, no matter how the variable is measured. For example, if the industry-invariant FDI variable is measured by the log of per capita FDI and share of FDI in provincial GDP, the estimated coefficients from two regressions turn out to have the same sign but

[108] As we have seen in Section 5.2.2, the estimation procedure of the LSDV*j*FE*i* approach includes industry dummies and demeaned (i.e. differenced) province dummies, whereas the LSDV procedure includes industry and province dummies. Andrews *et al*. (2006) claim that the two estimators are 'identical in the results that they produce, but differ in how they are computed' (p.5).

[109] Therefore, regional population gives more weight to the provinces and less to the municipalities.

different magnitudes. For this, Levine and Renelt (1992, p.943) in *A sensitive analysis of cross-country growth regressions* argue that '... almost all identified relationships are very sensitive to slight alternations in the conditioning set of variables.' For this reason, it was decided that the aim of the current analysis was to investigate the correlates of industrial growth in the Coastal Area of China rather than to find a specific model. The empirical results concerning province-specific factors reported here are only those which are robust to various specifications based on the sensitivity tests to be discussed in section 5.5.

Table 5-7 Determinants of industrial growth G_{ijt} in coastal China, 2001-2005

	(1)	(2)	(3)	(4)
Constant	-1.049	-0.854	-1.921	-2.146**
Industry specific				
Specialization index, *S* (%)	0.237***	0.303***	0.271***	0.309***
S squared (%)	-0.044***	-0.051***	-0.045***	-0.049***
Competition index, *C* (%)	0.046	0.076**	0.056*	0.046
C squared (%)	-0.024***	-0.035***	-0.028***	-0.026***
ln(initial industrial size)	-0.134***	-0.188***	-0.158***	-0.194***
Industrial spillovers				
Growth in industry outside region (%)	0.387***	0.424***	0.457***	0.476***
Region specific				
Education	0.126	0.120	0.152*	0.152*
Export (%)	0.333***	0.328***	0.333***	0.315***
ln(local market size)	0.094	0.046	0.170*	0.158*
ln(transportation)	0.101	0.138	0.136	0.180*
Adjusted R-squared	0.2412	0.3066	---	---
Wald chi-square	---	---	617.11	767.75
Total number of observations	1170	1170	1170	1170

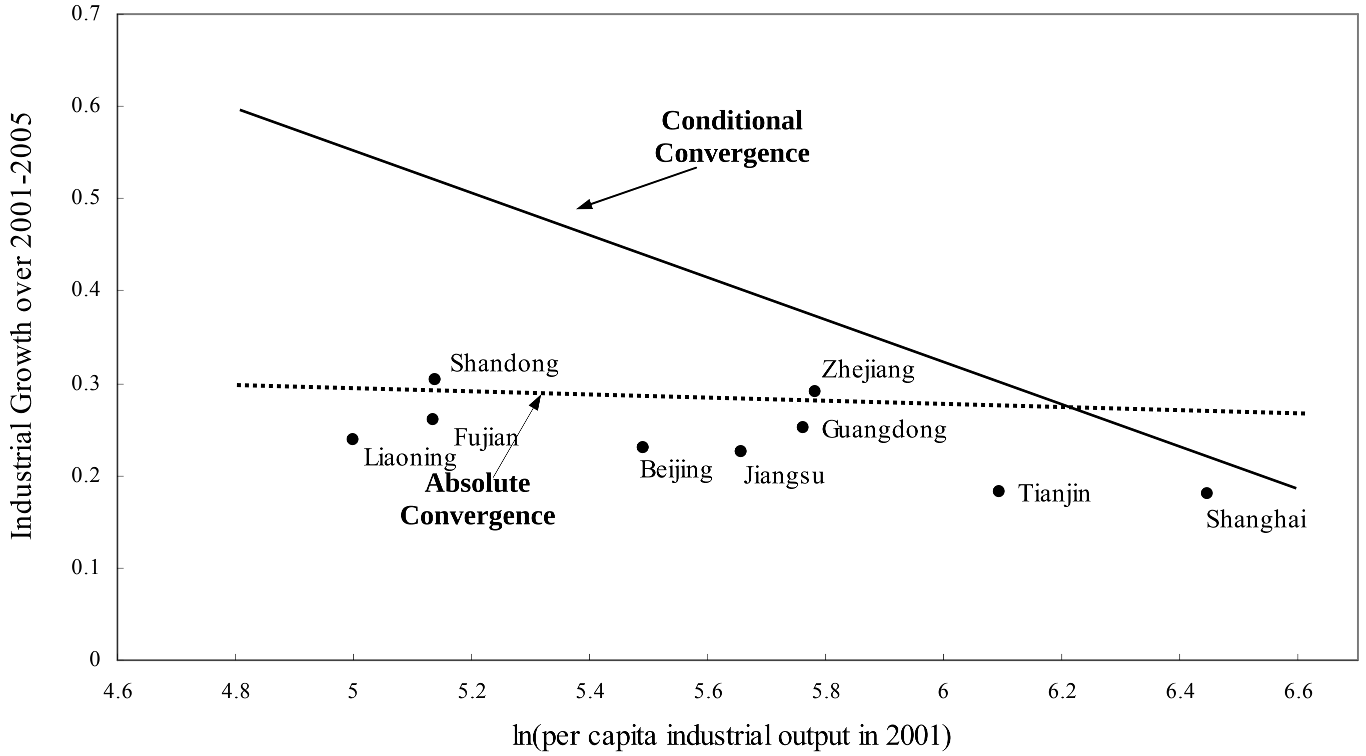
Note:

1. The dependent variable is growth of industry *i* in province *j* at time *t*, G_{ijt}.
   All regressions include time, region, and industry dummy variables.
2. Regression (1) employs the LSDV estimator;
   Regression (2) employs LSDV and observations are weighted by regional population;
   Regression (3) employs the FGLS estimator with the regression having controlled for panel heteroskedasticity; and
   Regression (4) employs the FGLS with the regression having controlled for panel heteroskedasticity and observations weighted by regional population. The FGLS technique does not automatically provide (adjusted) R-squared. The value of adjusted R-squared in column 3 is calculated manually.
3. $S_{ijt} = \dfrac{(\text{value-added in industry } i \text{ / total industrial value-added}) \text{ for province } j}{(\text{value-added in industry } i \text{ / total industrial value-added}) \text{ for all nine provinces}}$;

   $C_{ijt} = \dfrac{(\text{number of firms / total output}) \text{ for industry } i \text{ in province } j}{(\text{number of firms / total output}) \text{ for industry } i \text{ in all nine provinces}}$;

   Initial industrial size is measured by per capita province-industry output in 2001;
   Education is represented by ln(share of government expenditure on education);
   Export is represented by share of export in industrial output (%);
   Local market size is represented by per capita retail sales at 2000 prices (Yuan); and
   Transportation is represented by volumes of freight traffic (10,000 tons).
4. The R-squared statistic is less useful as a diagnostic tool for GLS regressions. Instead, Wald chi-square is reported for the FGLS regressions. The values for prob>chi-square are 0 for all FGLS regressions.
5. *** Significant at 1% significance level.
   ** Significant at 5% significance level.
   * Significant at 10% significance level.

