UNIVERSITY OF BIRMINGHAM

DETERMINANTS OF RESEARCH AND DEVELOPMENT ON THE ALTERNATIVE INVESTMENT MARKET (AIM)

by

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Abstract

This doctoral thesis contributes to the existing corporate finance literature by investigating the incentives that affect the decisions of firms to undertake R&D investment and by examining the impact of financial constraints on the levels of R&D expenditure of AIM-listed firms in the UK. The thesis comprises six chapters. The first chapter provides an introduction to the research, followed by an overview of the Alternative Investment Market (AIM) in Chapter 2, from which several promising ideas were derived. Chapter 3 investigates the incentives that influence a firm's decision to carry out R&D investment. The key empirical findings from a dynamic logistic regression suggest that large sized firms are better at generating innovative activities, that young firms tend to be more likely to innovate, that competitive markets are better at stimulating innovative activities, and that corporate income tax rates have a positive impact on this probability. Chapter 4 explores the impact of financing constraints on the levels of expenditure by directly examining the role that working capital plays in buffering the path of R&D spending from transitory finance shocks. Using a system GMM estimator, the empirical findings suggest that working capital buffers R&D levels from transitory financial shocks, thus avoiding the high adjustments costs associated with any change in levels of R&D investment. Chapter 5 investigates the impact of the proceeds from the disposal of fixed assets on the R&D expenditure of AIM-listed firms. Using several estimation approaches, and in contrast to prior literature, the main findings of this chapter suggest that there is a negative association between R&D expenditure and the cash raised from voluntary asset sales, indicating severe binding financing constraints. Practical implementations, promising ideas for future research, and the main findings of this research are summarized in the concluding chapter of the thesis.

Dedication

To my dear parents

and to my country, the Hashemite Kingdom of Jordan.

Acknowledgment

I would like to express my special thanks, gratitude and appreciation to everyone who encouraged and supported me during my PhD journey, including my supervisors Professor Andrew Mullineux and Nicholas Horsewood. Without their support and guidance, achieving my goal and completing my thesis would not have been possible. I would also like to thank my sponsors, Yarmouk University, for their generous support in covering the cost of my studies, and the staff at Birmingham Business School for their greatly appreciated efforts during this journey. Finally, I would like to extend my gratitude to those who I am forever in debt to, including my dear parents Abdullah and Amneh AlKhataybeh and my siblings, for their unconditional love and support, as well as my inspiration, Mira Hamad.

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Chapter 1

Introduction

1 Introduction

1.1 Research Background

The capital structure irrelevance principle, proposed by the works of Modigliani and Miller (1958) and later Miller and Modigliani (1961), suggests that, in perfect capital market conditions, external and internal sources of capital are considered to be perfect substitutes. Accordingly, it is proposed that corporate financing and investment decisions are entirely independent in such a situation. Not surprisingly, by relaxing the assumption, a large body of research has shown that corporate decisions on both investing and financing are closely related, and that decision-making is a complex process. As illustrated by the financial constraint literature[1], the higher the costs of external sources of finance, the lower the level of corporate investment (Myers and Majluf, 1984). On the other hand, corporate investment may also affect corporate financing decisions, especially when considering the nature and type of investment (Bond and Meghir, 1994).

According to the financial constraint literature, and based on the required type of investment, when considering the availability of and accessibility to means of finance, firms are classified into two types: finance-constrained and finance-unconstrained. Financial managers in both types of firm face two broad questions: what investment should the firm make and how should this investment be financed (Brealey *et al.*, 2011). According to Bodie *et al.* (2011), investment is defined as "The current commitment of money or other resources in the expectation of reaping future benefits". In competitive environments, companies are required to invest in assets that allow them to increase profitability and market share and to confront competition. These assets can be categorised into two types: tangible assets (such as machinery and plant)

[1] Please refer to section 4.3.2 for further illustrations.

and intangible assets (for example, research and development (R&D), patents and brand names). Companies can finance their investments either internally, externally or by using both sources. Figure 1-1 below illustrates the investment types and sources of funds.

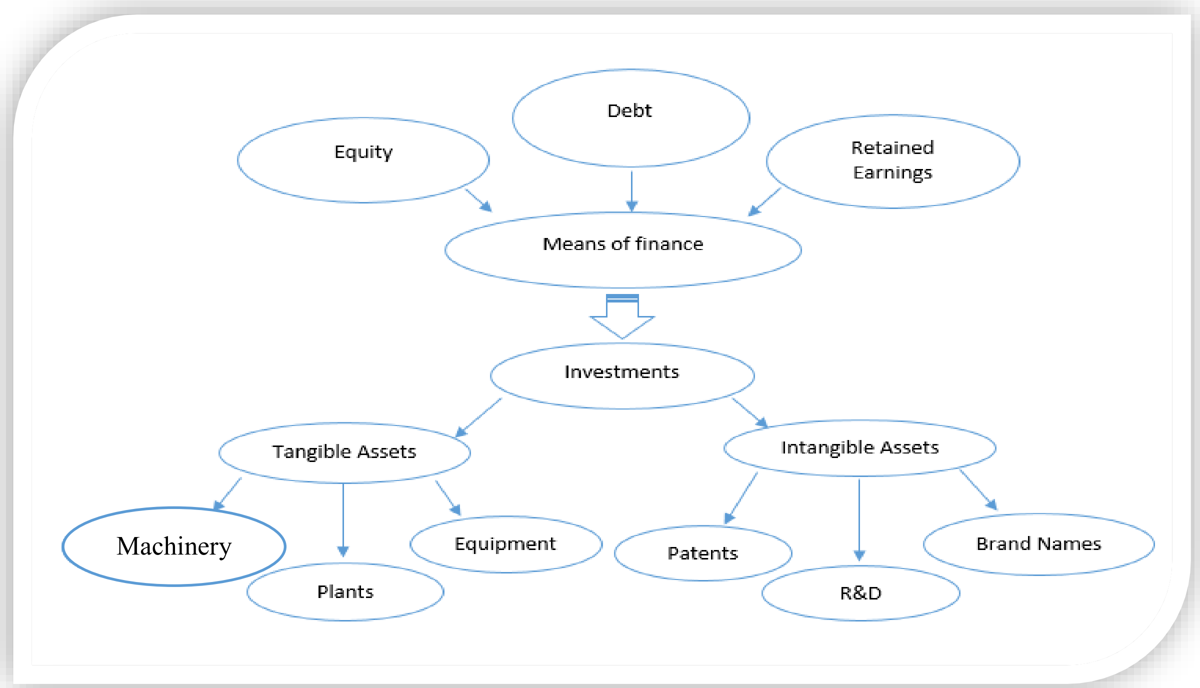

Figure 1-1: Investment types and sources of funds.

Among other types of investments, and due to the importance of the technological changes in recent decades, R&D investment has become a core capital expenditure for a large number of firms. It has been stated officially and internationally that "Research and Experimental Development comprise creative work on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (Bosworth *et al.*, 1993).

Researchers have classified R&D as an important driver for the long-run growth of both firms and economies, and as a critical input for innovation. R&D and the utilization of new technology, for creating new products and developing new production processes, are used to provide product differentiation which leads to competitive advantage over competitors, as well as to enhance the growth of society by creating more employment and income opportunities (Rothaermel, 2008; Miyamoto, 2014).

Unlike other types of investment, R&D is characterized by its riskiness and the high degree of uncertainty associated with it[2]. Further, it offers little or no collateral value, and is linked with high levels of asymmetric information problems, making it more prone to financing constraints (Himmelberg and Petersen, 1994; Brown *et al.*, 2012). In addition, this type of investment involves salary payments to highly skilled and trained workers (e.g. engineers and scientists), who require considerable firm-specific training, and cannot be fired in the case of any temporary cutting back on R&D activity in response to any financing shocks[3].

The attention of researchers and policymakers has been drawn to the importance of R&D. Accordingly, governments have started introducing several schemes as incentives to promote R&D activities at corporate levels. Researchers have studied the factors that influence the decisions to undertake such investment, as well as the determinants that affect the level of expenditure on it.

More precisely, little research has focused on the factors that influence a firm's decision to carry out R&D investment, and of this, much has been rooted in the industrial organization framework (Tirole, 1988; Symeonidis, 1996; Hall and James, 2009), examining external factors influencing R&D activity; for instance, the concentration of the industry in which the firm is

[2] R&D is considered a risky and uncertain investment, as the success of its output is not guaranteed, and will only generate profits with a time lag in the case of success.
[3] If the cut in R&D is temporary and is due to financing shocks, firms should bear the costs of hiring and training new workers in the future. Potentially, more costly, firms should bear in mind that fired R&D workers know valuable information and commercial secrets (firm-specific) that they would not want imparted to other competitors. So the dissemination of information that fired workers may transfer to competitors is considered as being too costly for firms, as such a situation would damage the value of the innovation being undertaken by these firms (Himmelberg and Petersen, 1994; Brown, *et al*., 2012; Brown, *et al*., 2013).

competing (Shrieves, 1978; Kamien and Schwartz, 1982; Takahashi, 1999). Another branch of research has considered the effect of internal factors on firms' R&D activities, for example their resources and capabilities when carrying out R&D activity (Del Canto and Gonzalez, 1999). However, less attention has been devoted to government incentives to encourage R&D activities. The lack of research on the role of fiscal policy in R&D activities lies behind this research, which assesses the role that the R&D schemes introduced by the UK government and corporate tax rates plays in firms' decisions to carry out R&D activities.

On the other hand, and considering the financing menu, empirical research on firms' level of R&D expenditure is based almost exclusively on the availability of internal cash flow and tested on large and mature firms (Grabowski, 1968; Hall, 1992; Himmelberg and Petersen, 1994; Bhagat and Welch, 1995). These studies find evidence that firms' level of R&D is mainly linked to the availability of internal cash flow. However, since riskiness and the lack of collateral value are two characteristics of R&D, it has been found that debt finance (as an external source of funds) is not a realistic source of funds to finance R&D (Switzer, 1984; Hall, 1992; Piga and Atzeni, 2007; Brighi and Torluccio, 2009; Wang and Thornhill, 2010). It has been widely accepted that equity is the only realistic source of external funds to finance R&D investment (Brown and Petersen, 2009; Chen *et al.*, 2010; Brown *et al.*, 2012).

While the vast majority of the existing research on both the incentives for and determinants of R&D has been mainly conducted on large and mature firms, small and young ones have been given little attention and have been clearly overlooked. Furthermore, the focus has mainly been on US firms, with little attention paid to listed firms in other developed economies, particularly the UK. The lack of research on the factors that affect firms' decisions to undertake R&D activities in the UK, and whether the sources of finance matter, is a puzzle. There is a dearth of knowledge on whether financing constraints are important for R&D expenditure in Britain. This has been the motivation for this research to be conducted on and devoted to young and small listed firms in particular. Such an investigation might dramatically alter the conclusions regarding the importance of fiscal policies and the impact of financing constraints on corporate R&D activities.

1.2 Development in entrepreneurial finance

Although typical financing sources for listed firms are mainly in the form of debt, equity and returned earnings, difficulties faced by entrepreneurs in raising funds have led to the recent developments in entrepreneurial finance and the offer of alternative financing options, especially in the aftermath of the recent financial crisis. Angel networks, corporate venture capital (CVC), crowdfunding, mini-bonds, and initial coin funding are examples of the new trends in entrepreneurial financing[4] (Adhami *et al.*, 2017; Block *et al.*, 2017; Bottiglia and Pichler, 2016; Mietzner *et al.*, 2017).

Initially, angel networks and corporate venture capital were the first and more traditional financing means for innovative start-up businesses that were facing difficulties in accessing external finance. Angel networks are networks of affluent individuals who provide equity capital for early-stage high growth ventures under the networks of business angels. Similarly, corporate venture capital (CVC) refers to the investment of large corporate funds in external start-ups or growth firms. These means are considered as solutions for financing businesses that are looking to grow and require extra network access and management support (Block *et al.*, 2017).

[4] Please refer to Bottiglia and Pichler (2016), Adhami *et al.* (2017), Block *et al.* (2017) and Mietzner *et al.* (2017) for more comprehansive reviews on recent developments in entrepreneurial finance.

On the other hand, crowdfunding is an alternative financing tool for ventures, which mainly comes in four different types, based on debt, equity, reward and donation. The practice of crowdfunding is achieved by pooling small amounts of money from many people to support a particular project, typically via the internet (Block *et al*., 2017).

The most recent trends in entrepreneurial finance are mini-bonds and initial coin funding. Mini-bonds are a special SME bond segment from public bonds. They emerged as a consequence of banks' unwillingness and inability to provide debt finance in the wake of the recent financial crisis. The rise of this trend in entrepreneurial finance is considered as a financing solution, especially for innovative firms whose survival might be threatened by financing constraints (Bottiglia and Pichler, 2016). Initial coin funding, on the other hand, is an unregulated means of funds that has recently become available to start-up businesses, through which they can avoid the rigorous process required by banks or venture capitalists. This new financing trend allows businesses to acquire the required funds through cryptocurrencies, in exchange for a 'token', which can be used to acquire services or products in the future, or can be sold on the secondary market (Adhami *et al*., 2017).

It is worth noting that crowd motivations for debt-based, equity-based crowdfunding and angel networks are purely financial (to achieve financial rewards), while donation-based crowd motivation is social, and based on the reward of product-related goals; that is, for future delivery of a service or a product. The motivations of the corporate venture capital (CVC) equity providers are financial, strategic and technological; for example, the strategic goals of accessing new markets or technology.

1.3 Data and methodology

The flowchart in Figure 1-2 shows the research process adopted to conduct this study. The process starts by a comprehensive and critical review of the existing research on the field of corporate finance. The importance of this step is not only to understand the core and relevant context of the study, but also to identify the existing gaps, which helps to derive the proposed ideas of this research. Accordingly, promising ideas are translated into testable hypotheses and empirical model formulation.

The data used in this thesis are secondary, which have been electronically collected through different economic and financial data providers. More precisely, the accounting and financial data of the AIM-listed firms for the period 1999-2014 were extracted from the Datastream and Worldscope databases via Thomson One Banker Analytics. The list of active and inactive firms was publicly available and obtained from the Worldscope database via Datastream and the main website of the London Stock Exchange (LSE). The economic figures relating to tax rates and R&D incentive schemes were retrieved from the main website of Her Majesty's Revenue & Customs department (HMRC), and were publicly available.

R&D activities mainly take place in high-tech industries. The initial dataset comprised 747 firms listed under AIM manufacturing and services industries, over the period between 1999 and 2014. In the empirical analysis, the sample size varied in accordance with the aim and objectives of the study, the form of the model utilised, as well as the required adopted estimation approach. More details of each sample size are given in each of the empirical investigations separately.

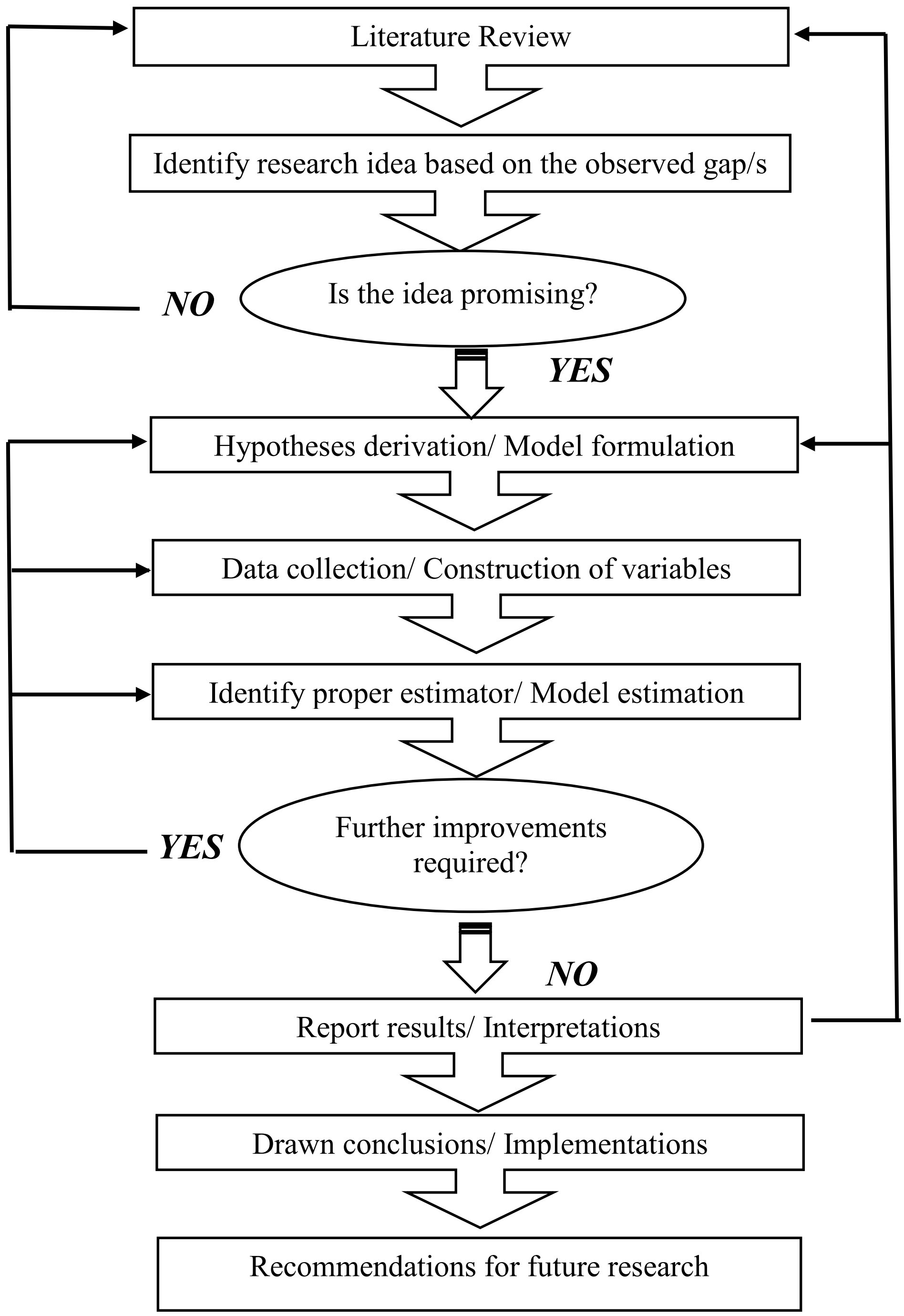

Figure 1-2: Flowchart of the adopted research process.

The dataset of this thesis is defined as panel data, having dimensions of both time-series and cross-sectional data. In the context of empirical corporate finance research, rich structuring of the dataset by pooling company-year observations is more preferable than pure time series or cross-sectional data. Such a structuring allows for better control of the potential estimate biases in accordance with the existence of the dynamic generation process, the heterogeneity among individuals, and endogeneity problems. However, based on the nature of each empirical investigation, several models have been formulated and estimated.

The empirical models in this thesis are analysed using several estimation techniques. These techniques are Ordinary Least Squares (OLS), Least Squares Dummy Variable (LSDV), Dynamic Logistic Regression, Difference Generalized Method of Moment (Difference-GMM) and System Generalized Method of Moment (System-GMM) estimations. The choice of estimator for each empirical study mainly depends on the panel size, model specification, generation process and the variable types.

In each study, several robustness tests are carried out to statistically evaluate the sensitivity of the main results. In all cases, if inadequacy in the statistics of models is observed, the models are either reformulated or re-estimated using more appropriate estimation techniques. Accordingly, the results of the models estimation are reported and interpreted in accordance with prior research findings, theoretical predictions and research hypotheses. Overall, the steps followed in structuring the overall thesis and its three stand-alone empirical chapters (chapters 3, 4 and 5) are adopted to ensure that the conclusions and findings of the study are reliable and solid enough to enrich the existing literature.

1.4 Structure and storylines of the thesis

The thesis comprises six chapters. Chapter 2 briefly presents an overview of the Alternative Investment Market (AIM) in the UK. It covers the benefits that a firm may achieve by becoming a public company, the balanced admission criteria of AIM, and a comparison between AIM and the Main Market on the London Stock Exchange (LSE). The chapter also contains information on corporate tax rates applied in the UK and the tax benefits of being listed on AIM. Furthermore, it reviews the incentives for innovation in the UK represented by R&D tax relief and R&D tax credit schemes. Finally, it considers the motives for choosing AIM.

Chapter 3 comprises the first original research of the thesis. This empirical work investigates the incentives that influence a firm's decision to carry out R&D investment. Most empirical research on this topic has examined the effect of market factors, while others have investigated the impact of firm-specific factors. Accordingly, the aim of this research is to investigate the effect of government tax policies on R&D activities. Its intended contribution is to focus on an analysis of the role of micro, miso and macro-level factors on R&D investment. Specific hypotheses on the effect of these factors on the probability of a firm to carry out R&D investment are derived and tested on a sample of 630 AIM-listed firms. Using a dynamic logistic regression model to control for initial condition problems, the findings suggest that the larger the size of the firm, the higher the probability that it will undertake innovative activities; that young firms tend to have a higher probability of innovating, that competitive markets are better at stimulating innovative activities; and that corporate tax rates have a positive impact on this probability.

Chapter 4 is the second chapter to contain original work. This empirical research investigates the determinants of R&D expenditure on AIM; the effect of financing constraints on R&D

investment; and the role that working capital (as a store of liquidity) plays in maintaining a stable R&D path in the presence of financial constraints.

In this chapter, we address the often ignored role of working capital on R&D investment, as we aim to examine the role that this plays in buffering the path of R&D spending in face of transitory finance shocks for young and small firms listed on AIM. Working capital is defined as current assets minus current liabilities, and measures a firm's net position in liquid assets.

In this chapter, our basic argument proceeds as follows. As R&D investment is associated with high adjustment costs, it is expensive for firms to change their level of R&D investment, so they will seek to maintain a stable R&D investment path, other things being equal. Financial constraints may impede this objective whenever firms are not able to offset cash-flow fluctuations with external funds. Even constrained firms, however, can offset the impact of cash-flow shocks on R&D investment by adjusting working capital, even by setting working capital investment to negative levels. These actions provide short-run liquidity, allowing firms to maintain a stable path of R&D investment relative to cash flow and finance shocks.

In order to examine the aim of this study, specific testable hypotheses have been derived and tested on a sample of 235 UK firms listed on AIM. When using the dynamic system-GMM estimator, the findings suggest that firms appear to maintain a stable level of R&D investment spending by drawing down liquidity from working capital when the availability of finance is low, and by building up liquidity in the form of working capital when finance is readily available. However, the results show that, regardless of the applied splitting criteria, that are dividend pay-out ratios, all firms are found to be financially constrained. Indeed, the differences in dividend pay-out among firms helps to differentiate between the uses of typical financing means.

Chapter 5 presents the third original piece of research. It extends the previous chapter by considering the impact of the disposal of fixed asset proceeds on the level of R&D expenditure. In this chapter, we examine the importance of financial constraints on corporate R&D expenditure by directly examining the role that the disposal of fixed asset proceeds plays in determining the level of R&D spending of the AIM-listed firms. The hypothesis on the impact of these proceeds was derived and tested on a sample of 235 firms. Using several estimation approaches, and in contrast to the previous literature, the research finds a negative association between R&D expenditure and cash raised from voluntary asset sales, indicating severe binding financing constraints. These findings highlight the importance that financing constraints have in their negative impact on corporate R&D investment. To the best of knowledge, this study is the first that emphasizes the importance of financing constraints on the R&D investment of AIM-listed firms.

Finally, chapter 6 concludes the main findings, highlights the contributions of the original research, and presents the implications of the study and its limitations. Moreover, it presents the recommendations and proposed ideas for future research on firms listed on AIM.

Chapter 2

The Alternative Investment Market (AIM)

2 The Alternative Investment Market (AIM)

Although firms aim to sustain growth through the initial capital provided by backing investors, this is insufficient to sustain the required capital. Therefore, firms often join a public equity market as a stepping-stone to achieve their desired growth and development. Once a firm decides on listing, by observing the admission criteria of the appropriate markets, it is required to decide on a market that best fits the criteria and supports its needs in the short and long run. However, it may not be ready for a traditional listing; for instance, on the UK Main Market. Firms at early stages of development would aim to join a market that support their needs, but requires fewer regulations and admission requirements.

Therefore, the Alternative Investment Market (AIM) plays an essential role in the funding environment. It bridges the gap for growing firms that seek to enhance their business to benefit from external finance from capital markets. AIM is a sub-market of the London Stock Exchange (LSE). It was launched on 19 June 1995, as one of the world's leading growth markets. It provides an equity market for firms from a wide range of sectors around the world and allows small firms to float stocks with a much flexible regulatory system than other applicable regulatory systems of more established markets.

Although there are other markets available, for example NASDAQ, firms choose to join AIM for a number of key reasons. First, it offers a balanced regulatory environment, which is specifically tailored to fit the needs of small and growing firms. Furthermore, it gives firms access to a diverse and wide range of investors, such as the international investor base. Moreover, AIM provides firms with a large number of expert advisers, thus acts as an aid in the process of joining the market, and supports them during their time of being listing in the market.

Therefore, investors, firms and scholars have recognised AIM as the market of choice for small and growing firms, which fosters financial growth opportunities (Nielsson, 2013).

Since the launch of the market in 1995, AIM has helped more than 3500 firms to finance their growth opportunities, through raising over £90 billion (London Stock Exchange, 2015). The stock exchange comprises small and growing firms that fit the requirements at early stages of development and supports their ongoing needs (Nielsson, 2013). Benefits for firms joining a public market can be in the form of raising capital at admission and throughout their time on the market. In addition, listing on a public market allows firms to create market shares, and to expand their number of shareholders.

Furthermore, a market helps firms to obtain an objective market value for their business, as well as encouraging employees' long-term motivation, by enhancing share schemes, and by increasing attention through the public market. Moreover, a market increases the ability to expand and make acquisitions by using quoted shares as currency (i.e. paper as opposed to cash). Joining a market is also considered as a significant approach to enhancing status with suppliers and customers (Fabozzi, 1981; Sanger and McConnell, 1986; London Stock Exchange, 2015).

As summarized in table 2-1, between the two major markets in the UK, small firms aim to be listed on AIM rather than the Main Market. The main differences between the admission criteria are that, first, a more established market requires applicant firms to have at least three years' of audited records before listing to ensure that the issuer has representative financial information. As a result, this provides investors with a reasonable assessment of the new applicant firm and its future performance and prospects. However, other applicants may not have representative historical financial records to make them eligible for listing in established markets. AIM does not require firms to have any audited records, so allowing less established and high growth firms (with confident future growth prospects) to benefit from the more flexible regulatory environment and to achieve growth by being admitted to a public market.

Second, the more established market requires firms to have a certain level of revenues to be listed, in order to ensure that the applicant firms are well established and of relatively low risk. However, less established firms can be listed on a stock market to finance their growth opportunities, and find AIM to be the most beneficial market, thus acting as a stepping-stone for those that seek official listing through simplified admission criteria. Third, this market does not specify the level of a firm's stocks that are in public hands, unlike the criteria of other markets (that is, this market does not impose any restrictions on the size of the investor base). Furthermore, the market does not have any minimum requirements for public flotation (giving the applicant flexibility to issue equity as they require, with no minimum requirements).

Moreover, considering the ongoing criteria, AIM does not require prior approval of the firm's stockholders for most of its transactions, which gives firms more flexibility in the process of making important transactions. Furthermore, AIM obliges a firm to appoint a nominated advisor (Nomad[5]) at all times, to assess the criteria for listing, and to ensure awareness of the assigned responsibilities when it is quoted. However, it has been observed that AIM is a less regulated market in comparison to the official list of other markets, thus requiring applicants to have the same level of transparency as the more established markets.

[5] The exchange requires the Nomad to be able to assess the suitability and the reputation of the firm, its potential advisers and directors, and to confirm that a firm is appropriate for AIM and potential investors. Further to the assessment of the firm's appropriateness, the Nomad must provide it with guidance throughout the flotation process, and should prepare it for life on the public market (AIM). The Nomad might be an accountancy firm, corporate finance firm or an investment bank, which is approved by the exchange to act in such a capacity.

As observed, from the ongoing financial information requirements UK listed firms (on both AIM and the Main Market) are obliged to report more frequently in comparison to the other markets, indicating that firms' performance and progress in the UK are more transparent. Furthermore, investors can easily obtain details on performance, as they have access to more frequent historic performance records (financial records).

Table 2-1: Differences between admission criteria and continuing obligations for the Main Market and AIM in the UK.

Differences between admission criteria and continuing obligations for the Main Market and AIM in the UK.		
	London	
	Main Market	*AIM*
Audited track record	Three year track record required	No minimum requirement
Profits	No minimum requirement	No minimum requirement
Assets/Equity	No minimum requirement	No minimum requirement
Revenues	An entity's business must be supported by revenue earnings by at least 75% (track record for three-year period)	No minimum requirement
Market capitalisation	£700K	No minimum requirement
Financial information requirements	International Financial Reporting Standards (IFRS) or equivalent	International Financial Reporting Standards (IFRS) or equivalent

Investors		
Minimum number of shareholders	No minimum requirement	No minimum requirement
Minimum shares traded on market	≥25% of the listed shares to be held in public hands	No minimum requirement
Minimum public float	£700K	No minimum requirement
Sponsor/equivalent[6]	✓	✓ Nominated advisor required at all time (key advisor)
Ongoing requirements-financial information		
Annual financial reports	✓	✓
Half yearly reports	✓	✓
Prior shareholder approval of major transactions	✓	✗ Not for most transactions
Major transaction disclosure	✓	✓

[6] As part of the IPO process, the listing authority requires a listing document to be reviewed by a relevant regulator.

Although AIM-traded SMEs comprise the minority of the SME population of the UK market, AIM presents a stepping stone to those who aim to achieve further growth and development by joining a public market. As reported in table 2-2, the total SME population in the UK was around 5.687 million in 2017, representing 99 percent of all businesses (5.695 million). Breaking down UK businesses based on the number of employees, the figures show that micro-businesses account for 96 percent of the total population, 3.5 percent are small-businesses, 0.5 percent are medium-businesses and only 0.1 percent are large ones (Rhodes, 2017).

Table 2-2: Unlisted businesses in the UK by number of employees, 2017.

	Micro 0-9 employees	Small 9-49 employees	Medium 49-250 employees	large >250 employees	Total businesses
Actual Number[7]	5445	208	34	7	5695
Percentage of total	96%	3.5%	0.5%	0.1%	100%

Considering the motivations for investors on the AIM market, that is the supply side of AIM finance. The UK government has introduced several schemes to support investors who invest in risky and high growth AIM firms, which helps firms to reach their required capital and achieve their desire growth. As summarized in table 2-3, unlike the Main Market, both types of investors (individual and institutional) in AIM can benefit from a set of five different schemes (London Stock Exchange, 2017; European Commission, 2017).

Individual investors in AIM firms can benefit from capital gains tax gift relief and entrepreneurs' relief. In the first type of relief, if shares of an AIM trading firm are transferred (gifted), the deemed capital gain on it can be postponed until they are disposed of by the

[7] Figures reported are in 1000s.

transferee. In the second type, individual investors[8] can reduce the rate of capital gains tax from 28 to 10 per cent.

The enterprise investment scheme (EIS) can benefit individual investors who invest in new AIM firms by a 30 per cent initial income tax relief on investment, as well as exemption from the capital gains tax on disposals for the original gross investment. Third, the inheritance tax allows individual investors to benefit from 100 per cent exemption from inheritance tax in respect of transfer value; that is, the shares that rise in value following the death of the shareholder.

The relief for loss, however, is designed to benefit both individual and institutional investors. In this type of relief, if investments in AIM shares are disposed of for less than their initial cost, investors can relieve the arising losses against capital gains during that year or in the subsequent one. In this relief, the cap on the amount of losses that can be relieved is restricted to £50,000 or 25 per cent, whichever is the higher. However, separate rules apply for institutional investors.

Finally, the Venture Capital Trust scheme allows individuals and institutional investors (of business angels and venture capital trusts) to benefit from exemption from tax on dividends, and exemption from capital gains tax on the disposal of shares in a venture capital trust (30 per cent income tax relief on amounts of up to £200,000 invested in new ordinary shares issued by venture capital trusts and held for five years).

[8] Certain conditions need to be met; please see a guide to AIM UK tax benefits (London Stock Exchange, 2017).

Table 2-3: UK tax incentives for investors in London Stock Exchange

UK tax incentives for investors in London Stock Exchange[9]				
	AIM		MAIN	
	Individual Investors	Corporate Investors	Individual Investors	Corporate Investors
— Capital gains tax (CGT) – Gift relief – Entrepreneurs' relief	✓	✗	✗	✗
— Enterprise Investment Scheme (EIS)	✓	✗	✗	✗
— Inheritance tax (IHT) – Business property relief	✓	✗	✗	✗
— Relief for losses	✓	✓	✗	✗
— Venture Capital Trusts (VCTs).	✓	✓	✗	✗

[9] Please refer to A guide to AIM tax benefit (London Stock exchange, 2017) for further and more in depth details of the introduced schemes.

Based on official statistics of the London Stock Exchange, the flexibility of the regulatory environment of AIM has resulted in attracting a large number of foreign firms[10] to join the market. As presented in table 2-4, the number of traded foreign firms increased from 3 in 1995 to 219 in 2014. The percentage distribution of international firms and the number of admissions, as shown in tables 2-4 and 2-5, demonstrate that percentage increases were observed during the year 2004; subsequently, as a consequence of the amendments to the market regulations and intensive marketing campaigns, this resulted in a more broadly based market.

The trend of foreign listing on AIM is mainly explained by AIM's flexible regulatory environment compared to other equity markets; the simplicity of its listing process; the tax incentives offered to firms and investors; and the fact that AIM has competitive strength in capital raising options, as it lies within the city of London financial services (Arcot *et al.*, 2007; London Stock Exchange, 2018).

[10] Based on the statistics of the London Stock Exchange, foreign listings include firms from across six continents and 100 countries.

Table 2-4: Distribution of foreign firms listed on AIM during 1995-2014.

Year	Number of Firms			Percentage distribution (%)		
	UK	International	Total	UK	International	Total
1995	118	3	121	97.5	2.5	100
1996	235	17	252	93.3	6.7	100
1997	286	22	308	92.9	7.1	100
1998	291	21	312	93.3	6.7	100
1999	325	22	347	93.7	6.3	100
2000	493	31	524	94.1	5.9	100
2001	587	42	629	93.3	6.7	100
2002	654	50	704	92.9	7.1	100
2003	694	60	754	92.0	8.0	100
2004	905	116	1021	88.6	11.4	100
2005	1179	220	1399	84.3	15.7	100
2006	1330	304	1634	81.4	18.6	100
2007	1347	347	1,694	79.5	20.5	100
2008	1233	317	1,550	79.5	20.5	100
2009	1052	241	1,293	81.4	18.6	100
2010	967	228	1,195	80.9	19.1	100
2011	918	225	1,143	80.3	19.7	100
2012	870	226	1,096	79.4	20.6	100
2013	861	226	1,087	79.2	20.8	100
2014	885	219	1,104	80.2	19.8	100

Table 2-5: Distribution of new admissions of foreign firms on AIM during 1995-2014.

Year	Number of admissions			Percentage distribution (%)		
	UK	International	Total	UK	International	Total
1995	120	3	123	97.6	2.4	100
1996	131	14	145	90.3	9.7	100
1997	100	7	107	93.5	6.5	100
1998	68	7	75	90.7	9.3	100
1999	96	6	102	94.1	5.9	100
2000	265	12	277	95.7	4.3	100
2001	162	15	177	91.5	8.5	100
2002	147	13	160	91.9	8.1	100
2003	146	16	162	90.1	9.9	100
2004	294	61	355	82.8	17.2	100
2005	399	120	519	76.9	23.1	100
2006	338	124	462	73.2	26.8	100
2007	197	87	284	69.4	30.6	100
2008	87	27	114	76.3	23.7	100
2009	30	6	36	83.3	16.7	100
2010	76	26	102	74.5	25.5	100
2011	67	23	90	74.4	25.6	100
2012	47	24	71	66.2	33.8	100
2013	77	22	99	77.8	22.2	100
2014	95	23	118	80.5	19.5	100

Based on the data employed[11], the total sample was 1859 listed firms (both active and inactive) throughout the period 1999 to 2014. As summarized in Figure 2-1, during the study 1393 new listings were added to the market, yet the majority were recorded during the years 2004 to 2006. However, 922 firms were delisted from the records with the majority being recorded during the period of the global financial crisis and afterwards. Among all the listed records, 929 are active firms and 930 are dead ones. The average age of active firms is 7 years, while that of the dead ones is 3.85 years.

It worth noting that the reasons for delisting are not purely bankruptcy or liquidation. Based on the recent investigation of Pour and Lasfer (2013), a significant number of AIM firm delistings were voluntary, when firms decided to become privately traded rather than publicly. This type of information, however, was not available for this research. However, it is acknowledged that it is required for reader information, and that further investigation would be considered advantageous in future research.

[11] We construct our research sample on all active and inactive firms listed on AIM. The dataset of the thesis covers all publicly listed firm included on the Worldscope database and the London stock exchange official website, over the period 1999-2014.

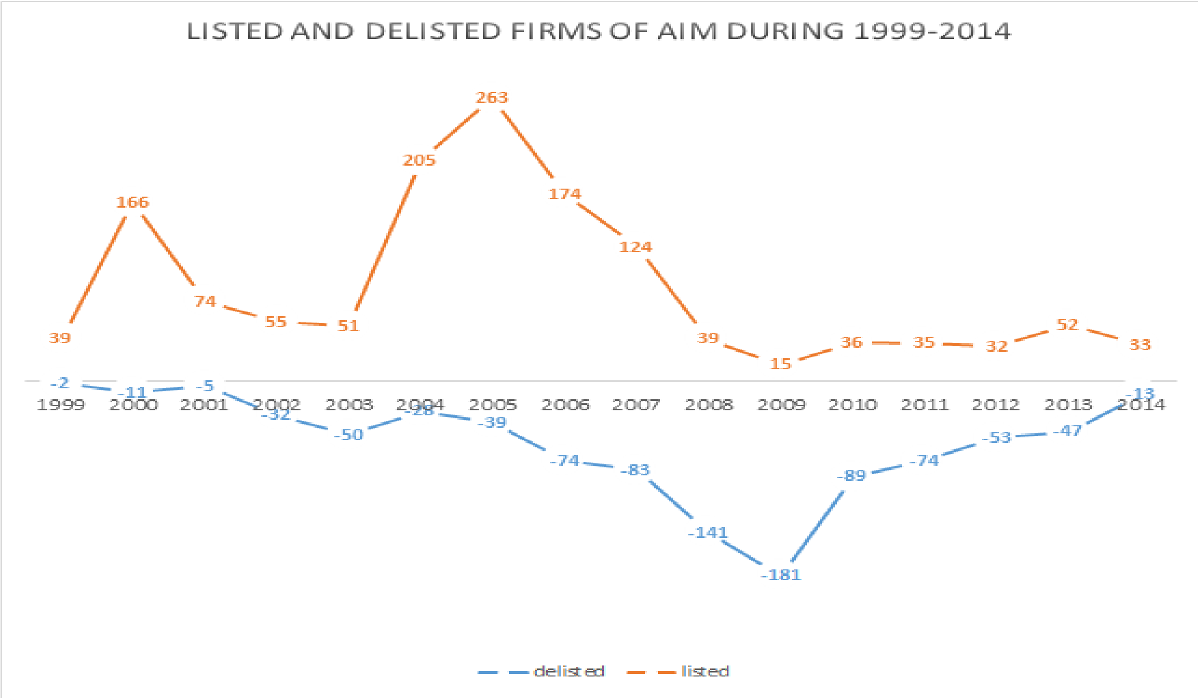

Figure 2-1: Listed and delisted firms of AIM between 1999 and 2014.

The high number of new listings observed from 1999 to 2001 is explained by the dot.com boom period, when many new listings were recorded for internet and high technology stocks. However, the number declined in 2002, as a consequence of the burst of the dot.com bubble, when 36 new listings were recorded for companies moving from the main market to AIM. The globalization period of the AIM market is represented by the year 2003, which explains the renewed increase in the number of new listings. In this period, AIM regulations allowed for dual listing, by which firms listed on certain designated exchanges were able to obtain a secondary listing on AIM (with the target of Commonwealth countries). The increasing number of new listings was due to the dual listing of mining, oil and gas exploration companies from Commonwealth countries (mainly Canadian and Australian firms). By 2007, the marketing campaigns had paid off, making AIM a more broadly based market. As shown in records of 2006 and 2007, many of the new listings were now recorded for mining and oil companies from

Russia, and close-end investment entities from emerging markets (for example, China and India). Finally, the high level of delisting observed in 2007 and subsequently was due to the recent financial crisis and it consequences (Arcot *et al.*, 2007; London Stock Exchange, 2018).

The distribution size of the sample firms is shown in Figure 2-2, based on employment thresholds[12], and indicates that the majority of firms are classified as micro, small and medium size enterprises, at 5, 23 and 41 percent respectively. However, large enterprises under this threshold represented 31 per cent of the full sample throughout the period.

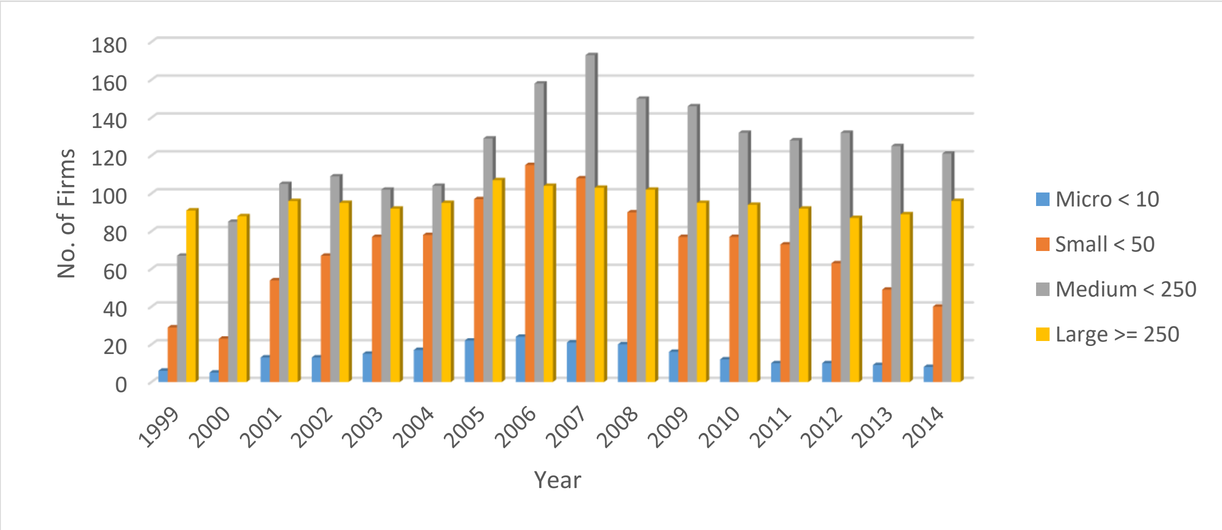

Figure 2-2: Distribution size of AIM-listed firms during 1999-2014.

The 1859 firms are distributed among 69 industries, as shown in table 2-6; the majority of the firms are divided between Metal Mining, Business Services and Engineering & Management Services.

[12] Based on the employment thresholds, firms with fewer than 10 staff are defined as micro enterprises, while those with fewer than 50 staff are defined as small enterprises, those with fewer than 250 medium sized, and if the number of staff exceeds 250 as large (European Commission, 2018).

Table 2-6: Distribution of the AIM-listed firms across all industries.