Figure 5-2 Absolute convergence versus conditional convergence within the industrial sector in the Eastern Zone of China, 2001-2005



Note: The Absolute Convergence curve is found to have a slope -0.002 and intercept 0.242. Conditional convergence is plotted according to column 4 in Table 5-7. Its slope is based on the coefficient on initial industrial output, and its intercept is the sum of the products of the mean values of the independent variables (except initial industrial output) and their respective coefficients.

5.4.1 Performances of Industry-specific Variables

Performance of Industrial Specialization

As a measure of the local concentration of an industry, the specialization variable turns to have had large and positive effects on province-industrial growth in the Eastern Zone of China between 2001 and 2005 (Table 5-7). This is consistent with the argument in Gao (2004, p.109) that 'If the Marshall–Arrow–Romer externality exists, technological spillovers among local firms in the same industry facilitate innovation and improve productivity. Everything else equal, a higher degree of local specialization leads to a higher rate of industrial growth.'

The performance of this variable is similar across various regressions with the magnitude of the coefficient at around 0.3,[110] which indicates that a ten per cent increase in *S* increases industrial growth by around 3 percentage points. Moreover, the relationship between industrial specialization and growth does not appear to be linear. All regressions indicate that the positive effects of province-industrial specialization on industrial growth in the Chinese Eastern Zone are subject to diminishing returns with a rate of around -0.05. The current findings on the role of regional specialization suggest that a higher degree of province-industry specialization facilitates the industrial growth of the province and that as *S* increases, 'knowledge flows will be increasingly restricted to sources within that industry' (Mody and Wang 1997, p.302).

Positive correlation between industrial specialization and province-industrial growth

[110] The value of around 0.3 is obtained in various regressions, using different estimation methods (Table 5-7), different samples (Table 5-8) and different sets of static externalities (Table 5-9).

is found in a majority of studies in the literature. For example, Gao (2004), who studies industrial growth for 32 two-digit Chinese industrial classification industries in 29 Chinese provinces over the period of 1985-1993, discovers a positive coefficient on *S*, with a magnitude of around 0.15 (Gao 2004, column 4 of Table 10, p.120). However, a negative relation between *S* and industrial growth has also been found in some previous studies. For example, Mody and Wang (1997), who study industrial growth for 23 industries in 7 provinces in the Coastal Area over 1985-1989, find a significant and negative coefficient on *S*, with a magnitude of around -0.06 and negative impacts of *S* which are subject to increasing returns (Mody and Wang 1997, column 1 of Table 7, p.307). The different samples used in the two papers could be the reason for the different findings on *S* in the above two papers. The negative coefficient on *S*, which is found in Mody and Wang (1997), suggests that industries in the Coastal Area had a low level of specialization between 1985-1989 and they learned more from other industries than from other organizations in their own industry.

Performance of Industrial Competition across Provinces

The competition variable *C* measures the inverse of the relative size of firms, that is, a higher *C* implies smaller firm size. The statement that a province has smaller average firm size indicates that more competition exists within an industry across provinces. The parameter of *C* turns out to have correct signs across regressions and its statistical significance is sensitive to econometric techniques. The finding on *C* is the same across specifications: competition, rather than monopoly, is good for industrial growth by more effectively encouraging the adoption of new technologies.

The base regression in column 4 of Table 5-7 suggests that competition positively affects industrial growth with an exponent of around 0.05 and that the positive effect of *C* is subject to diminishing returns with a rate of around -0.03. This supports Mody and Wang's argument (1997, p.302) that competition 'can spur investment, although too much competition can lead to diminished investible surpluses.' The finding of the positive impacts of *C* from the present study is consistent with previous studies. For example, Gao (2004) finds a positive coefficient on *C* with a magnitude of around 0.07 for the sample of 29 provinces over 1985-1993 (Gao 2004, column 4 of Table 10, p.120). Mody and Wang (1997) discover the exponent of *C* to be around 0.03 for the sample of 7 coastal provinces over 1985-1989 and the positive effect of competition is found to be subject to diminishing returns with a rate of around -0.006 (Mody and Wang 1997, column 1 of Table 7, p.307). A comparison of the coefficients' magnitudes of *C* in the current analysis and Mody and Wang (1997) indicates that competition in coastal China between 2001 and 2005 was more conducive to industrial growth than that between 1985 and 1989.

The current finding provides further empirical evidence to support Gao's argument that 'Fierce competition in the same market provides firms with strong incentives to innovate quickly ... the geographic concentration of a highly competitive industry is likely to generate more positive spillovers than geographic concentration where a small number of firms dominate, as long as economies of scale in the industry are modest' Gao (2004, p.104).

Performance of Initial Industrial Size

To measure the extent of initial backwardness in the province-industry dimension, the natural logarithm of per capita province-industry value-added in 2001 is included as a control in the regression. The finding of the statistical importance of the backwardness variable is consistent across all the regressions in Table 5-7. The strongly negative relation between industrial growth and initial industrial base is identified in all regressions, suggesting that initially ‘poor’ industries have great potential to catch up with rich industries.

Empirical results on the initial industrial size variable presented in Table 5-7 illustrate a strong trend of conditional convergence within the province-industry dimension. The estimated coefficient on this variable in the base regression, -0.194, suggests a fast convergence speed of 22 per cent per annum. Furthermore, regressing industrial growth on initial industrial size solely produces a negative coefficient on this variable with a magnitude of -0.002, which is both statistically and quantitatively insignificant.[111] This provides evidence of weak absolute convergence within the province-industry dimension in the Eastern Zone of China. The trends of weak absolute convergence and strong conditional convergence are graphically illustrated in Figure 5-2.

In contrast with the convergence study on Chinese aggregate economic growth in Chapter 3, the current study suggests that the trend of convergence within the

[111] The absolute convergence regression output is not presented in the table, but is available upon request.

industrial sector is more obvious and the progress of convergence is faster.[112] This provides further empirical evidence to support the argument concerning the so-called 'club-convergence' (see, for example, Islam (1995) and Durlauf and Johnson (1995)), that entities with similar economic levels converge faster than entities which are very different in economic level; in the current case, the entities are industries rather than countries or regions.