Division	***Industry***	***Number of Firms***			***Percentage Distribution (%)***		
		Inactive	Active	Total	Inactive	Active	Total
01	AGRICULTURAL PRODUCTION-CROPS	3	4	7	43	57	100
02	AGRICULTURAL PRODUCTION-LIVESTOCK	0	1	1	0	100	100
07	AGRICULTURAL SERVICES	1	2	3	33	67	100
08	FORESTRY	1	1	2	50	50	100
09	FISHING, HUNTING, AND TRAPPING	0	1	1	0	100	100
10	METAL MINING	33	103	136	24	76	100
12	COAL MINING	5	10	15	33	67	100
13	OIL AND GAS EXTRACTION	27	79	106	25	75	100
14	NONMETALLIC MINERALS, EXCEPT FUELS	9	16	25	36	64	100
15	GENERAL BUILDING CONTRACTORS	9	10	19	47	53	100
16	HEAVY CONSTRUCTION.	2	2	4	50	50	100
17	SPECIAL TRADE CONTRACTORS	3	3	6	50	50	100
20	FOOD AND KINDRED PRODUCTS	12	10	22	55	45	100
22	TEXTILE MILL PRODUCTS	4	2	6	67	33	100
23	APPAREL AND OTHER TEXTILE PRODUCTS	7	5	12	58	42	100
24	LUMBER AND WOOD PRODUCTS	1	3	4	25	75	100
25	FURNITURE AND FIXTURES	8	3	11	73	27	100
26	PAPER AND ALLIED PRODUCTS	4	6	10	40	60	100
27	PRINTING AND PUBLISHING	15	4	19	79	21	100
28	CHEMICALS AND ALLIED PRODUCTS	41	37	78	53	47	100
29	PETROLEUM AND COAL PRODUCTS	1	5	6	17	83	100
30	RUBBER AND MISC. PLASTICS PRODUCTS	2	3	5	40	60	100
31	LEATHER AND LEATHER PRODUCTS	2	1	3	67	33	100

32	STONE, CLAY, AND GLASS PRODUCTS	8	6	14	57	43	100
33	PRIMARY METAL INDUSTRIES	1	2	3	33	67	100
34	FABRICATED METAL PRODUCTS	6	10	16	38	63	100
35	INDUSTRIAL MACHINERY AND EQUIPMENT	27	23	50	54	46	100
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	33	41	74	45	55	100
37	TRANSPORTATION EQUIPMENT	4	3	7	57	43	100
38	INSTRUMENTS AND RELATED PRODUCTS	31	35	66	47	53	100
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	2	5	7	29	71	100
40	RAILROAD TRANSPORTATION	1	0	1	100	0	100
41	LOCAL & INTERURBAN PASSENGER TRANSIT	3	1	4	75	25	100
42	TRUCKING AND WAREHOUSING	0	4	4	0	100	100
44	WATER TRANSPORTATION	4	7	11	36	64	100
45	TRANSPORTATION BY AIR	2	4	6	33	67	100
46	PIPELINES, EXCEPT NATURAL GAS	NA	NA	NA	NA	NA	NA
47	TRANSPORTATION SERVICES	8	1	9	89	11	100
48	COMMUNICATIONS	26	12	38	68	32	100
49	ELECTRIC, GAS & SANITARY SERVICES	8	19	27	30	70	100
50	WHOLESALE TRADE-DURABLE GOODS	18	5	23	78	22	100
51	WHOLESALE TRADE-NONDURABLE GOODS	7	6	13	54	46	100
52	BUILDING MATERIALS & GARDEN SUPPLIES	4	0	4	100	0	100
53	GENERAL MERCHANDISE STORES	2	1	3	67	33	100
54	FOOD STORES	0	2	2	0	100	100
55	AUTOMOTIVE DEALERS & SERVICE STATIONS	4	2	6	67	33	100
56	APPAREL AND ACCESSORY STORES	6	0	6	100	0	100
57	FURNITURE AND HOMEFURNISHINGS STORES	5	1	6	83	17	100

58	EATING AND DRINKING PLACES	21	10	31	68	32	100
59	MISCELLANEOUS RETAIL	13	9	22	59	41	100
60	DEPOSITORY INSTITUTIONS	6	9	15	40	60	100
61	NONDEPOSITORY INSTITUTIONS	13	8	21	62	38	100
62	SECURITY AND COMMODITY BROKERS	31	38	69	45	55	100
63	INSURANCE CARRIERS	6	7	13	46	54	100
64	INSURANCE AGENTS, BROKERS & SERVICE	7	3	10	70	30	100
65	REAL ESTATE	49	29	78	63	37	100
67	HOLDING & OTHER INVESTMENT OFFICES	56	52	108	52	48	100
70	HOTELS AND OTHER LODGING PLACES	6	7	13	46	54	100
72	PERSONAL SERVICES	2	2	4	50	50	100
73	BUSINESS SERVICES	175	159	334	52	48	100
75	AUTO REPAIR, SERVICES, AND PARKING	3	2	5	60	40	100
76	MISCELLANEOUS REPAIR SERVICES	2	0	2	100	0	100
78	MOTION PICTURES	13	10	23	57	43	100
79	AMUSEMENT & RECREATION SERVICES	42	13	55	76	24	100
80	HEALTH SERVICES	11	3	14	79	21	100
81	LEGAL SERVICES	NA	NA	NA	NA	NA	NA
82	EDUCATIONAL SERVICES	3	1	4	75	25	100
83	SOCIAL SERVICES	1	2	3	33	67	100
84	MUSEUMS, BOTANICAL, ZOOLOGICAL GARDENS	1	0	1	100	0	100
86	MEMBERSHIP ORGANIZATIONS	NA	NA	NA	NA	NA	100
87	ENGINEERING & MANAGEMENT SERVICES	64	60	124	52	48	100
89	SERVICES, NEC	4	5	9	44	56	100
	Total	***929***	***930***	***1859***	***50***	***50***	***100***

Other than the balanced regulatory environment offered by AIM, firms who are listed on this market can gain benefits in relation to the corporate income tax rates applied in the UK. As shown in Figure 2-3, in the UK the high tax rates on corporate income declined from 30% in 1999 to 21% in 2014. The rate is much lower in the UK than other developed countries; for example, 39% in the US. Similarly, the low tax rate (applied to firms with small profits) is also among the lowest in developed countries and is considered attractive specifically for small firms with relatively small profits. The reasonable tax rates applied are especially designed to govern and support firms' growth.

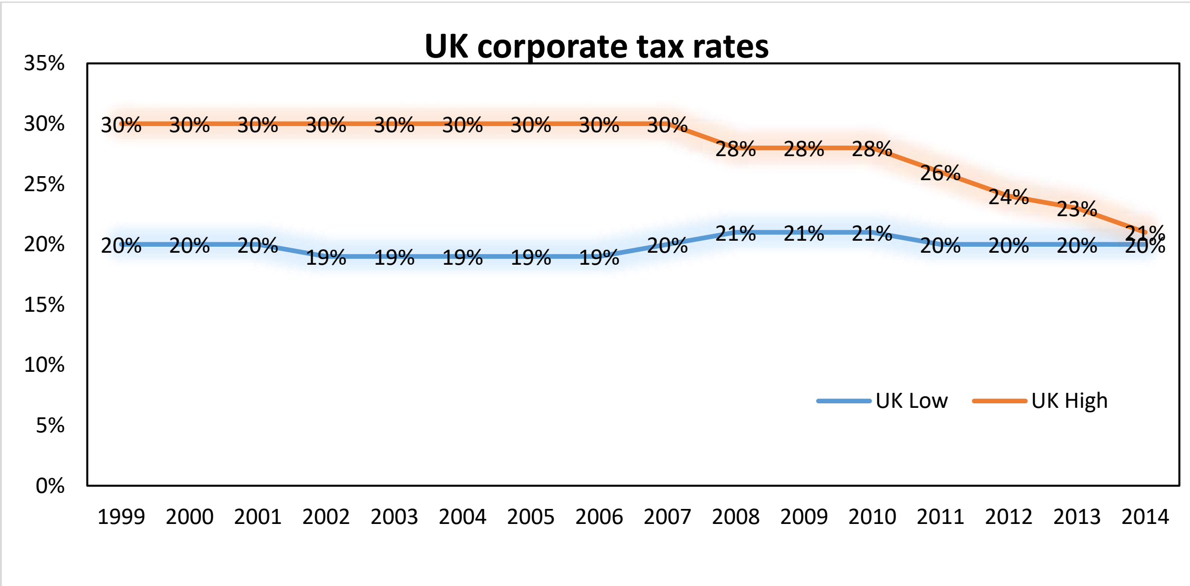

Figure 2-3: The UK's corporate tax rates from 1999 to 2014 (OECD, 2015).

Notes:
UK Low refers to the small profits tax rate applied to firms with profits of ⩽ £300,000.
UK High refers to the main tax rate (top rate) applied to firms with large profits (i.e. ⩾ £300,000).

The designed rates and rules of AIM allowed a large number of firms to join this market in order to achieve growth. Achieving growth can be obtained in two ways, either organically or by making acquisitions. Both ways require a demand for cash, albeit in different ways. Acquisition may require firms to have high up-front cash levels. However, in an organic approach, growth makes firms increase their demand for working capital.

In simple terms, firms raise money through stock issuing or by increasing debt. In stock issuing, money is obtained by inviting investors to participate in the equity share capital of the business. Increasing debt is generated by borrowing from banks. Money raised in either process can be used differently. Firms may use raised fund to reduce pressure on working capital, reduce their dependency on bank finance, pay down significant creditors, or to finance promising investment opportunities.

Based on the nature of a firm and its investments, it may not wish to raise money by issuing equity. Obtaining funds through banks can be more convenient. Firms with risky investments (for example, research and development) which have low collateral value may prefer raising funds through equity issuing, which is considered to be more flexible, to finance their investments, and avoid rigorous structuring processes by banks.

R&D is becoming a core investment in many firms. In some industries, it is strategically crucial for firms to invest in it in order to maintain their competitive advantage. The critical importance of R&D can be shown by the creation of new products or the development of new production processes that are part of the success of a firm. This investment takes a number of years to be completed. Firms cannot cutback their investments until projects are completed, since they are associated with high adjustment costs. In AIM specifically, a significant number of firms have invested in R&D[13]. Table 2-7 shows the distribution of the firms based on whether they are carrying out R&D activities or not, across all industries. Twenty-nine percent of the total of listed firms have invested in R&D, of which the majority are quoted under manufacturing (two-digit SIC 20-39) and service (two-digit SIC 73) industries.

[13] Firms invest in R&D to obtain process and/or product innovations that lead to competitive advantage. Product innovations create new goods and services, while process innovations yield reductions in the cost of producing existing services and products (Tirole, 1988).

Table 2-7: Distribution of the AIM-listed firms based on whether they are carrying out R&D activities or not, across all industries.

Division	***Industry***	***Number of Firms***			***Percentage Distribution (%)***		
		Innovative Activity (R&D)	No Innovative Activity (R&D)	Total	Innovative Activity (R&D)	No Innovative Activity (R&D)	Total
01	AGRICULTURAL PRODUCTION-CROPS	2	5	7	29	71	100
02	AGRICULTURAL PRODUCTION-LIVESTOCK	0	1	1	0	100	100
07	AGRICULTURAL SERVICES	1	2	3	33	67	100
08	FORESTRY	0	2	2	0	100	100
09	FISHING, HUNTING, AND TRAPPING	1	0	1	100	0	100
10	METAL MINING	15	121	136	11	89	100
12	COAL MINING	0	15	15	0	100	100
13	OIL AND GAS EXTRACTION	10	96	106	9	91	100
14	NONMETALLIC MINERALS, EXCEPT FUELS	2	23	25	8	92	100
15	GENERAL BUILDING CONTRACTORS	0	19	19	0	100	100
16	HEAVY CONSTRUCTION.	2	2	4	50	50	100
17	SPECIAL TRADE CONTRACTORS	2	4	6	33	67	100
20	FOOD AND KINDRED PRODUCTS	5	17	22	23	77	100
22	TEXTILE MILL PRODUCTS	2	4	6	33	67	100
23	APPAREL AND OTHER TEXTILE PRODUCTS	2	10	12	9	91	100
24	LUMBER AND WOOD PRODUCTS	1	3	4	25	75	100
25	FURNITURE AND FIXTURES	2	9	11	18	82	100
26	PAPER AND ALLIED PRODUCTS	5	5	10	50	50	100
27	PRINTING AND PUBLISHING	3	16	19	16	84	100
28	CHEMICALS AND ALLIED PRODUCTS	61	17	78	78	22	100
29	PETROLEUM AND COAL PRODUCTS	3	3	6	50	50	100
30	RUBBER AND MISC. PLASTICS PRODUCTS	1	4	5	20	80	100

31	LEATHER AND LEATHER PRODUCTS	1	2	3	33	67	100
32	STONE, CLAY, AND GLASS PRODUCTS	5	9	14	36	64	100
33	PRIMARY METAL INDUSTRIES	1	2	3	33	67	100
34	FABRICATED METAL PRODUCTS	8	8	16	50	50	100
35	INDUSTRIAL MACHINERY AND EQUIPMENT	36	14	50	80	20	100
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	61	13	74	82	18	100
37	TRANSPORTATION EQUIPMENT	2	5	7	29	71	100
38	INSTRUMENTS AND RELATED PRODUCTS	50	16	66	76	24	100
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	4	3	7	57	43	100
40	RAILROAD TRANSPORTATION	0	1	1	0	100	100
41	LOCAL & INTERURBAN PASSENGER TRANSIT	0	4	4	0	100	100
42	TRUCKING AND WAREHOUSING	0	4	4	0	100	100
44	WATER TRANSPORTATION	0	11	11	0	100	100
45	TRANSPORTATION BY AIR	0	6	6	0	100	100
46	PIPELINES, EXCEPT NATURAL GAS	NA	NA	NA	NA	NA	NA
47	TRANSPORTATION SERVICES	0	9	9	0	100	100
48	COMMUNICATIONS	8	30	38	21	79	100
49	ELECTRIC, GAS & SANITARY SERVICES	6	21	27	22	78	100
50	WHOLESALE TRADE-DURABLE GOODS	3	20	23	13	87	100
51	WHOLESALE TRADE-NONDURABLE GOODS	2	11	13	15	85	100
52	BUILDING MATERIALS & GARDEN SUPPLIES	1	3	4	25	75	100
53	GENERAL MERCHANDISE STORES	0	3	3	0	100	100
54	FOOD STORES	0	2	2	0	100	100
55	AUTOMOTIVE DEALERS & SERVICE STATIONS	0	6	6	0	100	100
56	APPAREL AND ACCESSORY STORES	0	6	6	0	100	100
57	FURNITURE AND HOMEFURNISHINGS STORES	0	6	6	0	100	100

58	EATING AND DRINKING PLACES	0	31	31	0	100	100
59	MISCELLANEOUS RETAIL	1	21	22	5	95	100
60	DEPOSITORY INSTITUTIONS	3	12	15	20	80	100
61	NONDEPOSITORY INSTITUTIONS	1	20	21	5	95	100
62	SECURITY AND COMMODITY BROKERS	1	68	69	1	99	100
63	INSURANCE CARRIERS	0	13	13	0	100	100
64	INSURANCE AGENTS, BROKERS & SERVICE	0	10	10	0	100	100
65	REAL ESTATE	3	75	78	4	96	100
67	HOLDING & OTHER INVESTMENT OFFICES	7	101	108	6	94	100
70	HOTELS AND OTHER LODGING PLACES	0	13	13	0	100	100
72	PERSONAL SERVICES	1	3	4	25	75	100
73	BUSINESS SERVICES	166	168	334	50	50	100
75	AUTO REPAIR, SERVICES, AND PARKING	0	5	5	0	100	100
76	MISCELLANEOUS REPAIR SERVICES	0	2	2	0	100	100
78	MOTION PICTURES	0	23	23	0	100	100
79	AMUSEMENT & RECREATION SERVICES	6	49	55	11	89	100
80	HEALTH SERVICES	2	12	14	14	84	100
81	LEGAL SERVICES	NA	NA	NA	NA	NA	NA
82	EDUCATIONAL SERVICES	0	4	4	0	100	100
83	SOCIAL SERVICES	1	2	3	33	67	100
84	MUSEUMS, BOTANICAL, ZOOLOGICAL GARDENS	0	1	1	0	100	100
86	MEMBERSHIP ORGANIZATIONS	NA	NA	NA	NA	NA	NA
87	ENGINEERING & MANAGEMENT SERVICES	44	80	124	35	65	100
89	SERVICES, NEC	2	7	9	22	78	100
	Total	***546***	***1313***	***1859***	***29***	***71***	***100***

Small firms who invest highly in R&D may find it more attractive to join a UK public market (AIM), since the applied tax procedure for R&D in the UK is considered among the best in the world (please refer to section 3.1, table 3-1).

After reviewing the balanced regulatory environment and the admission criteria of AIM, the attractive corporate income tax rates, the R&D tax relief scheme, and the R&D tax credit incentive applied in the UK, how these incentives affect a firm's decision to undertake R&D activities will be investigated. Furthermore, how AIM-listed firms finance their R&D investments and whether the investments of the small listed firms are facing binding financial constraints will be investigated.

The research is focused on UK-listed firms, with special attention paid to small and young firms, since the financial constraints on corporate investment are more severe in market-based economies (for example, the UK and USA) than in bank-based economies (for example, European countries). Bond *et al.* (2003) suggest that, among the European financial markets, the UK is the weakest in channelling funds towards firms with more promising investment opportunities, due to the arm's-length relationship between finance providers and companies. Thus, the market-based UK financial system may give rise to financial constraints amongst UK-listed firms.

Few studies have concentrated on how finance affects the R&D expenditure of small size and high growth firms. The financing constraints that are present may also influence R&D levels. Since AIM in the UK is as developed as the capital markets in the US, the lack of evidence on R&D determinants in the UK is a puzzle, and calls into question whether small firms listed on AIM face binding financing constraints on their R&D investments.

Chapter 3

Incentives of innovation on the AIM market

3 Incentives of innovation on the AIM market

3.1 Introduction

In the current economic environment, innovation is considered as a major source of competitive advantage[14], and is achieved through intensive research and development (R&D) expenditure and the utilization of new technology. For firms to provide some differentiation that would lead to competitive advantage, that is to create new products or develop new production processes, they invest in R&D, which is a critical input for innovation. As a consequence, the innovation factor has a growing importance for society as a whole, which will benefit from the progress of firms in terms of generating new services and products, and consequently creating further employment and income opportunities, which all contribute to societies' needs and wants (Miyamoto, 2014; Rothaermel, 2008).

There are various ways in which firms can carry out innovative activities; for instance, through constant internal investment, thereby generating the minimum requirements (sufficient critical mass) for further innovative developments[15]. These internal activities include R&D investment, as indicated by Hay and Morris (1991), but also others which are executed outside the structured area of R&D activities, and are interconnected with other functions of the firm, such as engineering works, quality control or design improvement (Del Canto and Gonzalez, 1999).

On the other hand, firms can execute innovative activities through external sources, by adopting the new technology developed by other industries (Dahlander and Gann, 2010; Huizingh,

[14] The business term "competitive advantage" refers to the attributes that allow an organization to perform at a higher level than its rivals. These attributes can be, for example, geographical location, highly skilled employees, or the application of new technology in creating new products or production processes. (Porter, 1990).

[15] It is important to distinguish between process innovations and product innovations. Product innovations create new services and goods, while process innovations yield reductions in the cost of producing existing services and products (Tirole, 1988).

2011). The classic way is via license agreements. However, one could also argue that the adoption of external sources is embodied in capital equipment and intermediate inputs (Pavitt, 1984; Tirole, 1988), the intermediate mechanism between the market and organizations can be achieved by R&D cooperation between firms (Veugelers, 1997; Del Canto and Gonzalez, 1999; Laursen and Salter, 2006).

Internal development of innovation has some advantages over external acquisition. However, cooperation is difficult to achieve as it generates competitive advantage. There is no dependence on third parties for development activities and it eliminates any potential restrictions on firms to make improvements in their existing technology, regardless of its high risk (Tirole, 1988; Cassiman and Veugelers, 2006; Vega-Jurado *et al.*, 2008). In reality, the success of the vast majority of firms is due to their superior technological and innovation capability. It is therefore logical to understand why academics, as well as policymakers, are focusing on understanding the factors and the determinants that facilitate these internal mechanisms.

One of the key determinants of technological change is knowledge accumulation, which is chiefly presented through investment in R&D. Researchers have provided an extensive body of empirical evidence on the theoretical argument that R&D investment has a significant positive effect on the growth of economies at both aggregate and disaggregate levels[16]. The recognition of the importance of R&D, for the long-run growth of economies and for living standards within society, has drawn the attention of policymakers and been reflected in government policies.

In the UK, the government has introduced special tax schemes to encourage firms to conduct R&D activities, namely R&D tax relief and R&D tax credit, on top of the continuous reductions

[16] As explained by endogenous growth theory, research and development makes a significant contribution to economic growth; see, for example, Arrow (1962), Cohen and Levinthal (1989), Romer (1990) and Laincz (2009).

in corporate tax rates. These schemes are UK tax incentives aimed at reducing a firm's tax bill and/or at allowing a firm to claim payable cash credits as a proportion of their qualifying spending[17] on R&D, therefore reducing the cost of corporate R&D, and encouraging firms to invest in R&D.

The rationale for the introduction of these schemes by the UK government was due to the country's spending on R&D as a proportion of gross domestic product, which was lagging behind many other countries, especially during the period 1981-1999 (HMRC, 2015; The World Bank, 2016). However, owing to the importance of R&D in building a modern knowledge-based economy and improving productivity, the UK government has made an effort to increase the amount spent on R&D by firms. For this purpose, it introduced the two relief schemes for firms incurring expenditure on this type of investment (HMRC, 2015).

There is one scheme for large firms and another for Small and Medium Enterprises (SMEs). A general comparison and overview of the R&D tax relief and R&D tax credit schemes are presented in Table 3-1. The first scheme was introduced in 2000 for SMEs, giving both tax relief and tax credit, while separate schemes for large firms came into being in 2002 for tax relief and in 2013 for R&D tax credit.

[17] The definition of qualifying R&D expenditure is reasonably broad, and qualifying R&D activities cover the whole range of firm operations (see the definition of R&D for tax purposes (HMRC, 2015)).

Table 3-1: General comparison of R&D tax schemes in the UK.

SME[18] R&D Scheme		
Active date from	Enhanced deduction rate on qualifying R&D expenditure	R&D expenditure credit (payable credit rate)
01/04/2000	150%	16%
01/08/2008	175%	14%
01/04/2011	200%	12.5%
01/04/2012	225%	11%
01/04/2014	225%	14.5%
01/04/2015	230%	14.5%
Large firm R&D scheme		
01/04/2002	125%	No payable credit
01/04/2008	130%	No payable credit
01/04/2014	130%	10%
01/04/2015	130%	11%

Although the UK government introduced policies to motivate firms to undertake R&D activities, no research has been devoted to assess the impact of these government policies on such activities, with very little special focus on young and small listed firms (the government's target group).

[18] For a firm to fall within the definition of an SME it must have a staff headcount of below 500, and have either less than €100 million turnover, or less than €86 million gross balance sheet assets; that is, approximately less than £85 and £73 million in turnover and balance sheet total respectively.

3.2 Research aim and objectives

Despite the renewed interest in the impact of R&D investment on the growth of firms and economies, relatively little is known about the determinants of firms' innovative activities, either in the UK or in other developed countries. This chapter aims to fill the gap and investigate the incentives and the determinants of the innovative activities of AIM-listed firms.

Most of the recent empirical and theoretical research has focused on the factors influencing R&D activity at the firm level. A great amount of research on the factors behind R&D activities was rooted in an industrial organization framework (Tirole, 1988; Symeonidis, 1996; Hall and James, 2009). Studies focused on the external factors for carrying out R&D activity; for instance, the degree of concentration of the industry in which the firm operates (Shrieves, 1978; Kamien and Schwartz, 1982; Takahashi, 1999). Another stream of research has focused on the effect of internal factors on a firm's R&D activities; for example, resources and capabilities in carrying out R&D activity (Del Canto and Gonzalez, 1999). This chapter aims to evaluate the effect of government policies on firms' R&D activities, explaining why firms pursue such promising and risky investments.

The empirical results of this research are of high importance, providing a clearer view of the factors that influence a firm's decision to undertake R&D investment, and measuring the role that government policies have on firms' decisions to perform R&D activities.

To the best of the researcher's knowledge, no such investigations have been made on the effect of fiscal policy on R&D activities. Investigating the effect that such policy has on the carrying out of R&D investment in the UK is of great importance, especially for firm managers and policymakers, and calls into question whether these government incentives play a significant role in motivating firms to undertake R&D activities. The second contribution of this research is that most of previous research conducted on the incentives for carrying out R&D investment has been almost exclusively based on the investigation of large and mature firms. Thus, in this work we contribute to the literature by investigating the determinants of and the incentives for carrying out R&D activity for small and young firms in particular, owing to their important contributions to society and the economy.

The third contribution of this research lies in the applied methodology; that is, the dynamic logistic model that controls for the initial condition issues with unobserved heterogeneity. Previous research has not considered the role of the dynamic process in the probability of undertaking R&D expenditure, nor has controlled for the initial condition issues. In addition, this work will contribute to the literature related to corporate tax changes and R&D tax schemes on corporate financing and investment policies.

3.3.1 Introduction

Traditionally, in the economic literature on industrial organizations, one of the most important questions has been the connection between market structure, industry characteristics and innovation. From this theoretical perception, it is assumed that the differences between firms' innovative activities are illustrated by the industry's structural characteristics. In this respect, sources of inter-industry that have been studied with regard to the varied innovative strategies are technological strategy, demand growth intensity and appropriability[19] conditions (Tirole, 1988; Takahashi, 1999; Lopez, 2009). The effect of some firm characteristics are also considered, but are relatively limited to firm size and other variables, for instance diversification or profitability and liquidity, which are relatively correlated with size (Grabowski, 1968; Adams, 1970; Hundley *et al.*, 1996; Cohen, 2010).

On the other hand, unlike industrial organisational and from another theoretical perspective, the resource-based perspective, research has also been conducted on the effect of internal resources and capability on innovation strategies. This research has devoted efforts to developing models and frameworks to analyse the firm environment rather than organizational factors in determining the relationship between internal firm characteristics and innovation activities (Del Canto and Gonzalez, 1999; Galende and de la Fuente, 2003; Webster, 2004). The view of the resource-based perspective is that innovation does not come merely by surveying external characteristics for market opportunities, but by looking in-depth internally, to form and build the core competencies of the firm. It states that incentives to innovate are also found in the funding resources of the firm, which are simply heterogeneous between firms. Hence,

[19] Appropriability is defined as the environmental factors that govern an innovator's ability to obtain profits generated from inventions or innovations (Lopez, 2009).

innovation is relatively tied to particular resources and can be explained as a function of a firm's internal resources (Arrow, 1962; Kamien and Schwartz, 1982; Becker, 2013).

Instead of explaining the determinants of innovation and the incentives to innovate from industrial structure and resource-based perspectives only, this analysis also considers fiscal policy incentives as possible causes of innovativeness. In order to do this, we will distinguish three types of determinants that could influence a firm's decision to carry out R&D activity: firm-specific factors, market structure factors, and fiscal policy factors. However, for simplicity, these factors will be classified into micro-level, meso-level, and macro-level factors. Figure 3-1 illustrates the theoretical model which is the map for this work and which is the object of the empirical tests of the research.

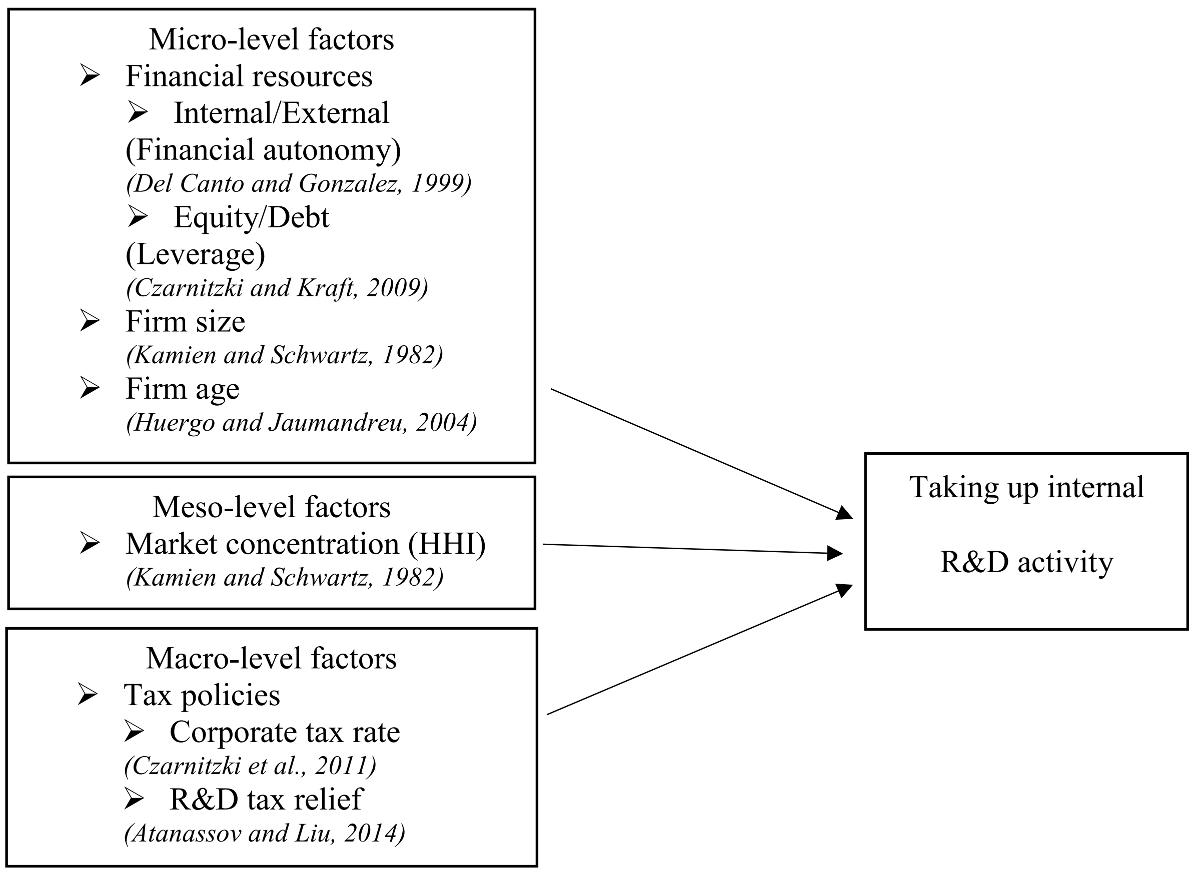

Figure 3-1 : Factors determining internal R&D investment activity.

3.3 Theoretical framework and hypotheses derivation

3.3.2 Micro-level factors

3.3.2.1 Financial Resources

Financial resources include retained earnings, debt, equity and working capital (Scherr, 1989; Bond and Meghir, 1994). The availability of a firm's financial resources can affect its decision to undertake internal R&D activity. According to the imperfect capital market and agency literature, internal funds are much favoured by firms over external funds. Thus, the availability of internal funds should be more positively related to R&D investment than external sources. If internal funds are exhausted, and external funds are needed, investment in R&D will be ideally financed through equity rather than debt (Wang and Thornhill, 2010; Martinsson, 2010; Brown *et al.*, 2012).

First, the lack of internal sources of funds can limit a firm's capacity to support its R&D activity and expenses, whereas a firm's internally generated cash flow can make these activities more possible (Grabowski, 1968; Hall, 1992; Himmelberg and Petersen, 1994; Bhagat and Welch, 1995; Carpenter and Petersen, 2002). Internal funds are more preferable than external funds because of the asymmetric information problem; that is, when the firm's management and external capital markets do not have the same information available about the firm (Myers and Majluf, 1984).

Internal management (insiders) have more information about their internal projects, including R&D, due to disclosure issues to capital markets, than outsiders. Information about the R&D projects of a firm should not be fully revealed, as this would become a signal to competitors, which could result in losing the opportunity to maintain control over innovative activity. Consequently, a firm would not be able to convert its innovative activity (innovation) into a source of competitive advantage. The control and demands for information required by the providers of external funds, therefore, offer an example of the pecking order theory of capital structure (Myers and Majluf, 1984; Myers, 1984).

The principle of this theory is centred on the idea that in the presence of the information asymmetry problem, if firms try to issue risky securities, outside investors will interpret this effort as a sign that the firm is overvalued. Based on this, investors will reasonably discount the price of a firm's security, leading to a negative market reaction. According to this theory, firms will prefer to finance their investment opportunities by available internal funds, debt issuance, and equity issuance in that order, creating a hierarchy of finance (Oliner and Rudebusch, 1992), and according to which firms will prefer to finance their R&D activities by their own available internal funds rather than external sources of funds.

Second, a firm's capital structure that is based on debt can dampen the incentive to undertake R&D activities. Theories that support this argument can be found in transaction-cost economics and the agency theory (Jaffee and Russell, 1976; Fazzari *et al.*, 1988; Williamson, 1988; Wang and Thornhill, 2010). Williamson (1988) and Wang and Thornhill (2010) state that the determinants of financing a project through debt or equity depend mainly on the characteristics of the assets. Accordingly, equity is suggested to be the ideal financing means, especially when a firm is investing in firm-specific assets (for example, R&D investment), and debt is more appropriate to finance non-specific or re-deployable assets. Assets have a higher resale value and are easily redeployed if they have a low degree of firm specificity, so debt providers have the option of forcing assets sales or liquidation if the company fails to meet its debt obligations (Wang and Thornhill, 2010).

As the asset-specificity of R&D investment is high, implying a low resale value, the protection offered to debt providers against this type of investment is low and affords limited protection. Thus, debt providers can intervene in the conduct of management to avoid risky investments. Equity funding, which does not impose restrictions and so allows for much greater discretion, is considered as the preferred financing channel for projects where asset-specificity is high (Switzer, 1984; Hall, 1992; Brown and Petersen, 2009). Thus, the greater the intervention power of the debt providers in the firm, the greater their capacity to direct activities towards less risky investment, and therefore investment in R&D is expected to be lower (Scellato, 2006; Casson *et al.*, 2008; Czarnitzki and Kraft, 2009).

Moreover, in the cases of large firms, especially the ones that operate in mature sectors, Jensen (1986) states that these firms have a greater incentive to over-invest in projects, for example R&D, even if they do not generate value for shareholders. Consequently, debt providers impose more restrictions on firm managers to act more in the shareholders' interests; that is, by overriding decisions that would reduce a firm's productivity and profitability. Furthermore, researchers argue that firms would need to reduce their financial obligations in order to reduce the risk of financial distress and bankruptcy. Because firms' financial obligations are represented by debt interest payments, research assumes that they would try to limit their use of debt.

Despite the fact that the success of R&D investment may lead to better financial performance (Cohen and Levinthal, 1989; Fazzari and Petersen, 1993; Wang and Thornhill, 2010), which would lead to a future stream of cash flows that would make financing through debt relatively cheaper, firms place more emphasis on factors that might threaten their survival. Thus, firms with high levels of leverage would reduce their investment in risky activities in order to reduce the risk of financial distress and bankruptcy.

Taking the previous empirical findings, along with the roles of external and internal financing, into consideration, the proposed hypotheses are as follows:

H1: *High levels of equity and internally generated funds increase the probability that a firm will undertake R&D investment.*

H2: *High levels of debt decrease the probability that a firm will takes up R&D investment.*

3.3.2.2 Firm Size

There has been growing interest in the role of firm size[20] in R&D activities and the undertaking of them. This effect has been frequently studied, and the empirical evidence varies significantly. First, according to the Schumpeterian hypothesis, large firms are deemed to be comparatively more innovative than small ones, with the latter devoting little expenditure to this (Smyth *et al.*, 1972; Kamien and Schwartz, 1982; Acs and Isberg, 1991; Babutsidze, 2016). The economies of scale in this activity, or the existence of the required critical mass, make research and development difficult for small firms (Shefer and Frenkel, 2005). Furthermore, firm size is also considered as an indicator of firm power in the market, which would facilitate innovation by better ability to finance research and development (Symeonidis, 1996).

As pointed out by Nelson (1959), Cooper (1964) and Graves and Langowitz (1993), other factors favour larger firm size; for example, the lower probability of risk of failure owing to the fact that larger firms are more able to diversify their R&D projects. Equally, the successful R&D activities of large firms are more profitable due to their larger market. Furthermore, large

[20] Firm size can be measured by total assets, sales or by number of employees.

firms hire many highly skilled workers and scientists, who can interact and discuss their ideas, and rely on the expertise of colleagues at particular points when needed (Vaona and Pianta, 2008; Herrera and Sánchez-González, 2013).

On the other hand, several studies have failed to show the suitability of the Schumpeter hypothesis on the favouring of large sized firms (Cooper, 1964; Smyth *et al.*, 1972; Cohen *et al.*, 1987; Shefer and Frenkel, 2005; Pla-Barber and Alegre, 2007). Others have proposed an intermediate point; that is, medium size firms (Kamien and Schwartz, 1982; Laforet, 2008). In this sense, Acs and Audretsch (1988) state that although small and medium sized firms spend less on R&D than large firms, they produce a significant number of innovations, especially if comparison is on a per-employee basis. Similarly, Tether (1998) shows that small firms are much more innovative than large ones. As argued by the employment literature, while large firms often follow the rationalisation mode, small ones have a greater tendency to increase their rates of growth and employment opportunities. However, as these growths are associated with innovativeness, small firms are expected to be more innovative than large ones (Rothwell, 1984).

In addition, considering the types of innovation being undertaken by firms, Baumol (2002) and Baumol (2004) discriminate between firm innovation based on breakthrough and incremental innovations. In his research, Baumol revealed that breakthrough revolutionary innovation comes predominantly from small sized firms, while large sized ones contribute by their incremental innovation/improvement. The rationale behind these findings is that the innovative activities of large sized firms are carefully designed to avoid unnecessary losses or surprising outcomes; that is, keeping the risk level at a minimum hinders the imagination and risk taking of large firms.

On the other hand, small firms are marked by breakthrough innovations as a result of their being guided by risk taking entrepreneurs/investors, who seek to achieve high marginal growth and profit on their initial investments. Consequently, Baumol *et al*. (2007) conclude their research recommendations by emphasizing more support for small sized firms owing to their contribution in leading modern economies, through their breakthrough outcomes.

Furthermore, Cooper (1964), and Hitt *et al.* (1991) argue that small firms have positive effects on R&D activities, with these effects illustrated by their better networks of communication and better coordination between units. In addition, Tether (1998) states that small-size firms are more effective at generating innovative products, whilst large-sized ones are more effective at large scale production and product distribution.

Del Canto and Gonzalez (1999) argue that this relationship may depend on the characteristics of the industry in which the firm is operating and on the type of innovative activity and innovation being developed. Thus, Acs and Audretsch (1987) and Shefer and Frenkel (2005) argue that large-sized firms tend to stress innovation activities in sectors where capital and advertising are relatively intensive, as well as in sectors that are marked by high concentration. On the other hand, small firms tend to have a relative advantage in innovation in sectors that are in their early growth stages, and in those that are less concentrated (Tether, 1998). This argument is illustrated by the fact that these sectors are associated with low R&D costs and capital inputs (Rothwell, 1984).

The findings for UK firms have varied with regard to the positive relationship between R&D activity and firm size (for example, Smyth *et al.*, 1972; Tether, 1998). Taking the findings of the previous empirical studies into consideration, we conclude that the effect of firm size on the willingness to carry out R&D activity is complex and cannot be simplified in a single hypothesis. Considering that firms listed on the AIM market are small-size ones, the proposed hypothesis is as follows:

H3: *The greater the size of the firm, the greater the probability that it will undertake R&D investment.*

3.3.2.3 Firm age

One of the factors that has an effect on the growth process of firms, and which has received little empirical attention in the context of innovation, is experience as measured by firm age. Firm experience, ideally measured as cumulative output or proxied by time, has to some extent been used in the studies of firm survival and some studies of learning by doing. However, it has been relatively ignored in the innovation literature. Sørensen and Stuart (2000) were among the first to examine the relationship between firm age and innovation activity. They investigated the impact of firm age on innovation and its quality, providing evidence that older firms generate significantly more innovations. They state that the competence to produce new innovations appears to improve with age, "but these gains in organizational competence come at a price, namely, an increasing divergence between organizational competence and current environmental demands".

Moreover, and in another context, Huergo and Jaumandreu (2004) also investigated the impact of firm age on innovation. Their research concludes that young firms tend to have the highest probability of innovation, while the oldest ones tend to present a lower probability of innovative activity. They also show that firms of an intermediate age present a high probability of innovation, and that those that are exiting the market are the ones that present the lowest level of process innovation. They conclude that there is a nonlinear relationship between age and innovative activities.

These studies vary in support for the idea that the quality and quantity of firms' innovation activities change over time as they accumulate experience, and that this relationship may vary across industries. However, Balasubramanian and Lee (2008) examined the effect of firm age on innovation activities in accordance with the heterogeneity of technological changes across industries. They conclude that ageing has a negative effect on innovation, and that the effect varies with the level of technological activity. Furthermore, they suggest that younger firms are more likely to be better at contributing to innovation than older ones.

It is clear that little research has analysed the effect of firm age on innovation, and that there is no consensus. This chapter contributes to the literature by assessing the probability of innovation being carried out with firm age being one of the factors that influences a firm's decision to perform R&D activity. Taking the findings of the previous empirical studies into consideration, to capture the effect of firm age on the willingness to carry out R&D activity is difficult and needs further investigation. Considering the young age of the firms listed on the AIM market, the proposed hypothesis is as follows:

H4: *The older the firm the greater the probability that a firm will carry out R&D investment.*

3.3.3 Meso-level factors

3.3.3.1 Market concentration

Over the past decades, a large body of research has been devoted to how market structure affects innovation activities and their intensity. According to Schumpeter (1942), societies must be prepared to support imperfectly competitive markets in order to attain rapid technical progress. It is argued that large-sized firms in imperfectly competitive markets are considered to have the most conducive conditions for innovation progress, and that a firm in an imperfectly competitive industry is more able to prevent imitation and can therefore obtain more revenue from innovation. Furthermore, a firm with monopoly profits is better able to finance its innovative activities than other firms. Innovation is claimed to be greater in monopolistic industries than in more competitive ones (Symeonidis, 1996; Kamien and Schwartz, 1982).

In the Schumpeterian hypothesis, the degree of monopoly power did not influence the probability of successful innovation, but was a crucial incentive for firms to engage in innovation activities (Vossen, 1999; Gayle, 2001; Weiss and Wittkopp, 2005). This view led to the much debated and long-standing hypothesis that industries that are more concentrated have the most conducive conditions for innovation, leading to recent empirical research on the relation between market structure and innovation which has investigated the relationship between industrial concentration and R&D. With a few exceptions, a positive relationship has been found. However, these empirical results have been found to be inconclusive, as they fail to consider more fundamental sources of variation in innovative behaviour, and the performance of firms and industries (Cohen and Levinthal, 1989).

The Schumpeterian hypothesis challenged the classical economic understanding of the ideal market structure for optimal resource allocation, and has engendered empirical and theoretical literature on this topic. Based on the argument, policies that aim to reduce or eliminate imperfect competition could at the same time limit the amount of innovation in an economy (Gayle, 2001). Kamien and Schwartz (1982) conducted a comprehensive review of the empirical literature up to the late 1970s on the relationship between market structure and innovative activity and revealed the inappropriateness of this relationship. Findings vary, with some studies supporting the Schumpeterian hypothesis, that competitive markets are less active at stimulating innovative activity, while others suggest that competitive markets are better at stimulating innovative activities.

These studies offer several arguments on the advantages of market power on innovation and on how it results in greater innovative activities. Firms enjoying market power with their existing products can introduce new products, for instance through the domination of firms in the channels of marketing and distribution. As market power has the ability to extend new product ranges, a monopolist should find innovation more attractive (Nelson, 1959). Second, as innovative activities are more susceptible to moral hazard problems, Arrow (1962) has argued that firms will more ideally finance their innovation internally; therefore, firms with higher market power are in an advantageous position, as they are generally associated with supernormal profits. Third, firms with high market power often have more resources, which enable them to hire the most knowledgeable and innovative staff (Acemoglu, 1997).

More recently, researchers have found empirical evidence contrary to the Schumpeterian hypothesis; for instance, Geroski (1990), Blundell *et al.* (1992), Vossen (1999), Gayle (2001), and Weiss and Wittkopp (2005), among others. These recent studies claim that technological opportunity, which varies across industries, should not be neglected as a determinant of innovative activity and must be controlled for when examining the relationship between innovation and market structure. Several arguments have been offered for why a competitive market has advantages for innovation. As suggested by Gayle (2001), firms with more monopoly power may consider additional leisure to be superior to additional profits, due to the lack of active competition in the industry.

A firm that has market power from existing processes or products could be slower in replacing them with a superior ones than newcomers. Firms with monopoly profits calculate the profits from innovation as the difference between the profit that could be generated from new products and their current profits, while newcomers consider new product profits as the total gain (Kamien and Schwartz, 1982). As a result, the larger the current monopoly profits, the less incentive there is for monopolists to replace their processes or products.

Theoretical models on the incentives to innovate provide predictions about the impact of market concentration on innovative effort. Since there are arguments both for and against a positive relation between market concentration and innovative activity, the net result is an empirical matter. Considering that a pure monopoly is a rare case in the real world (and in our tested market in particular), the empirical research will examine the following hypothesis concerning market concentration and a firm's decision to carry out R&D activity:

H5: *Higher industry competition increases the probability that a firm will take up R&D investment.*

3.3.4 Macro-level factors

3.3.4.1 Tax policies

There are two different views on the relationship between government tax policies and innovation. In the first view, researchers argue that taxes can distort a firm's incentive to innovate or to carry out innovative activities. Higher corporate tax rates reduce after-tax profits, and any stakeholder (for example, firm managers or stockholders) that depends on these profits will be less likely to support any investment of money, time or effort in R&D investment.

The literature on the corporate tax effect on investment has offered several theories that explain how the tax rate could significantly affect innovation at the firm-level. First, as explained by Tirole (2010), a lower tax rate can increase the after-tax profit, which in turn increases the amount that a firm can offer to its stockholders in return for their investment. In this way, any potential innovative projects are more likely to be financed internally if the tax rates are low. Thus in the presence of information asymmetry and the agency problem, the higher after-tax profit as a result of low tax rates will have a significant effect on the probability of actively financing and carrying out R&D activities.

Second, lower tax rates also play a significant role in making alternative projects with higher tax rates less profitable, thus reducing the opportunity cost of innovation. As a result, if we assume two similar firms listed on competitive but scarce capital markets, shareholders would prefer to invest in the firm that has lower corporate tax, and therefore higher after-tax profits. Third, if the remuneration of the firm's managers and employees depend on the after-tax profits through annual bonuses, stock ownership and stock options, highly skilled and talented employees would prefer to join a firm that has low corporate tax rate and high after-tax profits (Atanassov and Liu, 2014).

Fourth, through low corporate tax, firms can save some of their after-tax profits as a precautionary reserve for difficult future times. Since innovation activity is considered to be a highly uncertain process, firms with more precautionary cash reserves will be in a better position in face of any volatility in funding and be able to continue with their innovation processes.

Fifth, adverse selection in the capital markets induces the pecking-order theory of financing new projects, in which a firm would prefer to finance its new projects (especially the more asset-specific ones) by its available internal rather than external funds. However, firms which engage in innovation process are more susceptible to asymmetric information problems. Brown and Petersen (2009) and Brown *et al.* (2012) state that firms are more dependent on internally generated funds to finance the expenditure of future innovation activities. Other factors being constant, internally generated funds will be higher for firms with lower tax rates, giving more incentive to innovate (Hall, 1992; Himmelberg and Petersen, 1994; Bhagat and Welch, 1995; Brown *et al.*, 2012).

On the other hand, considering the corporate tax effect on external sources of funds, debt in particular, researchers argue that, although a lower tax rate may increase the after-tax profit, a higher rate may give firms more incentive to invest more with debt financing instead. As explained in the trade-off theory, debt is considered as a shield for tax paying firms, where any interest on debt is tax deductible (Myers, 1984). However, considering the nature of innovation activities, increasing debt use as a result of a high tax rate would dampen a firm's incentive to invest in R&D. The reasons for this are covered in the literature on transaction-cost economies and agency theory (please refer to sections 3.4.1.1. and 4.3.3.1 for further illustrations).

Although the higher the tax rate, the higher the tax shield that firms can achieve, those that aim to engage in R&D activities will place more emphasis on the elements that might threaten their survival. The increase in the financial obligations through the use of debt, as well as the high asset-specificity of R&D projects, will offer limited protection to debt providers and a high probability of failure for firms. It is concluded that high after-tax profit gives more incentive to innovate, while a higher use of debt as a consequence to high corporate tax rates will discourage firms from becoming engaged in the process (Wang and Thornhill, 2010).

Finally, Atanassov and Liu (2014) argue that when the input market is not perfectly flexible, and if labour, especially the more skilled and the talented human capital, is a scarce resource, then firms will operate with maximum production possibilities, where resources will be allocated to the activities that yield the best approachable return. If corporate tax rates are high, firms will allocate relatively more of their resources to projects through which they can avoid paying taxes. If tax rates are low, some of these resources will be devoted and allocated to more innovative projects. In addition, high tax rates will give firms the incentive to invest their financial resources, such as cash, in government instruments that have lower tax rates, even if the return on these instruments are low. However, if tax rates are low, firms will shift those financial resources to more high return projects; for example, innovation projects.

A separate branch of the related literature has been devoted to investigating the effect and real influence of R&D tax relief and credit on R&D investment (Mukherjee *et al.*, 2017), and there is consensus on their significant positive influence, similar to the influence of corporate tax rate effects (Bloom *et al.*, 2002; Sakakibara *et al.*, 2002; Czarnitzki *et al.*, 2011).

Considering the previous findings with regard to the effect of both corporate tax rates and R&D tax relief, a spectator might consider the two rates as motives for firms to engage in an alternative investment financing strategy, consequently increasing the tax benefit via debt and moderating the corporate tax burden via R&D relief. This strategy might be viewed to be in a firm's benefit if considering R&D tax relief as an alternative means of avoiding a high tax burden and a way of obtaining high after-tax profit., while on the other hand considering a high tax rate as a benefit, through which firms can obtain more debt financing and benefit from the tax shield that can be obtained.

This might be viewed as a novel strategy that firms could follow. However, it leads to more concerns about the increasing factors that might threaten their survival. By following such a strategy, firms are increasing their use of debt, therefore increasing their financial obligations. At the same time, they are increasing their investment in risky projects, which as a consequence might lead to unexpected results and ultimately failure.

The alternative theoretical view on the role of corporate income tax on innovation states that taxes rate will have no impact, or have a positive impact, on innovation. First, if investment and expenditure were all tax deductible, there would be no private benefits of control for firm insiders and no asymmetric information. The after-tax profit would not affect the incentives of the firm's stakeholders, and the tax rate would be of no concern for any promising project, which would be financed whatever the level of tax rates (Atanassov and Liu, 2014). The effect of the tax rate will be present only when determining how the profit is shared out. Second, from a macro level effect, if the tax rate decreases, this will potentially lead to an increase in the budget deficit, and a decrease in the spending of the government on public goods, such as infrastructure, education and basic research. This will result in a slowdown in the growth of society and hinder innovation at the firm level.

To summarise, these two different views lead to opposing predictions. We conclude that the effect of tax policies on a firm's willingness to carry out R&D activity is very complex and cannot be simplified in a single hypothesis. Essentially, it is an empirical question that needs to be investigated. Considering the schemes offered by UK governments as incentives for firms to invest in R&D, especially the small and young ones, the hypotheses on the effect of tax policies on the probability of carrying out R&D activity are as follows:

H6: *Higher corporate tax rates decreases the probability that a firm will take up R&D investment.*

H7: *Higher R&D tax relief rates increase the probability of a firm taking up R&D investment.*

3.4 Operational Measures

Based on the theoretical framework and the derived hypotheses, this section will present the definition of the variables which are considered as potential determinants for a firm to decide whether or not to carry out R&D activity. The dependent variable is a dummy variable (R&D), which is equal to 1 if a firm undertakes research and development activity at time *t*, otherwise zero.

$$\textbf{R\&D} = \begin{cases} \mathbf{1} & \textbf{\textit{if a firm does R\&D activity at time t}} \\ \mathbf{0} & \textbf{\textit{otherwise}} \end{cases}$$

3.4.1 Micro-level factors

3.4.1.1 Financial resources

The relevant literature was presented in 3.3.2 and the hypotheses derived relating to the influence of a firm's capital structure as an incentive for carrying out R&D activity. It is important to measure the ability of a firm to obtain the financing that is needed for carrying out R&D activity. To analyse the size of a firm's equity, and its capacity to obtain internal and equity financing, the following variable will be used:

$$\textbf{Financial autonomy} = \left(\frac{\textbf{Total equity}}{\textbf{Total assets}}\right)$$

Leverage is a measure of debt financing and risk bearing and is calculated as:

$$\textbf{Leverage} = \left(\frac{\textbf{Total debt}}{\textbf{Total equity}}\right)$$

where total debt equals the sum of short-term and long-term debt.

Data were collected from the Thomson One Banker and Worldscope databases. According to hypotheses 1 and 2, we expect a positive sign for the coefficient on financial autonomy and a negative sign for the parameter on the ratio of leverage.

3.4.1.2 Firm size

The hypothesis presented in section 3.3.3 considers the influence of a firm's physical factors on the decision to carry out R&D activity. According to hypothesis 3, firm size should be positively related with the decision to carry out R&D activity and is measured as:

Size= (Total Assets)

Data were collected from the Worldscope via Thomson One Banker database.

3.4.1.3 Firm age

Intangible factors were proposed as determinants of the decision to carry out R&D activity. According to hypothesis 4, the age of a firm is claimed to be positively related with the decision to undertake R&D activity and is measured as:

Age= years since the firm's birth.

Data on firm age were collected from the Worldscope database via Thomson One Banker.

3.4.2 Meso-level factors

3.4.2.1 Market concentration

The role that the industry concentration factor plays as an incentive for a firm to carry out R&D activity is also considered; according to hypothesis 5 we expect a negative sign on the coefficient of industry concentration, reflecting a negative relationship between industry concentration and a firm's decision to take up R&D activity. This variable is measured as:

$$\textbf{Herfindahl-Hirschman index } (\mathbf{HHI_{jt}}) = \left(\sum_{i=1}^{n} S_{ijt}^{2}\right)$$

where, $\mathbf{HHI_{jt}}$ is the index for industry *j* at year *t*, and S_{ijt}^{2} is the sum of the squared market shares of firm *i* in industry *j* at year *t*, over all firms in industry *j*. This variable measures the market concentration based on the market share of each firm competing in an industry. The data for this measure were also collected from the Worldscope database via Thomson One Banker.

3.4.3 Macro-level factors

3.4.3.1 Tax polices

These variables analyse the possible effect that government tax policies have on the probability of a firm carrying out R&D activity. According to hypothesis 6, the corporate tax rate is expected to be negatively related with the decision to carry out R&D activity, and this factor is measured as:

$$\text{TaxChg} = \begin{cases} 1 & \text{if there has been an increase/decrease in the corporate tax rate,} \\ 0 & \text{otherwise} \end{cases}$$

Furthermore, and regarding the effect of R&D tax relief on a firm's R&D activity, hypothesis 7 states that R&D tax relief rate is expected to have a positive effect on a firm's decision to carry out R&D activity, and is measured as:

ReliefChg =

$$\begin{cases} \mathbf{1} \; \boldsymbol{if\ there\ has\ been\ an\ increase/decrease\ in\ the\ RD\ tax\ relief\ rate,} \\ \mathbf{0} \qquad \boldsymbol{otherwise} \end{cases}$$

Data on corporate tax rates and R&D tax relief rates were collected from the HM Revenue and Customs official website. However, 20 dummy variables will be included in the model to capture and control for inter-industry differences. A summary of the factors that affect firms' decision to undertake R&D activity, their operational measures and the expected effects are shown in Figure 3-2.

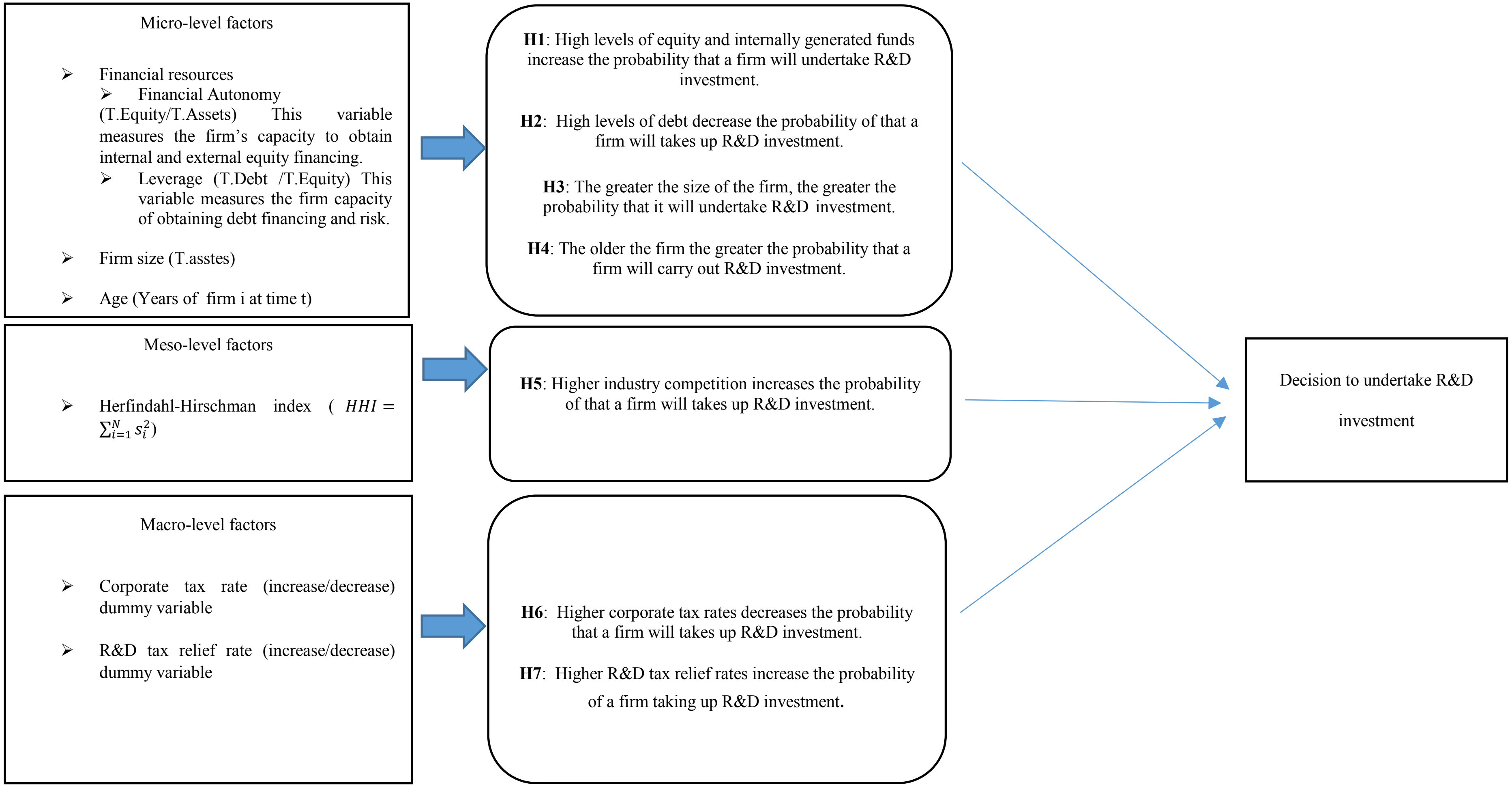

Figure 3-2 : Summary of the factors that affect firms' decision to undertake R&D activity, their operational measures and the expected effects (Del Canto and Gonzalez, 1999; Huergo and Jaumandreu, 2004; Kamien and Schwartz, 1982; Campello and Hackbarth, 2008; Czarnitzki and Kraft, 2009; Czarnitzki et al., 2011; Atanassov and Liu, 2014).

3.5 Data and preliminary analysis

3.5.1 Data and measurement

As the focus of this research is to examine the determinants and incentives that influence a firm's decision to make R&D investment, the variables have been constructed from firms listed on AIM. Our unbalanced dataset[21] covers all the publicly listed firms on AIM over the period from 1999 to 2014, which are contained on the Worldscope database and the London stock exchange official website. To be consistent with the previous literature[22], we only focus on the firms that are listed on the two-digit SIC industries 20-39 (manufacturing) and 73 (services), since R&D activities mainly take place in these high-tech industries.

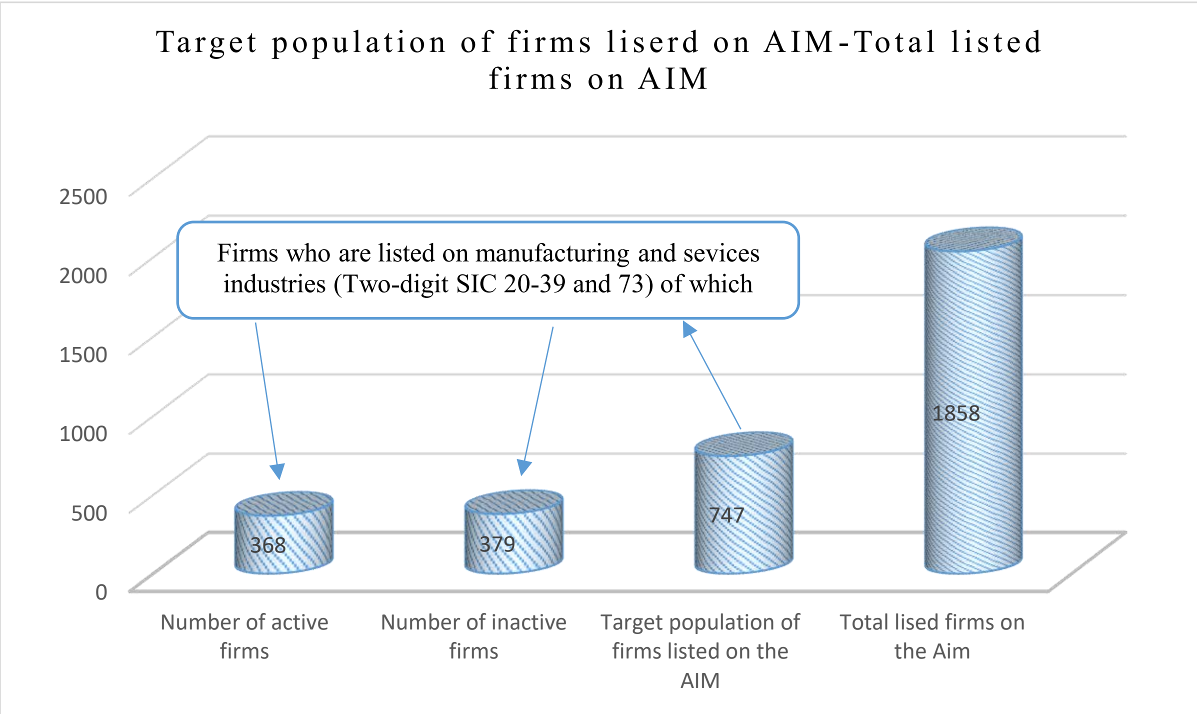

Figure 3-3: Summary of the research sample population of the firms listed on AIM between 1999 and 2014.

[21] Our research data have been collected from Worldscope, the DataStream via Thomson one banker analytics database and the HM Revenue and Customs official website.

[22] See, for example, Hall (1992), Himmelberg and Petersen (1994), Del Canto and Gonzalez (1999), Brown and Petersen (2011) and Brown *et al*. (2012).

The number of listed firms on AIM over the estimation period of 1999 to 2014 was 1858 active and inactive[23] firms. In December 2014, the total number of firms in the manufacturing (two-digit SIC 20-39) and the services (two-digit SIC 73) that was listed on AIM was 746, of which 379 firms have exited the market, delisted, over the sample period. Given the birth and death of firms, the econometrics analysis will use an unbalanced data set. This unbalanced panel avoids survivorship bias[24]. Referring to the investigation of Pour and Lasfer (2013), there is a significant number of AIM-firm delistings which are recorded as voluntary, although further investigation into the breakdown of reasons for delisting is required to achieve the intended to be mitigated survival bias. Figure 3-3 gives a summary of the dataset.

However, it is worth noting that the number of inactive firms in our dataset is slightly higher than the number of active firms; the number of delisted firms of these two industries was relatively high as a percentage of the newcomers during the tested period, as shown in Figure 3-4.

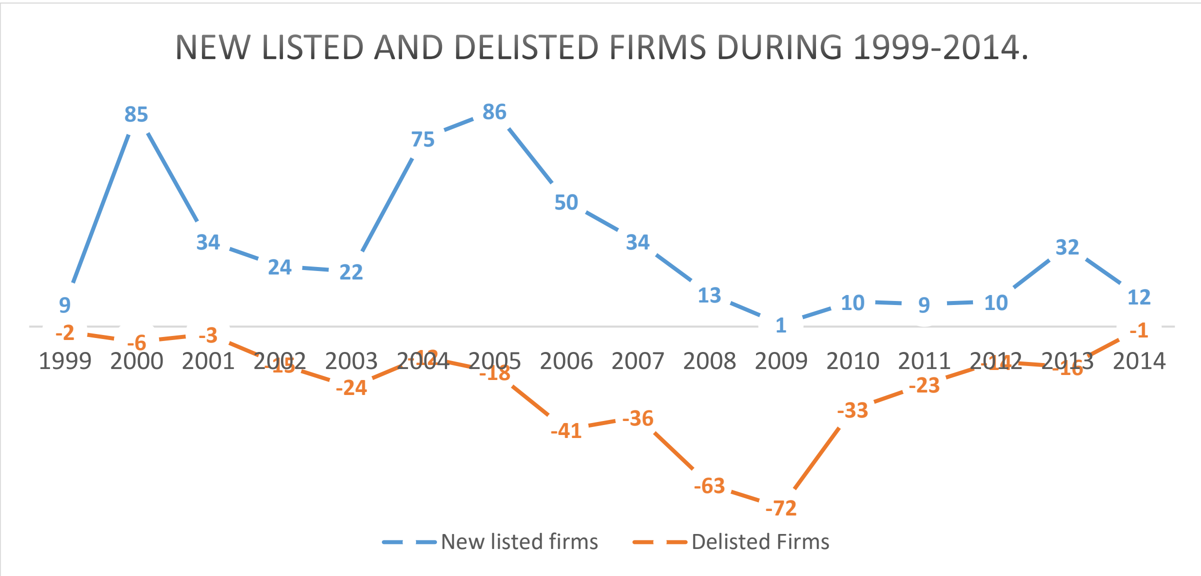

Figure 3-4: Summary of the new listed and delisted firms of our research sample between 1999 and 2014

[23] These inactive firms are dead firms, not firms involved in merger or acquisition.
[24] Elton *et al.* (1996) define survivorship bias as the tendency to exclude failed (inactive) firms from the sample study because they no longer exist. This bias often makes the obtained results skewed higher as a result of only including active or surviving firms.

The majority of firms delisting did so in the global financial crisis and its aftermath; during our sample period we observed 508 new firms in the industries with two-digit SIC 20-39 and 73. A significant number of these newcomers had been listed during the fiscal years 2000, 2004 and 2005. On the other hand, the observed number of total delisted firms of these sectors during our research period was 379, with a significant number of firms delisting during fiscal years 2008 and 2009.

Before moving to preliminary analysis of the incentives and factors that influence a firm's decision to carry out R&D activity, it is important to mention that the final number of firms used in the research was 630, with firms with fewer than two observations excluded from the analysis. Table 3-2 give a brief description of the main variables and the data source of each of these variables.

Table 3-2: Description of the main variables used in this paper

Variable Name	Description [a]	Source [b]
R&D $_{ijt}$	Dummy variable equal to ***1*** if firm ***i*** in industry ***j*** does research and development at time ***t*** , otherwise zero.	Worldscope
Financial Autonomy $_{ijt}$ ***(Fauto)***	The total equity of firm ***i*** in industry ***j*** at time ***t*** divided by the total assets of firm ***i*** at time ***t***.	Worldscope
Leverage $_{ijt}$ ***(Levage)***	The total debt of firm ***i*** in industry ***j*** at time ***t*** divided by the total equity of firm ***i*** at time ***t*** where total debt equals the sum of short-term and long-term debt.	Thomson One Banker
Firm Size $_{ijt}$ ***(Size)***	The logarithm of the total assets of firm ***i*** in industry ***j*** at time ***t***.	Worldscope
Age $_{ijt}$ ***(Age)***	Age of firm ***i*** in industry ***j*** in years ***t***. i.e. the period between a firms's start date on Worldscope and the date of observation.	Worldscope
Herfindahl-Hirschman index $_{jt}$ ***(HHI)***	Herfindahl-Hirschman index for industry ***j*** at time ***t,*** calculated as the sum of the squared market shares of all firms in a given two-digit SIC industry (***j***) based on sales.	Worldscope
Corporate tax rate $_t$ ***(TaxChg)***	Dummy variable equal to 1 if there has been an increase/decrease in the corporate tax rate by at least 1% at time ***t*** , otherwise zero.	HM Revenue & Customs
Tax relief change $_t$ ***(RelfChg)***	Dummy variable equal to 1 if there has been an increase/decrease in the R&D tax relief rate by at least 1% at time ***t***, and zero otherwise.	HM Revenue & Customs

Notes:
[a.] The measurement of variables and definition are based on the existing literature.
[b.] The data are collected from several data bases.

3.5.2 Summary statistics

Table 3-3: Distribution of the firm-year observations based on whether R&D activities are carried out or not, across different industries.

Division	***Industry***	***Number of Firm-year Observations***			***Percentage Distribution (%)***		
		Innovative Activity (R&D)	No Innovative Activity (R&D)	Total	Innovative Activity (R&D)	No Innovative Activity (R&D)	Total
20	FOOD AND KINDRED PRODUCTS	32	128	160	20	80	100
22	TEXTILE MILL PRODUCTS	4	32	36	11	89	100
23	APPAREL AND OTHER TEXTILE PRODUCTS	0	81	81	0	100	100
24	LUMBER AND WOOD PRODUCTS	1	12	13	8	92	100
25	FURNITURE AND FIXTURES	13	62	75	17	83	100
26	PAPER AND ALLIED PRODUCTS	46	60	106	43	57	100
27	PRINTING AND PUBLISHING	6	96	102	6	94	100
28	CHEMICALS AND ALLIED PRODUCTS	360	155	515	70	30	100
29	PETROLEUM AND COAL PRODUCTS	9	24	33	27	73	100
30	RUBBER AND MISC. PLASTICS PRODUCTS	16	25	41	39	61	100
31	LEATHER AND LEATHER PRODUCTS	16	9	25	64	36	100
32	STONE, CLAY, AND GLASS PRODUCTS	48	67	115	42	58	100
33	PRIMARY METAL INDUSTRIES	12	4	16	75	25	100
34	FABRICATED METAL PRODUCTS	49	101	150	33	67	100
35	INDUSTRIAL MACHINERY AND EQUIPMENT	223	103	326	68	32	100
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	383	171	554	68	32	100
37	TRANSPORTATION EQUIPMENT	17	34	51	33	67	100
38	INSTRUMENTS AND RELATED PRODUCTS	301	148	449	67	33	100
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	24	48	72	33	67	100
73	BUSINESS SERVICES	893	1408	2301	39	61	100
	Total	***2453***	***2768***	***5221***	***47***	***53***	***100***

The distribution of the firm-year observations based on who is carrying out R&D activities, broken down for different manufacturing and services industries, is summarized in Table 3-3. A significant number of the firm-year observations come from five industries, namely chemicals and allied products (515 firm-year observations), industrial machinery and equipment (326 firm-year observations), electronic & other electric equipment (554 firm-year observations), instruments and related products (449 firm-year observations), and business services (2301 firm-year observations). These industries account for 79 per cent of the total firm-year observations in our data set.

Table 3-4: Summary statistics of the main variables employed in this empirical chapter.

Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness
Fauto [a]	0.39	0.56	-17.32	0.99	1.02	-9.06
Levage [a]	31.01	7.50	-1027.70	1747.17	146.55	3.61
Size	2.63	2.70	-6.62	9.38	1.54	-0.19
Age	7.03	6.06	1.00	19.73	4.36	0.79
HHI	0.17	0.09	0.03	1.00	0.19	2.18
TaxChg	-0.32	0.00	-1.00	0.00	0.47	-0.74
ReliefChg	0.22	0.00	0.00	1.00	0.42	1.34
R&D	0.47	0.00	0.00	1.00	0.50	0.12
# of obs 5221						

Note:

[a] The Fauto and Levrage variables are winsorized at the 1% level.

However, as noted by Yuan and Bentler (2001), the presence of outliers in the datasets can lead to biased estimates of parameters and test statistics. Considering their presence in our dataset, we considered screening the financial factors of our variables to reduce the potential influence of the outliers on the estimated parameters. We winsorized the financial factors in our analysis, namely Financial autonomy (***Fauto***) and Leverage (***Levage***), at the 1 per cent level of their respective distribution. The mechanism of Winsor transformation works by setting all observations above the 99th percentile equal to the 99th percentile, and the sets of observations below the 1st percentile equal to the 1st percentile. This transformation is significantly important in reducing the impact of outliers, and allows full use of the set of observations.

Table 3-4 summarizes the descriptive statistics of the main variables, showing that the mean of ***Levage*** is slightly higher than the median, indicating that it is skewed to the right. Similarly, the means of ***Age*** and the ***HHI*** are all higher than their medians, indicating that they are also skewed to the right. While on the other hand, the means of financial autonomy (***Fauto***) and the ***Size*** are all lower than their medians, indicating that they are skewed to the left.

Table 3-5 presents the pair-wise correlation matrix among the potential determinants. Apart from R&D tax relief, the explained variable (***R&D***) is significantly correlated with all of the explanatory variables, a finding consistent with theoretical expectations. The correlation coefficient matrix of the independent variables suggests little collinearity, the highest correlations being those between (***TaxChg***) and (***ReliefChg***) with a value of -0.5696, and between (***Age)*** and (***TaxChg***), with a value of -0.3865. However, the pair-wise Pearson correlation coefficient matrix presents no evidence of the multi-collinearity problem between variables.

Table 3-5: Correlation coefficient matrix of the main variables employed in the analysis of the chapter.

Variable	Fauto	Levage	Size	Age	HHI	TaxChg	ReliefChg	R&D
Fauto	1.000							
Levage	0.0278**	1.000						
Size	0.3031***	0.1152***	1.000					
Age	-0.0006[a]	-0.0427***	0.1468***	1.000				
HHI	0.0629***[b]	0.0818***	0.1727***	0.0415***	1.000			
TaxChg	-0.0465***	0.0423***	-0.0973***	-0.3865***	0.0969***	1.000		
ReliefChg	0.0246**[c]	-0.0085	-0.0100	0.0657***	-0.0452***	-0.5696***	1.000	
R&D	0.0819***	-0.0693***	0.0330**	0.0235*	-0.0707***	-0.0253*[d]	0.0074	1.000

Notes:
[a] The reported figures are the pair-wise Pearson correlation coefficient between variables.
[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.

3.6 The dynamic logistic model of R&D investment

3.6.1 Methodology

A firm's decision to make R&D investment is determined by different factors. Most of the previous studies that have empirically investigated the determinants of a firm's decision to do this have focused on firm-specific or market structure factors, neglecting fiscal policy factors and their role in firms' decision-making. Furthermore, most of the applied literature has used static estimation techniques and neglected the dynamic process of undertaking such decisions. To overcome the drawbacks of these techniques, we attempt to fill these gaps by considering the potential influence of all of these factors together, and by considering the dynamic process associated with a firm's decision to make R&D investment.

Recent research by Power (1998), Nilsen *et al*. (2008), Hecker and Ganter (2014) and Grazzi *et al.* (2016) presents evidence of the spiky nature of firms' investment decisions, especially for lumpy investments, for example R&D. This spiky nature leads to lumpy investment behaviour by firms, producing investment spikes, with no or little investment activities in between (Nilsen *et al*., 2008). Since R&D tends to be lumpy investment, representing a cash flow problem for firms engaged in it, and is associated with high adjustment costs in the case of disruption or cuts in the process. Hecker and Ganter (2014) have introduced the idea of true persistence of the state dependence, as a result of the causal effect of the latest investment decision on the current decision, independent of the continuous influence of unobserved factors.

Hecker and Ganter argue that the persistence phenomenon in R&D or the innovation process can be explained by three important factors. First, the sunk cost factor explains persistence by arguing that when R&D investment creates long-term capital goods for the use of innovation activities, the costs of equipping and building R&D facilities, and hiring or training highly skilled workers, among other costs, are unrecoverable if R&D activities cease. As a result, these costs imply a barrier to exit from or entry to innovation activities, explaining the persistence in firms' behaviour of being innovative or non-innovative.

The second factor is the competence-based factor, which represents the mechanism of creative accumulation and capability building. When innovation is a process of reusing and recombining existing knowledge, the mechanism of this process works by building on accumulated knowledge, simultaneously setting up the foundation for future process opportunities. As a result, accumulating experience and knowledge over time gives motivation to firms to sustain their innovation processes, producing persistence in the innovation phenomenon (Hecker and Ganter, 2014).

Finally, Hecker and Ganter (2014) explain the persistence of the process by referring to the resource constraints factor. They argue that when R&D activities are risky, resource consuming, and hard to be assessed by external financing providers, they are more prone to serious financing constraints (Chen *et al*., 2010; Brown *et al*., 2012). Therefore, if successful innovations are recorded, their revenues will alleviate these constraints by providing internal funding for future process. Additionally, these success stories may be interpreted by external finance providers as a sign of firms' capacity for future success, encouraging resource providers to finance innovative activities. In conclusion, successful innovation facilitates access to resources, thus generating more future innovation success. Motivated by the above factors, therefore, this research considers the path-dependent process of R&D in the dynamics of undertaking investment decisions.

The inclusion of the lagged dependent variable in the estimated model causes the estimates to be biased, as a result of the correlation of both the past value of investment decisions and unobserved heterogeneity. The problem of biased estimates is the so called initial value problem. This problem occurs because the history of the stochastic process under investigation is not observed from the very beginning. The lagged dependant variable of the initial period is assumed to be exogenous; however, since it is correlated with the unobserved heterogeneity, the exogeneity assumption of the random effect model is accordingly violated.

There are three solutions that deal directly with the initial condition problem, proposed by Heckman (1979), Orme (1996) and Wooldridge (2005). The studies by Arulampalam and Stewart (2009) and Skrondal and Rabe-Hesketh (2014) investigate the performance of these estimation strategies and provide evidence that the differences between the three methods are minor. However, a simulation study by Akay (2009) shows that the simple and novel strategy by Wooldridge is found to perform well, and provides better performance for panels with a moderately longer duration than the Heckman estimator. Taking these findings into account, and considering that they can be implemented using standard software, the Wooldridge method is employed in this research.

The general model of the probability of carrying out R&D is formed as follows:

$$R\&D^{*}_{ijt} = \beta_1 R\&D_{ijt-1} + X_{ijt}\beta + \alpha_{ij} + \varepsilon_{ijt} \qquad (1)$$

where $\boldsymbol{i}$ indicates the $\boldsymbol{i}^{\text{th}}$ firm, $\boldsymbol{j}$ indicates the industry and $\boldsymbol{t}$ indicates the time periods with $(\boldsymbol{i} = \mathbf{1}, .., \boldsymbol{N}; \boldsymbol{t} = \mathbf{2}, ..\boldsymbol{T})$. $R\&D_{ijt-1}$ is the lagged dependent variable, X_{ijt} is the vector of independent variables, α_{ij} the unobserved individual random effect distributed as N $(0,\sigma^2_u)$, and ε_{ijt} is the error term distributed as N (0,1).

The simplified Wooldridge method works by using the following density function of the unobserved heterogeneity (unobserved individual-effects) conditional on the initial state (initial value) and the time-varying explanatory variables:

$$\alpha_{ij} = \gamma_0 + \gamma_1 R\&D_{ij1} + \bar{X}_{ij}\gamma + \epsilon_{ij} \qquad (2)$$

where ϵ_{ij} is a new unobserved heterogeneity, which is assumed to be normally distributed with a mean of zero and a variance of σ_ϵ^2, that is, $\epsilon_{ij} \sim iidN[0, \sigma_\epsilon^2]$; the density is assumed to be $\alpha_{ij} | X_{ij}, R\&D_{ij1} \sim [\gamma_0 + \gamma_1 R\&D_{ij1} + \bar{X}_{ij}\gamma, \sigma_\epsilon^2]$. Wooldridge's idea here is that the correlation between the initial value $R\&D_{ij1}$ and the unobserved heterogeneity α_{ij} is handled by the use of equation (2), producing another unobservable individual-specific heterogeneity, that is ϵ_{ij}, which is uncorrelated with the initial observation, $R\&D_{ij1}$. In this formulation, Wooldridge specifies all the time-varying variables of the whole time periods to be in vector $\bar{X}_{ij}$. In the application of our data set, individual-specific averages have been used to allow for the use of unbalanced panel data with some missing observations[25], although only for periods of 2 to T.

Hence, by substituting equation (2) into (1), the probability that firm ***i*** in industry ***j*** at time ***t*** will undertake R&D activity, conditional on the observed and unobserved characteristics and the previous firm status in ***t-1***, can be presented as:

$$
\begin{aligned}
&P(R\&D_{ijt} | X_{ijt},\ R\&D_{ijt-1}, \alpha_{ij}) \\
&\qquad = \Omega(\alpha_1 + \beta_1 R\&D_{ijt-1} + X_{ijt}\beta + \beta_3 R\&D_{ij1} + \bar{X}_{ij}\gamma + \epsilon_{ij} + \varepsilon_{ijt}) \\
&\qquad = \frac{exp(\beta_1 R\&D_{ijt-1} + X_{ijt}\beta + \beta_3 R\&D_{ij1} + \bar{X}_{ij}\gamma + \epsilon_{ij})}{1 + exp(\beta_1 R\&D_{ijt-1} + X_{ijt}\beta + \beta_3 R\&D_{ij1} + \bar{X}_{ij}\gamma + \epsilon_{ij})}
\end{aligned}
\tag{3}
$$

where $P\ (R\&D_{ijt})$ is the dependent variable, that is, the probability of carrying out R&D activity, Ω is the logistic cumulative distribution function, α_1 is a constant, β is a vector of the estimated coefficients of explanatory variables, X is a vector of independent variables, γ is a

[25] See, for example, Arulampalam and Stewart (2007), Akay (2009) and Skrondal and Rabe-Hesketh (2014).

vector of the estimated coefficients of individual-specific average explanatory variables, $\bar{X}$ is a vector of individual-specific average independent variables, and (exp) is the base of the natural logarithms (that is, approximately 2.718). The regression coefficients estimate the influence of the independent variables on the probability of carrying out R&D activities, where a positive value of these coefficients means that a variable increases the probability of carrying out R&D activities, while negative ones imply the opposite.

This binomial dynamic random effect logistic model has been used in this study because the probability of a firm carrying out R&D activity can be converted into two outcomes, 0 or 1, according to the definition of our dependent variable. The suitability of this mechanism is acquired from the binary nature of the dependent variable (i.e. qualitative and dichotomous), and the nature of our explanatory variables (a combination of continuous variables and categorical variables). Therefore, the final form of our suggested model on the probability of carrying out R&D investment is as follows:

$$\boldsymbol{R\&D_{ijt} = \beta_0 + \beta_1 R\&D_{ijt-1} + \beta_2 Fauto_{ijt} + \beta_3 Levage_{ijt} + \beta_4 Size_{ijt} + \beta_5 Age_{ijt} + \beta_6 Agesize_{ijt} + \beta_7 HHI_{jt} + \beta_8 TaxChg_t + \beta_9 ReliefChg_t + \beta_{10} R\&D_{ij1} + \beta_{11}\overline{Fauto_{ij}} + \beta_{12}\overline{Levage_{ij}} + \beta_{13}\overline{Size_{ij}} + \beta_{14}\overline{Age_{ij}} + \beta_{15}\, DI + \varepsilon_{ijt}}$$

(4)

Where

$$\boldsymbol{R\&D_{ijt} = \begin{cases} 1 & if\ firm\ i\ in\ industry\ j\ innovates\ at\ time\ t \\ 0 & otherwise \end{cases}}$$

Table 3-6 summarizes the expected effect of each of the explanatory variables on a firm's probability of undertaking R&D investment, as mentioned in the literature.

Table 3-6: Expected signs of the explanatory variables on the probability of undertaking R&D investment

Dependant Variable	***Research and Development Investment (R&D)***	
Explanatory Variables	***Expected Sign***	***References***
Financial Autonomy ***(Fauto)***	Positive *(+)*	Hall (1992), Himmelberg and Petersen (1994), Bhagat and Welch (1995), Carpenter and Petersen (2002), Martinsson (2010), Brown *et al.* (2012)
Leverage ***(Levage)***	Negative *(-)*	Scellato (2006), Casson *et al.* (2008), Czarnitzki and Kraft (2009), Brown and Petersen (2009), Wang and Thornhill (2010)
Size ***(Size)***	Positive *(+)*	Kamien and Schwartz (1982), Acs and Isberg (1991), Shefer and Frenkel (2005), Vaona and Pianta (2008), Herrera and Sánchez-González (2013), Babutsidze (2016)
Age ***(Age)***	Positive *(+)*	Sørensen and Stuart (2000), Huergo and Jaumandreu (2004), Balasubramanian and Lee (2008)
Herfindahl-Hirschman Index ***(HHI)***	Negative *(-)*	Kamien and Schwartz (1982), Geroski (1990), Blundell *et al.* (1992), Symeonidis (1996), Vossen (1999), Gayle (2001), Weiss and Wittkopp (2005)
Corporate Tax Change ***(TaxChg)***	Positive *(+)*	Bloom *et al.* (2002), Sakakibara *et al.* (2002), Czarnitzki *et al.* (2011), Atanassov and Liu (2014), Mukherjee *et al.* (2017)
R&D Tax Relief Change ***(ReliefChg)***	Positive *(+)*	Bloom *et al.* (2002), Sakakibara *et al.* (2002), Czarnitzki *et al.* (2011), Atanassov and Liu (2014), Mukherjee *et al.* (2017)

However, in order to interpret the estimated coefficients, the average marginal effect of each of them is also estimated. The average marginal effect is expressed as follows:

$$\frac{d_y}{d_x} = \beta_i \Omega' \left(\alpha_1 + \beta_1 R\&D_{ijt-1} + X_{ijt}\beta + \beta_3 R\&D_{ij1} + \bar{X}_{ij}\gamma + \epsilon_{ij} + \varepsilon_{ijt} \right)$$

Using the dynamic logistic model is considered to be the optimal analysis technique for investigating the probability of a firm carrying out R&D activities. As pointed by Skrondal and Rabe-Hesketh (2014) the results of this technique are consider easier for interpretation, as they reflect the probability of carrying out R&D activities. Furthermore, the effect of all the independent factors can be captured simultaneously, and the statistical tests are immediately available. Finally, this model is considered flexible enough to deal with different forms of relationships between the responding and explanatory variables, including the dummy variables (Skrondal and Rabe-Hesketh, 2014; White, 2013).

3.6.2 Results

In this sub-section we will discuss the maximum likelihood regression results. The results of the binomial dynamic logistic model are presented in table 3-7.

The second column shows the estimated coefficients of each of the independent variables, the third column presents their standard errors, and the statistical significance is presented in the fourth column, “p-value”. A significantly positive coefficient of an explanatory variable indicates that it tends to increase (influence) the probability that a firm will carry out R&D activities, while it reflects the opposite in the case of the independent variable “HHI”. However, in order to better interpret the parameters of our model, it is important to reflect on the marginal effect, as shown in the last column. The estimates of the logistic model are better interpreted in term of the margins, as they reflect the marginal effect on the probability of R&D activities occurring.

The regression estimates of the dynamic R&D logistic model, as reported in table 3-7, show that lagged R&D expenditure has a significantly positive effect on the current probability that that a firm will undertake R&D, reflecting persistence in R&D investment decisions. However, all the other variables have the expected signs predicted in the research hypotheses, apart from financial autonomy, firm age and corporate tax rate. Nevertheless, the financial factors that relate to financial resources, namely *Fauto* and *Levage*, have insignificant coefficients, suggesting that a firm’s financial resources have no effect on its probability of carrying out R&D activities. Consequently, hypotheses 1 and 2 are not accepted.

Table 3-7: Dynamic logistic model estimates of the probability of a firm carrying out R&D activities (applying the Wooldridge approach).

Dependent Variable $R\&D_{i,j,t}$	**Coef.**	**S.E.**	***p*-value**	**Marginals**
$R\&D_{i,j,t-1}$	4.1143***[b]	(0.1854)[a]	0.000	0.3093
$Fauto_{i,j,t}$	-0.1200	(0.0970)	0.216	-0.0090
$Levage_{i,j,t}$	-0.0002	(0.0005)	0.605	-0.0000
$Size_{i,j,t}$	0.4050***[b]	(0.1450)	0.005	0.0304
$Age_{i,j,t}$	-0.1448***	(0.0476)	0.002	-0.0108
$Agesize_{i,j,t}$	0.0233*[d]	(0.0135)	0.085	0.0017
$HHI_{j,t}$	-1.4614*	(0.7491)	0.051	-0.1098
$TaxChg_t$	-0.5272**[c]	(0.2427)	0.030	-0.0396
$ReliefChg_t$	0.1710	(0.2030)	0.400	0.0128
$R\&D_{i,j,1}$	2.0372***	(0.3278)	0.000	0.1531
$\overline{Fauto_{i,j}}$[e]	0.6071***	(0.1832)	0.001	0.0456
$\overline{Levage_{i,j}}$	-0.0022	(0.0015)	0.140	-0.0001
$\overline{Size_{i,j}}$	-0.5424***	(0.1341)	0.000	-0.0407
$\overline{Age_{i,j}}$	0.1067**	(0.0482)	0.027	0.0080
Industry Dummies	YES			
Constant	-2.8009	(0.4125)	0.000	
Number of Firms	630			
Number of obs	4437			
ChiSq	40.94		0.000	

Notes:
[a] The reported figures in parentheses are the standard errors.
[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.
[e] The bar sign reflects the individual-specific average of independent variable.