5.4.2 Performance of Inter-provincial Industrial Spillovers

The growth in industry outside the province measures the degree of synchronization of knowledge across provinces, which occurs 'as a result of technology diffusion or networking among decision-makers' (Mody and Wang 1997, p.313). The strong quantitatively and statistically significant parameter of this variable implies that there are strong inter-provincial industrial spillovers among the 26 industries in the Eastern Zone of China; in other words, an industry in a province is to a great extent influenced by the growth of the same industry in other provinces.

The empirical findings suggest that on average, a one per cent increase in the growth rate of an industry outside a particular province is associated with around a 0.48 per cent increase in the growth rate of that industry in the province (column 4 of Table 5-7). Significantly positive impacts of regional spillovers are also obtained in Glaeser *et al*. (1992) and Mody and Wang (1997).

The industrial spillovers variable is included in the model not only to describe the

[112] This argument is somewhat prejudged, since the sample for the convergence analysis within the whole of China in Chapter 3 is different from the sample in this chapter.

relation between the growth of an industry in a province and the growth of the same industry in other provinces, but also to condition for the correlations caused by the possible biases in the data-gathering process (Mody and Wang 1997, p.313).

5.4.3 Performances of Province-specific Variables

The current study has identified the four following province-specific variables, which have important static effects on industrial growth: education, exports, local market size and transport infrastructure. As well as these four static externalities, per capita FDI, the state sector's share of industrial value-added and provincial telecommunication level have also been taken into account. However, the empirical results suggest that the latter three factors are not statistically important to industrial growth in the Eastern Zone of China between 2001-2005 (columns 6-9 in Table 5-9).

Performance of Education

For a sample with a short time period, the measures for province-specific variables should be chosen carefully for the three-way dimension analysis. A province-specific variable, which is industry-invariant, should not be constant or nearly constant over the short time period; otherwise, it would be unlikely for the static effects to be distinguished from the intercept term.

For the education (or human capital) variable, the most frequently used proxies in the literature include the secondary school enrolment rate (see, e.g. Barro and Lee (1997) and Wang and Yao (2001)); government spending on education (see, e.g. Teles and Andrade (2004); Sun (2006) and Fan and Lai (2006)); average schooling years (see, e.g. Young (2000) and Wu (2006)), the literacy rate of workers (see, e.g. Gao (2004)) and investment on research and development (see, e.g. Mansfield (1972); Sjögren (1998); Wang and Li (2005) and Li (2006)). For the current analysis, with the data at hand, three sets of proxies have been tried: average schooling years per person, school enrolment rates at three education levels and the log of the share of government expenditure on education. The last of these three proves to be the most significant one for this study.

The results reported in Table 5-7 suggest that the education variable has positive effects on province-industrial growth and that such effects are only marginally significant at 10 per cent significance level in the regression using the FGLS estimator. The exponent of the education variable which is discovered in the base regression indicates that a ten per cent increase in the log of share of government expenditure on education increases industrial growth rate by around 1.5 percentage points.[113] Compared with the greater (in both quantitative and statistical terms) impacts of education on Chinese aggregate economies (see Chapter 3), this study seems to suggest that education is less effective in enhancing industrial growth than it is in enhancing aggregate economic growth.[114]

Performance of Local Market Size

It is obvious that industrial agglomeration normally takes place in regions with rich natural resources, easy access to large markets and/or good infrastructure. Take

[113] It could also be the other way around, that is, government expenditure on education may increase with industrial output.

[114] This argument could be forejudged, because the measure of education in this study and the measure of human capital in Chapter 3 are not exactly the same and also because the samples in the two studies are different, since the current sample period is short.

market size first. For an open economy, markets include the domestic market and the foreign market. If the relation between the two types of market is linear, we would encounter the problem of collinearity when we include the two markets in the regression at the same time. For the current analysis, the domestic market size variable is measured in absolute value, while the foreign market size (named 'exports' in the regression) is measured by the ratio of export value to total industrial output value, which thus avoids the problem of collinearity and makes it possible to simultaneously test for the importance of the two different markets.

In this study, local market size is indexed by the log of per capita retail sales of commodities. This variable turns out to have a positive coefficient across all regressions in Table 5-7. The base regression suggests a modest exponent of the variable, 0.16, which is marginally significant at the 10 per cent significance level. A positive correlation between domestic market size and industrial growth has also been found in Gao (2004), who finds a highly significantly positive coefficient on 0.20 (Gao 2004, column 4 of Table 10, p.120).

The magnitude of the coefficient on the local market size variable indicates that the effect of domestic consumers' purchasing power on industrial location is quantitatively huge, yet the weak significance of such behaviour to some extent suggests that domestically consumed industrial products are mainly for basic and moderate daily requirements.

Performance of Exports

The coastal Eastern Zone of China benefits from close proximity to foreign markets in terms of both geographical location and trade policies. Preferential trade policies in the coastal provinces remove trade barriers and give domestic producers better access to foreign markets. After nearly three decades' effort to open up to the world, costal China enjoys a similar degree of openness across the nine provinces. In these export-oriented provinces, export is one of the principal engines for the economy. In this regard, one would expect that the impact of exports on industrial growth is greater than on aggregate economic growth.

A positive correlation between exports and industry is identified across all regressions in the current analysis. The estimated coefficients on this variable are all highly statistically significant and the magnitudes are similar across all regressions. As we see, exports form the second largest factor, only next to the 'backwardness' factor, to stimulate industrial growth in the 'export-oriented' coastal economies. The estimated coefficient in the base regression, 0.32, suggests that a one per cent increase in the natural log of exports share in the total industrial output will increase provincial industrial growth by 0.32 percentage points.

As the exports variable reflects the size of the foreign market, given the more significant performance (both quantitatively and statistically) of this variable than the domestic market size variable, we can be assured that industrial growth in the Eastern Zone is stimulated more by the foreign market than by the domestic market and that industries in these economies are to a great extent export-directed.

The positive correlation between exports and industrial growth is widely perceived in the literature; see, for example, Dutta and Ahmed (2001) and Gao (2004). However, in recent years, some researchers, such as Lai and Yang (2002) and Bao *et al*. (2003) raise concern on the impact of exports on the Chinese economy. Bao *et al*. (2003), who study the relation between exports and economic growth among 29 provinces in China over 1990-1999, find a negative relation between exports' share of provincial GDP and provincial economic growth. They attribute this to the violation done by the structure of Chinese export goods to the structure of domestic manufacturing production,[115] which '... produces negative impacts on the long-run economic growth as a consequence' (Bao *et al*. 2003, p.5).[116] A perverse relationship between exports and economic growth is also observed by Lai and Yang (2002).

Performance of Transport Infrastructure

It is widely believed in the literature that industries grow faster in regions with better infrastructure. Rietveld (1989) argues that improving infrastructure leads to higher productivity of private production factors such as labour and capital while a neglect of infrastructure will lead to low productivity in the other production factors and that the importance of transport infrastructure can be analyzed via its impact on inter-provincial trade flows. Shleifer (1990) shows that good infrastructure not only facilitates the flow of information but also provides the focal point for the development of agglomerations. Martin and Rogers (1995) examine the impact of

[115] Bao *et al*. (2003) argue that domestic manufacturers have been shifting from producing labour-intensive products to capital- and/or technology-intensive products, but most of China's export goods are still labour intensive.