The negative sign of *Fauto* is contrary to what was expected in the first hypothesis. This result can be partly explained by the fact that the newest firms have had less time to generate internal earnings that can be converted into internal funds, so they are more likely to have a smaller volume of equity. These findings are consistent with previous research; for example, Del Canto and Gonzalez (1999) found that there was no association between the financial resources and the R&D expenditure of firms, as this insignificancy can be partially explained by the relationship between the financial resources and the age of the firm.

The coefficient of the firm size has, as expected, a positive sign, with statistical significance below 1%. The significance of the coefficient of the size of the firm indicates that this factor discriminates against firms that carry out R&D activities. In this way, a firm's probability of carrying out R&D activities increases when its size increases, so hypothesis 3 is accepted. This result supports the suitability of the Schumpeter hypothesis in proving that large firms are comparatively more innovative than small ones.

The results obtained support hypothesis 4, in relation to firm experience, measured by age. The results of the role of experience suggest a negative relationship between a firm's age and the probability of carrying out R&D activities; that is, young firms tend to have a higher probability of innovation, while the oldest firms tend to present a lower probability of such activity. However, the interaction signs of age and size show that a higher firm age is positively associated with the carrying out of R&D activities (only if mature firms are considered to be among the large sized firms), with a level of significance of $\rho < 0.07$.

The coefficient of the Meso-level factor in relation to the market concentration, measured by the Herfindahl–Hirschman Index, is negatively associated with a firm's decision to carry out R&D activities, with a level of significance of $\rho < 0.05$. These findings do support the claim that competitive markets are better at stimulating innovative activity, in contrast to the Schumpeterian hypothesis. With this result, hypothesis 5 is accepted

Furthermore, Macro-level factors in terms of the corporate tax rate is opposite to what was predicted, being positively and significantly associated with the carrying out of R&D activities (given that the rates were just decreasing, negative coefficient sign reflect the positive effect of the corporate tax rate). In this way, a firm's probability of carrying out R&D activities increases when the corporate tax rate increases; consequently, hypothesis 6 is not accepted. This result can be explained in part from a macro-level effect, where low tax rates impose in most of the cases a decrease in the budget surplus, or at worst an increase in the budget deficit, which results in a decrease in government spending on public goods, infrastructure and basic research. This hinders firms' incentive to innovate.

An alternative explanation of the corporate tax rate effect is seen in the behaviour of firms to allocate more of their resources to projects through which they can avoid paying taxes, which is often the case in innovative projects (i.e. since the R&D expenditure is tax deductible, a higher corporate tax rate represents a degree of risk sharing with the government).

On the other hand, the variable relating to R&D tax relief did not enter the equation with a significant coefficient, suggesting that government tax relief on R&D has no effect on the probability of undertaking R&D activities. This result can be explained in part by the fact that firms focus more on the factors that threaten their survival, and avoid investing in risky investments, regardless of the level of incentives offered to firms undertaking R&D. Finally, the results also show that the initial investment decision is very important. The estimate reveals that there is a significant correlation between the initial conditions and the unobserved heterogeneity. The coefficient of the initial R&D investment is almost half the size of the lagged R&D investment decision.

The coefficients of the industry dummies are not all significant. A significant industry effect can be found in Chemicals and Allied products, Leather and Leather products, Machinery and Equipment, Electronic and other Electric equipment, and Instruments and related products Miscellaneous industries, which is consistent with the view that these industries are more likely to be engaged in highly technological activities (Balasubramanian and Lee, 2008).

In this section, we consider re-estimating our dynamic logistic model by adjusting and applying the raw corporate tax and the R&D tax relief rates, rather than the dummy variables used, as previously explained in the definition of the variables in table 3-2. As reported in table 3-8 below, we continue to find that the micro-level factors that are related to financial resources (namely **Fauto and Levage**) have not entered into our equation with significant coefficients, implying that a firm's financial resources have no effect on the probability of it carrying out R&D activities. Moreover, we continue to find that R&D tax relief has no significant association with the probability of firms carrying out R&D activities.

Table 3-8: Dynamic logistic model estimates of the probability of a firm carrying out R&D activities with the level data of the tax rates (applying the Wooldridge approach).

Dependent Variable $R\&D_{i,j,t}$	**Coef.**	**S.E.**	***p*-value**	**Margins**
$R\&D_{i,j,t-1}$	4.1020***[b]	(0.1856)[a]	0.000	0.3087
$Fauto_{i,j,t}$	-0.1231	(0.0967)	0.203	-0.0092
$Levage_{i,j,t}$	-0.0002	(0.0005)	0.624	-0.0000
$Size_{i,j,t}$	0.4011***[b]	(0.1445)	0.006	0.0301
$Age_{i,j,t}$	-0.1669***	(0.0512)	0.001	-0.0125
$Agesize_{i,j,t}$	0.0258*[d]	(0.0137)	0.059	0.0019
$HHI_{j,t}$	-1.4192*	(0.7455)	0.057	-0.1068
$TaxRate_t$	8.9468*	(4.8745)	0.066	0.6734
$ReliefRate_t$	0.4756	(0.4086)	0.244	0.0358
$R\&D_{i,j,1}$	2.0179***	(0.3264)	0.000	0.1518
$\overline{Fauto_{i,j}}$[e]	0.5851***	(0.1828)	0.001	0.0440
$\overline{Levage_{i,j}}$	-0.0022	(0.0015)	0.147	-0.0001
$\overline{Size_{i,j}}$	-0.5187***	(0.1345)	0.000	-0.0390
$\overline{Age_{i,j}}$	0.1232**[c]	(0.0498)	0.013	0.0092
Industry Dummies	YES			
Constant	-6.2483	(1.9510)	0.001	
Number of Firms	630			
Number of obs	4437			
ChiSq	40.18		0.000	

Notes:
[a] The reported figures in parentheses are the standard errors.
[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.
[e] The bar sign reflects the individual-specific average of independent variable.

3.6.3 Robustness test and results

To check the robustness of the findings from the dynamic logistic model, we consider running an alternative model specification to investigate the probability of a firm's carrying out R&D activities of the listed firms on the AIM market. This section presents the re-estimation of the dynamic logistic model by including the initial values of time-varying covariates. The inclusion of the initial values of the micro-level time-varying covariates, a modification by Skrondal and Rabe-Hesketh (2014) based on the Wooldridge approach to allow for additional effects on unobserved-heterogeneity, and to avoid any potential finite sample bias of the Wooldridge solution. The advantage of this technique is that the dependence of the distribution on the covariates is taken into account, and a complete dataset is not required when there are missing data. This recommendation allows the coefficients of the initial values of the time-varying covariates to be different from the coefficients of the mean time-varying covariates.

The results in Table 3-9 show that the micro-level factors that are related to financial resources (namely *Fauto* and *Levage*) are not statistically significant, indicating that a firm's financial resources have no effect on the probability of it carrying out R&D activities. Moreover, the estimates continued to present a significant positive association between firm size and the probability of R&D activity. The results further support the initial findings that competitive markets are better at stimulating innovative activity, and that young firms tend to have a higher probability of innovation compared to the more mature firms. In addition, it was found that the probability of a firm carrying out R&D activities increases when the corporate tax rate increases, and that government tax relief on R&D has no effect on the probability of investing in R&D, both findings being totally opposite to the research hypotheses.

Table 3-9: Dynamic logistic model estimates of the probability of a firm carrying out R&D activities (applying the Skrondal and Rabe-Hesketh approach).

Dependent Variable $R\&D_{i,j,t}$	**Coef.**	**S.E.**	***p*-value**	**Margins**
$R\&D_{i,j,t-1}$	4.1051***[b]	(0.1855)[a]	0.000	0.3092
$Fauto_{i,j,t}$	-0.1165	(0.0970)	0.230	-0.0088
$Levage_{i,j,t}$	-0.0003	(0.0005)	0.503	-0.0000
$Size_{i,j,t}$	0.4070***	(0.1445)	0.005	0.0303
$Age_{i,j,t}$	-0.1303***	(0.0479)	0.007	-0.0098
$Agesize_{i,j,t}$	0.0207	(0.0135)	0.126	0.0015
$HHI_{j,t}$	-1.3810*	(0.7524)	0.066	-0.0913
$TaxChg_t$	-0.5921**[c]	(0.2499)	0.018	0.0434
$ReliefChg_t$	0.2053	(0.2055)	0.318	0.0146
$R\&D_{i,j,1}$	2.0834***	(0.3311)	0.000	0.1540
$Fauto_{i,j,1}$	0.1242	(0.2198)	0.572	0.0096
$Levage_{i,j,1}$	-0.0007	(0.0007)	0.298	-0.0000
$Size_{i,j,1}$	-0.2119	(0.1376)	0.124	-0.0160
$Age_{i,j,1}$	-0.0865	(0.1154)	0.453	-0.0063
$\overline{Fauto_{i,j}}$[e]	0.4782**	(0.2022)	0.018	0.0356
$\overline{Levage_{i,j}}$	-0.0014	(0.0018)	0.419	-0.0001
$\overline{Size_{i,j}}$	-0.3245*[d]	(0.1887)	0.086	-0.0234
$\overline{Age_{i,j}}$	0.1268**	(0.0562)	0.024	0.0097
Industry Dummies	YES			
Constant	-2.9033	(0.4308)	0.000	
Number of firms	627			
Number of obs	4419			
ChiSq	41.55		0.000	

Notes:
[a] The reported figures in parentheses are the standard errors.
[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.
[e] The bar sign reflects the individual-specific average of independent variable.

Table 3-10: Dynamic logistic model estimates of the probability of a firm carrying out R&D activities with the level data of the tax rates (applying the Skrondal and Rabe-Hesketh approach).

Dependent Variable $R\&D_{i,j,t}$	Coef.	S.E.	*p*-value	Margins
$R\&D_{i,j,t-1}$	4.0883[***b]	(0.1857)[a]	0.000	0.3077
$Fauto_{i,j,t}$	-0.1182	(0.0967)	0.222	-0.0089
$Levage_{i,j,t}$	-0.0003	(0.0005)	0.530	-0.0000
$Size_{i,j,t}$	0.4050[***]	(0.1441)	0.005	0.0304
$Age_{i,j,t}$	-0.1503[***]	(0.0518)	0.004	-0.0113
$Agesize_{i,j,t}$	0.0228	(0.0137)	0.098	0.0017
$HHI_{j,t}$	-1.3567[* d]	(0.7489)	0.070	-0.1021
$TaxRate_t$	9.4689[*]	(4.9298)	0.055	0.7128
$ReliefRate_t$	0.42853	(0.4117)	0.298	0.0322
$R\&D_{i,j,1}$	2.0711[***]	(0.3303)	0.000	0.1559
$Fauto_{i,j,1}$	0.1283	(0.2191)	0.558	0.0096
$Levage_{i,j,1}$	-0.0007	(0.0007)	0.292	-0.0000
$Size_{i,j,1}$	-0.2104	(0.1372)	0.125	-0.0158
$Age_{i,j,1}$	-0.0576	(0.1147)	0.615	-0.0043
$\overline{Fauto_{i,j}}$[e]	0.4592[** c]	(0.2017)	0.023	0.0345
$\overline{Levage_{i,j}}$	-0.0014	(0.0018)	0.434	-0.0001
$\overline{Size_{i,j}}$	-0.3072	(0.1885)	0.103	-0.0231
$\overline{Age_{i,j}}$	0.1346[**]	(0.0568)	0.018	0.0101
Industry Dummies	YES			
Constant	-6.4366	(1.9628)	0.001	
Number of firms	627			
Number of obs	4419			
ChiSq	41.08		0.000	

Notes:
[a] The reported figures in parentheses are the standard errors.
[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.
[e] The bar sign reflects the individual-specific average of independent variable.

In relation to the application of the raw corporate tax and R&D tax relief rates, table 3-10 shows that the estimated coefficients and significance of the explanatory variables are almost the same as those reported in table 3-9. However, although the sign of the corporate tax rate coefficient has changed from negative to positive, it presents the same positive effect on R&D as in table 3-9. This can be explained by fact that corporate tax rates were just decreasing, and by considering this variable definition as in table 3-9, the significance of its negative coefficient sign reflects its positive effect on R&D.

3.7 Conclusion

This chapter contributes to the literature by analysing the role of market structure, firm resources, and government tax policy factors in firms' R&D activities in a dynamic logistic model which controls for the initial conditions. The most relevant explanatory factors are the meso-level and macro-level ones. In addition to lagged firm R&D expenditure, firm size and firm age, the meso- and macro-level factors are the main influencing ones on the probability that a firm will make internal R&D investment. These associated variables are those that have greater weight in discriminating between firms that carry out R&D activities and those that do not, namely market concentration and corporate tax rate.

The chapter presents new evidence of the factors that have an impact on a firm's decision to carry out R&D activities. Competitive markets are better at stimulating innovative activities, in contrast with the Schumpeterian hypothesis, and the corporate income tax rate has a positive significant impact on a firm's decision to undertake innovation. We show that tax increases have a positive impact on firms' innovative activities; this finding has a strong implication for UK tax policy on long-run firm performance and economic growth. Finally, since this chapter has focused on the factors and determinants that influence a firm's probability of carrying out R&D activities, the complementary question would be what the determinants that affect the level of expenditure invested by firms in R&D is. Therefore, the following chapter of this thesis will focus on the determinants of R&D expenditure amongst AIM-listed firms.

Chapter 4

The Financing Menu of R&D on the AIM Market: New Evidence on Financing Constraints

4 The Financing Menu of R&D on the AIM Market: New Evidence on Financing Constraints

4.1 Introduction

Research and Development expenditure is considered as a major driving force for the growth of firms and consequently for the growth of economies. In competitive environments, firms are obliged to adopt strategies that allow them to confront competition, and increase market share and profitability. Despite the fact that R&D has distinguishing characteristics from other investment, it plays an essential role in these strategies. R&D and the utilization of new technology in the creation of new products and development of new production processes are used to provide some differentiation that leads to a competitive advantage over competitors. Hence, firms invest in R&D to increase their profitability and market share.

As an important driver of firms' growth opportunities, and as one of the most important reasons that allows firms to remain competitive in the market, R&D investment has become a core type of investment in a large number of firms in recent decades. Lee and Shim (1995) investigated the impact of R&D investment on firms' long-run performance, and the role that R&D investment plays in the growth of high-tech firms. They point out that there is a positive relationship between market growth and firms' R&D activities, and that the deployment of R&D activities in high-tech industries helps firms to build competitive advantage and market growth in the long run.

Although R&D expenditure is crucial for a firm's competitive advantage and long-run success, this investment creates intangible assets. The characteristics of R&D investment, including the lack of collateral value, asymmetric information problems and the degree of uncertainty associated with its output, make it susceptible to financing constraints[26]. For young and small firms, R&D may face significant adverse selection problems. For such firms, financing constraints can lead to a considerably lower level of R&D investment than the optimal level that they would choose in a world without financing constraints. If financing constraints bind firms' level of R&D investment, such constraints will lead to lower growth levels than would have been achieved in a world with no constraints.

Despite the fact that R&D investment plays an important role in firms' growth and is prone to financing constraints, few studies have focused on the effects of financing constraints on R&D investment for young and small firms. Empirical studies that have examined firms' level of R&D investment are based almost exclusively on the availability of internal cash flow and tested on large and mature firms (Grabowski, 1968; Hall, 1992; Himmelberg and Petersen, 1994; Bhagat and Welch, 1995). They find evidence that firms' levels of R&D are linked to the availability of internal cash flow. However, since riskiness and lack of collateral value are two of the characteristics of R&D, debt finance as an external source of fund is not a realistic source of funds to finance R&D (Switzer, 1984; Hall, 1992; Piga and Atzeni, 2007; Brighi and Torluccio, 2009; Wang and Thornhill, 2010). Equity is the only realistic source of external funds to finance firms' R&D investment (Brown and Petersen, 2009; Chen *et al.*, 2010; Brown *et al.*, 2012).

Both internal and external sources of funds are considered volatile sources of finance (Brown *et al.*, 2009). Because R&D investment is associated with high adjustment costs and is financed with volatile sources, firms will find it very expensive to adjust the flow of R&D in response to transitory finance shocks. Researchers therefore argue that firms which are facing binding financing constraints, or facing financing frictions, may not be able to maintain a relatively

[26] R&D is considering risky and an uncertain investment as the success of its output is not guaranteed, and will only generate profits with a time lag if successful.

smooth path of R&D spending. Therefore, the role that firms' cash liquidity can play in smoothing the path of R&D has been analysed (Brown and Petersen, 2011; Guariglia and Liu, 2014). Empirical evidence has been found to show that constrained firms can maintain a relatively smooth path of R&D spending by drawing down their precautionary cash holdings. However, few researchers have investigated the potential role of working capital as a source of liquidity for smoothing R&D investment in the presence of R&D financing constraints[27]. This chapter addresses this problem by emphasizing the overlooked role of working capital as an input and an easily reversible store of liquidity in R&D smoothing. Working capital is defined as the current assets, principally cash and equivalents, inventory and accounts receivable, less current liabilities, chiefly accounts payable and short-term debt. It is a common measure of whether a firm has enough short-term assets to cover its short-term liabilities; that is, it measures a firm's liquidity and efficiency through its net position in liquid assets.

4.2 Research aim and objectives

In this study, we explore two issues that are practically ignored in previous studies, and which are likely to be crucial for understanding the impact of financial constraints on R&D investment. The first is young, small and high growth firms, which have turned to stock markets for funding purposes to finance their growth opportunities. Firms mainly rely on issuing stock to finance R&D investment. R&D-intensive firms suffer, however, as they have little or no access to debt and limited amounts of internally generated funds to finance their investment. Scholars argue that stock issues are the main marginal source of funds for firms to finance R&D.

[27] Fazzari and Petersen (1993) make a similar investigation on the role of smoothing fixed investment with working capital.

However, as firms at some points in their life cycle appear to rely heavily on stock issues as a source of external funds to finance their R&D investment (Brown *et al.*, 2012), these firms suffer from financial market problems, such as the high cost of raising capital and adverse selection, because of asymmetric information problems. For this type of firm, R&D is almost exclusively financed by volatile sources of funds, internally generated funds and stock issues. An important research question is whether financial constraints play an important role in the R&D investment of the young, risky and high growth firms listed on AIM, dramatically altering the conclusions regarding the importance of financing constraints. The second issue is that R&D-intensive firms have a strong incentive to keep R&D investment smooth because of the high adjustment costs (Brown *et al.*, 2012). The most sensible way to smooth R&D for firms facing binding financing constraints, relative to transitory finance shocks, is to manage internal stocks of liquidity, for example working capital, to buffer these transitory shocks.

In this chapter, we aim to examine directly the role that working capital, as a store of liquidity, plays in buffering the path of R&D spending from transitory finance shocks for the young, small and high growth firms listed on AIM. To the best of knowledge, this is the first study to test the role of working capital on R&D smoothing and to emphasize its importance for a firm's financial policies. Further, it aims to solve the puzzle of whether financing constraints play an important role in R&D and the innovation of the young, small firms listed in the UK. These objectives could help these young, small and high growth firms listed on AIM to take advantage of designing proper strategies, which by taking into account the accessibility of sources of funds, and the importance of working capital, and so pointing out, the general dimensions of their financing and investments choices and decisions.

4.3 Theoretical background and Literature Review

4.3.1 Introduction

Investment and financing choices are the most important corporate decisions that have been highlighted in the last decades (see, for example, Fazzari *et al.*, 1988; Bond and Meghir, 1994; Hubbard, 1997). The original works of Modigliani and Miller (1958), and later of Miller and Modigliani (1961), show that external and internal capital are considered as perfect substitutes for firms to finance their investment opportunities, and thus the optimal level of firms' investment and investment decisions are totally independent of their financial structure.

Since the original work of Modigliani and Miller, scholars have focused on understanding how market imperfections affect firms' investment decisions and their financing choices. However, by relaxing the perfect capital market assumptions, research in the corporate finance area has intensively examined each of these two types of decisions. Mueller (1967) shows that firms' decision-making is a complex process, in which decisions that could be made by a particular department in a firm are likely to be affected by the decisions made in other departments. In practice, however, financial constraints, such as limited access to external capital and insufficient availability of internal capital, may tie up firms' ability to invest efficiently (Fazzari *et al.*, 1988). Under such circumstances, Gatchev *et al.* (2010) argue that firms need to study their financing choices in parallel with their investment decisions; that is, if any one policy is changed, other polices should also be changed accordingly.

Over the last decades, much effort has been devoted to investigating the characteristics of firms and how they could be classified into constrained or unconstrained categories. The subsequent issue is whether firms can finance their investment activities based on the nature and type of investment opportunity (Bond and Meghir, 1994; Brealey *et al.*, 2011).

Corporate investment activities are concentrated in investment in two types of assets: tangible, such as machinery, land and inventories; and intangible, for instance patents, brand names and research and development. Consequently, researchers have increasingly paid attention to investigating financing constraints and firms' investment activities in both tangible and intangible assets. Apart from the tangible asset financing studies, scholars have extensively investigated the financing choices for intangible assets, specifically R&D, owing to their special characteristics and importance. This investment, rather than any other type of investment, can be differentiated in terms of its riskiness, collateral value and the cost of adjustment. It is considered to be much riskier, offers little or no collateral value, and has higher adjustment costs than other investment types (Himmelberg and Petersen, 1994).

The remainder of the theoretical background and literature review will proceed as follows. Section 4.3.2 briefly reviews the corporate investment theories, while section 4.3.3 considers the corporate finance theories of investment. Section 4.3.4 briefly reviews R&D investment smoothing and financing constraints and Section 4.3.5 develops the research hypotheses.

4.3.2 Corporate investment theories

4.3.2.1 Net present value theory

The aim of management is to increase and create value for stockholders. In this regard, corporate investment decisions become some of the core decisions that any firm needs to take when investing funds in the expectation of reaping future benefit. There need to be some estimates of the returns from these potential projects. The best known estimates to determine the worthiness of targeting projects are the Discounted Cash Flow (DCF) valuation and standard Net Present Value (NPV) estimate. The DCF is considered as a part of the NPV. The principle of this estimate is fairly simple; it discounts the expected future cash inflow out of the potential project back to its present value at a particular discount rate, the required rate of return, and then adds it to the initial cost of the project. If the NPV is positive, this means that the project should be accepted, as it would add value to the firm and would increase stockholders' wealth. On the other hand, if the NPV is negative, then the project should be abandoned, as it would damage firm value and reduce the stockholders' wealth. The Net Present Value estimate is:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+r_t)^t} - CF_0$$

where:

CF_t is the expected net cash flow of a project at time *t*.

CF_0 is the initial cash outlay on a project.

r_t is the required risk-adjusted rate of return (discount rate).

T is the life of the project.

NPV is widely used in all segments of business. A survey by Graham and Harvey (2001) showed that almost three out of four chief financial officers in the US heavily relied on NPV estimation to evaluate their investment projects. However, with regard to firm size, they found that large size firms are significantly more likely to use NPV estimates than small firms. On the other hand, a survey by Murinde and Ow-Yong (2009) on the non-financial firms listed on the London Stock Exchange showed that in general the finance managers of UK firms did not use the Discounted Cash Flow analysis to evaluate their investment projects, and that large size firms were more likely to use DCF than small ones. They also reported that a significant number of large firms relied on more sophisticated estimates to evaluate their projects, such as scenario analysis and decision trees.

However, Carlsson *et al.* (2005) argue that the lack of application of these two techniques in business is partly due to the assumptions underlying the estimates. More specifically, if we consider the different characteristics of potential projects, for example the characteristics of Research and Development investment, the estimates do seem to be unreliable. There are multiple sources of uncertainty and an R&D investment produces a stream of cash flow after many potential stages of research. As a result, Carlsson *et al.* conclude that DCF and NPV techniques provide little explanatory power for the practical behaviour of corporate investment. Given the importance of corporate investment decisions in creating more value for stockholders and maximizing their wealth, a number of more powerful theories have been developed, such as Tobin's Q theory, accelerator theory and financial constraint theory.

4.3.2.2 Tobin's Q theory

Tobin's Q, developed by Tobin (1969), represents the ratio between the market value of the installed capital assets and the replacement costs of these capital assets.

$$Q_{ratio} = \frac{\text{market value of the installed capital assets}}{\text{replacement costs of capital assets}}$$

Firms with a Q ratio higher than one should invest more, since the market value of their underlying assets is greater than the current replacement cost, implying that they are overvalued. On the contrary, firms with Q ratio lower than one are undervalued and should curtail investment. Accordingly, Hayashi (1982) defined marginal Q, the ratio of the market value of a firm's additional investment to its replacement cost, as a measure that summarises all the factors that have an effect on firms' investment decisions. These decisions should be positively related to their marginal Q ratio, which is an increasing function of marginal Q. In other words, Tobin's Q theory indicates that all the factors relevant to expected future profitability affect a firm's investment decisions through their effects on marginal Q. The underlying principle of marginal Q is the same as the principle of Tobin's Q. That is, if marginal Q exceeds unity, this indicates that firms should have an incentive to undertake or to expand their investment activities, while if the marginal Q value is below unity, firms should reduce their existing activities or should reject new investment opportunities. In conclusion, an optimal investment level can be reached when the market value of additional investment units is equal to their replacement cost, when the marginal Q value is equal to one.

Empirical studies find that firms' investment rates and Tobin's Q are positively related. More specifically, and regarding the type of investment that firms are aiming to undertake, the relevance of the Tobin Q effect has been identified as important in a significant number of empirical studies. Blundell *et al.* (1992) found that the Q model does have significant power in explaining firms' rate of investment in tangible assets in the UK. However, other factors, such as cash flow and output, should be considered as they have significant power in determining firms' rate of investment. Further, Cuthbertson and Gasparro (1995) show that although this model explains the investment rate, the effect of some other factors, such as capital gearing and output, should also be considered as important determinants of firms' investment levels. On the other hand, regarding different types of investment, e.g. intangible capital, Klock *et al.* (1996) found that the Q model does have significant power in explaining firms' investment level in intangible assets (R&D in particular) in the US market. It was also found that firms' financial policy plays an important role in their level of investment decisions.

Bardhan *et al.* (2010) showed that the effect of intangible assets on firms' Tobin's Q is positively and statistically significant. Further, Bharadwaj *et al.* (1999) examined the association between intangible investment (IT investment) and firms' Q value in the US. It was found that IT investment does have a statistically significant positive effect on firms' Tobin's Q value. Similarly, Connolly and Hirschey (2005) and Parcharidis and Varsakelis (2010) show that there is a significant effect of R&D capital on firms' Tobin's Q value, and that this effect seems to be more significant for small firms than large firms. All in all, we conclude that markets really value firms that make intangible investment such as R&D, while at the same time firms rely on Tobin's Q value to determine their rate of investment.

Although some empirical studies have found that firms' investment rate is positively correlated with Tobin's and marginal Q values, Lensink and Murinde (2006) noted that measurement of the marginal Q is problematic, since proxies of it vary across the empirical literature. They found that the disappointing performance of Tobin's Q model of investment is mainly due to serious measurement errors. They further argue that this model does not carry all the relevant information concerning investment decisions, as some other factors, such as adjustment costs, uncertainty and capital market constraints, play an important role in investment decisions. Ferderer (1993), for example, found that the impact of uncertainty on investment is much larger than the impact of Tobin's Q. He suggested that extending the Tobin's Q model by including uncertainty measures would improve the performance of the model of investment significantly. In addition, Dixit and Pindyck (2012) state that the underlying principle of Tobin's Q model is the same as the basic NPV model. The capitalised value of an investment used to determine the Tobin's Q value needs to be calculated as the expected present value of the cash flow stream that the investment would yield.

4.3.2.3 Accelerator theory

The principle of the accelerator theory is based on the idea that there is a constant capital-output ratio, and firms engaging in capital investment should endeavour to close the gap between the required stock of capital and the existing stock of capital goods (Mairesse and Siu, 1984; Shapiro *et al.*, 1986; Sargent, 1989). According to this view, any increase in firms' sales or output requires an appropriate increase in the amount of investment to adjust its stock of capital towards the required level. The logic implied in the accelerator model is that any increase in a firm's level of sales indicates that it is likely to make more profits and have greater use of its existing capital in the future; consequently, if firms expect the sales stream to last, this would encourage them to spend more funds on capital. The increased stock of capital would lead to a further increase in sales and profits, causing a multiplier effect. On the other hand, if firms' level of sales decreases, this would reduce their profits and lower the use of stock of capital, which would in turn discourage firms from investing, and therefore worsen their perspectives. In other words, the level of capital investment is a function of firms' output.

A large number of empirical studies support the relevance of the accelerator model for firm investment. For instance, Shapiro *et al.* (1986) find that firms' investment is highly sensitive to increases in sales, consistent with the main prediction of the accelerator model. Further, based on the accelerator model, Bo and Lensin (2005) tested the investment-uncertainty relationship on Dutch non-financial firms. They found that investment growth is positively related with the sales growth, as expected. Further, Mairesse and Siu (1984) show that an increase in physical investments is highly significant and reacts proportionally with a growth of sales. More specifically, and concerning intangible investments (e.g. R&D), Mansfield (1964) shows that there is no significant relationship between the level of R&D investment and firms' sales growth. Similar findings were reported by Cohen *et al.* (1987), who found that the relationship between firms' sales and R&D investment was statistically insignificant.

However, the accelerator model of investment has been criticised for ignoring the role of other factors, for example financial variables, in investment decisions. Lensink (2002) and Lensink and Sterken (2000) examined corporate investment behaviour. They reported that the standard accelerator model is neither statistically adequate nor economically complete, as it fails to capture the roles played by other factors in determining firms' investment decisions, such as financial constraints.

4.3.2.4 Financial constraints theory

Over the last decades, researchers have constructed models of business investment to identify "financing constraints". Under the Modigliani-Miller proposition, it is assumed that all companies have the same access to the capital market, and the response of firms to changes in the cost of capital will only differ due to differences in their investment demand. It is also assumed that internal funds can be perfectly substituted by external funds, and firms' investments decisions are not characterised by financial structure or their condition. However, the Modigliani-Miller proposition fails to take account of information asymmetry in the financial market, which causes financial constraints and introduces capital market imperfections. To fill this gap, Myers and Majluf (1984) showed that with imperfect capital markets, external and internal capital cannot be considered as perfect substitutes. According to this view, corporate investment levels will depend on firms' financial factors, such as access to new equity or debt and the availability of internal funds.

Recognising the results of the previous models, corporate investment decisions can be affected by different factors, such as NPV, Tobin's Q value and sales growth. However, the availability of and accessibility to internal and external funds cannot be neglected in corporate investment decisions. Due to the costs of these financial sources, researchers indicate that firms prefer to rely on internally generated cash flow to finance their investment opportunities rather than other external sources, since internal funds are cheaper than new equity finance and debt. Apart from NPV, Tobin's Q value and sales growth, a firm's level of investment is considered to be interdependent with the financing choices; that is, accessibility to new equity or debt and the availability of internal finance (Fazzari *et al.*, 1988; Bond and Meghir, 1994; Hubbard, 1997).

4.3.2.4.1 Preferences over external and internal finance

The link between real investment spending and firms' financial structure is based on the reasons why external and internal finance are not perfect substitutes due to the imperfect capital market model. In fact, internal finance could be much more favourable for companies than external finance, as it is considered as less costly for reasons such as transaction costs, agency problems, asymmetric information, tax advantages, and the cost of financial distress.

(a) Stock Issues

New stock issues of listed firms are carried out by underwriters, who purchase blocks of newly issued stock and resell them. The cost of new issues, such as the underwriters' discounts, administrative sales expenses, registration fees and taxes, are all deducted from the issuers' gross proceeds. However, such expenses may vary, according to the size of the offering. Fazzari *et al.* (1988) argue that an initial public offering is much more expensive (in terms of indirect and direct costs) than a seasoned offering, and the cost of a small offering in both cases is relatively higher than a large one. On the other hand, regarding the corporate tax system, internal finance has a cost advantage over external equity finance, as in most countries the tax rate on dividends is higher than that on the capital gains, implying that tax saving can arise when firms' earnings are retained rather than paid out.

Further to the above argument, Auerbach (1979) computed the shadow prices for the cost of new stock issues (s), and the cost of internal finance (r). He found that $\mathrm{s} = \rho/(1-\pi)(1-\vartheta)$ and $\mathrm{r} = \rho(1-\pi)(1-\delta)$, where ρ is defined as the required after-tax return by the capital market, π is the corporate tax rate, ϑ is the tax rate on dividends, and δ is the tax rate on capital gain. He states that the tax rate of new stock issues can be formed as $\frac{\mathrm{s}-\mathrm{r}}{\mathrm{r}} = (\vartheta-\delta)/(1-\vartheta)$. Alternatively, within a Q framework, for the marginal Q to value a project, whether a project should be undertaken depends on how it is being financed[28]. Externally financed projects can reap profits for shareholders only if their marginal Q exceeds unity, and projects that are financed with retained earnings can benefit shareholders only if attain a Q of $(1-\vartheta)/(1-\delta) < 1$.

Regarding the asymmetric information problem, Akerlof (1970) considered that this problem would potentially generate a significant cost disadvantage of equity finance. The theoretical arguments suggest that if the seller or the issuer of the security has more information about the quality of the asset than the buyer, the seller would be unwilling to accept the terms offered by the buyers, forcing an asset to be sold at a lower price than would otherwise be the case, if both parties had the same information (known as the "lemons").

However, assuming that a firm's managers have more information on their existing capital and the return from new investment, Myers and Majluf (1984) argue that external investors cannot differentiate between the value and quality of firms, forcing them to value firms at the population average. Thus, new external investors will demand a premium to offset the losses from purchasing stocks of relatively good firms that would arise from funding lemons.

(b) Debt Finance

Increasing marginal costs of new debt for leveraged firms is due to agency costs and the cost of financial distress. The first costs arise as firm mangers will to some extent have an incentive to act in the interests of creditors, due to the limited liability feature of debt. The cost of financial distress occurs when firms default on the interest and principal obligation of the debt. Fazzari *et al.* (1988) argue that long-term debt is the cause of the agency problem, whereby managers

[28] Marginal Q is a ratio that measures the market value of an additional unit of capital in relation to its replacement cost (Hayashi , 1982).

of firms with a high debt-equity ratio are more likely to act in the interests of the debt providers rather than those of the firm, believing they could neglect some positive present value investment opportunities and adopt negative ones instead. However, such financial inflexibility implies that mangers' choices of investments and financing opportunities are more expensive, especially when a firm's internal fund levels are low.

Asymmetric information in the debt markets causes the same drawbacks as mentioned regarding the equity market. It has the same impact, in that it may raise the cost of new debt, or worse, introduce credit restrictions. Jaffee and Russell (1976) indicate that when lenders cannot distinguish between good and bad borrowers, the market interest rate must increase and loan sizes could be limited. However, when the interest rate rises, marginally good quality borrowers will leave the market, making the probability of default on lenders higher and the expected profits lower.

On the other hand, Calomiris and Hubbard (1988) focused on the heterogeneity of firms in credit markets, which researchers classify into two types: the "full information" market (e.g. commercial papers or bonds) and the "information intensive" market (e.g. bank loans). Credit markets sort borrowers in terms of different asymmetric information degrees. Calomiris and Hubbard claim that, depending on borrowers' per capita levels of internal net worth, lenders will allocate new funds to these different classes of borrowers. Thus, borrowers could either follow the full information credit allocation or information intensive credit allocation, taking funds away from high asymmetric information borrowers. Researchers also suggest that banks which are specialized in financing firms' projects that are characterised by severe information problems can reduce the average information costs by maintaining long-run relationships.

Finally, and according to the various features of firm heterogeneity, Calomiris and Hubbard (1988) state that mature and large firms are the only types to face smoothly increasing loan interest rates, and are more likely to have access to the debt market than small and medium sized "young" firms, which are less likely to have access to it. All in all, firms with high asymmetric information problems in the credit market will probably face the same problem in the equity market and most probably will have to pay a premium to obtain new debt. Thus, equity finance cannot be considered as a substitute for debt finance; in general, it cannot solve the asymmetric information problems associated with debt.

The above discussion can be summarized clearly by the finance hierarchy model of the finance model, which starts from the assumption that retained profits are relatively less expensive than external finance, either stock issues or debt issues. Therefore, firms prefer to rely on internal finance when it is available (Bond and Meghir, 1994). However, considering the firms' investment spending, it is easier to consider firms that do not have access to debt financing, and only choose between new stock issues and retained profits, in order to observe the consequences of their investment spending. This situation is explained in Figure 4-1 below.

The Hierarchy of Finance Model with No Debt Finance

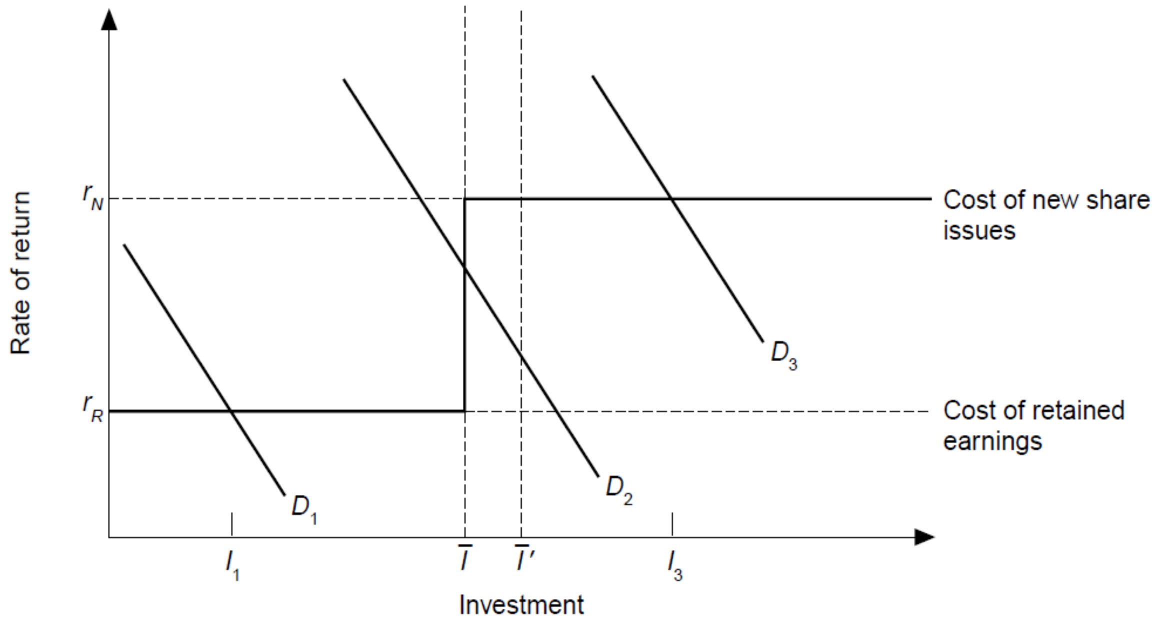

Figure 4-1: The hierarchy of finance model with no debt finance (Bond and Meghir, 1994).

The required rate of return is denoted by r_R, and represents the cost of finance from retained earnings; r_N is the higher required rate of return, and is the cost of finance from new stock issues. D_1, D_2 and D_3 are the sloping lines that represent the three possible positions of the firms' available investment opportunities, reflecting the rate of return that can be earned from the chosen investment projects. The firms' maximum level of investment that can be financed from internal sources is represented by the level of investment spending $\bar{I}$, indicating that firms are not willing to reduce their dividend payments any further. This investment level is noted to be positively related to the generated cash flow of firms' existing activities, i.e. internally generated cash flow.

The investment demand curve D_1 represents firms with investment opportunities relatively lower than their generated cash flow. In this case, they are willing to finance their desired investment opportunities, as well as paying out relatively high dividend rates. Investment spending at level I_1 will not be affected by the fluctuations in cash flow, in correspondence with $\bar{I}$ spending level.

In the second scenario with the investment demand curve D_2, firms' investment spending is in the intermediate position. In this case, they have sufficiently attractive investment opportunities for their internal funds. The other remaining projects are not considered to be sufficiently attractive to issue new stocks, given the higher rate of return required. Thus, firms in this scenario are described as being financially constrained as their investment spending is just tied to $\bar{I}$ spending level financed from retained profits, with the dividend pay-out ratio being relatively low or zero.

In the third scenario, where the investment demand curve is D_3, the investment opportunities of firms are considered to be relatively higher than the firms' internally generated cash flow. In this scenario, firms find the investment projects sufficiently attractive to issue new stocks, despite the extra cost. Investment spending will be at the I_3 level, at which it will not be affected by the cash flow fluctuations corresponding to the $\bar{I}$ spending level. This scenario is characterised by new stock issues and low or zero dividend pay-out ratios.

The firms' investments in the second scenario can be described as being financially constrained for this feasible sense. Any unexpected increase in cash flow, not reflected by any new information about the firms' investment opportunities, will increase their investment. This can be explained in the diagram in Fig. 4-1 by the upward shift of the spending level that can be financed internally, from $\bar{I}$ to $\bar{I}'$. As a result, there will be a significant increase in the firms' investments, and they will move down the demand curve D_2. Note that firms in this scenario are financially constrained, in the sense that their investment spending is limited to the availability of internal finance, bearing in mind that they have access to equity finance at r_N cost of issues.

Investment levels are not significantly affected by the possibility of using other external financing sources (i.e. using debt), considering that the effective cost of borrowing increases as firms' borrowing levels increase. One of the most important reasons that makes the effective cost of borrowing increase is the risk premium, reflecting the asymmetric information problem between lenders and borrowers. The rate of interest charged rises as the probability of firms' default increases. Figure 4-2 illustrates the case in which firms have access to debt finance along with equity finance. In such a case, firms' investment level $\bar{I}$ represents the maximum levels that can be financed through internal funds.

The Hierarchy of Finance Model with Debt Finance

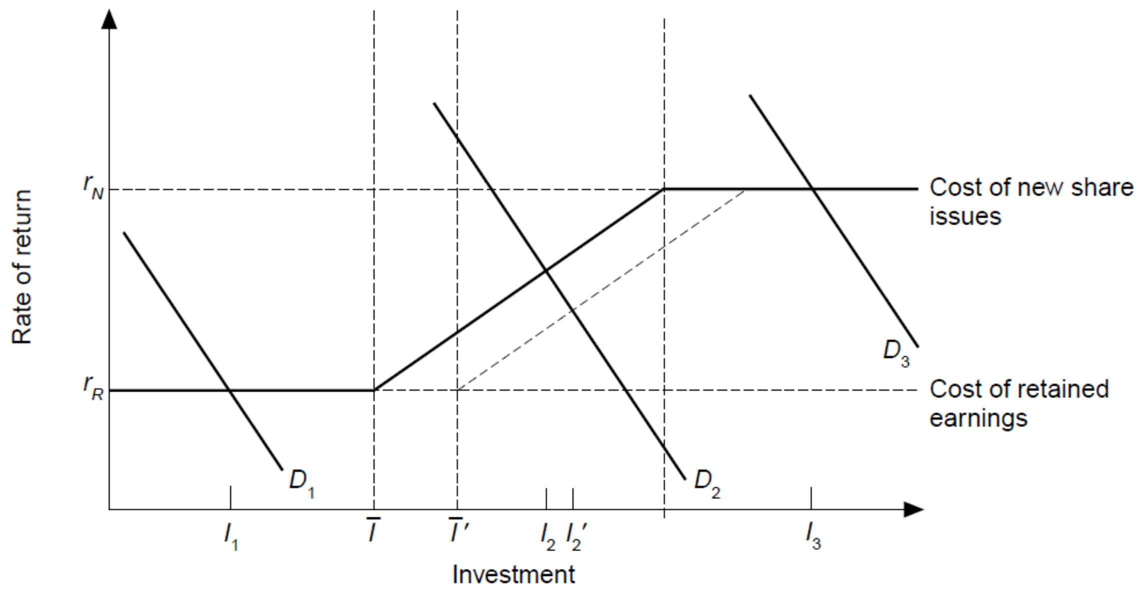

Figure 4-2: The hierarchy of finance model with debt finance (Bond and Meghir, 1994).

For firms in the first and third scenarios, the implications of investment demand are unchanged from the no-debt cases. However, firms in the first scenario may use their internally generated funds, as well as debt, to finance their investments, and firms in the third scenario may use new stock issues as well as debt for this financing.

Firms that have used all of their internal funds, but did not issue new stocks, are no longer constrained to the investment spending level, $\bar{I}$. They can finance any further investment opportunities through debt borrowing. In this case, firms' investments are determined by the rising cost of debt, producing the I_2 spending level. However, these firms are still financially constrained, in the sense that they are hampered by the rising cost of debt and the availability of internal funds. Any unexpected increase in cash flow helps investment levels above I_2 to be financed at lower borrowing levels. This reduces the effective cost of debt, and produces higher investment spending levels at I_2'.

With regard to the external and internal financing choices, Fazzari *et al.* (1988) documented differences in financing patterns regarding firm size, and gave some explanations for the imperfect substitution of internal and external finance. Using the market imperfection model, firms' investment model and an individual firm's access to the capital market, they tested the relevance of a firm's financial structure in relation to its investment decisions, claiming that firms that use nearly all of their internal funds, i.e. have a high retention ratio, should be more sensitive to cash flow fluctuations than those with a lower retention ratio. Their results indicate that financial factors were important for investment decisions at all firm levels, but greater investment sensitivity was observed among the high retention ratio firms, implying that capital market imperfection creates financial constraints on investment.

In summary, it clear that a firm's cost of capital differs according to the different sources of funds, and the availability of such sources has an effect on the decisions on the investment level of the different types of firms. As presented in the hierarchy of finance diagrams, the availability of internal funds makes it easier for firms to undertake their desired investment projects without the need for costly external finance, which helps increase their worth by lowering the cost of external funding.

4.3.3 Corporate Finance Theories

The financial structure of firms is highly debated in corporate finance research. Using the assumption of perfect capital markets, Modigliani and Miller provide the foundation for modern corporate financing theories. They show that in efficient markets, with no asymmetric information, taxes and transaction costs, and external and internal funds are considered as perfect substitutes for firms to finance their investment opportunities. As a consequence, corporate investment decisions are totally independent of the firm's financial structure and its value. Although the assumption of the perfect capital market has been accepted in theory, the focus of research on corporate financing policies has moved towards the real world and the level of investment relevant to firms' financing choices and policies. As corporate financing decision-making is one of the most important choices, the remainder of this literature section will briefly review the main corporate financing theories which explain corporate financing decision-making, namely trade-off, pecking order and market timing theories.

4.3.3.1 The trade-off theory

By relaxing the assumptions of the perfect capital market theory, the absence of tax and bankruptcy costs, the trade-off theory stands on the idea that firms will seek to reach optimal debt-to-equity levels in order to maximize their value, by weighing up the costs and benefits of obtaining more debt (Myers, 1984). Firms' optimal debt ratio should be determined based on a trade-off between the tax saving benefits of additional debt and its associated costs of bankruptcy and financial distress. Since interest on debt is considered as a tax-deductible expense for tax paying firms, debt can create a tax shield for them, which can increase their value, but additional debt increases firms' cost of distress. Therefore, they should seek to keep moderate levels of debt, meaning the probability of firms' bankruptcy and financial distress is low and the tax benefits of debt are high. However, when levels of debt increase above a certain point, a firm's marginal benefit of additional debt decreases, and the marginal cost of additional debt increases. Therefore, trade-off theory indicates that an optimal debt-to-equity ratio can only be achieved when the marginal cost of additional debt is exactly offset by its marginal benefit.

Graham and Harvey (2001) indicate that the trade-off theory provides a partial explanation of the differences in corporate financial structure between firms. They show that 55% of the large surveyed firms had at least somewhat strict target debt-ratios, while just 36% of small firms had this target. On the other hand, Fama and French (2002) highlight that the trade-off theory has some serious problems, as firms associated with similar levels of operating risk have different capital structures. Since the cost of distress is an important determinant of the level of the debt-equity ratio, firms engaging in high risk projects reduce their financial obligations in order to lower the risk of financial distress by limiting the use of debt. More specifically, R&D performing firms will find it difficult to achieve a target debt-ratio because of the nature and the characteristics of their investment. Switzer (1984) shows that firms making R&D investments cannot consider debt as a determinant of their R&D investment, nor as a significant source of funds for this investment. Similarly, Hall (1992) and Ho *et al.* (2004) show that debt as a source of external funds is not favoured by firms to finance their R&D investment. Indeed, R&D-intensive firms carry marginally less financial leverage compared to others.

4.3.3.2 The pecking order theory

By relaxing the assumption of no information asymmetry, Myers and Majluf (1984) and Myers (1984) developed the pecking order theory of capital structure. This theory attempts to explain corporate financing behaviour from the perspective of the cost of financing. The principle of this model is based on the idea that firm managers know more information about the value and risk of their firm than outside investors, so there is an information asymmetry problem. Consequently, if a firm tries to issue risky securities, this will be interpreted by outside investors as a sign that it is overvalued. As a result, investors will reasonably discount the price of the firm's security, provoking a negative market reaction. Thus, in order to avoid negative market reactions, firm managers prefer to finance all their promising investment opportunities by internally generated funds, which have a cost preference over external funds and have no information asymmetry problems. According to this theory, if the available internal funds are exhausted and external financing is required, firms will first consider debt financing as a source of external funds, which is less likely to be affected by information asymmetry problems. Equity financing will be considered as the last resort for external finance, as it is more likely to be affected by the information asymmetry problem. However, in the presence of asymmetric information, and signaling problems associated with external finance, the pecking order theory states that firms will prefer to finance their investment opportunities with internal funds, debt issuance, and equity issuance in that order, creating a hierarchy of finance (Oliner and Rudebusch, 1992).

By introducing the cost of financial distress and the odds of future positive-NPV projects into the negative market reaction (adverse selection), Myers (1984) modified the pecking order theory, arguing that firms tend to issue new equity before it is needed in order to build up liquid assets which will enable them to take advantage of future promising investment opportunities. Unlike trade-off theory, according to pecking order theory there is no optimal debt ratio. However, supporting the argument of Myers (1984), and considering the special types of firms' investment opportunities (future positive-NPV projects), firms making research and development investment prefer to finance their projects through equity issuance rather than debt (Wang and Thornhill, 2010; Martinsson, 2010; Brown *et al.*, 2012). Research and development is a high-risk venture and so firms reduce their financial obligations in order to minimise the risk of financial distress; that is, they try to limit the use of debt. Firms engaging in R&D investments find that equity issues are an ideal source of external funds when debt cannot be considered as a realistic source fund for such an investment type. Firms use the proceeds of the stock issuance to build up a liquid reserve in order to finance this investment in the future (Bates *et al.*, 2009; Brown and Petersen, 2011). Shin and Kim (2014) found that R&D performing firms issue new equity in order to create a reserve of liquidity to smooth future R&D projects, especially when they face financing issues. Further, Brown and Floros (2012) state that making R&D investment is considered to be a key motive for firms to keep precautionary cash reserves. These reserves can be built up from the proceeds from the issuing of new stock, which supports the view that firms may issue new equity before it is needed in order to build up liquid asset reserves, which enable them to undertake promising investment opportunities later.

4.3.3.3 The market timing theory

By relaxing the assumptions of the perfect capital market, the market timing theory states that firms' capital structure is constructed based on the accumulative attempts of managers at timing the capital market (Baker and Wurgler, 2002). Baker and Wurgler offer two explanations of equity market timing behaviour. They first argue that, based on the adverse selection problem introduced by Myers and Majluf (1984), adverse selection costs vary across firms and over time, as the degree of information asymmetry also similarly varies. However, adverse selection is inversely related to firms' market-to-book ratio (Myers and Majluf, 1984). Under this condition, market timing opportunities emerge because of the changes in the levels of information asymmetry between rational investors and firm managers. Second, based on managers' understanding of the time-varying aspect of market mispricing, they will issue stocks when they believe that the market is irrationally overvaluing their firms, and will repurchase their stocks when they are undervalued. Market timing opportunities emerge as long as firm managers believe that their firms are irrationally mispriced in the market. With both explanations, it can be said that a firm's capital structure is based on the cumulative attempts of managers at timing the equity market.

On the other hand, and concerning debt as a source of finance, a survey by Graham and Harvey (2001) showed that market timing plays an important role in making corporate financing decisions. They found evidence that firms issue debt in an effort to exploit market interest rates; firm managers take on debt when they feel that interest rates are particularly low, or when they expect that the rates will fall in the future. Baker and Wurgler (2002) conducted an investigation into the relationship between the historical path of the market-to-book ratio and firms' capital structure. Their findings show that managers' understanding of market timing opportunities, which is represented by the ratio of firms' market-to-book value, has a significant effect which helps to explain the differences in corporate capital structure, consistent with market timing predictions.

However, linking the levels of information asymmetry with the types of investment (specifically R&D), Chen *et al.* (2010) investigated firms' preferences between private investment in public equity (PIPEs) and secondary equity offering (SEO). Their findings show that when the potential of undervaluation is high (when the levels of information asymmetry are high), firms are more likely to turn to private investors; that is, the PIPE mechanism. Management is more likely to select the PIPE mechanism over SEO when it offers a relative cost advantage, avoiding the adverse selection costs of information asymmetry.

4.3.4 R&D investment and financing constraints

4.3.4.1 Investment in assets and working capital with finance constraints

For firms to optimise returns, they should not keep any unproductive assets and should finance their investment with the cheapest sources of funds. In this section, we will discuss why firms favour investing in short-term assets and to finance with short-term liabilities. Detailed and practical explanations for the existence of the role of working capital assets and liabilities as an input and an easily reversible store of liquidity are provided in Appendix 1a and 1b.

In a world with perfect capital markets, working capital assets and liabilities would not be needed. There would be no uncertainty, asymmetry information, nor transaction costs, and no financial constraints. The capital market would reflect all available information, and firms would lend and borrow at the same interest rate. In such a world, there would be no advantage for firms to finance or invest in the short term. Relaxing the capital market irrelevance assumption, recent research has shown that a firm's real investment may depend on financial factors. External finance, if accessible, is considered to be more costly than internal finance because of asymmetric information, transaction costs, tax advantages and the cost of financial distress[29].

Many of the arguments rest on the distinction between insiders or firm managers, who have full information regarding existing capital and investment prospects, and outsiders (or investors) who cannot differentiate between the value and quality of firms, forcing them to value individual firms at the population average. In debt markets, Jaffee and Russell (1976) argue that asymmetric information causes lenders to raise the cost of new debt, or to worsen credit rationing. They argue that if the lenders cannot distinguish between good and bad borrowers, the market interest rate must rise and loan sizes may be limited. However, when the interest

[29] For further explanation, see section 4.3.2.4 of the financial constraint model.

rate rises, marginally good quality firms will leave the market (adverse selection) or it will induce firms to undertake riskier projects (moral hazard), making the probability of default on lenders higher and the expected profits lower (Myers and Majluf, 1984; Toivanen and Cressy, 2002).

In the equity markets, new outsiders may be less informed than the insiders about firms' existing capital and their new investment prospects. In these circumstances, Akerlof (1970) explains why firms can be forced to sell new stock issues at a discount. If insiders, the issuers of the equity, have more inside information about the quality of the firm than outsiders, investors or buyers, they would not be willing to accept the terms offered by the outsiders, forcing the sale of new stocks to be at a lower price than it would have been if both parties had had the same information. However, when external funds are available only at a premium, or are rationed, fluctuation in internally generated funds may affect firms' investment.

These real-world circumstances introduce several problems that firms need to deal with. While firms have many available strategies in such circumstances, Scherr (1989) indicates that strategies that involve investment and financing with working capital accounts often offer a real substantial advantage. He argues that when a firm is faced with uncertainty regarding its expected levels of future cash flows, such uncertainty will incur substantial costs for a firm with insufficient cash balances to cover expenses. Different strategies could be devised to deal with this uncertainty and the substantial costs that it may induce. Among these strategies, some employ working capital investment or financing, such as holding a reserve of short-term marketable securities or inventories, holding additional cash balances above the expected needs, or arranging for the availability of additional use of free capital (trade credit) or additional short-term borrowing capacity.

Scherr (1989) argues that a combination of these strategies, or just one of them, might be the lowest cost approach to the problem, and that strategies using working capital accounts are some of the most important ways in which firms can respond to problems of financial constraints. Cash flow uncertainty gives rise to several strategies that employ working capital accounts. Scherr (1989) and Petersen and Rajan (1997) conclude that working capital accounts can be used as a means of handling uncertainty, with the management of these accounts playing an important role in maintaining a firm's financial health during normal and abnormal courses of business.

4.3.4.2 The role of working capital

Like any other part of firms' stock of capital, working capital is recognised as an important component (Fazzari and Petersen, 1993; Ding *et al.*, 2013). Working capital is a common measure of a firm's liquidity and efficiency through its net position in liquid assets, both liquid and financial. Defined as current assets minus current liabilities, the three main components of current assets are cash and equivalents, inventory, and accounts receivable. Current liabilities consist chiefly of accounts payable and short-term debt. It has been recognised that working capital, along with other elements of a firm’s capital, is one of the key components of firms (Scherr, 1989; Hampton and Wagner, 1989; Seidman, 2005; Watson and Head, 2016), and they are encouraged to value it.

Fazzari and Petersen (1993) argue that inventories are often divided into finished goods, work-in-process, and raw materials. The last two categories are considered to be more volatile than finished goods inventories. Deloof (2003) explains that the components of inventories in working capital enter directly into the production function. Researchers argue that firms could store up materials to reduce the likelihood of shortages which could slow down production (reducing the risk of running out of stock[30]), and that they could operate at a high production level to achieve economies of scale by using work-in-progress inventories. Other components of working capital, such as large finished goods inventories and generous trade credit policy, facilitate and may lead to higher sales. Petersen and Rajan (1997) emphasize the role that accounts receivable, in particular, can play in facilitating sales to customers, who may themselves be liquidity constraints.

Another component of working capital is accounts payable. Deloof (2003) argues that this component allows firms to delay payment to suppliers, as well as allowing them to assess the quality of the product that they have bought before paying for it. Accounts payable are also considered as an inexpensive and flexible source of finance for firms; suppliers may have a significant cost advantage over financial institutions. In this context, Petersen and Rajan (1997) indicate that firms can be financed by their suppliers, especially when their access to the capital market is limited. They found evidence that when small firms have limited access to capital markets, and/or when credit from financial institutions is unavailable, they use more trade credit; suppliers tend to lend to constrained firms because they have an implicit equity stake in them, and they believe that firms can liquidate assets more efficiently. Finally, cash and equivalents, as other components of working capital, allow firms to reduce costs through their liquidity position. Adequate cash balances allow firms to reduce their financing costs, allowing them to take advantage if they are offered a discount for early payment.

Fazzari and Petersen (1993) and Weigand and Audretsch (1999) point out that the key differences between investments in assets, both tangible and intangible, and working capital are the liquidity of the latter and its reversibility[31]. In contrast to other investments, Fazzari and

[30] The risk of running out of stock can be explained (or defined) by a situation in which a firm cannot fulfil the demand for products from its current inventory.
[31] A large volume of literature focuses on the impact of the irreversibility of tangible and intangible investments on a firm's behaviour. Irreversibility arises when firms find it costly or difficult to reverse an investment decision,

Petersen (1993) and Brown and Petersen (2011) argue that firms can easily adjust their working capital. For instance, when firms consume raw materials faster than they are replaced, working capital investment can temporarily be at negative levels. Furthermore, by intensive efforts to collect accounts receivable or by tightening up the credit policies on new sales, firms can easily liquidate working capital. Petersen and Rajan (1997) found that when firms are confronted by tight money they make intensive efforts to collect accounts receivable (to cut accounts receivable) to overcome their weak liquidity. Fazzari and Petersen (1993) also found evidence that firms use liquid assets as collateral for short-term borrowing, which increases current liabilities, leading to a reduction in net working capital.

4.3.4.3 R&D investment smoothing with working capital

The main distinguishing characteristic of R&D is the size of adjustment costs (see Himmelberg and Petersen, 1994; Brown and Petersen, 2011). Because R&D investment is associated with high adjustment costs and is financed using volatile sources, firms will find it very expensive to adjust the flow of R&D in response to transitory finance shocks. Thus, firms facing binding financing constraints may not be able to maintain a relatively smooth path of R&D spending, and therefore they should have strong incentives to build up and manage a stock of liquid reserves, in the form of working capital for example, in order to dampen the shocks of cash flows, and to maintain a relatively smooth path of R&D spending.

In this context, Fazzari and Petersen (1993) advocate the idea of investment smoothing[32] with working capital. When there is a negative shock to cash flow, the shadow value of finance will rise for firms that are financially constrained. In response, they will reduce their rate of asset

because of the significantly high costs (for example, the difference in costs between the capital purchasing price and the resale market price) (Chirinko and Schaller, 2009; Ding *et al*. (2013). Scholars argue that this problem is severe, especially when capital goods are industry-specific or highly specialized.

[32] Please refer to sections 5.3.3 and 5.3.4 for more details on R&D investment smoothing.

accumulation; firms prefer to cut investment in working capital proportionally more than other investments. Firms choose working capital to absorb most of the temporary cash flow fluctuation rather than other investments in order to reduce the potential losses and adjustment costs that could arise due to the temporary cutting of those already in progress. However, because working capital is reversible, it is argued that it can even become a source of funds for firms that choose to reduce or even have a temporary negative level of working capital investment (Fazzari and Petersen, 1993; Ding *et al.*, 2013). Therefore, the existence of working capital can be considered as an alternative source of funds for firms during short-run financing constraints. A symmetric argument is applied in response to positive cash-flow shocks.

Weigand and Audretsch (1999) point out that the extent of investment smoothing depends on firms' stock of working capital[33]. The higher this is, the lower its marginal value to firms. Therefore, firms will be more willing to use it to offset negative shocks to cash flow. If the stock of working capital is relatively low, there will be fewer opportunities for investment smoothing, and so cash flow shocks will have a marginally higher impact on firms' investment. In this sense, Fazzari and Petersen (1993) conclude that the strength of a firms' working capital position can affect the link between its investments, for example R&D investment, and internal and external cash flows.

A number of studies provide theoretical models showing how the stock of working capital and its accounts can benefit firms facing financing constraints. However, as cash holding is a component of working capital accounts, Bigelli and Sánchez-Vidal (2012) found empirical evidence that firms determine their optimal cash holding based on the trade off between the costs of holding liquid assets and the benefits of reducing the need for costly external finance

[33] Fazzari and Petersen (1993) and Weigand and Audretsch (1998) argue that firms use working capital as a stock of precautionary liquidity, as it provides insurance against future shortfalls in cash. Therefore, the marginal value of working capital to firms rises as its stock declines.

to fund future investment opportunities. However, with regard to transaction costs and the risk of future cash shortfalls, Han and Qiu (2007) found evidence that constrained firms can save such costs by increasing their cash holding, especially when they cannot fully diversify the risk of future cash flow, as they can trade-off between future and current investments. Almeida *et al.* (2004) point out that the benefit for firms of holding cash can be seen in their ability to finance future projects that might arise. If future growth opportunities are expected to be greater than the current ones, the more cash firms will store. Acharya *et al.* (2007) provide empirical evidence that constrained firms with high hedging needs prefer to have higher cash balances to hedge future investment against future income shortfalls.

More specifically, with regard to the role of cash holding as a component of working capital accounts on R&D smoothing, Brown and Petersen (2011) investigated the role of corporate cash holding in buffering R&D investments from transitory finance shocks. They found that firms' paths of R&D investment are less volatile than their key sources of funds, so they smooth such investments by drawing down cash holdings in cases when financing is unavailable, and build up their reserves when financing is available. Similarly, Guariglia and Liu (2014) found that the R&D expenditure of small unlisted Chinese firms was constrained by the availability of internal finance, and that firms smoothed their R&D investments by drawing down cash holdings when faced with transitory finance shocks.

Trade credit, or accounts payable, is a component of working capital accounts. Petersen and Rajan (1997) suggest that trade credit is the most important source of external finance for firms, especially young and small ones. They point out that suppliers have advantages for firms over traditional lenders (specialized financial institutions); trade credit provides access to capital for firms that are unable to raise it through traditional channels. However, they argue that suppliers may be better at evaluating and controlling the credit risk of buyers than the traditional specialized financial institutions. In this sense, Petersen and Rajan found empirical evidence that small firms (whose access to the capital markets is limited) use more trade credit, especially when credit from financial institutions is unavailable.

By considering accounts receivable as another component of working capital accounts, Deloof (2003) argues that when firms have a shortage of cash balances and do not have access to external sources of finance, they reduce their investments in accounts receivable to free up liquidity. When they are able to obtain funds at low costs, they increase their investment in accounts receivable, increasing their trade credit to firms who are facing limited access to traditional lenders or facing higher financing costs. Deloof argues that firms who have better financial balances invest more in trade credits, as they are marginally considered as one of the most profitable short-term investments. Such a view confirms the findings of Petersen and Rajan (1997), who found that firms with limited access to traditional financial institutions rely on trade credit as a source of external finance.

Fazzari and Petersen (1993) found empirical support for the role of working capital in finance constraints on fixed investment. They point out that working capital is used by firms as a source of liquidity to smooth fixed investment relative to negative cash-flow shocks, and that it is considered to be an important use of funds if firms are facing finance constraints. Furthermore, Ding *et al.* (2013) analyse firm sensitivity to investment in fixed and working capital to the fluctuation in cash flow. They found that in the presence of fluctuations in cash flow, large and mature firms adjust their investment in fixed capital, while in response to cash flow shocks, young and small firms tend to maintain smooth fixed investment levels by adjusting working capital. Considering different industries, Weigand and Audretsch (1999) point out that as with non-science-based firms, in the presence of cash flow shocks and liquidity constraints, science-based firms[34] smooth their investment significantly by adjusting their investment in working capital.

A number of studies provide theoretical and empirical support for how working capital and related accounts can help firms facing financing frictions to smooth their investments. This chapter of the thesis comprises unique research in two important ways. First, we direct examining the use of working capital for smoothing R&D investment rather than fixed investment (Fazzari and Petersen, 1993). Second, we use working capital rather than one of its individual accounts, for example the role of cash holding on R&D smoothing (Brown and Petersen, 2011; Guariglia and Liu, 2014). The aim of this work is to examine to what extent the AIM-listed firms are able to adjust their working capital instead of their R&D investment in the presence of fluctuations in cash flows, to alleviate the effects of cash flow shocks on R&D. The work is similar to that of Fazzari and Petersen (1993), who conducted a similar investigation into the role of working capital in finance constraints on the fixed investment of US firms. They found that firms are indeed able to dampen the effects of cash flow fluctuation by using working capital.

To the best of knowledge, this is the first study to explore how the use of external sources of finance and active R&D smoothing with working capital influence financing constraints on R&D. The lack of evidence for why the sources of finance matter for R&D in the UK is a puzzle, and calls into question whether financing constraints play an important role in R&D and innovation in the modern economy. A second contribution is that whereas most previous empirical studies which have examined the existence and importance of financing constraints on R&D were based almost exclusively on testing large and mature firms, this work is more

[34] Those firms which are engaged in science-based activities; that is, associated with a high degree of information asymmetries and a greater degree of uncertainty, for example R&D performing firms (Weigand and Audretsch, 1998).

focused on young, small listed firms. It could be argued that investigating whether financial constraints may play a significant role in the R&D investment of young, small and high growth firms can dramatically alter the conclusions regarding the importance of financing constraints. This work fills these gaps in the literature by focusing on the case of the UK, with particular attention paid to young, small listed firms on AIM.

The third contribution of this work is that it provides accurate and more decisive tests for the presence of financing constraints on R&D investment by employing the overlooked role of working capital. In particular, if financing constraints matter for R&D, a negative link between it and the changes in net working capital should be observed, implying that firms draw down liquidity reserves in form of working capital for R&D smoothing. The present study is the first of its kind that tests the role of working capital in R&D smoothing, emphasizing its importance for a firm's financial policies. The fourth contribution is that a large number of researchers rely on either firm age or size, or the firm's dividend pay-out ratio criteria, to separate the sample into constrained and unconstrained[35] firms; this research aims to contribute to the literature by considering the three mechanisms of dividing firms into the two categories. This approach will add a more precise classification to the sample firms, and will eliminate any potential biases in the previously applied techniques which could affect the empirical results and conclusions drawn.

[35] Researchers argue that small or young firms are more prone to financing constraints (having high levels of information asymmetric) than large or mature firms, and firms with zero dividend pay-outs are more financially constrained than firms with positive dividend pay-outs (Fazzari and Petersen., 1993; Weigand and Audretsch., 1999; Brown and Petersen., 2011).

4.3.5 Hypothesies development

Taking into consideration the role of external and internal financing for R&D expenditure, together with the findings of previous empirical studies, this section presents this study's four testable hypotheses on the effect and the role of each financial tool on the level of R&D investment.

R&D investment helps firms to attain better performance through developing new services and products (Cohen and Levinthal, 1989). Firms keep certain levels of R&D investment to generate new products and develop new production processes which provide some differentiation that leads to competitive advantages over competitors (Bosworth *et al.*, 1993). The most important characteristic of R&D investment is the size of adjustment costs[36]. R&D investment, rather than any other type of investment, can be differentiated in terms of riskiness, collateral value and the cost of adjustment. R&D is considered much more risky than other investments, and offers little or no collateral value ((Himmelberg and Petersen, 1994; Wang and Thornhill, 2010). Firms' sources of funds are internally and externally generated. Internally generated funds are in the form of internally generated cash flow, while externally generated funds are in form of cash generated through stock and debt issues. Due to financial market imperfections, external sources of funds are considered to be more expensive than internal sources (Myers and Majluf, 1984). These imperfections are adverse selection (when two parties have different information sets prior to a deal) and moral hazard (asymmetry in information due to the inability to observe behaviour after the deal). Moral hazard is empirically the more dominant of the two (Toivanen and Cressy, 2002). Equity finance incurs sizable flotation costs for initial offerings, with a lemon premium for new stock issues (Myers and Majluf, 1984). Debt finance incurs interest

[36] Adjustment costs in this context are defined as the costs associated with making any changes or cuts in R&D investment at the firm level (e.g. the costs of hiring and training new employees, or the costs of lost production in the case of having to lay off knowledge workers).

expenses (financial obligations), and increases the risk of financial distress (Wang and Thornhill, 2010). Thus, funds generated from stock and debt issues are considered to be expensive, especially for young and small firms. R&D-intensive firms use significantly little or no debt to finance their R&D investments, and prefer equity financing if needed to reduce the risk of financial distress and bankruptcy (Wang and Thornhill, 2010; Brown and Petersen, 2011). Although firms could rely on external sources of funds if they had the choice, they prefer not to invest at the margin if the rising costs of external funding are too high, and prefer internal cash flow as the source of funding. As summarized in the pecking order theory (Myers and Majluf, 1984; Myers, 1984; Oliner and Rudebusch, 1992), the availability of internal funds makes it easier for firms to undertake desirable investment projects without the need for expensive external funds, which enhances firms' worth by lowering the cost of funds (the availability of internal cash flow allows firms to invest more cheaply) (Bond and Meghir, 1994). Because of the cost preference for internal funds over external funds, this paper suggests that internal funding should be considered as the first source of finance for R&D investment (Fazzari and Petersen, 1993; Himmelberg and Petersen, 1994; Martinsson, 2010; Brown and Petersen, 2011; Brown *et al.*, 2012). It is therefore proposed that:

Hypothesis 1. *There is a positive relationship between R&D investment and financing through internally generated cash flow.*

R&D investment is risky by nature, and yields uncertain returns (Hall, 2002; Ho *et al.*, 2004) as the success of its output is not guaranteed, and will only generate cash profits with a time lag in the case of success (Himmelberg and Petersen, 1994; Brown and Petersen, 2011; Brown *et al.*, 2012). R&D-intensive firms would need to reduce their financial obligations in order to reduce the risk of financial distress and bankruptcy. Because their financial obligations are represented by interest expenses, this chapter assumes that R&D-intensive firms would try to limit their use of debt. Despite the fact that the success of R&D investment may lead to better financial performance (Cohen and Levinthal, 1989; Fazzari and Petersen, 1993), generating a stream of cash flows that would make financing through debt relatively cheaper, firms place more emphasis on factors that might threaten their survival. Therefore, firms with high levels of R&D investment will reduce their reliance on financing through debt to reduce the risk of financial distress and bankruptcy. According to the transactional cost economy, the asset-specificity of R&D investment has a lower resale value, which would shackle firms' access to debt financing (Wang and Thornhill, 2010). Although debt providers can intervene in the conduct of management to avoid risky decisions, and firm managers will to some extent have an incentive to act for the debt providers (Fazzari *et al.*, 1988), debt providers will seek protection against these types of risk. They may require a higher interest rate, they may select firms with higher asset resale values, or they may refuse to lend to firms with high levels of R&D investment that cannot serve as collateral (Wang and Thornhill, 2010). Hence, R&D-intensive firms with more specific assets will face difficulties in securing debt. Based on these facts, a negative relationship between R&D investment and debt financing is expected.

Hypothesis 2. *There is a negative relationship between R&D investment and financing through long-term debt.*

Common stocks do not require firms to pay fixed interest. Fewer financial obligations are in the interest of firms that heavily invest in R&D. This type of investment is risky by nature (Ho *et al.*, 2004). Innovation helps firms to attain better performance by developing new products (Cohen and Levinthal, 1989), which are subject to both technological and market uncertainties (Fazzari and Petersen, 1993). Market uncertainty makes it difficult to decide whether competitors' actions and customers' tastes will affect the value of the newly generated products (Cohen and Levinthal, 1989; Ho *et al.*, 2004). Technological uncertainty makes it hard to know if the R&D expenditure will result in new products or services (Fazzari and Petersen, 1993), and this expenditure will expose businesses to risk (Ho *et al.*, 2004). Reduced financial obligations through common stock financing will help R&D-intensive firms buffer expected failures in R&D projects. However, R&D investment is considered as resource-consuming. Scholars have explained that reduced financial obligations through common stock financing can be considered as supportive sources for R&D investment (Martinsson, 2010; Brown *et al.*, 2012). The benefits to the common stockholders are the residual profits of the firm (Auerbach, 1979) which may be raised through R&D investment. Success of such investment helps firms build their specific resources (Ho *et al.*, 2004), thus leading to improvement in performance. The risk attached to R&D investment could expose the holders of common stocks to losses, although they can mitigate this unsystematic risk through portfolio diversification (Brenner and Smidt, 1978). Accordingly, this chapter suggests that common stock is an ideal financing means for both R&D-intensive firms which have exhausted all of their internally generated cash flow, and for their common stock investors.

Hypothesis 3. *There is a positive relationship between R&D investment and financing through common stock issues.*

The most important characteristic of R&D investment is the size of adjustment costs. R&D is considered much more risky than other investments, and offers little or no collateral value (Himmelberg and Petersen, 1994; Wang and Thornhill, 2010). Such investment includes wage payments to highly skilled and trained workers, who require considerable firm-specific training. These workers cannot be made redundant in the case of any temporary cutting back on R&D

activity in response to any financing shocks. If the cut in the R&D is temporary, firms should bear the additional costs of hiring and training new workers in the future. Potentially more costly is the fact that these workers know valuable information and firm-specific commercial secrets, which firms do not intend to transfer or share with their competitors. The dissemination of information that a fired worker may transfer to competitors is considered too costly for firms, as such a situation would damage the value of innovation being undertaken by them. This investment is often conducted in teams, and continual turnover of workers would lead to undesirable and costly disruptions in the process. These reasons suggest that R&D investment has a higher adjustment cost than other types of investment (Himmelberg and Petersen, 1994; Brown *et al.*, 2012; Brown *et al.*, 2013). For firms to minimise these significant adjustment costs, they should maintain a smooth R&D path (Brown and Petersen, 2011). For unconstrained firms, smoothing R&D investment is straightforward, as there are multiple sources of finance (such as stock issues) that can be used to recompense for internal finance shocks. On the other hand, for constrained firms with high R&D intensity, other sources of external funds may be extremely costly or may be unavailable for them to dampen the shocks of internal finance, especially during periods of negative shocks (Bond and Meghir, 1994). Another potential source of funds for smoothing could be debt, but the asset-specificity of R&D makes smoothing with debt problematic (Wang and Thornhill, 2010). Both external and internal financing sources are volatile (Petersen and Rajan, 1997). For these constrained firms, the strategy of smoothing R&D is to not rely on external sources of funds, but to build and manage a reserve of liquidity, for example in a form of working capital. The key differences between R&D and working capital investments are the liquidity of the latter and its reversibility (Fazzari and Petersen, 1993; Weigand and Audretsch, 1999). During negative cash flow shocks, firms prefer to cut investment in working capital proportionally more than other investments because of its liquidity and reversibility (Fazzari and Petersen, 1993). Firms choose working capital investment to absorb most of the temporary cash flow fluctuation effects, in order to reduce the potential losses and adjustment costs that could arise due to temporary cutting back on projects in progress (Petersen and Rajan, 1997; Ding *et al.*, 2013). Constrained firms can offset the short-run effect of cash flow fluctuation on R&D investment by adjusting working capital (Fazzari and Petersen, 1993; Chan, 2008). Although this action may lead to a negative net working capital position, it would release short-run liquidity, and would allow firms to offset cash flow shocks and smooth their R&D investment activities. Based on the above discussion, this chapter suggests that working capital is the last resort for smoothing R&D investment if firms are facing binding cash flow shocks and financial constraints.

Hypothesis 4. *In financially constrained firms, working capital acts as the last resort for smoothing R&D investment. A decrease in working capital will result in an increase in R&D investment.*

Based on our predictions, in the case of firms that are facing binding financial constraints, working capital investment competes with R&D investment for the available pool of finance. In these circumstances, working capital investment as a variable in the R&D investment regression should have a negative coefficient sign (i.e. a reduction in working capital frees liquidity for R&D smoothing). However, for firms not facing binding financial constraints, there is no role for working capital on smoothing R&D. Accordingly, the expected sign for the working capital coefficient in the model should be negative and significant for constrained firms, and positive and insignificant for unconstrained ones.

4.4 Data and preliminary analysis

4.4.1 Data and measurement

In order to empirically examine the determinants of firms' R&D expenditure, the existence of financial constraints on R&D, and the role that working capital plays in smoothing R&D, we estimate a general equation for R&D investment. Our sample comprises all surviving and non-surviving (inactive) firms that were listed on the Alternative Investment Market (AIM) at any time between 1999 and 2014, with coverage on the Worldscope database and the official site of the London Stock Exchange. We collected annual data from the Worldscope database via DataStream and Thomson One Banker Analytics database, and the London Stock Exchange official site. Only the listed firms in manufacturing (two-digit SIC 20-39) and service (two-digit SIC 73) industries were included in the sample, since R&D investment mainly takes place in these areas.

Based on our data, as of December 2014, 1859 firms had been listed firms on AIM, of which 933 were delisted. After inspection, 746 firms were considered to be our target population, all in the manufacturing and service industries. However, 379 firms from our dataset were inactive, having been delisted from the market at some time during the period 1999 to 2014. The data forms an unbalanced panel, on which not all of the firm-year observations were available for our firms during the entire testing period. This unbalanced panel was formed to avoid survivorship bias[37]. A summary of these results is given in Figure 4-3.

[37] Elton et al. (1996) defined survivorship bias as the tendency to exclude failed (inactive) firms from a sample study because they no longer exist. This bias often causes the obtained results to be skewed higher as a result of only including active or surviving firms. However, further investigations on the breakdown reasons for delisting is required, based on the investigation by Pour and Lasfer (2013), significant number of AIM-firms' delisting was recorded as a voluntary.

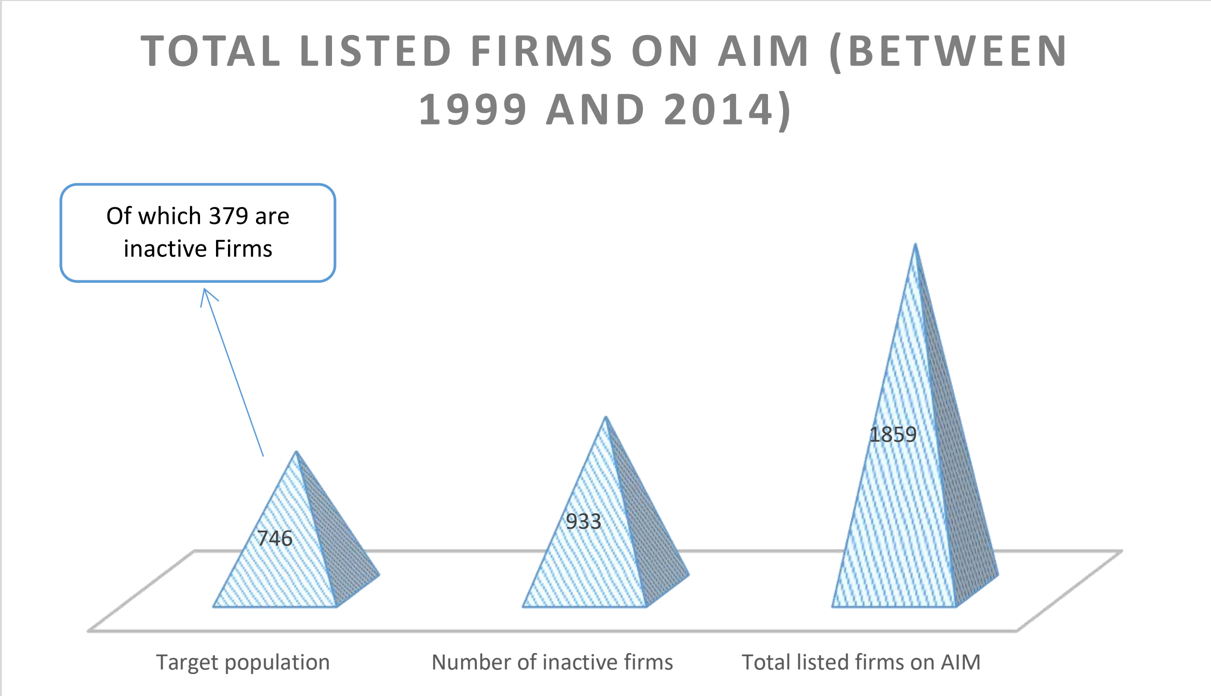

Figure 4-3: Summary of all listed firms on AIM between 1999 and 2014 and the target population.

Our target population was divided into two groups, based on whether firms were undertaking R&D expenditure or not in our given sample period. It is worth noting that the firms reporting no R&D were in industries which traditionally do little or no R&D, that is, firms listed in the textile products, apparel, furniture, lumber, printing and publishing industries.

This research will primarily focus on the R&D reporting firms, while non-R&D firms will be excluded from the sample as they are not useful in the analysis of the determinants of firms' R&D investment expenditure model (these excluded firms do not report any information on R&D expenditure; that is, R&D reports are missing rather than zero), while they are useful for understanding how the level of financial variables differs across firms. This chapter covers the period of 1999 to 2014 because the Alternative Investment Market was launched in 1995, and information of the listed firms for the years 1995-1998 are not available on the databases. Table 4-1 gives a brief description of the main variables used in this chapter.

Table 4-1: Description of the main variables used in this chapter [a]

R&D $_{it}$: The ratio of the research and development expenses of firm ***i*** at time ***t*** divided by the book value of total assets at the end of time ***t-1***. [b]

MktBook $_{it}$: The ratio of the market value of the total assets of firm ***i*** at time ***t-1*** divided by the book value of total assets at time t_{-1}.

SGr $_{it}$: The change in net sales of firm ***i*** between the end of time t and the end of time t_{-1}, divided by the value of net sales at the end of time ***t-1***.

CF $_{it}$: The ratio of the gross internally generated cash flow of firm ***i*** at time ***t*** divided by the book value of the total assets at the end of time t_{-1}, where the gross cash flow is defined as after tax income before extraordinary items and preferred dividend, plus depreciation, depletion and amortisation expenses and research and development expenses [c].

Stk $_{it}$: The net cash raised from the stock issues of firm ***i*** at time ***t*** divided by the book value of total assets at the end of period t_{-1}, where net cash raised from stock issues is equal to sales or the issuance of common and preferred stocks, minus the purchase of common and preferred stocks.

LTD $_{it}$: The net cash raised from the long-term debt issues of firm ***i*** at time ***t*** divided by the book value of total assets at the end of period t_{-1}, where net cash raised from long-term debt issues is equal to long-term debt issues minus long-term debt reductions.

Δ***WC*** $_{it}$: The change in the stock of net working capital of firm ***i*** between the end of time ***t*** and the end of time t_{-1}, divided by the book value of total assets at the end of time t_{-1}, where net working capital is current assets, defined principally as cash and equivalents, inventory and accounts receivable, minus current liability, chiefly accounts payable and short-term debt.

Notes:
[a] The measurement of variables and definitions are based on the existing literature.
[b] The data were collected from Datastream and Worldscope via Thomson One Banker Analytics.
[c] Since firms treat R&D as an expense, R&D has been added back into the usual accounting definition of cash flow (Himmelberg and Petersen, 1994; Brown and Petersen, 2011).

4.4.2 Summary statistics

As noted previously, the presence of outliers in the datasets can strongly affect the parameter estimates. Verardi and Croux (2009) and Brown and Petersen (2011) point out that the values of the Cash flow-to-Total assets and R&D investment-to-Total assets ratios and the Market-to-Book values outside the 1st and the 99th percentile range may affect the parameter estimates, and so should be screened to reduce the potential influence of outliers on the parameter estimates. Therefore, we winsorized the sales growth (***SGr***) and cash flow (***CF***) of the explanatory variables in our analysis at 1st and the 99th percentiles of their respective distribution. The winsor transformation specifically set all observations below the 1st percentile equal to the 1st percentile, and set observations above the 99th percentile equal to the 99th percentile. Such transformation reduces the potential impacts of the outliers, as well as allowing usage of the full data set.

Panel A of table 4-2 presents the summary statistics of the main variables for the firms reporting no R&D, and Panel B shows the statistics for those which did report R&D. These statistics are based on firm-year observations, and all investment and finance values are scaled by the book value of total assets at the end of period *t*-1. The no R&D reporting sample is almost two-thirds in size as the sample of R&D reporting firms.

Apart from the absence of R&D in panel A, and considering the results of the means equality tests shown in table 4-3, there are three noteworthy differences between the descriptive statistics reported in the two panels. The first difference is that the mean value of cash flow (***CF***) of the no R&D reporting firms is negative and significantly lower than the R&D reporting firms, at -5% compared to 1% for the no R&D firms. The negative ***CF*** mean value of the no R&D reporting firms could indicate that these firms are not profitable enough to engage in R&D investments (Brown and Petersen, 2011). Alternatively, it could be that a large number of these firms are newly listed and so expecting a negative mean of cash flow.

Table 4-2: Summary statistics for the main variables used in this chapter [a].

Panel A: Firms reporting no R&D (323) Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness	Obs.
R&D	.	.	.	.	.	.	0
MktBook	3.20	1.48	-2424.0	1140.05	64.95	-19.79	2284
SGr	0.36	0.06	-1.00	70.17	2.69	18.88	2078
CF	-0.05	0.06	-7.78	0.58	-2.96	83.53	2114
Stk	0.20	0.00	-48.38	54.35	2.08	6.79	2038
LTD	0.09	0.00	-0.03	55.23	1.29	40.69	1935
ΔWC	-0.05	0.01	-203.65	65.90	5.04	-31.29	2092

Panel B: Firms reporting R&D (423) Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness	Obs.
R&D	0.13	0.06	0.00	5.66	0.25	9.10	2011
MktBook	2.93	1.70	-2424.48	1412.16	63.62	-20.74	2130
SGr	0.46	0.08	-1.00	46.51	2.59	11.13	1969
CF	0.01	0.07	-4.77	4.75	0.43	-3.31	2009
Stk	0.28	0.00	-0.71	28.16	1.24	14.04	1930
LTD	0.06	0.00	0.00	13.03	0.39	29.50	1831
ΔWC	0.08	0.00	-3.02	26.64	0.88	19.04	2011

Note:
[a] All variables are winsorized at the 1% level.

The second difference is that the no R&D firms issued little stock compared to the R&D reporting firms, 20% compared to 28% for the R&D firms. On average, this supports the argument of Myers (1984) in the pecking order model. R&D performing firms prefer to finance their projects through stock issuance rather than debt (Brown *et al.*, 2012; Wang and Thornhill, 2010; Martinsson, 2010); firms engaged high risk projects would need to reduce their financial obligations in order to reduce their risk of financial distress. Finally, and the most important difference to note, is that the mean value of the net working capital of the R&D firms is relatively high compared to the no R&D group. This observation may suggest that firms with a high need for investment smoothing carry more assets in the form of current accounts, which might be used in periods with cash flow fluctuation/shortfalls in the future.