[116] The original words are in Chinese.

public infrastructure on industrial location when returns are increasing and they find that firms tend to locate in countries with better domestic infrastructure.

For the current analysis, two proxies have been tried to measure the infrastructure level of a province: telecommunication infrastructure and transport infrastructure. The former is measured by per capita telephone lines (including landline and mobile phones) and turns out to have a positive but insignificant impact on the industrial growth in the Eastern Zone of China. The latter, transport infrastructure, is represented by the log of volumes of freight traffic rather than the length of highways or railways, since the highway and railway systems have hardly developed, in terms of the extent of operating highways and railways, during the period under study.

The transport infrastructure variable turns out to have positive coefficients across all regressions and the magnitudes of the parameters are quantitatively important. In the base regression, the coefficient suggests that a one per cent increase in the measure of this variable will cause 0.18 percentage point of increase in industrial growth. Given that there was little development in the Chinese transport system over the period under study and that this system has been most used, it is within expectation that this variable could turn to be statistically insignificant. As we see, the transport infrastructure variable is only marginally significant at the ten per cent level when the FGLS estimator is employed with the regression's having controlled for heteroskedasticity and observations being weighted by regional population.

As a summary of the empirical findings, 'there are potentially large gains (for

Chinese firms) from both dynamic and static externalities to be realized' (Gao 2004, p.103).

5.5 SENSITIVITY TESTS

In this section, sensitivity tests are carried out to see whether the above empirical results from regressions with pooled data are robust.

The unit of analysis in the current study is the annual industrial growth of 26 industries in the Eastern Zone of China during the period 2001-2005. So far, we have assumed that all industries respond to the externalities in the same manner. The fact that industrial growth has not been uniform across industries raises the possibility that externalities may differently influence different industries. However, the limited number of observations makes it unfeasible to run separate regressions for each industry. An intermediate solution to this problem is to group all the 26 industries into the light industrial sector and the heavy industrial sector, in view of the similarities within each sector. For example, light industries are generally more labour intensive than heavy industries; light industries are more consumer-oriented than heavy industries; light industries have less environmental impact and are therefore more tolerated in residential areas; and, in recent years, the light industrial sector grew faster than the heavy industrial sector. As light and heavy industries have considerable structural differences, we tried including a dummy variable, which distinguishes light industries from heavy ones, in the pooled regressions. The empirical analysis[117] shows that the dummy variable itself has a significant

[117] The results are not reported in the context but are available from the author upon request.

coefficient,[118] but the inclusion of the dummy does not at all change the performances of the dynamic and static externalities.

By running two separate regressions for the light and heavy industrial sectors in turn and comparing the results (columns 2 and 3 of Table 5-8) with those from the pooled regression (the base regression in column 4 of Table 5-7 or column 1 of Table 5-8), we find that the results are similar in terms of the signs of the estimated coefficients. Nonetheless, some differences, which mainly concern the magnitudes of the parameters, do exist in response to the differences in nature between light industries and heavy industries (see the above list). The similarities and differences are summarized as follows:

To begin with, the specialization variable has a higher coefficient for the heavy industrial sector (0.456) than the light industrial sector (0.299). Together with the fact that the heavy industrial sector has a higher degree of specialization (with the average value of the specialization index 1.074 over 2001-2005) than the light industrial sector (with the average value of this index 1.015), the finding suggests that the more specialized heavy industries grow faster than the less specialized light industries. Given that the coefficients on *S-squared* are significantly negative for both industrial sectors and the magnitude of the coefficient in absolute value for the heavy industrial sector is greater, we further confirm that the positive effects of *S* are subject to diminishing returns.

[118] The dummy variable, which has the value 1 for heavy industries and 0 for light industries, turns out to be highly significant and have a negative coefficient -0.512. This suggests that the increases in the light industries promoted industrial growth in the Eastern Belt of China during 2001-2005, while the increases of heavy industries hampered regional industrial growth.

Second, competition has a positive coefficient for the heavy industrial sector, 0.088, which is statistically significant at a 10 per cent level. The highly significant and negative coefficient on *C-squared* suggests that the positive effects of competition on this sector are strongly subject to diminishing returns. In column 2 of Table 5-8, the coefficient on *C* for the light industrial sector is negative, -0.013, which is not statistically different from zero. The average value of the competition index is 1.104 for the light industrial sector and 1.086 for the heavy industrial sector,[119] suggesting that competition is slightly fiercer in the light sector than that in the heavy sector.[120] Yet it is plain that the slight difference in the level of competition within the two sectors results in very different impacts on industrial growth. Even though the coefficients on *C* for the two sectors are different, they tell the same story about the impacts of *C*: that modest competition spurred industrial growth while too much competition was deleterious to industrial growth in the Eastern Zone of China between 2001-2005.

Third, the initial industrial size variable, which is quantified by per capita industrial value-added in 2001, has significant and negative coefficients for both sectors. The negative impact of the 'initial backwardness' variable is slightly greater on the heavy sector than on the light sector. Together with the law of diminishing returns of capital, this suggests that a higher capital-intensive heavy industry benefits more from its initial backwardness than a light industry does and thus the progress of convergence

[119] Figures are calculated by the author.

[120] This may well explain why the light industrial sector grew more slowly than the heavy industrial sector in terms of the number of firms (see Table 5-3).

is faster within the heavy sector than that within the light sector.

Fourth, industrial spillovers across provinces, which are measured by the growth of an industry outside a province, have a significantly positive impact on both sectors. This indicates that both sectors benefit greatly from a high degree of inter-provincial knowledge synchronization within the same industry (0.257 of the average spillovers index for the heavy sector and 0.214 for the light sector in the Eastern Zone of China over 2001-2005). The coefficient for the heavy sector regression is higher than that for the light sector, 0.464 and 0.367 respectively, meaning that heavy industries benefit more from knowledge diffusion than light industries do. Together with the finding that specialization had greater impact on the heavy sector, which had a higher degree of specialization, the current analysis implies that an industry with higher capital intensity makes greater efforts to introduce advanced technologies and thus keep its specialization on the specific industry.

Finally, turning to the static effects of province-specific variables, exports have greater impact on the heavy sector, which suggests that heavy industries are more export-directed than light industries. In contrast, local market size has more significant impact on light industries. The positive effect of the transport infrastructure is more evident in the light sector than in the heavy sector. Furthermore, the impact of education on the light sector is slightly greater than on the heavy sector and the effect of education is not statistically different from zero for both sectors. If the variable employed in this study reflects the true level of education of a province, the finding on education implies that 'although formal education is important, its relationship with growth is imprecise' (Mody and Wang 1997, p.317).

Therefore, as we have seen, heavy and light industries in the Eastern Zone of China have been subject to similar growth impulses over the period under study.

Besides running the regressions to distinguish light and heavy industries, the sensitivity analysis has also been conducted by using different samples, which consist of different industries (both light and heavy), provinces and time periods. We drop one observation at a time, excluding from regressions an industry, a province and a year and find that no single observation significantly influences the general conclusions about industrial growth which were reported in section 5.4. Results in columns 4-8 of Table 5-8 are some examples of the robustness tests of this type.

Another type of sensitivity analysis is made by changing the static province-specific variables. The results of this type of robustness test are presented in Table 5-9, where the first column is the base regression. As we see, omitting the education, export, local market size and transport infrastructure variables one at a time has little effect on the sign, magnitude and statistical significance of the remaining coefficients (columns 2-5 of Table 5-9). Moreover, the results are not sensitive to specifications which add, either one at time or simultaneously, the industrial diversity *D*,[121] telecommunications, the state sector's share and per capita FDI variables, which prove statistically unimportant in the current study (columns 6-9 of Table 5-9).

[121] See footnote 103 for a description of the diversity variable.

The sign of the coefficients on the four additional variables, in particular the state sector's share and per capita FDI, provides an interesting intuition about the corresponding factors, even though the four variables are not statistically significant. The industrial diversity of industrial products (*D*) within a province has a consistently negative coefficient across all specifications. This is to be expected, given that a higher *D* implies less diversity and thus the negative coefficient on *D* suggests that industrial diversity promotes the industrial growth of a province. Similarly, telecommunications have a positive impact on industries (columns 6 and 9), which is expected. Moreover, since this index reflects the telecommunication level within a province and not within an industry, the statistical insignificance of this variable is to be expected, given that a large proportion of local telephones are for household use.

The coefficient on the state sector's share of industrial value-added is positive though not statistically significant (columns 7 and 9 in Table 5-9). This finding seems to suggest that the impact of SOEs on Chinese industries has become positive, which is different from what has been claimed by other researchers. In past decades, most state-owned enterprises were more government-directed than market-oriented. Previous studies, such as Otsuka *et al*. (1998), Preston and Xing (2002) and Siddique (2006), suggest that SOEs were inefficient in resource allocation and making production decisions. However, 'Price reform, the growing importance of the non-state sector, incentive mechanisms designed for state-owned enterprises and the significant presence of firms established by foreign direct investment all point to the fact that firms are facing increasing competitive pressure' (Gao 2004, p.105). In addition, the late 1990s' reforms on the state sector further stimulated the SOEs to be market-directed. Therefore, given the growing competitiveness of the state sector, even though it is undoubted that some industries with a large state sector are still protected by the Chinese government, one surely believes that state ownership is no longer inefficient these days. Therefore, the current finding on the positive coefficient on the state sector variable is not unacceptable (see column 7 in Table 5-9).

For the FDI variable, suppose there are no serious problems of misspecification and mis-measurement. The unexpected sign of the coefficient suggests that FDI, which provides China with mass capital and advanced technologies, have had disadvantages for the industries in the FDI-abundant coastal region in recent years (columns 8 and 9).[122] However, the controversial partial correlation between FDI and industrial growth may also reflect or be explained by inaccurate FDI data. In the past few years, people are arguing that the published FDI data at the province level are exaggerated to a great extent.[123]

To conclude, the empirical results do not change much with the choice of sample size and conditioning set of variables. For this reason, when interpreting industrial growth, we can rely on the findings from the pooled regressions in section 5.4.

[122] The results remain the same no matter how this variable is measured.

[123] For this reason, the National Bureau of Statistics of China has stopped reporting FDI data at the province level since 2004. Nonetheless, FDI data of recent years are still available from statistical bureaus at the province level.

Table 5-8 Robustness tests of externalities using different samples (Dependent Variable: Industrial Growth G_{ijt})

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Analysis Sample:	All industries	Light industries	Heavy industries	Mining industries	Non-ming industries	All industries	All industries
Constant	-2.146**	-3.614***	-0.184	-5.630*	-1.495	-1.871	0.164
Industry specific							
Specialization index, *S* (%)	0.309***	0.299***	0.456***	0.397***	0.330***	0.362***	0.194*
S squared (%)	-0.049***	-0.047***	-0.105***	-0.080**	-0.051***	-0.058***	-0.060
Competition index, *C* (%)	0.046	-0.013	0.088*	-0.045	0.057	-0.017	-0.044
C squared (%)	-0.026***	-0.007	-0.039***	0.020	-0.030***	0.001	-0.002
ln(initial industrial size)	-0.194***	-0.185***	-0.229***	-0.235***	-0.205***	-0.231***	-0.084**
Industrial spillovers							
Growth in industry outside region (%)	0.476***	0.367***	0.464***	0.550***	0.418***	0.495***	0.316***
Region specific							
Education	0.152*	0.158	0.137	0.164	0.139	0.159	0.073
Export (%)	0.315***	0.280***	0.335***	0.508**	0.274***	0.316***	-0.890*
ln(local market size)	0.158*	0.219*	0.082	-0.304	0.236**	0.239*	0.179
ln(transportation)	0.180*	0.267**	0.012	0.779***	0.069	0.117	-0.056
Wald chi-square	767.75	402.75	364.06	232.21	662.71	585.97	144.84
Prob>chi-square	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of industries included	26	14	12	5	21	26	26
Number of provinces included	9	9	9	9	9	6 provinces	3 municipalities
The sample of period included	2001-05	2001-05	2001-05	2001-05	2001-05	2001-05	2001-05
Total number of observations	1170	630	540	225	945	780	390

Table 5-9 Robustness tests of externalities using different sets of static externalities (Dependent Variable: Industrial Growth G_{ijt})