Table 4-3: Results of the independent means-equality *t*-test between firms with R&D expenditure and those without.

Variable Name	Levene's test of equality of variances [a]		*t-test for equality of means*					95% confidence interval of the differences	
	F	*P-value*						Lower	Upper
Equal variance assumed	1.0422	0.3319	0.1394	4412	**0.8892**	0.27	1.9371	-3.5278	4.0678
Equal variance not assumed			0.1395	4401.37	0.8891	0.27	1.9357	-3.5250	4.0650
Equal variance assumed	1.0787	0.0888	-1.2036	4045	0.2288	-0.1	0.0830	-0.2628	0.0628
Equal variance not assumed			-1.2048	4043.96	**0.2283**	-0.1	0.0830	-0.2627	0.0627
Equal variance assumed	1.8194	0.0000	-3.7580	4121	0.0002	-0.06	0.0159	-0.0913	-0.0286
Equal variance not assumed			-3.7859	3893.49	**0.0002**	-0.06	0.0158	-0.0910	-0.0289
Equal variance assumed	2.8137	0.0000	-1.4615	3966	0.1439	-0.08	0.0547	-0.1873	0.0273
Equal variance not assumed			-1.4806	3353.99	**0.1388**	-0.08	0.0540	-0.1859	0.0259
Equal variance assumed	10.9408	0.0000	0.3182	3764	0.7503	0.01	0.0314	-0.0516	0.0716
Equal variance not assumed			0.3256	2302.96	**0.7447**	0.01	0.0307	-0.0502	0.0702
Equal variance assumed	32.8017	0.0000	-1.1401	4101	0.2543	-0.13	0.1140	-0.3535	0.0935
Equal variance not assumed			-1.1615	2223.41	**0.2456**	-0.13	0.1119	-0.3494	0.0894

Note:
[a] The null hypothesis of Levene's test is that there is equal variance (homogeneity of variance) between the two groups - the no R&D reporting firms and the R&D reporting firms.

However, considering the summary statistics of panel B (R&D reporting firms), there are two figures that are particularly important. First, the mean value of new stock issues, 0.28, is larger than the mean value of internally generated cash flow, 0.01, showing the importance of new stock issues as a source of funds. Second, the mean value of the change in net working capital is well above the internally generated cash flow, and relatively lower than stock issues, showing that firms have an intent to maintain liquidity that can potentially be used to offset future finance shocks and buffer R&D investment.

4.4.3 **Correlation coefficients**

Table 4-4 shows the pair-wise correlation matrix of the main variables used in this chapter after excluding the no R&D firms. It shows that the four sources of funds (*CF, Stk, LTD and the* ΔWC) are significantly correlated with one another.

Table 4-4: Correlation coefficient matrix of the variables used in this chapter.

Variable	*R&D*	*MktBook*	*SGr*	*CF*	*Stk*	*LTD*	ΔWC
R&D	1.00						
MktBook	0.1068 ***[b]	1.00					
SGr	0.1354 ***	0.0060[a]	1.00				
CF	-0.2061 ***	-0.0570 **	-0.0395 *	1.00			
Stk	0.6691 ***	0.0673 ***	0.0711 ***	-0.2632 ***	1.00		
LTD	0.2023 ***	0.0094	0.2243 ***	-0.0776 ***	0.1340 ***	1.00	
ΔWC	0.4005 ***	0.0946 ***	0.0544 **	0.1318 ***	0.7513 ***	0.0823 ***	1.00

Notes:
[a.] The reported figure in each cell is the pair-wise Pearson correlation coefficient between variables.
[b.] $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

R&D is significantly correlated with all of the sources of funds, which is entirely consistent with the implications of the determinants of the R&D investment expenditure framework. It also shows that the sales growth is positively and significantly correlated with R&D investment, and the *MktBook* ratio is significantly correlated with R&D, the controls for the investment demand in our model.

However, after excluding the no R&D reporting firms from our tested sample, the total number of R&D reporting firms becomes 423. Further, we require firms to have at least six records for the essential variables from 1999-2014, namely R&D, total assets, cash flow, new stock and debt issues, since we are using the system-GMM estimators that rely on the variables' lagged values as instruments. Excluding firms with no R&D reports and firms with fewer than four records of the essential variables leaves us with a final sample of 235 firms.

4.5 The dynamic model of R&D investment

4.5.1 Methodology

One of the core assumptions in regression analysis is that explanatory variables should not be correlated with the disturbance term (u_i).

$$y_i = X_i + u_i \qquad (1)$$

$$E\ (X_i\ u_i\ ) = 0$$

However, in reality such an assumption can be violated, as there could be some endogenously determined variables or variables measured with errors on the right-hand side of the equation, which results in biased and inconsistent estimations of the OLS estimator. Wooldridge (2010) argues that the standard approach to such a problem of "endogeneity" can be overcome by using instrumental variable regression. This approach works by finding a set of variables that is correlated with the original explanatory variables, but not with the disturbances in the main equation. However, Baum *et al.* (2003) and Wooldridge (2010) state that the key approaches using instruments to remove the effect of residual and variable correlations are the Two-Stage Least Squares (2SLS) and the Generalized Method of Moments (GMM) estimators.

According to Wooldridge (2010), the two-stage least squares estimator is considered as a special case of instrumental variable regression. The procedure works in two distinct stages. The first stage is carried out to find the proportion of the exogenous and endogenous variables that can be assigned to the instruments. This stage involves running an OLS regression for each of the endogenous variables on the set of instruments. The second stage is the regression of the original equation, where all the variables are replaced by the fitted values obtained from the first stage regressions. The coefficients acquired from the second stage are the 2SLS estimates.

Let us denote the matrix of instruments as Q, and the explanatory and dependent variables as X and Y. The linear 2SLS objective function is given by:

$$\varphi(\beta) = (y - X\beta)'Q(Q'Q)^{-1}Q'(y - X\beta) \qquad (2)$$

Then the acquired coefficients from the two-stage least squares regression are presented by

$$\beta_{2SLS} = (X'Q(Q'Q)^{-1}\,X'Q)^{-1}X'Q(Q'Q)^{-1}Q'y \qquad (3)$$

and the coefficients' standard estimated covariance matrix can be calculated using

$$\widehat{\Sigma_{2SLS}} = S^2(X'Q(Q'Q)^{-1}X'Q)^{-1} \qquad (4)$$

where S^2 is the regression squared standard error (estimated residual variance).

$$S^2 = \sum_t^T u_t^2/(T - K) \qquad (5)$$

K in the estimated residual variance equation represents the unknowns, while $(T - K)$ represents and refers to the degree of freedom.

The regression residuals $\hat{u}_t$ are calculatied as follows:

$$\hat{u}_t = y_t - X_t'\hat{\beta}_{2SLS} \qquad (6)$$

These regression residuals are different from the second stage ones, which we can obtain if we run the two-stage least squares estimator separately. The second stage residuals can be obtained by:

$$\widetilde{u}_t = \widehat{y}_t - \widehat{X}_t{}'\beta_{2SLS} \qquad (7)$$

where the $\widehat{X_t}$ and $\widehat{y_t}$ are the obtained fitted values from the first-stage regressions.

However, in the area of corporate finance, dynamic panel models play a natural role in this area of research because most corporate decisions involve inherently dynamic interactions. The 2SLS estimator is considered to be a biased estimator for many reasons. Flannery and Hankins (2013) argue that such dynamic models that empirically investigate corporate decisions require the use of firm-fixed effects to control for differences across firms (i.e. to control for unobserved time-invariant effects). Since 2SLS estimates ignore the dynamic panel structure of the data, Flannery and Hankins argue that applying the 2SLS estimator, in the presence of unobserved heterogeneity, in dynamic panels produces an upward-biased coefficient estimate for the lagged dependent variable. The biased coefficient of the lagged dependent variable is due to the correlation between it and the fixed effect. For these reasons, the system GMM estimator has become a widely used approach in estimating dynamic panel data in the area of corporate finance. The system GMM estimator contains large sample properties that are easy to describe and make comparisons easier. Another reason make GMM is widely used by researchers is that they have found that constructing the GMM estimator can be approached without specifying the full data generating process (Hansen, 2010).

Theoretically, the instrumental variable estimator is a special case of the GMM technique (Hansen and Singleton, 1982; Baum *et al.*, 2003). The assumption of exogeneity of the instruments Q_i can be expressed as E $(Q_i\ u_i) = 0$. The L instruments provide a set of L moments,

$$g_i(\widehat{\beta}) = Q_i'\hat{u}_i = Q_i'(y_i - x_i\hat{\beta}) \quad (8)$$

where g_i is L × 1. The instruments' exogeneity means that there are orthogonality conditions, or L moment conditions, that will be content at the true value of β:

$$E\{g_i(\beta)\} = 0 \quad (9)$$

Each of the L moment equations is consistent with a sample moment; these L sample moments can be written as:

$$\bar{g}(\widehat{\beta}) = \frac{1}{n}\sum_{t=1}^{n} g_i(\widehat{\beta}) = \frac{1}{n}\sum_{t=1}^{n} Q_i'(y_i - x_i\hat{\beta}) = \frac{1}{n}Q'\hat{u} \quad (10)$$

The purpose of using the GMM procedure is to obtain an estimator for β that solves $\bar{g}(\hat{\beta}) = 0$. If L = K, then equations are called to be exactly identified, and so we have as many equations as we have unknowns. In such a circumstance, it is possible to find $\hat{\beta}$ that solves $\bar{g}(\widehat{\beta}) = 0$, and this GMM estimator is exactly the same as the 2SLS estimator. In the case of the over-identified equations (i.e. L > K), then we do have more equations than we have unknowns, where generally speaking it will be impossible to find $\hat{\beta}$ that solves $\bar{g}(\widehat{\beta}) = 0$. In this circumstance, we use the L × L weighting matrix (W) to construct a quadratic form in the moment conditions. The GMM objective function in this case can be expressed as:

$$j(\hat{\beta}) = n\bar{g}(\hat{\beta})'W\bar{g}(\hat{\beta}) \quad (11)$$

A $\hat{\beta}$ that minimizes $j(\hat{\beta})$ is the GMM estimator for β; the GMM estimator can be obtained by solving and deriving the K first-order conditions, and can be expressed as:

$$\hat{\beta}_{GMM} = (X'QWQ'X)^{-1}X'QWQ'y \quad (12)$$

Flannery and Hankins (2013) and Roodman (2009) argue that the system GMM estimator is designed for panel data analysis, and is considered as the best econometric methodology to use in estimating dynamic models in corporate finance. The system-GMM estimator is designed to cope with the different assumptions about the data-generating process. This estimator is designed to cope with the dynamic generating process; that is, when lagged dependent variables influence the realization of the current dependent variable. Second, it copes with the presence of unobserved heterogeneity and controls for unobserved time-invariant effects. Third, this methodology is designed to cope with the endogeneity problem associated with the explanatory variables. Fourth, it is specially designed to deal with panels that are characterized by few time periods and many individuals (small T and large *N*), and also to cope with the assumption that good instruments are not available outside the immediate data set; that good instruments are only available (internally) based on the lags of the instrumented variables.

However, this chapter will investigate the connection between R&D investment and all financial variables, namely internally generated cash flow, net stock issues, and net debt issues (Brown and Petersen, 2011; Brown and Floros, 2012). The focus will be on the changes in net working capital to examine the role that working capital (as a source of funds rather than a use of funds) plays in buffering the path of R&D spending from transitory finance shocks in a standard dynamic investment model. However, the variables that control for a firm's investment demand (namely market-to-book ratio and the sales growth) are also included in the model. The form of our empirical model is as follows:

$$\boldsymbol{R\&D_{i,t} = \beta_1 R\&D_{i,t-1} + \beta_2 R\&D^2{}_{i,t-1} + \beta_3 MktBook_{i,t} + \beta_4 SGr_{i,t} + \beta_5 CF_{i,t} + \beta_6 CF_{i,t-1} + \beta_7 Stk_{i,t} + \beta_8 Stk_{i,t-1} + \beta_9 LTD_{i,t} + \beta_{10} LTD_{i,t-1} + \beta_{11} \Delta WC_{i,t} + \beta_{12} \Delta WC_{i,t-1} + f_i + d_t + \varepsilon_{i,t}} \quad (13)$$

Based on the dynamic optimisation "Euler condition", this model includes the quadratic term of the lagged dependent variable $\boldsymbol{R\&D^2{}_{i,t-1}}$ which controls for the desired level of R&D

investment in the presence of adjustment costs. R&D is highly persistent; accordingly, we expect the coefficient of $\boldsymbol{R\&D_{i,t-1}}$ be close to one, while we expect the coefficient of the $\boldsymbol{R\&D^2{}_{i,t-1}}$to be negative. This model also includes the firm-fixed effects ($\boldsymbol{f_i}$), to control for all unobserved determinants of R&D at the firm-specific level (e.g. industrial and technological characteristics), year-fixed effects ($\boldsymbol{d_t}$) to control for any shocks that may influence R&D demand (e.g. macroeconomic fluctuations), and $\boldsymbol{\varepsilon_{i,t}}$ (which denotes white noise disturbances).

Table 4-5 summarizes the expected effect of each of the explanatory variables on R&D investment in empirical results according to the existing literature. The expected signs of each of the explanatory variables are consistent with the main predictions of our stated hypotheses and the existing literature. Table 4-5 summarises all the variables used in the literature on R&D investment; each row of the table shows the name of the researcher/researchers, the variables used and the results obtained. Based on the main expected relation of each of the explanatory variables with R&D investment, a tick (✓) has been used to indicate that this variable has been used by previous researchers, and that the finding of this variable is consistent with the theoretical prediction. Furthermore, a cross (×) has also been used to indicate that the variable has been used by previous researchers, but that the findings of this research were not consistent with the theoretical predictions as expressed in the expected signs row.

Table 4-5: Expected effect of the explanatory variables on the R&D investment, and their previous empirical results.

	Dependent Variable	***Explanatory Variables***						
	Research and development investment (R&D)	Lag dependent (L.R&D)	Market-to-book ratio (MktBook)	Sales growth (SGr)	Internally generated cash Flow (CF)	Net new stock issues (Stk)	Net new long-term debt issues (LTD)	Change in net working capital (ΔWC)
	Expected Sign	(+)	(+)	(+)	(+)	(+)	(-)	(-) constrained firms (+)unconstrained firms
References	Grabowski (1968)				✓			
	Link (1982)				✓			
	Switzer (1984)	✓		✗	✓			
	Hall (1992)	✓	✓	✗	✓		✓	
	Himmelberg & Petersen (1994)		✓	✓	✓			
	Bhagat and Welch (1995)	✓			✓	✓	✓	
	Bond *et al*. (1999)	✗		✓	✓			
	Czarnitzki (2006)	✓			✓		✓	
	Piga and Atzeni (2007)				✓		✓	
	Brighi and Torluccio (2009)				✓		✓	
	Wang and Thornhill (2010)	✓		✗	✗	✓	✓	
	Martinsson (2010)	✓		✓	✓	✓		
	Brown and Petersen (2011)	✓	✓	✗	✓	✓	✗	
	Brown *et al*. (2012)	✓	✓	✗	✓	✓		
	Brown and Floros (2012)	✓	✓	✗	✓	✓	✗	
	Borisova and Brown (2013)	✓	✓		✗	✓	✗	
	Shin and Kim (2014)		✓	✓	✓	✓	✗	
	Guariglia and Liu (2014)			✗	✓		✓	

References	***Dependent Variable***	***Explanatory Variables***						
	Fixed asset investment (FA)	Lag dependent (L.FA)	Market-to-book ratio (MktBook)	Sales growth (SGr)	Internally generated cash flow (CF)	Net new stock issues (Stk)	Net new long-term debt issues (LTD)	Change in net working capital (ΔWC)
	Expected Sign	(+)	(+)	(+)	(+)	(+)	(+)	(-) - constrained firms (+) - unconstrained Firms
	Fazzari and Petersen (1993)		✓		✓		✓	✓
	Weigand and Audretsch (1999)			✓	✓		✓	✓
	Ding *et al*. (2013)			×	✓			✓

Given the potential endogeneity of the explanatory variables[38] and the dynamic structure of the R&D investment model, we estimate our empirical model using the System Generalized Methods of Moments (system-GMM) estimator developed by Arellano and Bond (1991) and Blundell and Bond (1998). This estimator forms a system by combining an equation in differences of the variables with another equation of the levels of variables, in which the lagged differences will be used as instruments for the equation in levels and the lagged levels will be used as instruments for the equation in differences. The use of instruments in the system estimator addresses the weak instrument problem and is considered as a solution to the endogeneity problem (a causal connection between the independent and dependent variables).

In the application of the system-GMM estimators, we have a choice of using one-step or two-step estimation. The difference between the two estimations is that the one-step method assumes homoscedastic errors, while the two-step assumes heteroscedastic errors. Roodman (2009) states that the two-step estimator is asymptotically more efficient than the one-step. However, Roodman further states that the reported standard errors tend to be downward biased in the two-step estimation, and so it important to apply the finite-sample correction to the standard errors in the two-step estimations to correct the downward bias. Therefore, to estimate the dynamic equation of firms' R&D investment, we applied the two-step system-GMM estimators with finite sample correction to the standard errors.

All the financial variables, including $\Delta \boldsymbol{WC}$, were treated as potentially endogenous, and we used lagged differences dated *t*-2 as instruments for the regression in levels, and lagged levels dated *t*-3 to *t*-6 for the regression in differences. However, given the fact that the consistency of

[38] Since there is a causal connection between firm-level investment and the source of financing (internal or external), we treated all financial variables in our empirical model (including the change in working capital) as potentially endogenous ones (Bond and Meghir, 1994; Fazzari *et al.,* 1988; Flannery and Hankins, 2013). For example, a decision to raise funds through external sources is endogenous and jointly determined by the decision on where and how to spend the funds; further, a decision on the level of R&D investment is endogenous and jointly determined by the sources and levels of funds.

the system-GMM estimator depends on the assessment of the instruments' validity and the autocorrelation of the error terms, the instrument validity was checked by the Hansen *J*-test of over-identifying restrictions, and Arellano and Bond's (1991) test of autocorrelation.

According to the corporate finance literature, a large number of researchers rely on firm age or the firm size, apart from firm dividend pay-out ratios, to divide firms into groups which are either financially constrained or unconstrained. Since we are dealing with young and small firms, according to the previous literature these are considered to be more likely to be financially constrained, which is an important issue. We considered three ways of splitting the group, since we are already dealing with young and small firms. Fazzari *et al.* (1988) and Fazzari and Petersen (1993) argue that firms which are more likely to face financing frictions will have zero dividend pay-outs, while firms that are less likely to face these frictions will have positive dividend pay-outs.

Accordingly, the firms of our sample were classified into two groups, based on the dividend pay-out ratio. Firms with zero dividend pay-outs were classified as constrained firms, while those with positive pay-outs were classified as unconstrained[39]. The logic of this classification criterion is that when the marginal cost of external finance is considered much higher than the opportunities cost of internal funds, firms which exhaust their internal funds will be more susceptible to face binding finance constraints. In this case, firms will tie their investment spending to the level of their available internal funds (Fazzari *et al.*, 1988; Fazzari and Petersen, 1993).

[39] In this chapter we have classified our firm sample into two groups based on the dividend pay-outs criterion mainly because the age and the size techniques of splitting the sample have already been applied to the type of firms that we are dealing with (i.e. since the Alternative Investment Market was launched in 1995 and the cut off period of our research is 2014). This means our sample firms from the young firm group are based on the age classification and all the sample listed firms are considered as small firms, based on the number of employees classification (i.e. fewer than 500 employees).

However, considering the three ways of splitting the group, there is a more precise classification for the sample firms. This would eliminate any potential biases in the previous techniques applied, which could affect the empirical results and the conclusions drawn. Table 4-6 presents the estimated model of the determinants of R&D investment of the young, small and high growth firms listed on the Alternative Investment Market, based on their classifications.

4.5.2 Results

The regression estimates of the dynamic R&D investment model are shown in table 4-6 for the full sample, the constrained and unconstrained groups. In all the regressions we can see that the lagged R&D has a significantly positive effect on the current levels of firms' R&D (reflecting the persistence in R&D investment), and the coefficient of the square lagged R&D is negative and less than minus one, as expected, based on the specification of the Euler equation model and the findings of Bond and Meghir (1994) and Brown and Petersen (2011). The negative coefficient of the square lagged R&D implies that the presence of adjustment costs increases the distance between the current level of R&D investment and the target level (i.e. the chosen new level in presence of adjustment costs will be lower than the target level). This gives the incentive for firms to spread these costs out over several periods, generating a continuous and smooth adjustment towards their long-run target (Bond and Söderbom, 2013).

The coefficient of the market-to-book value (*MktBook*) is significant in all regressions but the unconstrained group, which is not at all surprising, as this ratio (average Q) does not contain all the investment information relevant to investment demand. Other factors, such as adjustment cost and capital market constraints, play an important role in investment demand apart from the market-to-book value (Ferderer, 1993; Lensink and Murinde, 2006). Furthermore, in the presence of stock prices bubbles, average Q could be poorly measured using stock market valuation, leading to a disappointing performance of this measure. On the other hand, the coefficients of sales growth (*SGr*) are statistically significant in the unconstrained group and insignificant in the full sample and constrained groups, which is consistent with the findings of Mansfield (1964), Lensink and Sterken (2000) and Lensink (2002).

Table 4-6: System-GMM estimation results for the dynamic R&D equation.

In these dynamic R&D regressions, we treated all the financial variables, including $\Delta \boldsymbol{WC}$, as potentially endogenous variables, and we used lagged differences dated t-2 as instruments for the regression in levels, and lagged levels dated t-3 and t-6 for the regression in differences. The firm fixed effect and time effect are included in all the regressions. Standard errors are robust to within firm serial correlation and heteroskedasticity.

Dependent Variable: *R&D*

Sample split [a]	Full Sample [b]	Constrained Firms [c]	Unconstrained Firms [d]
R&D $_{i,t-1}$	0. 924*** [e]	0.880***	0.922***
	(11.47) [f]	(8.58)	(10.24)
R&D $_{i,t-1}^2$	-0. 475***	-0.405***	-0.698***
	(-5.44)	(-3.74)	(-12.36)
MktBook $_{i,t}$	0.000***	0.000***	0.000
	(5.68)	(5.94)	(0.53)
SGr $_{i,t}$	0.000	-0.000	0.048**
	(0.32)	(-0.00)	(2.41)
CF $_{i,t}$	0.060*	0.052	0.127***
	(1.82)	(1.26)	(3.20)
CF $_{i,t-1}$	-0.055***	-0.033	-0.080***
	(-3.55)	(-1.58)	(-3.71)
Stk $_{i,t}$	0. 079*	0.081*	0.114*
	(1.87)	(1.95)	(1.84)
Stk $_{i,t-1}$	-0. 013	-0.014	-0.017**
	(-1.08)	(-0.78)	(-2.56)
LTD $_{i,t}$	0. 067*	0.092**	-0.117**
	(1.79)	(2.50)	(-2.24)
LTD $_{i,t-1}$	-0.012	-0.015	-0.014
	(-0.85)	(-1.09)	(-0.70)
Δ***WC*** $_{i,t}$	-0. 021	-0.031	-0.065
	(-0.72)	(-0.79)	(-1.47)
Δ***WC*** $_{i,t-1}$	-0.052***	-0.057***	-0.040*
	(-4.00)	(-3.40)	(-1.77)
No. of Firms	235	132	103
No. of observations	1286	592	694
No. of Instruments	94	88	94
Arellano-Bond test for AR(1) in first differenced errors [g]	-3.16 (*p*=0.002)	-2.61 (*p*=0.009)	-3.15 (*p*=0.002)
Arellano-Bond test for AR(2) in first differenced errors [h]	-0.85 (*p*= 0.397)	0.06 (*p*=0.950)	-1.10 (*p*=0.272)
Hansen test of over-identifying restrictions [i]	75.38 (*p*= 0.201)	69.76 (*p*= 0.182)	74.69 (*p*= 0.217)

Notes:

[a.] Based on the dividend pay-out ratio, firms have been split to two groups (constrained firms and unconstrained firms).

[b.] This sample contains all the firm-year observations for the full sample (constrained and unconstrained firms).

[c.] This sample contains all the firm-year observations for the constrained firms (firms with zero dividend pay-outs).

[d.] This sample contains all the firm-year observations for the unconstrained firms (firms with positive dividend pay-outs).

[e.] * indicates that the coefficient is significant at the 10% level; ** significant at the 5% level; and *** significant at the 1% level.

[f.] Values reported in parentheses are the t-statistics.

[g.] The Arellano-Bond test is designed to test the serial correlation in the first-difference errors in order to remove the unobserved firm-specific effect. First order autocorrelation in the first differences is expected, as the $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$ could correlate with $\Delta\varepsilon_{it-1} = \varepsilon_{it-1} - \varepsilon_{it-2}$ since they share the ε_{it-1} term. The null hypothesis of the Arellano-Bond test is that there is no serial correlation in the first differenced equation.

[h.] Rejecting the null hypothesis at the second order condition implies that the model is misspecified.

[i.] The Hansen test of over-identifying restrictions is designed to deduce whether the instruments as a group are exogenous. The Sargan statistics under the two-step robust GMM estimation are not robust to heteroscedasticity or autocorrelation, while the Hansen j-statistics are robust.

The coefficient of the current cash flow (CF) is positive and statistically significant in the full sample and the unconstrained regressions, which is consistent with the main prediction of Hypothesis 1. According to the pecking order theory, firms prefer to use their internally generated funds to finance their investment rather than use costly external sources (Bond and Meghir, 1994; Carpenter and Petersen, 2002; Brown and Petersen, 2011). Furthermore, the lagged cash flow CF_{t-1} is negative and statistically significant. This is consistent with the findings of Brown and Petersen (2009), and can be explained by the significance of the lagged change in net working capital, reflecting the low or negative levels of internal earnings, and thus producing a negative coefficient sign of the lagged cash flow.

However, the coefficient of the cash flow of the constrained group is statistically insignificant, indicating that the R&D investment of this group is not determined by the availability of internal finance unlike the unconstrained group. The insignificancy is consistent with the findings of Del Canto and Gonzalez (1999) and is explained by the fact that the constrained group of small firms are generating less or negative cash flow. This is because they are young and have had less time to generate internal earnings.

However, considering the external sources of finance, the coefficients of the new stock issues Stk_t are positively and statistically significant in all three regressions. This indicates that firms rely heavily on stock issues to finance their R&D, suggesting the importance of and the strong link between stock issues and R&D for the small and young firms. Unconstrained firms rely more on internally generated cash flow, and on stock issues rather than debt finance, to finance their R&D. These findings are, however, consistent with the main prediction of Hypothesis 3, which considers common stocks as an ideal financing tool to finance firms' R&D investment, especially for those who have exhausted all their internally generated cash flow. In addition, the lagged values of stock issues $(Stk)_{t-1}$ are negatively and statistically significant for the unconstrained group at the 5 percent significance level.

Further, long-term debt issues have a significant positive effect on the R&D investment of the constrained group and the full sample, suggesting that these firms do rely on this source of external funding to finance their R&D investment. While on the other hand, debt issue has a negative effect on unconstrained firms, reflecting their keenness to reduce their financial obligations in order to reduce their risk of financial distress and bankruptcy (Himmelberg and Petersen, 1994; Wang and Thornhill, 2010). These findings are inconsistent with Hypothesis 2, and do not support the argument that R&D-intensive firms give more emphasis to factors that could reduce their risk of bankruptcy or financial distress, unlike the unconstrained firms.

The results of the effect of stock and debt issues on the R&D investment of the constrained firms indicate that, in the absence of internally generated funds, these firms follow the pecking order theory, preferring to finance their investments by debt and equity financing in that order, reducing the presence of asymmetric information effect on external means of finance (Oliner and Rudebusch, 1992). These firms rely more on long-term debt to finance R&D investment than stock issues, as suggested by the two variable coefficients, 0.092 and 0.081, for debt and stock issues respectively.

Most importantly, the coefficients of the current and the lagged change in net working capital (ΔWC) are negative and statistically significant for all three regressions, with negative signs of -0.052, -0.057 and -0.040 respectively. This indicates that when firms are facing financing frictions, they rely on working capital as a source of funds to finance and smooth their R&D investment. The negative coefficient indicates that firms who are likely to face financing friction will rely on working capital (as a store of liquidity) by drawing down liquidity to absorb the shocks of the cash-flow variations in the short run.

However, the coefficient of the change in net working capital of the unconstrained group has a statistically negative effect. This shows that this group of firms is more likely to face financing problems and the negative sign is unexpected, according to Hypothesis 4 (Fazzari and Petersen, 1993). These results of the estimated coefficients of the financial variables for the unconstrained group suggest that this group of firms relies on working capital to smooth R&D in the periods when they are facing high financing frictions.

Accordingly, the results of this research present evidence that firms are all financially constrained, regardless of the criteria used. Indeed, the dividend pay-out criteria helped to differentiate the financing preference between small and young financially constrained firms listed on AIM, providing a more precise picture of the R&D financing menu of the two different groups.

Beside the coefficient estimates, the results shown in table 4-6 suggest that our dynamic R&D investment model performs well. The results of the Arellano-Bond test of the first-difference errors at the second order show no auto-correlation, indicating that our model is well specified in the three regressions. Further, the results of the Hansen test of over-identifying restrictions confirm the validity of our instruments of both first-difference and level equations used in the system-GMM estimation, for all three regressions.

4.5.3 Robustness tests and results

To check the robustness of the system-GMM estimations, three alternative estimation approaches were run to test the determinants of the R&D investment of the young, risky and high growth firms listed on AIM. First, we re-estimated our dynamic model using an alternative estimation procedure, the ordinary least squares (OLS) estimator with control for the year fixed effect. Second, we re-estimated our dynamic model with a yearly and firm fixed effect (FE). Although the OLS and FE estimations are not reliable and the two-step estimator is asymptotically more efficient than the OLS estimations, Borisova and Brown (2013) states that, the reported OLS and FE estimations are useful in providing a boundary test for the coefficient of the GMM estimations. In the presence of the correlation between the firm fixed effect and other explanatory variables in the model, OLS estimations on the lagged dependent variable are expected to be upward biased. On the other hand, a downward bias in the FE estimations is expected, due to the correlation between the firm fixed effect and lagged dependent variable (Nickell, 1981; Hsiao, 1985; Flannery and Hankins, 2013).

As reported in table 4-7, apart from sales growth, all the explanatory variables are significantly consistent with the expectations of the research. However, the OLS estimations present an upward bias of the lagged and squared lagged dependent variables in the full sample, the constrained and unconstrained groups, as shown in columns 1, 2 and 3 in table 4-7. Controlling for the firm fixed effect, the FE estimates in table 4-8 are very similar in nearly all respects to the OLS results reported in table 4-7. In particular, we continue to find a statistically significant effect of all the explanatory variables apart from sales growth and net change in working capital.

However, the magnitude of the lagged dependent variable is almost halved, representing downward bias, which is expected and caused by the estimations of the dynamic models with firm fixed effect (Borisova and Brown, 2013). It is noted, however, that the magnitudes of the lagged dependent variable of the GMM estimations lie in-between the OLS and FE estimations, providing robustness to the main findings of this research that is, the reported GMM estimations as in table 4-6.

Table 4-7: Ordinary least square estimation results for the dynamic R&D equation.

Dependent Variable: *R&D*			
Sample split [a]	Full Sample [b]	Constrained Firms [c]	Unconstrained Firms [d]
R&D $_{i,t-1}$	1.014*** [e]	1.071***	1.051***
	(28.93) [f]	(20.32)	(30.62)
R&D $_{i,t-1}^2$	-0. 422***	-0.407***	-0.629***
	(-13.40)	(-8.53)	(-13.65)
MktBook $_{i,t}$	0.000***	0.000	0.000
	(5.74)	(4.25)	(-0.80)
SGr $_{i,t}$	-0.000	0.000	-0.042***
	(1.46)	(0.74)	(6.19)
CF $_{i,t}$	0. 058***	0.052***	0.126***
	(5.70)	(3.39)	(8.77)
CF $_{i,t-1}$	-0. 069***	-0.050***	-0.113***
	(-6.80)	(-3.18)	(-9.57)
Stk $_{i,t}$	0. 071***	0.072***	0.107***
	(9.09)	(6.15)	(8.74)
Stk $_{i,t-1}$	-0. 031***	-0.036***	-0.031***
	(-5.53)	(-4.15)	(-5.26)
LTD $_{i,t}$	0. 070***	0.079***	0.109***
	(11.48)	(9.14)	(-7.20)
LTD $_{i,t-1}$	-0. 023***	-0.032***	-0.002
	(-3.58)	(-3.42)	(0.16)
Δ***WC*** $_{i,t}$	-0. 018*	-0.027*	-0.060***
	(-1.86)	(-1.89)	(-5.08)
Δ***WC*** $_{i,t-1}$	-0.054***	-0.056***	-0.024**
	(-7.17)	(-5.00)	(-2.13)
Year dummies	Yes	Yes	Yes
No. of Firms	235	132	103
No. of Observations	1286	592	694
R-Squared	0.7215	0.6985	0.7762

Notes:

a. Based on the dividend pay-out ratio, firms were split into two groups (constrained and unconstrained).

b. This sample contains all the firm-year observations for the full sample (constrained and unconstrained firms).

c.. This sample contains all the firm-year observations for the constrained firms (firms with zero dividend pay-outs).

d. This sample contains all the firm-year observations for the unconstrained firms (firms with positive dividend pay-outs).

e. * indicates that the coefficient is significant at the 10% level; ** significant at the 5% level; and *** significant at the 1% level.

f. Values reported in parentheses are the t-statistics.

Table 4-8: Firm fixed effect estimation results for the dynamic R&D equation.

Dependent Variable: *R&D*			
Sample split [a]	Full Sample [b]	Constrained Firms [c]	Unconstrained Firms [d]
R&D $_{i,t-1}$	0.518*** [e]	0.521***	0.529***
	(9.92) [f]	(6.44)	(7.93)
R&D $_{i,t-1}^{2}$	-0. 232***	-0.222***	-0.384***
	(-6.10)	(-3.74)	(-6.36)
MktBook $_{i,t}$	0.000***	0.000**	0.000*
	(3.27)	(2.33)	(1.94)
SGr $_{i,t}$	-0.000	0.000	0.055***
	(1.52)	(0.98)	(7.85)
CF $_{i,t}$	0. 058***	0.046***	0.119***
	(5.36)	(2.81)	(8.34)
CF $_{i,t-1}$	-0. 044***	-0.029	-0.072***
	(-4.00)	(-1.63)	(-5.86)
Stk $_{i,t}$	0. 056***	0.058***	0.099***
	(7.01)	(4.75)	(8.10)
Stk $_{i,t-1}$	-0. 010	-0.003	-0.011***
	(-1.45)	(-0.25)	(-3.18)
LTD $_{i,t}$	0. 082***	0.089***	-0.102***
	(13.27)	(10.14)	(-6.55)
LTD $_{i,t-1}$	-0. 007	-0.009	-0.011
	(-1.07)	(-1.03)	(-0.394)
Δ***WC*** $_{i,t}$	-0. 004	-0.009	-0.055***
	(-0.40)	(-0.62)	(-4.69)
Δ***WC*** $_{i,t-1}$	-0.056***	-0.067***	-0.019
	(-6.42)	(-4.53)	(-1.63)
Year dummies	Yes	Yes	Yes
No. of Firms	235	132	103
No. of Observations	1286	592	694
R-Squared	0.6359	0.5936	0.7029

Notes:

a. Based on the dividend pay-out ratio, firms were split into two groups (constrained and unconstrained).

b. This sample contains all the firm-year observations for the full sample (constrained and unconstrained firms).

c. This sample contains all the firm-year observations for the constrained firms (firms with zero dividend pay-outs).

d. This sample contains all the firm-year observations for the unconstrained firms (firms with positive dividend pay-outs).

e. * indicates that the coefficient is significant at the 10% level; ** significant at the 5% level; and *** significant at the 1% level.

f. Values reported in parentheses are the t-statistics.

Finally, where this research follows the homogenous purposeful sampling technique, requiring firms to be listed in industries with two-digit SIC (20-39 and 73), reporting positive R&D expenditure and to have at least six observations, resulting in a sample of 235 firms, and where the research of the third chapter adopted the purposeful sampling technique, requiring firms to be listed in industries with two-digit SIC (20-39 and 73) and to have at least two observations, resulting in a sample of 630 firms. The results of this chapter are more prone to the selection bias problem as it does not account for the decision to carry out R&D expenditure or not. It only focuses on the positive R&D reporting firms and not for all firms.

As a consequence, in the robustness tests of this chapter, we considered re-estimating our dynamic model in two stage procedure. The first is by calculating the Inverse Mills Ratio (IMR) from the selection equation that predicts the firms' probabilities to invest in R&D (as of the third chapter). Second, entering IMR into the second stage of the model that estimates the determinants of R&D investment using GMM estimations.

As reported in table (4-9), the new GMM estimations after adding the IMR into the model are very similar in nearly all respects to the reported results in table 4-6. In particular, we continue to find significant effect of stock issues and debt issues on R&D of the constrained group, and similar significant link between the change in net working capital (ΔWC) and R&D. Similarly, for the unconstrained group, the two stages estimations continue to show a significant effect of cash flow, stock issues and the change in net working capital (ΔWC) on R&D. The Arellano-Bond and Hansen tests suggest that our regressions are well specified, and that the instruments used are significantly valid. The findings of the two-stage procedure as in table (4-9) support the initial ones in table 4.6, that regardless of the dividend pay-outs as a criteria of splitting firms into constrained and unconstrained groups, firms of this research sample are all financially constrained.

Table 4-9: Two-stage estimation results for the dynamic R&D equation (Including the Inverse Mills Ratio).

In these dynamic R&D regressions, we treated all the financial variables, including ΔWC, as potentially endogenous variables, and we used lagged differences dated t-2 as instruments for the regression in levels, and lagged levels dated t-3 and t-6 for the regression in differences. The firm fixed effect and time effect are included in all the regressions. Standard errors are robust to within firm serial correlation and heteroskedasticity.

Dependent Variable: *R&D*

Sample split [a]	Full Sample [b]	Constrained Firms [c]	Unconstrained Firms [d]
R&D $_{i,t-1}$	0. 908*** [e] (10.52)[f]	0.870*** (8.44)	0.898*** (9.67)
R&D $_{i,t-1}^2$	-0. 445*** (-5.09)	-0.400*** (-3.81)	-0.711*** (-12.53)
MktBook $_{i,t}$	0.000*** (7.68)	0.000*** (6.43)	0.000 (0.63)
SGr $_{i,t}$	0.000 (0.20)	-0.000 (-0.07)	0.049** (2.48)
IMR $_{i,t}$ [g]	-0.059 (-0.58)	-0.104 (-0.80)	0.046 (-0.96)
CF $_{i,t}$	0.063* (1.83)	0.055 (1.32)	0.111*** (2.79)
CF $_{i,t-1}$	-0.051*** (-2.97)	-0.030 (-1.27)	-0.056*** (-3.25)
Stk $_{i,t}$	0. 086** (2.19)	0.082 (1.80)	0.116* (1.70)
Stk $_{i,t-1}$	-0. 014 (-1.00)	-0.015 (-0.77)	-0.013** (-2.08)
LTD $_{i,t}$	0. 079*** (3.03)	0.089** (2.55)	-0.123** (-2.21)
LTD $_{i,t-1}$	-0.008 (-0.66)	-0.013 (-0.95)	-0.022 (-1.00)
Δ***WC*** $_{i,t}$	-0. 028 (-0.95)	-0.034 (-0.89)	-0.062 (-1.28)
Δ***WC*** $_{i,t-1}$	-0.060*** (-4.25)	-0.061*** (-3.61)	-0.050** (-2.29)
No. of Firms	234	131	103
No. of observations	1279	586	693
No. of Instruments	94	88	94
Arellano-Bond test for AR(1) in first differenced errors [h]	-4.15 (p=0.000)	-2.62 (p=0.009)	-3.02 (p=0.003)
Arellano-Bond test for AR(2) in first differenced errors [i]	-0.59 (p= 0.557)	0.06 (p=0.956)	-1.12 (p=0.262)
Hansen test of over-identifying restrictions [j]	76.91 (p= 0.148)	70.79 (p= 0.140)	80.52 (p= 0.093)

Notes:
[a.] Based on the dividend pay-out ratio, firms have been split to two groups (constrained firms and unconstrained firms).
[b.] This sample contains all the firm-year observations for the full sample (constrained and unconstrained firms).
[c.] This sample contains all the firm-year observations for the constrained firms (firms with zero dividend pay-outs).
[d.] This sample contains all the firm-year observations for the unconstrained firms (firms with positive dividend pay-outs).
[e.] * indicates that the coefficient is significant at the 10% level; ** significant at the 5% level; and *** significant at the 1% level.
[f.] Values reported in parentheses are the t-statistics.
[g.] The Inverse Mills Ratio calculated from the selection equation that predicts corporate probabilities to invest in R&D, as in the third chapter.
[h.] The Arellano-Bond test is designed to test the serial correlation in the first-difference errors in order to remove the unobserved firm-specific effect. First order autocorrelation in the first differences is expected, as the $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$ could correlate with $\Delta\varepsilon_{it-1} = \varepsilon_{it-1} - \varepsilon_{it-2}$ since they share the ε_{it-1} term. The null hypothesis of the Arellano-Bond test is that there is no serial correlation in the first differenced equation.
[i.] Rejecting the null hypothesis at the second order condition implies that the model is misspecified.
[j.] The Hansen test of over-identifying restrictions is designed to deduce whether the instruments as a group are exogenous. The Sargan statistics under the two-step robust GMM estimation are not robust to heteroscedasticity or autocorrelation, while the Hansen j-statistics are robust.

4.6 Conclusion

To the best of knowledge, this is the first study to examine the determinants of R&D expenditure, the existence of financing constraints and the role of working capital on R&D smoothing of the young, small and high growth firms listed on the AIM market. The research has included the change in net working capital as a source of funds, along with other financial variables, to emphasize the importance for financially constrained firms to smooth R&D when faced with transitory finance shocks. To formally test the use of these financial variables on R&D investment for the firms listed on the alternative investment market, we used the system-GMM estimator to estimate our dynamic R&D investment model, which included firms' source of finance (cash-flow, new stock issues or long-term debt issues) and the change in net working capital as explanatory variables. For financially constrained firms with zero dividend pay-outs, we find strong evidence that the determinant of R&D investment is the level of previous R&D investment, and that firms rely on stock issues to finance this investment. Moreover, our results show that constrained firms rely heavily on debt issues to finance this type of investment, but do not rely on internally generated funds as a source of finance. Further, we find strong evidence that working capital is used by firms to finance their R&D investment when they are likely to face financing frictions, as they rely on working capital (as a store of liquidity) and draw down liquidity to absorb the shocks of cash flow variations in the short run, in order to maintain a smooth flow of R&D spending in the presence of finance shocks.

On the other hand, our findings show that the level of R&D investment of the unconstrained firms (firms with positive dividend pay-outs) is greatly determined by the previous levels of R&D, and that firms rely mostly on internally generated funds to finance this type of investment. Unlike constrained firms, unconstrained ones do not rely on new long-term debt issues to finance their R&D investment, but rather rely partially on new stock issues. Further, our results show that a change in working capital does have an impact on the level of R&D for unconstrained firms; in contrast to this research expectation, these firms were assumed to be less likely to face financing frictions.

Chapter 5

The Impact of the Disposal of Fixed Asset Proceeds on R&D expenditure: Evidence from the AIM Market

5 The Impact of the Disposal of Fixed Asset Proceeds on R&D expenditure: Evidence from the AIM Market

5.1 Introduction

Over the last decades, attention has been paid to investigating corporate investment and financing decisions, and the effect of financing constraints on firms' investment activities, with regard to both tangible and intangible assets. A firm's manager faces the decision of how to raise finance. Current research mainly focuses on firms' choices between internal and external financing channels, these being those internally generated funds, issuing equity and obtaining debt. Consequently, various theories classifying different vital factors for a firm's external financing decisions have emerged. By relaxing the assumptions of the perfect capital market model of no information asymmetry, the pecking-order theory of Myers and Majluf (1984) and Myers (1984) argues that corporate external financing is favoured as it exhibits the least information asymmetry.

Similarly, concerning the existence of tax and bankruptcy costs, the trade-off model states that firms would seek to reach optimal debt-to-equity levels in order to maximize their value, by weighing the costs and benefits of having more debt; that is, the reduction in the agency cost of equity and tax shields (Myers, 1984). The market-timing model claims that firms' capital structure is based on the accumulated attempts of managers to time the securities market (Baker and Wurgler, 2002). Baker and Wurgler suggest that managers are in favour of selling securities when mispricing is greater.

The literature claims that, because of capital market imperfection and severe information asymmetries, corporate investment expenditure is greatly affected by the available sources of finance. Consistent with the view that corporate investment expenditure is correlated with the means of financing it, corporate expenditure is influenced by a firm's financial structure and financial constraints (Fazzari *et al.*, 1988; Bond and Meghir, 1994; Hubbard, 1997; Borisova and Brown, 2013; Guariglia and Liu, 2014). While there is solid research on corporate financing through issuing securities, another core source of finance is the proceeds of selling tangible assets[40], which has not been examined in detail.

Hite *et al.* (1987) investigated motives for corporate asset sales and stated that "in several cases, management indicated that assets were being sold to raise capital for expansion of existing lines of business or to reduce high levels of debt. In other words, selling assets was viewed as an alternative to the sale of new securities". Other researchers have found that management sells assets for a financing motive, providing the cheapest available funds to pursue their objectives (Brown *et al.*, 1994; Lang *et al.*, 1995; Borisova *et al.*, 2013). Hovakimian and Titman (2003) show that sales of tangible assets lead to increased corporate investment, and Borisova and Brown (2013) found that financially constrained firms sold assets to finance R&D investment, suggesting that asset sales are mainly undertaken to raise cheap capital. Maksimovic and Phillips (2001) and Edmans and Mann (2013) also report that companies sell assets in response to financial constraints.

The vast majority of the related research mainly focuses on fixed capital investment, and ignores other firm activities, some of which are critical drivers for firm expansion and general macroeconomic growth, in particular R&D investment. The characteristics of R&D investment[41], make it more susceptible to financing difficulties. It is of great importance to

[40] Tangible assets in this context are defined as assets which are insignificant for the firm's operations (non-core tangible assets). However, they act as spare finance if needed and can often be sold; they can also contribute to the business but are not vital for its success.

[41] R&D investment is mainly characterised by offering low collateral value, associated with asymmetric information problems, and risky and uncertain investment, as the success of its output is not guaranteed, and only generates profits with a time lag if successful.

provide more information on how R&D expenditure is affected by capital market imperfections (Brown and Floros, 2012; Guariglia and Liu, 2014).

Despite the fact that R&D investment plays an important role in firms' growth and is prone to financing constraints, few studies have focused on the effects of financing constraints on R&D investment for young, small and high growth firms. For such firms, financing constraints can lead to a considerably lower level of R&D investment than what would be optimal. If financing constraints are binding firms' level of R&D investments, such constraints will lead to lower growth levels.

The lack of research on the financial constraint effect on the R&D activities of young and small firms has motivated this research. This chapter fills this gap, which is an overlooked issue in the current literature. More precisely, this research attempts to make progress in testing the sensitivity of investment in R&D to cash proceeds from the sale of tangible fixed assets of AIM-listed firms.

5.2 Research aim and objectives

Despite the fact that R&D investment has a significant positive effect on the growth of firms and economies at both aggregate and disaggregate levels (Arrow, 1962; Cohen and Levinthal, 1989; Romer, 1990) relatively little is known about the determinants of firms' expenditure on R&D activities, either in the UK or in other developed countries. This chapter aims to explore this important issue, frequently overlooked in the existing literature, to identify the impact of financial constraints on R&D investment. In the chapter, we aim to examine directly the role that the disposal of tangible asset proceeds has on the level of R&D expenditure of firms listed on AIM.

Young, small and high growth firms mainly turn to stock markets to finance their growth opportunities, in particular their R&D activities. R&D active firms suffer from little or no access to debt financing, since R&D offers little or no collateral value and is associated with a high degree of uncertainty (Piga and Atzeni, 2007; Brighi and Torluccio, 2009; Wang and Thornhill, 2010). Firms' internally generated funds are considered to be too volatile as sources to finance R&D investment in the early stages (Himmelberg and Petersen, 1994; Bhagat and Welch, 1995).

Stock issues are the main source of additional funds for firms to finance R&D (Brown and Petersen, 2009; Chen *et al.*, 2010; Brown *et al.*, 2012). R&D expenditure is almost exclusively financed from volatile sources, internally generated funds and stock issues. Investigating whether capital market imperfection significantly affects expenditure on the R&D investment of the young and small firms listed on AIM can dramatically change the existing view on financing constraints. Thus, this study falls within one of the current lines of research into the impact of financial constraints on R&D investment, emphasising the role that disposal of tangible assets has on determining the level of expenditure on this investment.

The role of the disposal of fixed asset proceeds in R&D expenditure has been overlooked and virtually no attention has been paid to young and small listed firms. This research attempts to fill this gap in the literature and provide a clearer view of the determinants that influence corporate expenditure on R&D investment. From a policy perspective, the findings should help design strategies, taking into account the accessibility to various sources of funds, to assist AIM-listed firms make R&D investment expenditure.

To the best of knowledge, no investigation has been made on the sensitivity of firm investment in R&D to cash raised from the sales of fixed assets due to the financing constraints on R&D. One contribution of this chapter is that no such study has been made on a developed country (in this case, the UK). The proportional lack of evidence on whether the sources of finance matter for R&D in the UK is a puzzle, and calls into question whether financing constraints are of considerable importance for R&D expenditure in the UK.

A second contribution is that, whereas most previous empirical studies have been almost exclusively based on testing large and mature firms, this work is devoted to focusing on young, small AIM-listed firms and their financing of R&D expenditure. A third contribution of this research relates to the applied methodology. A vast number of studies rely on either the firm's age or size or its dividend pay-out ratio to categorise them as financially constrained or unconstrained[42]. We considered three ways of separating the firms, since we are already dealing with young and small ones. For robustness, we follow Hovakimian and Titman (2003) and Borisova and Brown (2013) and estimate the likelihood of financial regimes for each firm based on its characteristics. This approach will eliminate any potential bias in the results and conclusions drawn.

[42] Researchers argue that small or young firms are more prone to financing constraints (have high levels of information asymmetry) than large or mature firms, and firms with zero dividend pay-out are more financially constrained than firms with positive dividend pay-outs (Fazzari and Petersen, 1993; Weigand and Audretsch, 1999; Brown and Petersen, 2011).

5.3 Theoretical framework and hypotheses derivation

5.3.1 Introduction

By relaxing the perfect capital market assumptions proposed by the work of Modigliani and Miller (1958), and later Miller and Modigliani (1961), we consider corporate investment in risky intangible investments that is, R&D (please refer to section 4.3.1 for further and deeper details). The remainder of the chapter will proceed as follows. Section 5.3.2 briefly reviews possible financing constraints and asset sell-off motives and section 5.3.3 reviews the corporate motives for investment smoothing. Section 5.3.4 will briefly review the role of the disposal of fixed asset proceeds on R&D investment, while section 5.3.5 reviews the development of the hypothesis of the role of disposal of fixed asset proceeds on R&D expenditure. However, it is worth mentioning that the core theories of corporate investment and corporate finance can be found in the previous chapter (specifically in section 4.3.2 and 4.3.3).

5.3.2 Financing constraints and asset sell-off motives

While the main objective of any individual firm is to achieve the best possible return for its owners, it should dispose of unneeded assets, as well as concentrating on financing its promising activities with the cheapest available source of finance. This section will discuss why firms favour the disposal of tangible assets, which enables current activities to be continued.

In a world with perfect capital markets, firms would not face any pressure to undertake any voluntary asset sell-offs. In such a world, there would be no transaction costs, asymmetric information, uncertainty, and no financial constraints. The money markets would reflect all available information, and firms would borrow and lend at the same interest rate. Previous studies have claimed that a firm’s expenditure on real investment depends on financial factors.

External finance, if accessible, is considered to be costlier than internal finance due to asymmetric information, transaction costs, tax advantages and the cost of financial distress.

Many of the arguments rest on the difference between firm managers having more information about the firm's investment horizons and existing capital than investors, who cannot distinguish between the quality and value of firms. The different information sets force outsiders to value individual firms according to the population average. In debt markets, Jaffee and Russell (1976) claim that severe information asymmetry causes lenders to raise the cost of new debt, and/or ration credit. Jaffee and Russell argue that if distinguishing between the quality of borrowers is a difficult process for lenders, the market reaction will result in increasing interest rates and/or limiting loan sizes. As a consequence, if the interest rate rises, marginally good quality borrowers will leave the market (adverse selection) or firms will undertake riskier projects (moral hazard), making the probability of default on creditors higher and expected profits lower (Myers and Majluf, 1984; Toivanen and Cressy, 2002).

In the equity markets, new investors may be less knowledgeable compared to insiders about firms' new investment opportunities and their existing capital. In such a state of affairs, Myers and Majluf (1984) point out that investors may not be able to differentiate between the quality and value of firms, forcing outsiders to value a particular firm at the population average. In these circumstances, Akerlof (1970) explains why firms sell new stocks at a discount. He states that if stock issuers have more information than investors about the quality of the firm, insiders would not be in favour of accepting the terms offered by outsiders, forcing the new stock issues to be sold at a lower price than would have been the case if the outsiders had had full access to the same information as the insiders. However, when the external fund channels are only available at a premium, or are rationed, the fluctuations in the internally generated funds (internal finance) will affect firms' investment.

Brown *et al.* (1994) and Hovakimian and Titman (2003) indicate that strategies that involve investment with financing from the disposal of tangible asset proceeds offer a real substantial advantage over others. When firms are faced with uncertainty concerning their expected levels of future cash flows, incurring extra costs for those with insufficient cash balances to cover expenses, several strategies need to be considered. Among these strategies, selling-off tangible assets is an option.

Hite *et al.* (1987) and Hovakimian and Titman (2003) claim that this strategy might be the lowest cost approach to the problem of uncertainty and its costs. Researchers argue that strategies involving the selling-off of tangible assets is one of the most efficient ways in which firms can respond to many of the problems that have been caused by the imperfections of the real-world. Like any other sources of financing, it is clear that economists have recognised the disposal of fixed asset proceeds as an important source of finance for financially distressed firms.

Previous research provides two main explanations for why healthy firms frequently sell-off tangible assets. Hite *et al.* (1987) and Ofek (1993) state that a firm's voluntary sell-off of assets can be motivated by the need for a restructuring process. The sale of assets allows firms to achieve the best operational efficiency by selling assets to improve productive departments or by selling assets that generate negative synergies to other core departments. Hovakimian and Titman (2003) argue that this motivation, asset sell-off, will mainly influence the corporate expenditure of firms that face financial constraints.

The second motive, as stated by Brown *et al.* (1994) and Hovakimian and Titman (2003), is mainly present in financially constrained firms, as the assets sale is an internally and privately negotiated transaction. In addition, it may represent the cheapest source of finance compared to external equity and debt sources for firms that face severe information asymmetry problems.

Financially constrained firms may have a strong motive to sell off assets to raise funds for alternative promising investments. In both cases, we would expect there to be a strong relationship between investment and asset sales for financially distressed firms (Lang *et al.*, 1995).

5.3.3 Investment smoothing

Several empirical studies have found evidence for the effects of constraints on a firm's capital structure (see, for example, Fazzari *et al.*, 1988; Oliner and Rudebusch, 1992; Bond and Meghir, 1994). These studies have ignored the possibility that financially constrained firms may choose to smooth their investments relative to transitory cash-flow shocks due to adjustment costs. In this context, Lucas (1967) proposed the idea of investment smoothing, by which the marginal adjustment costs of acquiring and obtaining capital rise as the rate of investment increases. Thus, if the marginal adjustment costs rise, firms with any long-term path of capital accumulation will tend to reduce these costs by maintaining a stable path of investment over time. Another motivation, identified by Fazzari and Petersen (1993), shows that firms cannot hold or delay investment projects without incurring costs, as in fast-growing industries, firms' innovations continuously generate new investment opportunities. These projects should be undertaken as they arise, or their value will sharply decline because of the appropriability[43] problem, and the short product life cycle. Furthermore, Brown *et al.* (2012) support the idea of firms' investment smoothing (specifically for R&D investment), as those firms engaged in this

[43] Appropriability is defined as the environmental factors that govern an innovator's ability to obtain profits generated from its inventions or innovations (Lopez, 2009)

type of investment have a strong incentive to keep R&D smooth in order to avoid the associated high adjustment costs[44].

Finally, whereas investment spending measures take place continuously, promising investment projects often take time to complete and will only generate profits with a time lag. Thus, it may be costly for a firm to make any changes to the expenditure on projects in progress when faced with financing shocks or any temporary shortfalls in cash flow. Large changes in employment or capital stock are considered too costly, and high adjustment costs give firms an incentive to spread out adjustment costs over time.

5.3.4 The role of the disposal of fixed asset proceeds in R&D investment

Among other investments, R&D is characterized by high adjustment costs (Himmelberg and Petersen, 1994; Brown and Petersen, 2011). The activity consists of high wage payments to trained and highly skilled workers, for example scientists, engineers and technology workers. These expert workers often require a lot of firm-specific training, which makes their laying-off a costly decision, even if the cutting back on R&D activity is temporary and due to transitory binding financing shocks. If such a temporary cutting back is required, firms have to consider the costs of such a decision; for instance, the cost of hiring and training new workers in the future. Cutting R&D expenditure in the short run and laying off workers creates extra hiring and training costs in the future.

Researchers state that, although these costs are very high for firms, the more costly drawbacks can be in relation to the fact that laid-off workers know firm-specific commercial secrets and

[44] Adjustment costs in this context are defined as the costs associated with making any changes or cuts in R&D investment at the firm level (e.g. the costs of hiring and training new employees, or the costs of lost production in the case of having to lay off knowledge workers).

valuable information, which could be transferred to competitors. This information may damage the value of the innovation in process, which is considered to be too costly for firms (Himmelberg and Petersen, 1994; Brown *et al.*, 2012; Brown *et al.*, 2013).

Another important characteristic of corporate R&D investment can be viewed from the aspect that this activity is hard to finance through external funding channels, but equity appears to be the only realistic source of finance (Switzer, 1984; Hall, 1992; Wang and Thornhill, 2010). The first reason can be explained by the fact that R&D is a risky investment and is considered to be uncertain. This is due to the output of such activities not being guaranteed, and its income inflows can only be generated with a time lag in cases of success. The second reason that makes equity the only realistic source of external finance is that R&D is associated with high levels of information asymmetry. Furthermore, when the R&D activities offer little or no collateral value, it makes it problematic for R&D expenditure to be funded by debt financing. Finally, as R&D is a risky and uncertain investment, firms attempt to reduce their financial obligations to avoid increasing the risk of financial distress, a problem that can be extremely severe for R&D performing firms.

External and internal equity have more advantages over debt as sources of finance for R&D investment. Equity by its nature does not impose financial obligations on firms; for example, making fixed interest payments. However, internally generated funds and external equity cannot be considered as perfect substitutes (Myers and Majluf, 1984). External equity financing incurs sizable flotation costs, as well as requiring a “lemon premium”. Thus, internally generated funds are more preferable for firms compared to the external equity channel, as they are less costly (Akerlof, 1970).

Because external and internal sources of finance are considered volatile sources of funds, and as internal financing is associated with a high degree of variability, researchers conclude that equity issues are the main marginal external source of finance for R&D activities (Brown *et al.*, 2009). However, considering the size of the R&D performing firm, researchers point out that issuing equity appears to be more volatile because of market timing[45]. As they are volatile sources of finance for the R&D expenditure of small and young firms, which need to avoid high adjustment costs, they must consider all options. Firms facing binding financing constraints may have a strong motive to voluntarily sell off tangible assets as a last resort, when considered as the cheapest available source of finance in order to finance their R&D activities.

In this context, Brown *et al.* (1994) have advocated the idea of investment financing with the selling off of tangible assets. Brown *et al.* point out that firms consider asset sales as a way of resolving financial distress. In an attempt to examine the motives and the consequences of the asset sales of financially constrained firms, it has been suggested that they consider asset sales as an important way of resolving financial distress. Creditors have a significant influence on the disposal of assets by financially distressed firms and the proceeds of the disposal of assets are more likely to be used for paying off creditors. Similarly, investigations by Lang *et al.* (1995) and by Shin (2008) on the use of asset sales proceeds suggest that firms sell assets when funds are needed to continue with long-term projects and when alternative means are either unavailable or too expensive.

More recently, pioneering work by Hovakimian and Titman (2003) examines whether proceeds from voluntary asset sales have an influence on corporate investment expenditure, especially for firms that are more likely to be financially constrained. Their findings suggest that firms' investments are significantly determined by the cash inflows from the sales of fixed assets and that this relationship is significantly stronger for firms that are more likely to be financially

[45] Several studies show that stock market mispricing substantially affects the cost of issuing new external equity and has a considerable impact on firms' use of external equity finance (Graham and Harvey, 2001; Baker and Wurgler, 2002)

constrained. These results lend support to the financing hypothesis and the conclusions of Lang *et al.* (1995) and Shin (2008).

A number of other studies provide theoretical models and empirical evidence to show how firms can finance their investment expenditure through asset sales, for example Edmans and Mann (2013). They find empirical evidence that the financing motive for firms to allow asset sales occurs when selling equity takes place at a discount. More specifically, and concerning the role that the disposal of asset proceeds plays in determining the level of expenditure on R&D investment, the recent pioneering work by Borisova and Brown (2013) provides evidence that there is a significant relationship between corporate R&D expenditure and the cash inflow proceeds from the disposal of fixed assets. However, this positive link is only observable among constrained firms (i.e. the ones most likely to face binding financing frictions).

A number of studies have provided theoretical rigour and empirical results on how the selling off of tangible assets can benefit firms facing financing frictions, and how the disposal of proceeds plays a role in determining corporate investment expenditure. However, few have investigated the role of the disposal of proceeds in the R&D by small and young firms listed on AIM.

5.3.5 Hypothesis development

Considering the relationship between internal and external financing and corporate R&D activities, this section will formulate a testable hypothesis on the association between the proceeds from the disposal of fixed assets and corporate R&D expenditure.

Management's objective is to maximise value for their shareholders. R&D activities help firms achieve a better performance by generating new products and developing new services (Cohen and Levinthal, 1989). The outcome of R&D helps to provide firms with some differentiation that creates opportunities in the market, thus increasing firms' competitive advantage over competitors (Bosworth *et al.*, 1993). R&D by its nature is a risky and uncertain investment, making it more susceptible to financing constraints. In contrast, fixed assets value a firm's size. Managers will have less incentive to sell assets, unless required funds cannot be raised cheaply on the capital market. Firms' motives for raising funds can be viewed by their need to reduce the possibility of financial distress, to undertake promising investments, increase their working capital accounts and to pay dividends (Scherr, 1989; Lang *et al.*, 1995). If firms need to raise funds to pursue R&D activities but cannot obtain debt financing because of the riskiness and the little or no collateral value that R&D investment offers (Himmelberg and Petersen, 1994; Wang and Thornhill, 2010), outsiders will know that the firms needs external funds, though they will find it difficult to access the capital market because of adverse selection and moral hazard problems (Toivanen and Cressy, 2002). Equity as a financing channel will incur a lemon premium for new stock issues (Myers and Majluf, 1984) and debt finance will incur high interest expenses for R&D expenditure, if available (Wang and Thornhill, 2010). If firms are in need of external funds to finance risky and uncertain investments, capital providers will require a higher rate of return or will impose a restriction on the use of funds (Fazzari *et al.*, 1988). Several reasons make asset sales more preferable as a source of finance for firms than the capital markets. For example, the information asymmetry problem would be less important for the asset that is intended to be sold than for the firm as whole. Selling assets to provide funds would potentially impose fewer restrictions on firms to pursue their R&D activities. Finally, asset sales may have an advantage in avoiding/saving on the recapitalization costs that would be required to be paid to raise funds (Lang *et al.*, 1995). Because of the lower cost of asset sales over external funds, this chapter suggests that funds from the disposal of fixed assets should be considered as a significant source of finance for R&D investment (Lang *et al.*, 1995; Hovakimian and Titman, 2003; Shin, 2008; Edmans and Mann, 2013; Borisova and Brown, 2013). Thus we state that

Hypothesis 1. *There is a positive relationship between R&D investment and financing through the disposal of tangible assets.*

5.4 Data and preliminary analysis

5.4.1 Data and Measurement

To examine the role that the disposal of fixed asset proceeds has on the level of R&D expenditure of small and young firms, a dataset has been constructed of all active and inactive firms listed on AIM. The unbalanced dataset comprises all publicly listed firms and was obtained from the Worldscope database and the London stock exchange official website covering the period from 1999 to 2014. We only focus on the listed manufacturing and service firms, with two-digit SICs of 20-39 and 73, as R&D activities mainly take place in these industries.

The total number of AIM-listed firms, both surviving and non-surviving, was 1858. There were 746 listed firms in manufacturing and services with two-digit SICs of 20-39 and 73, of which 379 firmed were delisted during the period 1999 to 2014. The delisted firms ceased trading and were not involved in mergers or acquisition.

Since this research uses the system-GMM estimators which rely on lagged values as instruments, we required firms to have at least six consecutive observations over the period 1999 to 2014. Excluding firms reporting no R&D and firms with fewer than six records of the essential variables, the final sample of the research comprised 235 firms. Before moving to preliminary analysis of the role of the disposal of fixed asset proceeds on R&D expenditure, it is important to define the main variables used in the analysis. Table 5-1 briefly describes the main variables and their data sources.

Table 5-1: Description of the main variables used in this chapter.

Variable Name	Description [a]	Source [b]
R&D $_{it}$	The ratio of research and development expenses at time ***t*** divided by the book value of total assets at the end of time ***t-1***.	Worldscope
Market to Book $_{it}$ (***MktBook***)	The ratio of the market value of total assets at time ***t-1*** divided by the book value of total assets at time ***t-1*****.**	DataStream
Sales Growth $_{it}$ (***SGrowth***)	The change in net sales between the end of time t and the end of time ***t-1***, divided by the value of net sales at the end of time ***t-1***.	Worldscope
Cash Flow $_{it}$ (***CF***)	The ratio of the gross internally generated cash flow at time ***t*** divided by the book value of total assets at the end of time ***t-1***, where the gross cash flow is defined as after tax income before extraordinary items and preferred dividend plus depreciation, depletion and amortisation expenses, proceeds from disposal of fixed assets plus research and development expenses [c].	Worldscope
Stock Issues $_{it}$ (***StkIssues***)	The net cash raised from stock issues in time ***t*** divided by the book value of total assets at the end of period ***t-1***, where net cash raised from stock issues is equal to the sales or issuance of common and preferred stocks minus the purchase of common and preferred stocks.	Worldscope
Long-Term Debt Issues $_{it}$ (***DbtIssues***)	The net cash raised from long-term debt issues at time ***t*** divided by the book value of total assets at the end of period ***t-1***, where the net cash raised from long-term debt issues is equal to long-term debt issues minus long-term debt reductions.	Worldscope
Change in Net Working Capital $_{it}$ (***DWC***)	The change in net working capital between the end of time ***t*** and the end of time ***t*-1**, divided by the book value of total assets at the end of time ***t-1***, where net working capital is the current assets (principally cash and equivalents, inventory and accounts receivable) minus current liability (chiefly accounts payable and short-term debt).	Worldscope
Disposal of Fixed Assets $_{it}$ (***DFA***)	The net cash proceeds from the sale of tangible assets (property, plant and equipment) at time ***t*** divided by the book value of total assets at the end of period ***t-1***.	Worldscope

Notes:

[a] The measurement of variables and definition is based on the current literature.

[b] The data were collected from Datastream and Worldscope via Thomson One Banker Analytics.

[c] Since firms treat R&D as an expense, R&D is added back into the usual accounting definition of cash flow (Himmelberg and Petersen, 1994; Brown and Petersen, 2011).

5.4.2 Summary Statistics

In order to avoid bias in the estimate of parameters and significant test statistics, Yuan and Bentler (2001) and Verardi and Croux (2009) warn about the presence of outliers in the datasets. Consequently, we screened some of our explanatory variables to reduce their potential influence on the estimate parameters. We winsorized the explanatory variables, namely Sales Growth (***SGrowth***) and Cash Flow (***CF***), at the 1 per cent level of their respective distribution. The winsor transformation mechanism simply works by setting all observations in the top 1% equal to value corresponding to the 99th percentile, with a similar process applied to the bottom 1%. The significant importance of this process is that it reduces the impact of outliers on the estimate parameters, as well as allowing for the full use of the data set.

Table 5-2 summarizes the descriptive statistics of the main variables. The statistics show that the mean of *R&D* is slightly higher than its median, indicating that it is skewed to the right; similarly, the means of *MktBook*, *SGrowth*, *StkIssues*, *DbtIssues*, the change in net working capital (*DWC*), and the cash raised from the disposal of fixed assets (*DFA*) are all skewed to the right, with mean values higher than the median. The mean of Cash Flow (*CF*) is lower than its median, indicating that this variable is skewed to the left.

Table 5-2: Summary statistics of the main variables employed in this empirical chapter.

Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness
R&D	0.13	0.06	0.00	5.66	9.10	156.56
MktBook	2.93	1.70	-2424.0	1412.16	-20.74	1110.38
SGrowth [a]	0.46	0.08	-1.00	46.51	11.13	155.03
CF [a]	-0.01	0.06	-4.13	4.74	-2.68	39.14
StkIssues	0.28	0.00	-0.71	28.16	14.04	268.41
DbtIssues	0.06	0.00	0.00	13.03	23.50	709.76
DWC	0.08	0.00	-3.02	26.64	19.04	509.03
DFA	0.01	0.00	-0.05	1.52	11.69	200.37
N	2338					

Note:

[a] The ***SGrowth*** and ***CF*** variables are winsorized at the 1% level.

The potentially constrained and unconstrained groups were split according to the dividend pay-outs ratio. Panel A of table 5-3 presents the descriptive statistics of the main variables for firms reporting positive dividend pay-outs, while panel B presents the descriptive statistics for firms that report zero dividend pay-outs. As shown in the figures, apart from the fact that firms reporting positive dividend pay-outs are almost two-thirds the size of firms with zero dividend pay-outs, there are six noteworthy differences between the two groups.

First, in contrast to the literature expectations, for example the financial constraint model, the mean value of R&D of the constrained group (firms with zero dividend pay-outs) is three times higher the mean value of the unconstrained group, at 19% compared to 6%. The second difference presented by the figures is that the sales growth of the constrained group is almost eight times higher than that of the unconstrained one. This difference might be explained by the difference in R&D expenditure between the two groups. Firms with high R&D expenditure might have more product and process innovations, thus increasing their sales growth, especially if compared to firms with lower R&D expenditure.

Table 5-3: Summary statistics of the main variables for constrained and unconstrained groups.

Panel A: Firms reporting no dividend pay-outs (264) Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness	Obs.
R&D	0.19	0.10	0.00	5.66	0.32	7.35	1021
MktBook	3.92	2.13	-2424.0	1412.16	87.91	-15.10	1112
SGrowth	0.81	0.13	-1.00	46.51	3.61	7.95	979
CF	-0.13	-0.06	-4.13	4.74	0.51	-2.00	980
StkIssues	0.50	0.01	-0.71	28.16	1.86	10.62	979
DbtIssues	0.04	0.00	0.00	13.03	0.54	17.73	915
DWC	0.13	-0.03	-3.02	26.64	1.23	13.89	1021
DFA	0.01	0.00	-0.05	1.52	0.06	18.78	981

Panel B: Firms reporting positive Dividend pay-outs (159) Variable	Mean	Median	Min.	Max.	Std.Dev.	Skewness	Obs.
R&D	0.06	0.03	0.00	1.14	0.08	4.53	990
MktBook	1.85	1.43	-92.10	55.17	5.43	-9.08	1018
SGrowth	0.11	0.06	-0.82	11.69	0.47	15.87	990
CF	0.12	0.12	-2.35	1.19	021	-2.37	960
StkIssues	0.05	0.00	-0.60	8.38	0.34	18.01	951
DbtIssues	0.04	0.00	0.00	2.11	0.12	8.59	916
DWC	0.02	0.01	-1.26	1.49	0.17	1.12	990
DFA	0.02	0.00	-0.02	0.98	0.07	7.25	960

The third important difference to note is that the mean value of the cash flow of the constrained group is large and negative compared to the unconstrained group, -13% compared to 12%. The mean of the cash flow might indicate that, although constrained firms have higher sales growth, they might be not profitable enough due to the nature of their investment (R&D) or alternatively because a large number of these firms are newly listed, so have had little time to generate internal cash flows (Brown and Petersen, 2011).

Fourth, in line with the expectations of the pecking order theory, the constrained group issues more stocks compared to the unconstrained group. This gives support to the argument of Myers (1984) that in the need for external sources of finance, R&D performing firms prefer to finance their R&D activities through stock issues rather than debt. Fifth, in contrast to research expectations, the constrained group with high means of R&D expenditure issue more debt than the unconstrained group, suggesting that unlike the constrained group, unconstrained firms are the ones that insist on reducing their financial obligations in order to reduce their probability of bankruptcy or financial distress (Wang and Thornhill, 2010; Martinsson, 2010; Brown *et al.*, 2012).

Finally, the mean value of the change in net working capital shows that constrained firms insist more on the short-term buffering sources of finance, as the mean value of this group is six times higher than that of the unconstrained group. This however, is logical, especially if considering the negative mean value of cash flow of this group.

Table 5-4 presents the pair-wise correlation matrix of the variables. The figures show that the dependent variable (*R&D*) is significantly correlated with all the explanatory variables, but not with the disposal of fixed assets (*DFA*). The correlation signs are not entirely consistent with the implication proposed in the prior sections, for example the correlation signs with Cash Flow (*CF*) and with the disposal of fixed assets (*DFA*). The higher coefficient values were observed in the change in net working capital (*DWC*) and the stock issues (*StkIssues*), the cash flow (*CF*) and the new stock issues (*StkIssues*) and in sales growth (*SGrowth*) and new debt issues (*DbtIssues*) respectively.

Table 5-4: Correlation coefficient matrix of the main variables employed in this research.

Variable	***R&D***	***MktBook***	***SGrowth***	***CF***	***StkIssues***	***DbtIssues***	***DWC***	***DFA***
R&D	***1.000*** [a]							
MktBook	***0.1068****** [b]	***1.000***						
SGrowth	***0.1354******	***0.0060***	***1.000***					
CF	***-0.2221******	***-0.0588*****[c]	***-0.0065***	***1.000***				
StkIssues	***0.6691******[b]	***0.0673******	***0.0711******	***-0.2595******	***1.000***			
DbtIssues	***-0.2023******	***-0.0094***	***0.2243******	***-0.0754******	***0.1340******	***1.000***		
DWC	***0.4005******	***-0.0946******	***0.0544*****	***0.1380******	***0.7513******	***0.0823******	***1.000***	
DFA	***-0.0144***	***-0.0081***	***-0.0269***	***-0.1028******	***-0.0011***	***-0.0041***	***0.0337***	***1.000***

Notes:

[a] The reported figures are the pair-wise Pearson correlation coefficients between variables.

[b] Statistically significant at the 1% level; [c] statistically significant at the 5% level; [d] statistically significant at the 10% level.

5.5 The dynamic model of R&D investment

5.5.1 Methodology

Expenditure on R&D activities can be determined by numerous factors. Most of the previous research conducted on the expenditure levels on R&D investment have focused on firms' sources of external finance and the availability of internally generated funds, neglecting the cash raised from the disposal of fixed assets and its connection with R&D investment. In order to investigate this connection, the dynamic nature of decisions must be considered.

Flannery and Hankins (2013) state that in corporate dynamic models, the unobserved time-invariant effects need to be controlled for, in particular differences across firms (the firm effects). They argue that applying the least squares dummy variable estimator in dynamic panels, in the presence of unobserved heterogeneity, produces a downward bias for the lagged dependent variable coefficient estimate. Bias in the coefficient estimate is caused by the correlation between the lagged dependent variable and the firm-fixed effect. For these reasons, the system-GMM estimator has become a widely used approach in the area of corporate finance using dynamic panel data (Hansen, 2010).

Roodman (2009) and Flannery and Hankins (2013) state that system-GMM is an estimator that has been specially designed for panel data analysis. It is considered to be the best estimator for use in estimating dynamic models in corporate finance and is designed to cope with the different assumptions about the data-generating process (please refer to section 4.5.1 for more details).

Following Hovakimian and Titman (2003) and Borisova and Brown (2013), we investigate the connection between R&D investment and the cash raised from the disposal of fixed assets to examine the role that disposal proceeds, as source of funding, play in determining the level of R&D spending in a standard dynamic investment model. The general form of our empirical model is presented below, with controls for investment demand, namely sales growth and the market-to-book ratio.

$$\boldsymbol{R\&D_{i,t} = \beta_1 R\&D_{i,t-1} + \beta_2 R\&D^2{}_{i,t-1} + \beta_3 MktBook_{i,t} + \beta_4 SGrowth_{i,t} + \beta_5 CF_{i,t} + \beta_6 CF_{i,t-1} + \beta_7 StkIssues_{i,t} + \beta_8 StkIssues_{i,t-1} + \beta_9 DbtIssues_{i,t} + \beta_{10} DbtIssues_{i,t-1} + \beta_{11} DWC_{i,t} + \beta_{12} DWC_{i,t-1} + \beta_{13} DFA_{i,t} + \beta_{14} DFA_{i,t-1} + f_i + d_t + \varepsilon_{i,t}} \qquad (1)$$

In this model, we control for the unobserved determinants of R&D at the firm-specific level by including the firm-fixed effect (i.e. to control for industrial and technological characteristics). Furthermore, we include the year fixed effect[46] to control for any shocks that may influence R&D demand, for example macroeconomic fluctuations. Table 5-5 summarizes the expected effect of each of the explanatory variables on firms' R&D expenditure.

[46] In implementing the GMM estimations, errors are assumed to be correlated within individuals only, and not across them. Therefore, Roodman (2009) indicates that time dummies should be included in the model in order to remove the time-related shocks from the errors.

Table 5-5: Expected signs of the explanatory variables on the corporate level of expenditure on R&D.

Dependant Variable	***Corporate R&D expenditure (R&D)***	
Explanatory Variables	***Expected Sign***	***References***
Lagged Dependent Variable (***L.R&D***)	Positive (+)	Switzer (1984), Hall (1992), Czarnitzki (2006), Wang and Thornhill (2010), Martinsson (2010), Brown and Petersen (2011), Brown and Floros (2012), Borisova and Brown (2013).
Market to Book (***MktBook***)	Positive (+)	Hall (1992), Himmelberg and Petersen (1994), Brown and Petersen (2011), Brown and Floros (2012), Borisova and Brown (2013).
Sales Growth (***SGrowth***)	Positive (+)	Switzer (1984), Hall (1992), Himmelberg and Petersen (1994), Martinsson (2010), Wang and Thornhill (2010), Brown and Petersen (2011), Brown and Floros (2012), Borisova and Brown (2013).
Cash Flow (***CF***)	Positive (+)	Switzer (1984) , Hall (1992), Bond *et al.* (1999), Czarnitzki (2006), Piga and Atzeni (2007), Brighi and Torluccio (2009), Martinsson (2010), Wang and Thornhill (2010), Brown and Petersen (2011), Brown and Floros (2012), Borisova and Brown (2013).
Stock Issues (***StkIssues***)	Positive (+)	Bhagat and Welch (1995), Martinsson (2010), Wang and Thornhill (2010), Brown and Petersen (2011), Brown and Floros (2012), Brown *et al.* (2012), Borisova and Brown (2013), Shin and Kim (2014).
Long-Term Debt Issues (***DbtIssues***)	Negative (-)	Hall (1992), Bhagat and Welch (1995), Czarnitzki (2006), Piga and Atzeni (2007), Brighi and Torluccio (2009), Wang and Thornhill (2010), Brown and Floros (2012), Borisova and Brown (2013), Shin and Kim (2014).
Change in Net Working Capital (***DWC***)	Negative (-)	Fazzari and Petersen (1993), Weigand and Audretsch (1999), Ding *et al.* (2013).
Disposal of Fixed-Assets (***DFA***)	Positive (+)	Lang *et al.* (1995), Hovakimian and Titman (2003), Shin (2008), Borisova and Brown (2013), Edmans and Mann (2013).

Considering the potential endogeneity among the variables[47] of our empirical model, and the dynamic structure of the R&D investment model, we estimate our research regression using the System Generalized Methods of Moments estimator (System-GMM), developed by Arellano and Bond (1991) and Blundell and Bond (1998). This estimator simply works by forming a system, combining an equation in differences with another equation in levels of variables, in which lagged differences are used as instruments for the equation in levels and lagged levels are use as instruments for the equation in differences. The use of instruments in such a way addresses the weak instrument problem of endogenous variables, and is considered as a solution to the endogeneity problem. The financial variables, including the cash raised from the disposal of fixed assets (DFA), are all treated as potentially endogenous variables.

5.5.2 Results

Table 5-6 presents the dynamic R&D regression results using ordinary least squares (OLS), least square dummy variable or firm-fixed effects (LSDV), difference-Generalized Method of Moment (Diff-GMM), one-step System GMM (One-GMM) and two-step System GMM (Two-GMM) on the full sample.

The first column presents the results of the OLS regression on the pooled firm-year observations with a control for the year-fixed effect. The second column presents the within-firm regression estimates with a control for yearly and firm-fixed effects. In the first regression estimates, all the explanatory variables are statistically significant, apart from the disposal of fixed assets and sales growth. Except for long-term debt, all the coefficient signs are consistent with

[47] Since there is a causal connection between firm-level investment and the source of financing (internal or external), we treated all the financial variables in our empirical model (including the disposal of fixed asset proceeds) as potentially endogenous variables (Fazzari *et al.*, 1988; Bond and Meghir, 1994; Flannery and Hankins, 2013). For example, the decision to raise funds through external sources is endogenous and jointly determined with the decision on where and how to spend the funds; further, the decision on the level of R&D investment is endogenous and jointly determined with the sources and the levels of funds.

expectations. In the second regression, apart from sales growth, net change in working capital and disposal of fixed assets, all the other variables have a statistically significant effect. The signs of the coefficient estimates are the same as those obtained from the OLS estimates, but the magnitude of the coefficient on the lagged dependent variable is almost halved. This fall in magnitude is consistent with the downward bias indicated by Flannery and Hankins (2013) when estimating dynamic data with the firm-fixed effect.

The sign of the squared lagged dependent variable is negative and statistically significant. This is consistent with the specification of the Euler equation model and the findings of Bond and Meghir (1994) and Brown and Petersen (2011). The market-to-book ratio is significantly and positively associated with R&D expenditure, consistent with its role as a control for investment demand. The coefficients of sales growth are statistically insignificant in both regressions, suggesting a poor control for R&D spending via the accelerator model.

The results of the OLS regression show that cash flow, stock issues and debt issues are all positively associated with spending on R&D. The positive sign of debt issues is consistent with some of the literature, but at odds with the research focus, with firms not recognising debt as a source for financing R&D to reduce the risk of default. However, the negative sign of the change in net working capital is consistent with our expectations, reflecting firms' use of their liquid assets to smooth R&D activities, as explained in the previous empirical chapter. Finally, the sign of the disposal of fixed assets is negative and statistically insignificant. However, these results are not reliable, as the correlation between lagged dependant variables and the unobservable fixed effect is not zero, making the regression estimates inconsistent.

Table 5-6: Estimation results of the dynamic R&D regression (R&D sensitivity to the disposal of fixed asset proceeds).

	(OLS)	(LSDV)	(Diff-GMM)	(One-GMM)	(Two-GMM)
	RD	RD	RD	RD	RD
R&D $_{i,t-1}$	1.015^{***}	0.535^{***}	0.053	0.952^{***}	0.941^{***}
	(29.17)	(10.16)	(0.67)	(11.87)	(12.60)
R&D $_{i,t-1}^{2}$	-0.420^{***}	-0.239^{***}	-0.099	-0.477^{***}	-0.475^{***}
	(-13.40)	(-6.28)	(-1.06)	(-5.62)	(-5.97)
Mkt/Book $_{i,t}$	0.0003^{***}	0.0002^{***}	0.0001^{***}	0.0002^{***}	0.0002^{***}
	(5.81)	(3.33)	(2.90)	(7.85)	(8.67)
SGrowth $_{i,t}$	0.0016	0.0013	-0.0002	0.0001	0.0002
	(1.58)	(1.20)	(1.50)	(0.33)	(0.60)
CF $_{i,t}$	0.0583^{***}	0.0583^{***}	0.0612^{**}	0.0645^{*}	0.0617^{**}
	(5.70)	(5.35)	(2.09)	(1.82)	(2.01)
CF $_{i,t-1}$	-0.0679^{***}	-0.0453^{***}	-0.0226	-0.0534^{***}	-0.0570^{**}
	(-6.59)	(-4.06)	(-1.35)	(-3.29)	(-3.06)
StkIssues $_{i,t}$	0.0714^{***}	0.0571^{***}	0.0447	0.0860^{**}	0.0873^{**}
	(9.14)	(7.03)	(1.26)	(2.14)	(2.52)
StkIssues $_{i,t-1}$	-0.0315^{***}	-0.0115	-0.0084	-0.0146	-0.0162
	(-5.66)	(-1.54)	(-0.60)	(-1.09)	(-1.05)
DbtIssues $_{i,t}$	0.0710^{***}	0.0828^{***}	0.0975^{***}	0.0789^{***}	0.0739^{**}
	(11.53)	(13.13)	(5.13)	(2.93)	(2.33)
DbtIssues $_{i,t-1}$	-0.0247^{***}	-0.0079	-0.0218	-0.0082	-0.0099
	(-3.75)	(-1.20)	(1.48)	(-0.60)	(-0.72)

DWC $_{i,t}$	-0.0183* (-1.88)	-0.0041 (-0.41)	0.0130 (0.48)	-0.0263 (-0.88)	-0.0224 (-0.88)
DWC $_{i,t-1}$	-0.0507*** (-6.68)	-0.0539*** (-6.15)	-0.0408*** (-2.67)	-0.0598*** (-4.56)	-0.0537*** (-3.25)
DFA $_{i,t}$	-0.0382 (-0.63)	0.0238 (0.36)	-0.0584 (1.07)	-0.0341 (-0.66)	-0.038 (-1.10)
DFA $_{i,t-1}$	-0.221*** (-5.46)	-0.119*** (-2.92)	-0.0483 (-1.11)	-0.2025*** (-5.07)	-0.172*** (-4.57)
Year dummies	Yes	Yes	Yes	Yes	Yes
No. of observations	1283	1283	1029	1283	1283
No. of Firms	235	235	199	235	235
R-Squared	0.7266	0.6480			
No. of Instruments			81	97	97
AR (1)			-3.13 (p= 0.002)	-4.22 (p= 0.000)	-3.29 (p= 0.001)
AR(2)			-1.23 (p= 0.219)	-0.83 (p= 0.406)	-0.92 (p= 0.358)
J-test			185.99 (p= 0.000)	74.86 (p= 0.239)	74.86 (p= 0.239)

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Consequently, as proposed by Arellano and Bond (1991), the difference Generalized Method of Moment estimator (diff-GMM) is specially designed to eliminate the firm-specific effect by taking the first difference. Although this procedure removes the firm-fixed effect problem, it cannot eliminate the correlation between lagged dependent variables and the disturbances. Therefore, instruments that are correlated with the independent variables but not with the error term are required to treat the endogeneity problem. Therefore, we use lagged levels of all the explanatory variables (dated *t*-2 to *t*-6) as instruments for the equation in differences. The results are presented in the third column of table 5-6 and the coefficient of the lag and the squared lag of the dependent variable and the stock issues all become insignificant. Blundell and Bond (1998), however, state that the difference-GMM estimator suffers from the weak instrument problem that arises because of the weak correlation between the instruments and endogenous variables in the model. This makes the results of the difference-GMM inconclusive.

However, Blundell and Bond have improved the GMM estimator by combining the moment conditions of the level equation with those for the difference equation, producing the System-GMM estimator. The application of this estimator allows us to choose between using one-step or two-step estimation. The main difference between these estimations is that the one-step estimator assumes homoscedastic errors, while the two-step one assumes heteroscedastic errors. Roodman (2009) points out that the second estimator is asymptotically more efficient than the one-step estimator. However, he further points out that the standard errors of the two-step estimation tend to be downward biased, so it is important to use finite-sample correction of the standard errors. Consequently, in the estimation of this model, we consider applying finite sample correction for the applied two-step system-GMM estimator. In the system specification, we use lagged differences dated *t*-2 as instruments for the equation in levels, and lagged levels dated *t*-3 to *t*-6 as instruments for the equation in differences.