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Analysis Sample:	All industries	All industries	All industries	All industries	All industries	All industries	All industries	All industries
Constant	-2.146**	-1.598	-1.271	-1.806*	-0.727	-1.997*	-2.332**	-2.782**
Industry specific								
Specialization index, *S* (%)	0.309***	0.313***	0.322***	0.309***	0.314***	0.310***	0.313***	0.312***
S squared (%)	-0.049***	-0.049***	-0.052***	-0.049***	-0.049***	-0.049***	-0.050***	-0.049***
Competition index, *C* (%)	0.046	0.051	0.050	0.047	0.049	0.046	0.047	0.049
C squared (%)	-0.026***	-0.027***	-0.027***	-0.026***	-0.027***	-0.026***	-0.027***	-0.027***
ln(initial industrial size)	-0.194***	-0.196***	-0.199***	-0.194***	-0.197***	-0.195***	-0.196***	-0.195***
Industrial diversity, *D* (%)		-0.343	-0.367	-0.315	-0.336	-0.350	-0.339	
Industrial spillovers								
Growth in industry outside region (%)	0.476***	0.474***	0.468***	0.474***	0.474***	0.475***	0.476***	0.498***
Region specific								
Education	0.152*		0.134	0.128	0.117	0.174**	0.151*	0.140*
Export (%)	0.315***	0.308***		0.289***	0.311***	0.293***	0.378***	0.289***
ln(local market size)	0.158*	0.128	0.081		0.230***	0.133	0.190*	0.172*
ln(transportation)	0.180*	0.131	0.162	0.260***		0.198**	0.170	0.227**
ln(per capita telephone lines)						0.075		
state sector's share of industrial output							0.289	
ln(FDI/Total Investment)								-0.301
Wald chi-square	767.75	736.90	763.14	760.26	768.25	768.65	770.41	773.68
Prob>chi-square	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total number of observations	1170	1170	1170	1170	1170	1170	1170	1170

5.6 CONCLUSIONS

5.6.1 Conclusions

Industries contribute significantly to GDP growth in industrialized coastal China. This study investigates the pattern of industrial growth of 26 industries in nine provinces and municipalities in the Eastern Zone of China over the period 2001-2005. Because results concerning province-specific variables (mainly concerning the magnitudes of estimated coefficients) of this type of study are sensitive to the samples, the conditioning sets of variables and measurement of variables, the object of this study was to investigate the general correlates of industrial growth in coastal China rather than to find a specific model.

The current study considers the influences of three types of externalities on industrial growth in coastal China: industry-specific dynamic externalities, industrial spillovers across provinces and province-specific static externalities. The first two types of externality vary with province, industry and time and the third type varies with province and time only. The findings are summarized as follows:

The relations between industrial growth and the two dynamic externalities, industrial specialization and competition, were non-linear. All the regressions suggested that industrial specialization significantly and positively influenced industrial growth in the Eastern Zone of China and the diminishing returns to specialization were also significant. This finding indicated that the positive influence of specialization reduces as the degree of specialization increases, due to the fact that 'knowledge flows will be increasingly restricted to sources within that industry' (Mody and Wang

1997, p.302).

The positive impact of industrial competition on coastal China's industries was less obvious than that of specialization, in terms of both quantitative and statistical importance; and this positive impact was subject to statistically significant diminishing returns. This suggests that moderate competition was good for industries but that too much competition was harmful, as a result of 'diminished investible surpluses' (Mody and Wang 1997, p.302).

The third industry-specific variable considered in the analysis was initial industry size, which captures the degree of initial backwardness of an industry. The highly significant negative coefficient on this variable strongly implied that initially 'poorer' industries grew faster than initially 'richer' industries and the speed of convergence was found to be 22 per cent per annum.

The inter-provincial industrial spillovers variable, which reflects the sharing of knowledge and technologies among firms within an industry, had a consistent performance across various specifications. The highly significantly positive coefficient indicated that firms benefited greatly from technological diffusion within the same industry.

With regard to static province-specific externalities, it is found that as long as these were properly measured, their performances across various specifications were consistent. Specifically, exports greatly promoted industrial growth in the 'export-oriented' coastal China and their impact was large and statistically significant. The other three static externalities, namely, education, local market size and transport infrastructure, were also important in explaining industrial growth; however, their statistical importance was not as great as that of the exports variable.

In the sensitivity analysis four additional variables: diversity of industrial outputs, telecommunications, the state sector's share of regional GDP and FDI, were included in the specifications to test for the robustness of the dynamic and static externalities. These four factors turned out to be unimportant in explaining industrial growth in coastal China and the inclusion of these variables did not change much of the overall result. Nonetheless, the signs of the coefficients on the four additional variables provide intuitively interesting stories: The negative sign for the diversity variable suggested that diversity in industrial outputs within a province encouraged industrial growth, which is within expectation; the positive sign for the telecommunications variable suggested that telecommunication infrastructure facilitated province-industrial growth, which again is within expectation; but the state sector's share of regional GDP turned to be positively correlated with industrial growth, which is opposite to the negative correlation in previous studies which use data on earlier years (usually until 1998). However, we would regard the current positive finding on the state sector's share as evidence of the success of the continuous reform policies in the SOEs; in addition, the negative coefficient on the FDI variable was found in various specifications. This controversial finding is least convincing. It either suggests that the inflows of FDI started to hurt Chinese industries in recent years, or that the FDI data at the province level were inaccurate.

5.6.2 Policy Implications

The policy implications of the above empirical findings can be summed up as follows:

First of all, Chinese enterprises should promote knowledge spillovers between them and improve their specialization level. Industrial specialization is good for Chinese enterprises in bringing the complementary advantages into full play, strengthening coordination between industries and promoting the realization of mutual benefit and common development. Promoting knowledge spillovers between enterprises can foster innovations, speed up the specialization of a firm and promote long-run economic growth. Therefore, in order to bring Chinese enterprises' complementary advantages into full play and promote their degree of specialization, the Chinese government should encourage free knowledge transfer among Chinese enterprises and encourage the optimal use of resources such as physical capital, human capital, information, techniques, management and natural resources.

Second, Chinese enterprises should make an effort to avoid excessive competition between them. Excessive competition can be seen from the excessive number of enterprises and surplus of production capacity. It directly results in the pricing behaviour that a firm's price is deliberately set below marginal cost and can cause uneconomical allocation of resources and serious resource waste. In contrast, moderate competition can encourage best resource allocation, enhance productivity, save resources, help reduce innovation cost and thus promote innovation efficiency. Given the existence of intense competition in most industries in China and the finding in the current analysis that moderate competition is good to Chinese enterprises but too much competition is harmful, an important policy suggestion is raised here: the Chinese government should help Chinese enterprises to set up a market system with unified, open and fair competition and avoid excessive competition by strengthening the supervision on the prices, quality and measures and cracking down on the illegal activities of producing and selling fake and inferior commodities.

Third, Chinese enterprises should make a great effort to expand local markets as well as exploiting foreign markets. In contrast to foreign markets, local markets have advantages in the aspects of low transport cost and easy access to prompt and precise marketing information. Moreover, given that the Chinese market has great potential for expansion and that the foreign market is shrinking due to the current global financial crisis, the local market seems to be more attractive to Chinese enterprises than the foreign market does. Therefore, Chinese enterprises should actively develop new and high-quality products to meet local market needs.

Finally, the empirical findings of the study also suggest that in order to accelerate and sustain rapid industrial growth in China, it is imperative for local governments to provide a more friendly investment environment to Chinese enterprises, including increasing investment in education to improve local education levels and enhancing the local transport infrastructure.