Columns 4 and 5 of table 5-6 present the one-step and two-step estimates respectively. The results of the two estimates are very similar in significance but slightly different in magnitude. In both regressions, the lagged dependent variable has a statistically significant positive effect on the current levels of R&D expenditure. Furthermore, the coefficient of the square lagged level of R&D is significantly negative, which is entirely consistent with our expectations and the findings of previous research (for example, Bond and Meghir, 1994; Brown and Petersen, 2011).

In comparison with the previous three regressions, the coefficient of the market-to-book ratio is statistically significant and positively associated with R&D expenditure, while the coefficients of sales growth are positively insignificant.

The significance of the cash flow variable was consistent with what was expected according to pecking-order theory (Myers and Majluf, 1984; Myers, 1984). However, the insignificance of lagged cash flow was contrary to this research expectation. One explanation could be that the youngest firms have had less time to generate internal funds, or worse, have had negative internally generated cash flows (Del Canto and Gonzalez, 1999).

The strong link between stock issues and R&D investment indicates that firms rely heavily on this funding to finance their R&D, which is consistent with expectations. However, the significant positive association between debt issue and R&D expenditure is unexpected, although consistent with previous research, as suggested by trade-off theory (Myers, 1984). Finally, the association of both change in net working capital and disposal of fixed assets and R&D expenditure are statically insignificant which is against expectations. However, the lagged values were negatively and statistically significant. The consistency of the system-GMM estimator was verified by Hansen's *J*-test of over-identifying restrictions, and the autocorrelation test of Arellano and Bond (1991).

The model presented in Table 5-6 was estimated for the full sample. However, classifying the data into two sub-samples[48], reflecting constrained and unconstrained firms, could provide a better picture of the association between explanatory variables and the R&D expenditure of AIM-listed firms. Using the dividend pay-out criteria, columns 1 and 2 of table 5-7 present the regression results for constrained and constrained firms.

[48] According to the corporate finance literature, a large number of researchers rely on firm age, firm size or the firm's dividend pay-out ratio to split their study samples (i.e. to split their samples into groups of firms which are less likely to be financially constrained and those that are more likely to be financially unconstrained). In this chapter, as we are dealing with young and small firms in particular, which, according to the previous literature, are considered to be more likely to be financially constrained (more prone to information asymmetry problems) (Brown and Petersen., 2011; Brown and Floros., 2012), we considered the dividend pay-out ratio as the way for splitting groups. Fazzari *et al*. (1988) and Fazzari and Petersen (1993) argue that firms which are more likely to face financing frictions will have zero dividend pay-outs, while firms that are less likely to face financing frictions will have positive dividend pay-outs.

Table 5-7: Estimates from the two step System-GMM for firms based on their classification.

	(No-Div) RD	(Div) RD
$R\&D_{i,t-1}$	0.9477^{***} (9.76)	0.9496^{***} (8.89)
$R\&D_{i,t-1}^2$	-0.4434^{***} (-4.69)	-0.7340^{***} (-11.21)
$Mkt/Book_{i,t}$	0.0002^{***} (7.45)	-0.0005 (0.53)
$SGrouth_{i,t}$	0.0000 (-0.19)	0.0466^{***} (2.34)
$CF_{i,t}$	0.0611 (1.45)	0.1161^{***} (2.81)
$CF_{i,t-1}$	-0.0369 (-1.27)	-0.0765^{***} (-3.02)
$StkIssues_{i,t}$	0.0888^{**} (2.04)	0.1130^{*} (1.96)
$StkIssues_{i,t-1}$	-0.0151 (-0.68)	-0.0189^{**} (-2.59)
$DbtIssues_{i,t}$	0.0880^{**} (2.05)	-0.1166^{**} (-2.38)
$DbtIssues_{i,t-1}$	-0.0160 (-0.90)	-0.0099 (-0.53)
$DWC_{i,t}$	-0.0324 (-0.81)	-0.0652 (-1.55)
$DWC_{i,t-1}$	-0.0570^{***} (-2.82)	-0.0411^{*} (-1.55)
$DFA_{i,t}$	-0.0574 (-0.36)	0.0625 (1.66)
$DFA_{i,t-1}$	-0.3419^{***} (-3.73)	-0.0631^{*} (-1.67)
Year dummies	Yes	Yes
No. of observations	590	693
No. of Firms	132	103
No. of Instruments	89	95
AR (1)	-2.67 (*p*= 0.008)	-3.04 (*p*= 0.002)
AR (2)	-0.19 (*p*= 0.846)	-1.08 (*p*= 0.278)
J-test	68.01 (*p*= 0.197)	75.59 (*p*= 0.174)

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

For both regression equations, the lagged level of R&D is positively and significantly associated with the current level of R&D expenditure, reflecting the persistence in R&D investment. The coefficient of the square lagged R&D is significantly negative, being close to one for both groups. These results are consistent with the previous findings of Bond and Meghir (1994) and Brown and Petersen (2011). The negative coefficient on the square lagged R&D implies that the presence of adjustment costs increases the distance between the current level of R&D investment and the target level.

The coefficients of the market-to-book value (*MktBook*) are positively and significantly associated with the level of R&D for the constrained group, but not for the unconstrained firms. On the other hand, sales growth for R&D investment, as with the accelerator model, is positively and statistically significant for the unconstrained group, but not for the constrained one. The difference in the results for the control variables is due to the information relevant to investment demand, with other factors such as capital market constraints and adjustment costs playing an important role in determining investment demand.

The coefficient of cash flow is positive and statistically significant in the second regression but not the first (i.e. firms with zero dividend pay-outs), which is consistent with the pecking order model. This suggests firms prefer to use internally generated funds to finance their investment first, rather than using costly external sources of funds. However, the insignificance of the first regression can be partially explained by the fact that the youngest firms have had less time to generate internal funds, or worse, have negative internally generated cash flows (Bond and Meghir, 1994; Del Canto and Gonzalez, 1999; Carpenter and Petersen, 2002; Brown and Petersen, 2011).

Considering external sources of finance, the coefficients of the issues of new stock are positively and statistically significant in both regressions. These findings are consistent with the previous literature and confirm that common stocks are an ideal financing means for funding

R&D investment. In addition, the issue of long-term debt, as an external source of finance, is statistically significant with a positive sign for the constrained group and negative for the unconstrained one.

The negative sign of the unconstrained regression suggests that these firms do not rely on this source of external funding to finance their R&D investment, whereas they insist more on reducing their financial obligations in order to reduce their risk of financial distress and bankruptcy (Himmelberg and Petersen, 1994; Wang and Thornhill, 2010). On the other hand, the positive and statistically significant effect of debt issues on R&D investment for the constrained group reflects that, in the absence of internally generated funds, these firms follow the trade-off theory in structuring their capital, which is contrary to our research expectation, but consistent with the previous literature. The coefficient of the change in net working capital is negatively but not statistically insignificant in both regressions, in contrary to their lagged values, being statistically significant. The negative coefficient sign indicates that firms rely on working capital as a store of liquidity, by drawing it down to absorb the shocks of cash flow variations in the short run.

Most importantly, the coefficient of the disposal of fixed assets is statistically significant in both regressions, with a negative sign, in contrast to what was expected. The significance of the lagged values indicates that when firms are voluntarily selling off their fixed assets, they reduce their expenditure on R&D investments; in contrast to the previous research findings, there is no positive association between the disposal of fixed asset proceeds and the R&D expenditure of the AIM-listed firms. The results suggest that the selling off of fixed assets, as a source of funds to finance R&D investment, does not take place. The negative sign may be explained by the fact that selling off assets reduces the value of firms, and may increase the firm's level of risk if the proceeds are devoted to more risky investments. An alternative explanation may be related to the characteristics of the AIM-listed firms that are small and young. Selling off tangible assets to avoid binding financing constraints presents a negative shrinking in size to firms. As a result, this requires firms to reduce and restructure their sources of risks (R&D) accordingly, in order to increase their probability of survival.

These results present evidence that, regardless of dividend pay-outs as the splitting criterion, both groups of firms (with positive and no dividend pay-outs) are financially constrained. However, this criterion has helped to differentiate the financing preferences of the two groups in the financing menu of their R&D activities.

5.5.3 Robustness tests and results

To check for the robustness of the system-GMM estimation results, we considered a number of alternative specification and estimation approaches to test the connection between the disposal of fixed asset proceeds and the level of R&D expenditure of AIM-listed firms. We re-estimated our dynamic model with an alternative estimation procedure, the one-step GMM estimator. Although finite-sample correction was employed to address the downward bias of the two-step estimations, Roodman (2009) states that the reported standard errors from the two-step estimator tend to be downward biased in small samples. However, we re-estimated the model using a one-step estimator to check the robustness of our results. The one-step estimates given in table 5-8 are similar in nearly all aspects to the reported results in table 5-7. In particular, we continue to find a significant positive effect for the stock and debt issue variables for the potentially constrained group. There is a similar significant link between the net change in working capital, disposal of fixed asset proceeds and R&D. However, for the unconstrained group (firms with positive dividend pay-outs), the one-step estimations continue to show a positive significant effect of stock issues and cash flow on R&D, and a negative association with debt issues. The Arellano-Bond and Hansen tests indicate that our regressions are well specified, and that the instruments employed are valid.

Table 5-8: One-step System-GMM estimates of the constrained and unconstrained groups.

	(No-Div) RD	(Div) RD
R&D $_{i,t-1}$	0.9448*** (10.10)	0.9485*** (9.04)
R&D $_{i,t-1}^{2}$	-0.4354*** (-4.96)	-0.7326*** (-11.37)
Mkt/Book $_{i,t}$	0.0002*** (7.40)	-0.0005 (0.53)
SGrouth $_{i,t}$	-0.0000 (-0.03)	0.0475** (2.31)
CF $_{i,t}$	0.0579 (1.39)	0.1169*** (2.74)
CF $_{i,t-1}$	-0.0343 (-1.61)	-0.0762*** (-2.99)
StkIssues $_{i,t}$	0.0887* (1.92)	0.1161* (1.95)
StkIssues $_{i,t-1}$	-0.0167 (-0.92)	-0.0192*** (-2.79)
DbtIssues $_{i,t}$	0.0883*** (3.76)	-0.1216* (-2.31)
DbtIssues $_{i,t-1}$	-0.0160 (-1.23)	-0.0122 (-0.65)
DWC $_{i,t}$	-0.0336 (-0.91)	-0.0662 (-1.45)
DWC $_{i,t-1}$	-0.0609*** (-3.64)	-0.0422* (-1.97)
DFA $_{i,t}$	-0.0370 (-0.25)	0.0729 (1.38)
DFA $_{i,t-1}$	-0.3409*** (-3.85)	-0.0672 (-1.63)
Year dummies	Yes	Yes
No. of observations	590	693
No. of Firms	132	103
No. of Instruments	89	95
AR (1)	-3.38 (p= 0.001)	-2.87 (p= 0.004)
AR (2)	-0.21 (p= 0.832)	-1.62 (p= 0.104)
J-test	68.01 (p= 0.197)	75.59 (p= 0.174)

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.6 Conclusion

This is the first study that investigates the sensitivity of R&D expenditure to proceeds from the disposal of fixed assets for AIM-listed firms. Along with the other financial variables, we included the disposal of fixed asset proceeds as a source of funds to emphasize its role in determining R&D expenditure. Several approaches were employed to estimate the dynamic R&D investment model.

For the financially constrained group, we find strong evidence that R&D expenditure is determined by the level of previous R&D investment, and that this group of firms relies on stock issues as a source of funds to finance this investment. In contrast to expectations, our results show that constrained firms rely on debt issues to finance R&D investment, but do not rely on internally generated funds as a source of finance. We further find evidence that the constrained group uses working capital as a source of funds to finance their R&D investment in the short run when they are likely to face binding financing constraints. Most importantly, in contrast to the previous literature, we find a negative association between R&D expenditure and the proceeds from the disposal of fixed assets. We argue that this negative association is observed because the selling off of tangible assets overcomes binding financing constraints, reduces a firm's value and increases the level of risk if proceeds are devoted to more risky investment. Therefore, firms are required to adjust their risky R&D investment in order to increase their survival chances in the market.

On the other hand, our findings show that the level of R&D investment of the unconstrained firms is largely determined by the previous levels of R&D, and firms rely mostly on internally generated funds and stock issues to finance their R&D activities. Unlike constrained firms, the R&D expenditure of the unconstrained firms is negatively associated with new debt issues, suggesting that this group of firms insists more on reducing their financial obligations in order to reduce their risk of financial distress and bankruptcy. Finally, our results show that there is an impact of working capital accounts and the proceeds from the disposal of fixed assets on R&D expenditure; in contrast to prior expectations, this group of firms is less likely to face binding financing constraints.

Chapter 6

Conclusion

6 Conclusion

6.1 Summary

In this thesis we have attempted to investigate some of factors that affect the probability of firms undertaking R&D investment, as well as the determinants that have an effect on the level of expenditure on this activity in the presence of financial constraints, using a panel dataset of the manufacturing and service firms listed on AIM. It is one of the first studies to focus on the AIM in the UK. It sheds more lights on the effects of the UK government's policies on R&D activities, and helps to solve the puzzle of whether financing constraints have a significant impact on the R&D and innovation of the young and small firms listed in the UK.

Drawing on a literature survey, we aimed to enrich the existing body of knowledge on the determinants of R&D investments by offering evidence from AIM for the period 1999 to 2014. In the analysis of the thesis, we attempted to build on and improve the previous work in each of the three stand-alone chapters, as well as attempting to improve the estimation techniques to lessen the disadvantages of applying inadequate statistics that may affect the conclusions drawn from each investigation.

This chapter aims to conclude the thesis by briefly summarizing the key findings and conclusions, highlighting the observed gaps and the research contributions. The practical implications of the findings are discussed and the research limitations and ideas for future research are presented.

6.2 Key findings and conclusions

6.2.1 Incentives for corporate decisions to make R&D investment

A survey of the literature shows that, although much effort has been devoted to investigating the determinants of R&D activities, industrial and financial factors have typically been considered and examined separately, rather than together. Hence there has been no overview of R&D determinants. However, researchers have recently started to consider both types of factors when modelling decisions to undertake R&D expenditure. The estimation approaches which have been taken in the current literature are mainly OLS, Logit and Probit, and the models are in a static form.

According to the review of the literature, there was a gap on the government fiscal impact on R&D activities. Chapter 3 analysed the micro, meso and macro level factors on R&D investment. Specific hypotheses where derived with reference to the literature and tested on a sample of 630 firms listed on AIM between the periods 1999 to 2014. The dynamic form of undertaking such investment decisions was estimated, avoiding the biased results achieved by testing static models; we applied the dynamic logistic estimation approach, which controlled for the initial condition problem.

In addition to the lagged dependent variable, the main results suggest that large-sized firms are better at stimulating innovative activities. This result can be explained by the fact that large firms are more able to diversify their R&D projects. A large firm can make the results of its R&D activities more profitable in a larger market, and cover the cost of hiring highly skilled workers (Nelson, 1959; Cooper, 1964; Graves and Langowitz, 1993; Vaona and Pianta, 2008; Herrera and Sánchez-González, 2013).

The results also suggest that age is negatively associated with the probability of carrying out R&D activities, which means that young firms tend to have the highest probability of investing in R&D. In addition, competitive markets were found better at stimulating innovative activities, which is in contrast to the Schumpeterian hypothesis. Finally, in contrast to the literature on the impact of fiscal policies on innovation, this work suggests that corporate tax rates have a positive impact on R&D investment. This finding can be explained by the fact that firms tend to allocate more of their resources to projects in which they can avoid paying taxes, since R&D expenditure is tax deductible. The higher the corporate tax rate, the higher the degree of risk sharing with the government.

6.2.2 Corporate R&D financing menu

Recent theoretical research explains that corporate investment expenditure is based on several investment theories and models; for example, Tobin's Q model, the accelerator model and the financing constraint model. Apart from Tobin's Q and the accelerator models, the financial constraint model considers sources of finance as the key determinants for investment. Accordingly, the second chapter of this research investigated the determinants of R&D expenditure on AIM; the effect of financing constraints on R&D investment; and the role that working capital plays in smoothing the path of R&D in the presence of financial constraints.

Due to the high adjustment costs associated with R&D investment, and the need for smoothing such an investment to avoid associated costs, researchers have considered the role that precautionary cash holding accounts may play in smoothing the path of R&D spending for firms that are facing binding financing constraints. For example, Brown and Petersen (2011) and Guariglia and Liu (2014) found evidence that constrained firms can maintain a relatively smooth path of R&D spending by drawing down their precautionary cash holdings accounts. However, little research has considered the role that working capital accounts may play in smoothing R&D spending in the presence of financing constraints. This work emphasizes the overlooked role of working capital as an input and an easily reversible store of liquidity in R&D smoothing.

Four testable hypotheses where proposed and tested on a panel data-set of the 235 UK firms listed on the AIM, over the period 1999 to 2014. The system-GMM estimator was used to estimate the model due to the dynamic nature of the model, to control for the biases that may occur because of the dynamic generating process, the presence of unobserved heterogeneity, the unobserved time-invariant effects and the endogeneity of explanatory variables.

For constrained firms, we found strong evidence that the sources of finance that determine R&D investment are the proceeds from stock issues and long-term debt issues, but not the internally generated funds. However, in the presence of financing constraints, firms draw down liquidity from working capital accounts to absorb the shocks of cash flow variations in the short run, maintaining a smooth path of R&D spending, and avoiding the high adjustment costs associated with it.

On the other hand, unlike constrained firms, the results suggest that the determinants of R&D spending for unconstrained firms (firms with positive dividend pay-outs) are internally generated funds and the proceeds from stock issues, but not the new long-term debt issues. Finally, the results suggest that working capital accounts have an impact on R&D expenditure for unconstrained firms, which is in contrast to this research expectation that firms with positive dividend pay-outs are less likely to face financing frictions.

6.2.3 Financing constraints, disposal of fixed assets and the impact on R&D expenditure

The comprehensive review of the literature also shows that, although firms rely on stock issues to finance their R&D investment, they do suffer from the capital market imperfection. These real world imperfections introduce several problems that firms need to deal with. For example, they can face uncertainty over their expected levels of future cash flows, and such uncertainty would incur extra costs for firms with insufficient cash balances to cover expenses. Several strategies need to be introduced, among them the selling off of tangible assets.

Hite *et al.* (1987) and Hovakimian and Titman (2003) claim that this strategy might be the lowest cost approach to the problem of uncertainty and its costs. The selling-off of tangible assets is one of the most important ways in which firms can respond to financing problems caused by the imperfections of the real world. Like any other source of financing, it is clear that economists have recognised the disposal of fixed asset proceeds as an important source of finance for financially constrained firms.

This work, however, has been devoted to examining the importance of financial constraints on R&D expenditure by directly examining the role that the disposal of fixed asset proceeds plays in determining the level of R&D spending. To the best of knowledge, this is the first study of its kind to emphasize the importance of financing constraints on R&D investment for AIM-listed firms. A hypothesis on the impact of the disposal of fixed asset proceeds was devised and tested on a panel of 235 firms, over the period 1999 to 2014.

In contrast to the current literature, this research found a negative association between R&D expenditure and cash raised from voluntary asset sales, indicating severe binding financing constraints. Using several estimation approaches, we did observe a negative association between the cash raised from the disposal of fixed assets and R&D investment. The selling off of tangible assets overcomes binding financing constraints but reduces a firm's value and increases its level of risk if the proceeds are devoted to more risky investments. This suggests that firms need to reduce and restructure their sources of risks to increase their chances of continuation and survival in the market.

6.3 Research contributions

The thesis analyses the factors that influence corporate decisions on undertaking R&D investment, and the determinants that affect the level of expenditure, with reference to the manufacturing and services firms listed on AIM. The first empirical chapter is original, as it uses a dynamic logistic model that covers the theoretical incentives of making R&D investment, including fiscal policy factors. Furthermore, the second and the third empirical chapters are pioneering as they emphasise the role of working capital accounts and the disposal of fixed asset proceeds in the presence of binding financial constraints. Conducting such research makes important contributions that may enrich the existing literature and improve understanding of the intangible corporate activities that contribute to the growth of economies, that is, R&D investment.

More specifically, the contributions of this thesis are categorised based on each of the stand-alone chapters. In chapter 3, while most empirical research on the incentives that influence a firm's decision to make R&D investment has considered the effect of market environmental factors and firm-specific factors, this analysis was mainly devoted to empirically investigating the effect of fiscal policy on undertaking such investment.

Such an investigation is of great importance, especially for policymakers, as it sheds light on whether these government incentives have a significant impact on motivating firms to carry out R&D activities in the UK. A second contribution is that most previous empirical research has been almost exclusively based on investigating large and mature firms. In this work we aim to contribute by investigating the determinants and the incentives of carrying out R&D activity of small and young firms. Owing to their different characteristics, importance and contributions to the economy, it is important to observe what influences firms on AIM, and further to assess the generous schemes offered by the UK government to this type of firm.

The third contribution of this work concerns the applied methodology. Previous research has ignored the dynamic process of undertaking such investment decisions, and has failed to control for the initial condition issues. However, this work contributes to the knowledge by building its results on the estimates of the dynamic logistic model which controls for the initial condition issues with unobserved heterogeneity.

Chapter 4 focused on R&D investment and its association with high adjustment costs and financing with volatile internal and external sources. It is argued that firms which are facing binding financing constraints may not be able to maintain a smooth path of R&D spending. Therefore, researchers have found evidence that corporate cash holding plays a role in this process, and provide evidence of corporate financial constraints. Drawing on an intensive survey of the literature, few studies have considered the potential role of working capital accounts as a source of liquidity in smoothing R&D investment in the presence of R&D financing constraints.

The contributions of this work are fourfold. First, this is one of the first studies to use UK data. The proportional lack of evidence that sources of finance matter for R&D in the UK is a puzzle, and calls into question whether financing constraints have a significantly important role in R&D and innovation in this modern economy. A second contribution is that, whereas most of the previous empirical studies that examine the existence and importance of financing constraints on R&D have been based almost exclusively on testing large and mature firms, this work is more focused on young, small listed firms. Considering this group in particular can dramatically alter the conclusions regarding the importance of financing constraints.

A third contribution is that this work provides more accurate and more decisive tests for the presence of financing constraints in R&D investment by employing the overlooked role of working capital. In particular, if financing constraints matter for R&D, a negative link between R&D and the changes in net working capital should be observed, implying that firms draw on liquidity reserves (in the form of working capital) for R&D smoothing. This study is the first of its kind to test the role of working capital on R&D smoothing and to emphasize its importance for firms' financial policies.

A large number of studies rely on either the firm age or size, or dividend pay-out ratio criteria to split their samples into financially constrained and unconstrained firms. This work considers a combination of all three mechanisms. A precise classification of the sample firms helps to eliminate biased estimations, which could affect the empirical results and conclusions reached.

In chapter 5, it is suggested that asset sales are mainly undertaken to raise cheap capital for financially constrained firms. However, only a few studies have examined the impact of the disposal of proceeds on R&D investment. This thesis has aimed to fill the gap. To the best of the knowledge, no such investigation have been made to explore how the sensitivity between firm investment in R&D and cash raised from the sales of fixed assets influences the existence of financing constraints on R&D. The second contribution is that no such investigation has been made on the UK, a developed country. And the third contribution is that this work is devoted to focusing on young, small listed firms in particular. Such an investigation of this type of firm can dramatically alter the conclusions regarding the importance of financing constraints.

6.4 Implications of the research findings

The research findings and conclusions will contribute to the existing academic knowledge. However, the broader practical implications may help policy makers, corporate managers and investors.

6.4.1 Implications for policy-makers

Since this thesis is mainly devoted to empirically investigating the corporate tax incentives of R&D and the financing of R&D for UK listed firms, we first consider the practical implementation for policymakers. First, the results suggest that the corporate tax rate is positively and significantly associated with R&D investment. The rationale is that, since R&D expenditure is tax deductible, it is a tax shield for firms to allocate more of their resources towards R&D projects, through which they can avoid paying taxes. Therefore, in practice, policymakers should consider the nature of the target business before setting tax policies. To encourage R&D expenditure, increasing the tax rate could be the right step, representing a degree of risk sharing by the government.

Second, where the empirical results show that the R&D investments of the AIM-listed firms are more likely to be financial constrained, it is argued that financially less constrained firms would be better at stimulating such investments compared to financially constrained firms. Previous research, for example Bond *et al.* (2003), has characterised the UK financial system as a highly challenging market in channelling investment capital towards firms with high growth opportunities because of the information asymmetry dilemma. This results from the arm's-length relationship between firms and finance providers. Therefore, an implication for policymakers is the need to mitigate the degree of information asymmetry. In this way, a highly motivating environment for corporate financing and investment can be created.

6.4.2 Implications for corporate managers

In addition to the implications for policymakers, the findings and conclusions of this research are relevant for corporate managers. First, there is an insignificant role of R&D tax relief, and according to the HMRC office, there is a small number of regular claimants. This implies that corporate decision makers need to consider the cost benefit of this relief, and consequently this may increase their probability of being engaged in the process.

Second, the empirical evidence suggests that UK firms are likely to be financially constrained, which presents a profound implication for corporate managers in ensuring smooth levels of R&D expenditure. The empirical findings suggest that, in the presence of financial constraints, firms draw down liquidity from working capital accounts to absorb the shocks that may affect the required smooth path of spending on R&D, or otherwise bear high adjustment costs. Managers therefore need to consider various cash flow possibilities, and also consider emergency action on the management of working capital accounts in such cases.

For example, when firms are faced with negative cash flow shocks, managers might be better off adjusting current asset accounts, thereby freeing liquidity to smooth R&D spending levels. More precisely, managers can draw down cash holdings, tighten up their credit sales and/or consume their raw materials faster than they are replaced. Similarly, managers can adjust their current liabilities accounts; for example, by delaying the payments on accounts payable and/or increasing their use of trade credit (considering free financing means in the short run).

In addition, managers might consider the use of short-term debt, which in some cases can be collateralized with credit sales accounts. Contrary management strategies are applied to working capital accounts when firms are faced with positive cash flow shocks, or have access to the capital market, through which they can build up their liquidity positions that might be easily liquidated into cash in emergencies, and generate profits in the normal circumstances.

However, it worth noting that strategies involving the management of working capital accounts are considered as short-term buffering strategies to smooth corporate R&D activities. Finally, managers may be advised to consider a market-timing strategy to ensure a strong working capital position and in this way to assure a successful escape in the presence of financial constraints in the short run.

6.4.3 Implications for investors

In addition to the implications for policymakers and corporate managers, the findings and conclusions of this thesis may also have implications for investors. While general investors consider the dividend pay-out ratio as a sign of a good corporate management and operations, they generally have more sentiment towards investing in firms with high dividend pay-out ratios. In practice, however, investors may not consider the interaction that might exist between the dividend pay-out ratio, the level of investment and financing sources. In fact, this ratio is greatly and directly affected by the corporate level of investment and the accessibility to sources of finance. In addition, it is highly affected by the type of business, and the nature of the industry in which it competes.

Subsequently, if investors give more weight to the dividend pay-out ratio when considering their investment decisions, this might direct corporations towards investing in less risky and low net present value projects. Therefore, an implication would be that investors should consider that the dividend pay-out ratio does not always reflect a true picture of firms, and a company with a high ratio is not always the best for shareholders. This ratio needs to be considered in the context of the firm's nature, investment opportunities and its financing abilities.

Further, risk averse investors may prefer to invest in large, mature firms rather than young, small ones, as they are considered to be less risky as they are more established. Young, small firms mainly turn to stock markets for funding purposes, to finance their growth opportunities. Considering the economic logic of "Small Is Beautiful" would be an important implication for investors, especially if small firms suffer from little or no access to debt and limited amounts of internally generated funds to finance their R&D activities.

6.5 Research limitations and ideas for further research

Like any other research, this thesis has faced a number of limitations that need to be addressed. First, to test the theoretical hypotheses of each chapter, this research has mainly relied on empirical research methodology. Second, the conclusions were drawn from the accumulated evidence obtained from the dataset. Therefore, a key limitation is the definition of the variables, the form of the models and the estimation techniques. In addition, considering that the vast majority of the data employed are financial and accounting statistics, the findings and conclusions of the research might also be sensitive to possible managerial manipulation of the data. Second, where the data-set of the research only covers SMEs listed on AIM, the findings are prone to selection bias, when the rest of population (unlisted SMEs) are not covered.

Third, although this research is classified under the corporate finance/financial economics category and is devoted to investigating the incentives for innovation, the financing menu of R&D and the financing constraints on the AIM-listed firms in the UK, some other factors, for example corporate governance ones, which may play a role in these investigations, are not addressed in this thesis, owing to their lack of availability and accessibility. Fourth, as this thesis includes three stand-alone chapters, which are all focused on R&D types of investment and employ similar theories, it is observed that there is some overlap. This, however, has been minimised where possible, but has necessarily been accepted to achieve the flow and maintain the status of each of the empirical chapters.

Finally, in the first empirical research of this study, it is important to acknowledge that the results are prone to endogeneity bias, due to potential level one endogeneity between firm-level covariates, for example the potential reverse causality between firms' financial structure and their decision to engage in R&D investment. Therefore, further improvements to the Wooldridge approach to handling the initial condition problem and level one endogeneity need to be considered in similar future research.

The literature review and the empirical findings have suggested a number of promising ideas for further research. For example, existing research on the corporate cash-holding role in R&D investment has found evidence that firms smooth their R&D investments by drawing down their precautionary cash accounts in cases where financing is unavailable and build up their reserves when financing is available (Brown and Petersen, 2011; Guariglia and Liu, 2014). Similarly, this research investigates the overlooked role of working capital accounts in R&D in the presence of financing constraints.

A promising research idea could be to investigate cash and non-cash working capital accounts with narrower classifications, that is, the role of non-cash working capital accounts and cash holdings. This would give more insight into the role that payable accounts may play in the process, and would give a clearer idea of the various reasons for cash holding accounts, and whether this variation is a consequence of the presence of financing constraints.

Moreover, investigating the different types of R&D would be a promising research idea; for example, the determinants and the financing menu of product development and process development. Such an investigation might give a more precise image of the determinants and sources of finance for different R&D types. Further, considering the corporate governance view in explaining firms' innovation; for instance, the role that ownership structure and board characteristics may play in undertaking such investment decisions, could be considered a significant contribution to the knowledge in this area of investigation.

In addition, it is worth considering or examining the connections between public policies in stimulating R&D activities at the firm level, the outputs of such activities and corporate productivity, as well as examining the links between corporate R&D activities, corporate capital structure and dividend pay-out policies. Finally, the possible connection between R&D activities and the probability of corporate failure could be examined.

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Appendixes

Appendix 1a: Numerical example clarifying how working capital accounts can be used as sources of finance by constrained firms, and to explain how onlt the use of cash holding may not be enough to explain all the sources of funds for smoothing R&D investment (in the case of a positive change in cash holding).

		Total Assets							=	Total Equity	+	Total Liabilities				
		Non-current Assets	+	Current Assets					=	Equity	+	Current Liabilities			+	Long-term Liabilities
		NCA	+	Inventory	+	AR	+	Cash	=	Capital/Equity	+	AP	+	S.T Debt	+	L.T Liab
Opening Balance	Transactions	10000		2100		1200		700		7200		1300		1500		4000
	300 units of inventory sold for £600			-300						300						
	(£500 in cash)							500								
	(£100 in AR)					100										
	AP reduced by £100 from cash balance							-100				-100				
	S.T debt reduced by £100 from cash							-100						-100		
		10000		1800		1300		1000		7500		1200		1400		4000
	Balance			14100					=			14100				
	400 units of inventory sold for £1000 (cash)			-400				1000		600						
	The firm collected £100 from its AR in cash					-100		100								
	£200 paid to creditors (AP)							-200				-200				
	£400 paid for S.Tdebt							-400						-400		
		10000		1400		1200		1500		8100		1000		1000		4000
	Balance			14100					=			14100				
	The firm has a £1000 short-term loan (collateralized with AR)							1000						1000		
	The firm bought inventory on account of £800			800								800				
	600 units of inventory sold for £700 (£500 in cash and £200 in AR)			-600		200		500		100						
	£100 from cash balance paid for S.T debt							-100						-100		
		10000		1600		1400		2900		8200		1800		1900		4000
	Balance			15900					=			15900				
	£2000 has been used for R&D (drawn from cash)							-2000		-2000						
	£400 collected from AR and paid for S.T Debt					-400								-400		
	300 units of inventory sold for £400 (in cash)			-300				400		100						
	£200 paid to creditors (AP)							-200				-200				
		10000		1300		1000		1100		6300		1600		1500		4000
	Balance			13400					=			13400				

After reviewing leading books on the management of working capital (such as *Modern Working Capital Management* by Scherr (1989), *Working Capital Management* by Hampton and Wagner (1989), *Economic Development Finance* by Seidman (2005) and *Corporate Finance: Principles & Practice* by Watson and Head (2016), and the leading literature on how each of the working capital components can be used as a source of finance for constrained firms (for example, Petersen and Rajan, 1997; Deloof, 2003; Ding *et al.*, 2013), a simple numerical example was created to show how working capital components can be used as a source of finance rather than a use of finance by firms (especially when they are facing finance constraints and need to offset the short-run effect of the cash flow fluctuation or finance shocks). Furthermore, this was done to show why net working capital (as a variable) should be used rather than net cash holdings in our model, in contrast to the previous literature on RD investment smoothing (Brown and Petersen, 2011; Guariglia and Liu, 2014); that is, raising the importance of the non-cash working capital components as sources of funds for firms.

It is assumed that ABC is an R&D performing firm listed on a public market (AIM). As in the example, it is also assumed that the above transactions took place during the year 2004, and that the firm in that particular year was facing cash flow fluctuations and financing frictions. However, to deliver the idea of this example, only the principal and chief accounts of current assets and liabilities[49] are mentioned. Furthermore, static balances of the non-current assets and long-term liabilities are assumed in order to focus on the working capital accounts. In addition, the cost of inventory sold and purchased is fixed at £1 per unit. As shown in the example above (appendix 1A), the opening balances of the current assets were £2100, £1200 and £700 for the inventory, accounts receivable and cash accounts respectively, and the opening balances of the current liabilities were £1300 and £1500 for the accounts payable and short-term debt accounts

[49] Working capital is defined as the current assets less current liabilities, the main three components of the current assets are principally cash and equivalents, inventory and account receivable, and the current liabilities consist chiefly of account payable and short-term debt.

respectively. During the first quarter of 2004, ABC firm made several transactions, as follows. The firm sold 300 units of its inventory (at an original cost of £1 per unit) for £600 (£500 in cash and £100 in AR), and paid off £100 of its trade credits (AP), reducing its short term debt by £100 (from its cash account). The transactions of this first quarter resulted in an increase in the cash balances by £300, reducing the AP by £100, and reducing the short-term debt by £100. During the second quarter, the firm sold another 400 units of its inventory (originally worth of £400) for £1000 (cash), and collected £100 (cash) from its AR. Furthermore, it paid off £200 for its creditors, and £400 for its short-term debt. As a result, the cash balance increased by £500, the accounts receivable (AR) balance was reduced by £100, accounts payable (AP) decreased by £200, and short-term debt decreased by £400.

In the third quarter, and in order to increase the precautionary cash balances, the firm obtained a short-term loan of £1000, collateralized with its accounts receivable, and bought 800 units of inventory (for £800) on account to maintain the role of trade credit. During this quarter, the firm sold 300 units of its inventory (at an original cost of £1 per unit) for £700 (£500 in cash and £200 in accounts payable), and paid off £100 of its short-term debt from its cash balance. These transactions yielded an increase in the inventory by £200, an increase in the accounts receivable of £200, and most importantly, an increase in the cash account by £1400. On the other hand, the current liabilities accounts increased by £800 and £900 for the accounts payable and short-term debt respectively. During the fourth quarter, the firm was facing a binding cash flows shock. As a result, it had to draw £2000 from it cash account to smooth its R&D investment path. Where the accounts receivable served as collateral for its short-term debt, the firm collected £400 from its debtors, and paid off £400 to reduce its short-term debt. Finally, it sold 300 units of its inventory (at an original cost of £1 per unit) for £400 (in cash), and paid off £200 to its creditors. The closing balances at the end of 2004 were £1300, £1000, and £1100 for the inventory, accounts receivable, and cash accounts respectively, and £1600 and £1500 for the accounts payable and short-term debt respectively.

The aim of this example is to show how the firm employed all its current asset and liabilities accounts to dampen the shocks of cash flow and to maintain a presumably smooth path of R&D spending. As we can see, the firm reduced its investment in inventory from £2100 to £1300 during the year, and reduced its investments in accounts receivable from £1200 to £1000 (i.e. it tightened up its credit policies) to free liquidity. However, the firm relatively increased its cash holding from £700 to £1100 as a precaution to hedge against any potential future risks of cash shortfalls. On the other hand, it increased its investment in trade credits (AP) from £1300 to £1600 and kept a static level of short-term debt to crucial its financial obligations.

However, as we have identified that the net working capital is current assets less current liabilities (thereafter, NWC), we can note that the change in NWC between the beginning of the year and the end of the year was -£900 (that is, £300-£1200), and the change in net cash holding (thereafter, NCH) was £400 (that is, £1100-£700). Accordingly, researchers of the effect of financial constraints on R&D investment, and the role that cash holding plays in smoothing R&D (for example, Brown and Petersen, 2011 and Guarling and Liu, 2014) should have used net working capital as source of smoothing rather than cash holding as a variable in their models, in which the NWC reflects more the total sources of funds that firms can use in the short run to smooth their R&D investment from any cash flow shocks, instead of using one of the working capital components (i.e. cash holding).

In this example, the ABC firm was financially constrained, and used most of its working capital components to free up liquidity to smooth its R&D. If cash holding (as the variable) was used as the only source of smoothing, based on this example we can see that the levels of cash increased rather than decreased to free up liquidity, but using net working capital (as the variable) reflects the full information about the use of all available sources of short-term funds to smooth R&D. According to this example, the firm chose to cut investment in working capital proportionally more than in R&D investment, because working capital is reversible and relatively liquid. That is, it chose working capital investment to absorb the effect of the temporary cash flow shocks rather than R&D investment, in order to reduce the potential losses and adjustment costs that could have arisen due to the temporary cutting back on R&D. In conclusion, the existence of working capital for firms can be considered as a way of relaxing sources of funds during financing constraints, whereas in our simple example we show that the firm freed up a total of £900 from its working capital to smooth its R&D.

Regarding the role of cash holding as a component of working capital on smoothing R&D investment, the second example shown below (appendix 1B), shows how a firm's cash account does have a role in buffering the transitory cash flow shocks along with the other components of working capital, but not alone. Similar to the previous example, it is assumed that XYZ is an R&D performing firm and that the transactions below took place during the year 2004, and that the firm in that particular year was facing cash flow fluctuations and financing frictions. Similarly, static balances of the non-current assets and long-term liabilities are assumed in order to focus on the working capital accounts (including the cash holding).

Appendix 1b: Numerical example clarifying how working capital accounts can be used as sources of finance by constrained firms, and to explain how the use of cash holding only may not be enough to explain all the sources of funds for smoothing R&D investment (in the case of a negative change in cash holding).

		Total Assets							=	Total Equity	+	Total Liabilities				
		Non-current Assets	+	Current Assets					=	Equity	+	Current Liabilities			+	Long-term Liabilities
		NCA	+	Inventory	+	AR	+	Cash	=	Capital/Equity	+	AP	+	S.T Debt	+	L.T Liab
Opening Balance	Transactions	10000		1900		800		1300		7200		1300		1500		4000
	100 units of inventory sold for £200			-100						100						
	(£100 in cash)							100								
	(£100 in AR)					100										
	AP reduced by £100 from cash balance							-100				-100				
	S.T debt reduced by £100 from cash							-100						-100		
		10000		1800		900		1200		7300		1200		1400		4000
	Balance			13900								13900				
	400 units of inventory sold for £800 (cash)			-400				800		400						
	The firm collected £100£ from its AR in cash					-100		100								
	£200 paid to creditors (AP)							-200				-200				
	£400 paid for S.T debt							-400						-400		
		10000		1400		800		1500		7700		1000		1000		4000
	Balance			13700								13700				
	The firm has a £1000 short-term loan (collateralized with AR)							1000						1000		
	The firm bought £800 of inventory on account			800								800				
	600 units of inventory sold for £700 (£500 in cash and £200 in AR)			-600		200		500		100						
	£100 from cash balance paid for S.T debt							-100						-100		
		10000		1600		1000		2900		7800		1800		1900		4000
	Balance			15500								15500				
	£2000 used for R&D (drawn from cash)							-2000		-2000						
	£300 collected from AR and paid for S.T debt					-300								-300		
	300 units of inventory sold for £700 (in cash)			-300				400		100						
	£200 paid to creditors (AP)							-200				-200				
		10000		1300		700		1100		5900		1600		1600		4000
	Balance			13100								13100				

As shown in the example above (appendix 1B), the opening balances of the current assets were £1900, £800 and £1300 for the inventory, accounts receivable and cash accounts respectively, and the opening balances of the current liabilities were £1300 and £1500 for the accounts payable and short-term debt accounts respectively. During the first quarter of 2004, XYZ firm made several transactions as follows. It sold 100 units of its inventory (at an original cost of £1 per unit) for £200 (£100 in cash and £100 in AR), and paid off £100 of its trade credits (AP), reducing its short term debt by £100 (from its cash account). The transactions in this first quarter resulted in a decrease in the cash balance of -£100, an increase in the AR balance of £100, a decrease in the AP balance of £100, and a decrease in the short-term debt of £100. During the second quarter, the firm sold another 400 units of its inventory (at an original cost of £1 per unit) for £800 (in cash), and collected £100 (in cash) from its AR. Furthermore, it paid off £200 to its creditors, and £400 for its short-term debt. As a result, the cash balance increased by £300, the accounts receivable (AR) balance was reduced by £100, accounts payable (AP) decreased by £200, and short-term debt by £400.

In the third quarter, and in order to increase the precautionary cash balances, XYZ firm obtained a short-term loan of £1000, collateralized with its accounts receivable balance, and bought 800 unit of inventory (for £800) on account to maintain the role of trade credit. During the third quarter, the firm sold 600 units of its inventory (at an original cost of £1 per unit) for £700 (£500 in cash and £200 in accounts payable), and paid off £100 of short-term debt from its cash balances. These transactions yielded an increase in the inventory of £200, an increase in the accounts receivable of £200, and, most importantly, an increase in the cash account of £1400. On the other hand, the current liabilities accounts increased by £800 and £900 for accounts payable and short-term debt respectively. During the fourth quarter, the firm was facing a binding cash flows shock. As a result, it had to draw £2000 from it cash account to smooth its

R&D investment path. As the accounts receivable balance served as collateral for short-term debt, £300 was collected from its creditors to pay for its short-term debt. Finally, the firm sold 300 units of its inventory (at an original cost of £1 per unit) for £400 (in cash), and paid off £200 to its creditors. The closing balances at the end of 2004 were £1300, £700, and £1100 for the inventory, accounts receivable, and cash accounts respectively, and £1600 and £1600 for the accounts payable and short-term debt respectively.

As we can see in this example, the firm reduced its investment in inventory from £1900 to £1300 during the year, and reduced its investments in accounts receivable from £800 to £700 (i.e. it tightened up its credit policies), and decreased its cash holding from £1300 to £1100 to free liquidity. On the other hand, it increased its investment in trade credits (AP) from £1300 to £1600 and increased its level of short-term debt from £1500 to £1600 to maintain its policy of additional use of trade credit and increasing the short-term borrowing capacity. As a result, we can see that the change in NWC between the beginning and end of the year was -£1300 (that is, -£100-£1200), and the change in NCH was -£200 (that is, £1100-£1300). Accordingly, we can observe that XYZ firm used all its working capital components to free liquidity to smooth its R&D. If cash holding (as the variable) was used as the only source of smoothing, based on this example we can see that the levels of cash decreased by -£200 to free up liquidity, but by using net working capital (as the variable) we can see that the firm reduced the non-cash working capital accounts by -£1100 to free up more liquidity to smooth its R&D investment. As in this example, the firm has chosen to cut investment in all of its working capital accounts proportionally to absorb the effect of the temporary cash flow shocks, rather than R&D investment. In conclusion, each of the working capital accounts can be considered as of a relaxing source of funds during financing constraints, whereas in our simple example we show that XYZ firm freed up £200 from its cash holdings, and £1100 from its non-cash working capital accounts (a total of £1300 from its working capital) to smooth its R&D.