CHAPTER 6: CONCLUSIONS

This thesis studied the Chinese economy in the post-reform period by focusing on three issues: convergence, total factor productivity and industrial growth. In this final chapter, the main findings on these three issues will be summarized and then the limitations of the current study will be pointed out.

6.1 THE MAIN FINDINGS

A brief look at the general background of China, which was provided in Chapter 2, showed that China has made great progress in the post-reform period in many aspects, such as its gross domestic product, investment, globalization in terms of FDI and foreign trade, education, transportation and telecommunication infrastructure. Substantial changes have taken place in, for example, the pricing system, the economic structure and the state sector's role in the economy.

6.1.1 Findings on Convergence in Chapter 3

The issue of convergence of the provincial economies within China's 28 provinces over the period 1979-2004 was investigated in Chapter 3. Feasible generalized least squares (FGLS) and GMM estimators were employed to estimate the parameters of the Chinese growth model. For the trend of convergence, the current study suggested no evidence of absolute beta-convergence in China. However, beta-convergence was evident in China. In the highly augmented growth model, industrialization, transportation and openness, besides the variables of saving, population growth and human capital which are suggested by the augmented neoclassical growth paradigm, were taken into account to model Chinese growth empirics. All the variables included in the model turned out to be significant in the regressions. This suggests that a Chinese province could benefit from its initial backwardness, higher investment rate, lower population growth, higher human capital, higher degree of openness, better condition of its transport infrastructure and higher degree of industrialization.

The present study identified the convergence speed of 5.6 per cent per annum for China between 1979 and 2004. Furthermore, with the acceptance of the hypotheses that the coefficients on investment rate and population growth have identical magnitudes but different signs in the neoclassical growth model and that the coefficients on human capital accumulation and population growth have identical magnitudes but different signs in the human-capital augmented Solow model, output share of physical capital α was found to be 0.23 and output share of human capital φ was found to be 0.27 for China as a whole during the period 1979-2004.

6.1.2 Findings on Productivity in Chapter 4

As we have seen, the 'observable' factors described in Chapter 3, which included factor inputs and infrastructure in the broad sense, were all essential to China's regional economies. But is that all? The analysis in Chapter 4 showed that there was still something left unexplained in the Chinese economy. The 'unobservable' part of growth is widely referred in the literature as 'total factor productivity'. Using the non-parametric Malmquist Index approach, TFP growth and its components, that is, the growth of productive efficiency and growth of technological progress, were calculated for China's 29 provinces, three zones and China as a whole for each year over the period 1979-2004.

The non-parametric Malmquist index approach has several advantages over the traditional growth accounting approaches and regression approach. For example, compared with the regression approach, the non-parametric Malmquist index approach does not impose a specific form on the aggregate production function, nor does it require the estimation of parameters of the production function. In contrast to the growth accounting approaches, the Malmquist index approach does not require the predetermined values of input factors' shares in output and thus avoids the assumption that factors are paid their marginal products; it does not impose the assumption of constant returns to scale; it does not require the prior ordering of members in the sample to calculate the productivity level; and it does not impose the assumption that technology is fully utilized.

The decomposition of TFP growth into technical progress and efficiency improvement has important policy implications, while equalizing TFP progress to technological progress neglects the contribution of productive efficiency to TFP change, which happens when using the traditional growth accounting approaches. Another concern of Chapter 4 was to highlight the inclusion of human capital in the productivity study. Human capital, in addition to the fundamental physical capital stock and labour inputs for this type of study, has proved important in improving the productivity of Chinese provincial production, enhancing productive efficiency and accelerating technological progress.

On average, TFP at the Chinese national level grew at a rate of 2.75 per cent per annum, which contributed 30.02 per cent to the China's real GDP growth. Given the impressive role played by TFP in the whole Chinese economy and provincial economies, we are able to conclude that China's fast economic growth is sustainable in the long run. By cumulating the Malmquist indices and their components, trends of 'divergence' in terms of productivity level and technology level were identified among Chinese provinces.

In addition, we found that although the relative role of technological progress and efficiency improvement in productivity growth differed province by province and period by period, on average, technological progress and efficiency improvement contributed almost evenly to TFP growth for China as a whole over the sample period. Turning to the three zones, in general, for the better developed Eastern Zone and the Central Zone technological progress was the main reason for TFP growth, while efficiency improvement explained almost all of the TFP growth for the less developed Western Zone. This finding further verifies the importance of distinguishing between productivity and technological progress.

6.1.3 Findings on Industrial Growth in Chapter 5

Following the productivity study was the analysis of industrial growth of 26 industries in the Eastern Zone of China over 2001-2005. Since the empirical results (for those province-specific static externalities, in particular) of this type of study are sensitive to the samples, the conditioning sets of variables and measurement of the variables, the object of Chapter 5 was set to examine the general correlates of industrial growth in the Eastern Zone rather than to find a specific model.

Using industrial growth in the industry-province dimension as the dependent variable has an important advantage: the province-specific static externalities were measured at the provincial level, which are likely to be influenced by overall provincial growth rather than by province-industrial growth, and, therefore, the endogeneity of province-specific variables posed a less serious problem. In addition, focusing on the relatively homogeneous Eastern Zone, this study has overcome the concerns in interpreting cross-sectional growth regressions where it is difficult to control for wide heterogeneities in economic, social and political systems. In addition, the problem of heteroskedasticity was controlled for via the employment of the FGLS estimator. And, the robustness of the correlates was tested in a variety of sensitivity tests.

To investigate the correlates of industrial growth at the Chinese province level, three types of externality were considered in the analysis: industry-specific dynamic externalities, industrial spillovers across provinces and province-specific static externalities. The analysis found that industrial specialization, which measures knowledge flows within an industry, had positive influences on province-industrial growth and such influences were found to be subject to diminishing returns. The positive effect of competition within an industry across provinces was less obvious than that of specialization, in terms of both quantitative and statistical importance, yet the positive effect was subject to statistically significant diminishing returns. This suggests that moderate competition was good for industries but too much competition was harmful, as a result of 'diminished investible surpluses' (Mody and Wang 1997, p.302). In addition, from the performances of the industrial spillovers and industrial diversity variables, one can see that Chinese firms benefited greatly from technological diffusion from other firms within the same industry, but did not significantly benefit from knowledge spillovers from other industries. The performance of the initial industry size variable strongly implied the trend of beta-convergence within the 26 industries in the 9 provinces. The recovered convergence speed is found to be 22 per cent per annum for the industries in the Eastern Zone.

Turning to static externalities, as long as province-specific externalities are properly measured, given such a short period, their performances were consistent across various specifications. It was expected that exports would be found especially important to the industries in the 'export-oriented' Eastern Zone of China; and education, local market size and transport infrastructure more or less facilitated industrial growth in this area.

To conclude, in the post-reform period China has, on the one hand, made great progress by many measures, which makes it the most successful case of transition from a centrally planned economy to a market-directed one. On the other, China is still a low-income, low-productivity country with large income disparity between provinces. Therefore, more effort should be made to reduce inter-provincial income inequality and improve productive efficiency whilst introducing new technologies.

6.2 POLICY IMPLICATIONS

This thesis has shown that the phenomenon of convergence occurs in the provincial dimension and the industrial dimension and that the Chinese economy is sustainable in the long run. The research findings have important policy implications for the Chinese government and economic entities in terms of ways to accelerate and sustain economic growth and industrial growth. The policy implications which arise from the current research can be seen from the following discussion:

First, the analyses of inter-provincial convergence, total factor productivity and industrial growth suggest that it would be beneficial for the Chinese provinces to accelerate economic growth and industrial growth by making greater efforts to increase the rate of human capital accumulation.[124]

In the current thesis, the accumulation of human capital is measured by student enrolment rate at the secondary school level in Chapter 3, student enrolment rates at three education levels in Chapter 4 and share of government expenditure on education in Chapter 5. It is found that a higher rate of human capital accumulation can improve production efficiency, accelerate technical progress, enhance TFP level and promote provincial economic growth and industrial growth.

The importance of the accumulation of human capital has been widely studied and acknowledged in the literature of economic growth and industrial growth, for example in Romer (1989), Mankiw, Romer and Weil (1992), Fare *et al*. (1994), Barro and Sala-i-Martin (1997), Ao and Fulginiti (2003), Carlaw and Lipsey (2003) and Islam (2003). Together with the growth experiences from other countries, empirical findings on human capital from the current research has an important policy implication: in order to help improve firms to efficiently use existing technologies and their ability to innovate and sustain rapid economic growth, the Chinese government should further increases financial investment on education to upgrade

[124] It could also be the other way around; that is, the acceleration of economic and industrial growth will speed up human capital accumulation.

the educational level of the Chinese people.

Second, in order to accelerate and sustain economic growth and industrial growth, the Chinese government should provide domestic and foreign investors with a more friendly investment environment.

It is found in the current analysis that a more friendly investment environment, including a higher degree of openness, regional transportation level and industrialization level, is good for the Chinese economy. In this thesis, openness is measured by the preferential foreign policy, regional transportation level is indexed by the level of freight traffic and industrialization level is indexed by the ratio of primary industry to regional GDP. Generally speaking, the rapidly developing Eastern Zone of China enjoys more preferential policies than the less developed Central and Western Zones; the Eastern Zone is more industrialized than the Central and Western Zones; and transportation in the Eastern Zone is much better developed than in the other two zones. Therefore, in order to effectively implement the Grand Western Development Programme, the Chinese government should efficiently exercise its power in allocating resources, by means of such tools as increasing investment in infrastructure construction, reducing tax rates and implementing more favourable policies, to attract domestic and foreign capital and advanced technologies to the less developed Central and Western Zones.

Third, Chinese enterprises should promote knowledge spillovers between one another, enhance their specialization level and avoid excessive internal competition. The current analysis suggests that knowledge spillovers, industrial specialization and moderate competition are good for industrial growth. Therefore, Chinese enterprises should strengthen the mechanisms of sharing knowledge, information and techniques and make great efforts to maximize the use of physical capital, human capital, information, techniques and natural resources; and the Chinese government should take effective measures in macroeconomic policy coordination and help set up a market system with unified, open and fair competition.

Fourth, Chinese enterprises should make great efforts to explore and expand local markets. It is found in Chapter 5 that local market size is as important as the foreign market to Chinese industrial growth. In contrast with the foreign market, the local market has advantages in low transport costs and easy access to prompt and precise marketing information. Moreover, given that the Chinese market has great potential for expansion and that the foreign market is shrinking due to the current global financial crisis, the local market looks more attractive to Chinese enterprises than the foreign market does. Therefore, Chinese enterprises should actively develop new and high-quality products to expand the local market.

6.3 LIMITATIONS OF THE STUDY

The limitations of the study are mainly issues concerning the data. First, there are measurements which may reduce the explanatory power of the results. For example, in the productivity study in Chapter 4, the labour input was measured by the number of workers rather than number of hours and this may cause the calculated TFP growth rates to be biased. In addition, there is no agreement on the value of the depreciation rate for Chinese capital stock. However, we found that after trying different values of depreciation rates, although the choice of the value of this rate slightly changed the calculated rates of productivity growth, the pattern of cross-provincial distribution of productivity growth remained unchanged.

Second, there are problems which originated from insufficient observations. In the convergence study in Chapter 3, the specification, which was used to test for beta-convergence, described a long-run equilibrium relationship and therefore should be investigated over a fairly long period. It is clear that the time period (1979-2004) in the current study was not long enough to study growth in a nation. In addition, an insufficient number of cross-sections (28 provinces for this study) restricted the analysis from using some specific econometric estimators, for example, the generalized method of moments, which has in recent years been popularly applied to estimate a dynamic unobserved effects model. In the study of industrial growth in Chapter 5, the analysis included only 26 industries in 9 provinces and the time period covered only 5 years. Although the panel data analysis (with 1170 observations in total) had sufficient observations for running regressions, the small number of industries and provinces made it impossible to distinguish unobserved industry- and province-effects from effects of time invariant industry-specific and province-specific variables, respectively.

Third, there is an issue about the quality of the data. The quality of the Chinese data has been questioned. For example, it is found that the FDI data at the province level for recent years are exaggerated and improperly reflect the actual level of the inflows of foreign capital in China. For this reason, after 2004, the State Bureau of Statistics of China stopped reporting the FDI data at the province level.[125] The direct impacts of this can be seen in the analysis of industrial growth in Chapter 5. Due to the above reason, FDI, which is widely believed to be essential in promoting the growth of industries in coastal China, had to be excluded from the conditioning set of province-specific externalities. The omission of this variable may change the performance of the other variables, which was, however, found to be robust in a series of sensitivity tests. Nonetheless, the issue of data quality is beyond the scope of the current studies.

In terms of modelling the economic growth of mainland China, future research may also focus on extending the model to something more general by taking into account the relation between FDI and growth, since the FDI data at the province level are accurate. Given the growing economic and trade cooperation between mainland

[125] FDI data for recent years are still published by local statistical bureaus and can be obtained from statistical yearbooks at the province level.

China and Hong Kong, Macao and Taiwan, it would be interesting to compare growth patterns between mainland China and the three other regions and to find how they affect each other. In addition, given that high inflation, the rapid rise of Chinese currency, the stock market crash, downturn of the housing market, natural disasters and preparation for the 2008 Olympic Games have taken place in China in the past few years, it would be intuitive to take these issues into account to see how the Chinese economy has corresponded. Each study may further justify the robustness of the present empirical results.

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