Financing constraints and R&D investments - Evidence from high-tech Swedish firms

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Abstract

Financing of research and development, as an important component of innovation, has attracted a renewed attention in academic financing literature. This paper examines the effect of financing constraints on R&D investments of high-tech Swedish companies over the period of 2010 to 2016. Accordingly, balance sheet data related to 49 companies, which has the smaller amount of employees in comparison with the rest of high-tech publicly listed companies is collected. Moreover, a dynamic model based on previous literature about financing constrained is developed to study the relation of both internal and external resources of financing with R&D investments of the selected companies. The result of this study shows that internal resources of financing such as cash holdings have a positive correlation with R&D investments. The coefficient of this financial variable is large enough to conclude that selected firms are financially constrained. However, based on other factors such as consideration of age and occurrence of global financial recession in the period that this study is accomplished, I concluded that dependence of companies to their internal resources for financing their R&D investments is an outcome of the characteristics of their environment.

*Keywords: R&D financing constraints, Invention, Innovation, Finance*
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1 Introduction

Innovations are costly procedures and take a long time to be accomplished and companies need significant financial resources to start, direct and complete projects that are based on innovation. However, raising credits from external resources of financing such as debt and equity in high-tech companies for investments in innovations has become a challenging procedure for these companies (O’Sullivan, 2005). Currently, more researchers are screening financing innovation and financing in research and development (R&D), since these activities are playing an important role in economic growth all over the world (Fagerberg et al., 2005, Brown et al., 2009; Brown et al., 2012, Fryges et al., 2015).

R&D activities fuel innovations and lead to the production of newer and better products and processes by companies (Fagerberg et al., 2005). They also cause knowledge spillovers, which is one of the key features of endogenous growth theory (Brown et al., 2009). However, R&D investments have special characteristics, which make its financing more complicated in comparison with other kinds of investments. For example, they have a high level of uncertainties in their outcomes. Moreover, the level of informational asymmetries with external investors is quite high. Consequently, innovative firms, usually face difficulties to raise external funds for their innovative projects (Savignac, 2008; Kerr & Nanda, 2015). In other words, they face financing constraints or excessive costs of external credits, which can influence their investment decisions and delay or hinder projects that are based on innovation (Almeida & Campello, 2007).

The notion of financing constraints and corporate investments can be followed back to Fazzari et al. (1988). These researchers linked traditional models of investment to the most recent financing studies of their time. In fact, traditional models of investment rely on the idea that the financial structure of companies is not related to their investment decisions (ibid.). These models consider the situation of perfect capital markets that internal resources and external resources of financing have the same price since all the firms have equal access to these markets (ibid.). Fazzari et al. (1988), on the other hand, showed that internal and external financing resources are not perfect alternatives since there are imperfections in the capital markets.
Recent financing studies also reflect the distinctions between the cost of external resources of financing such as debt and equity with internal resources such as cash flows. This difference causes financing constraints for physical and intangible investments of companies (Hall et al., 2016) and is more observable in intangible investments, which are aimed to improve the future operation of companies, such as their investments in R&D (OECD, 1998). One of the popular definitions of financing constraints, which has continuously brought up in different studies considers “the wedge between a firm’s opportunity cost of internal capital and its cost of external capital” (Farre-Mensa & Ljungqvist, 2016, 272). Accordingly, companies tend to rely on less expensive financial resources for their investments since there is a substantial difference between the cost of internal and external sources of financing (Fazzari et al., 1988). Financing constraints, nowadays, has attracted a renewed attention in financing literature since it negatively affects investments in innovations (Lin et al., 2017).

Presence and influences of financing constraints on innovation can be recognized directly through choices companies make for financing their R&D activities. In fact, raising external financing resources for R&D is accompanied by difficulties both in equity markets and banks due to the following reasons. Firstly, the degree of uncertainty in R&D projects is quite high and this uncertainty is the highest at the beginning of these projects. In fact, the investors on the stock market might consider R&D expenditures as short-term expenses instead of indications of long-term profitability (Hall, 2002; Lehmann-Hasemeyer & Streb, 2016). Secondly, in some projects, the probabilities of extreme successes are quite low and the way that profits are distributed in these projects make it impossible to calculate project risk with normal risk adjustment formulas (Hall, 2002). According to Mazzucato (2013, p. 851), “investment in innovation is a bet on the future and most attempts fail”.

At the same time, debt financing is very expensive or impossible to raise for R&D investments, since companies running these projects do not have sufficient collaterals (Hall et al., 2016). R&D intensive companies, as a result, mainly rely on their internal resources in consistent with the pecking order theory of Myers and Majluf (1984). This theory implies that companies that have a higher level of information asymmetry with their investors prefer their internal resources to debt and equity financing. Moreover, they might reject their valuable investment opportunities on occasions that they face scarcity of internal resources or hardships in raising external credits (Myers & Majluf, 1984).
Size of companies is also an important matter in raising external resources of financing for R&D investments. For example, small R&D-intensive companies face more financial constraints in their financing procedure since they generally have limited internal resources and a higher level of information asymmetries with their external investors in comparison with their larger counterparts (Hottenrott et al., 2016; Hall et al., 2016). These kinds of firms however, have a better reputation for undertaking riskier procedures and introducing more radical innovative products or processes to the market (Fryges et al., 2015). These products are generally substantially different from the traditional ones and result in significant changes in the market (Rothwell, 1989). The important role of small firms in aggregate R&D is also widely ignored through financing literature (Brown et al., 2009).

Debate continues about the best strategies for financing R&D for small companies (Hall, 2002; Sasidharan et al., 2015; Kerr & Nanda, 2015; Hall et al., 2016). In general, the multistage financing method is suggested for R&D intensive companies, which reveal the fact that government sources and debt financing might play an important role as primary resources of financing R&D because they normally tolerate more risks (Arrow, 1962; Fryges et al., 2015). However, they need to be replaced by private sources of financing and initial public offering (IPO) to increase the productivity of these projects (Prianichnikov, 2013; Kerr & Nanda, 2015; Mazzucato & Semieniuk, 2017).

Recently, researchers have shown that financial developments, which generally accompanied by advances in financial institutions such as banks and equity markets, can decrease the effects of financial constraints (Lerskullawat, 2018). Moreover, different studies have examined financing constraints on R&D investments in different industries and different countries (Brown et al., 2009; Brown et al., 2012; Sasidharan et al., 2015). However, the influence of financing constraints on R&D investments of high-tech companies that are listed in developed stock markets such as the Stockholm Stock Exchange and especially after the global financial crisis has stayed unanswered. As stated by Hall et al. (2016), the financial crisis had distinctive effects on European firms. Besides, different countries understood the importance of investments in R&D and innovation after this event (Brown et al., 2009; Lin et al., 2017). In this paper, evidences are collected from balance sheet information of small Swedish and high-tech publicly listed firms such as healthcare, industrials, and technology to answer the following research question.
How does financing constraints affect R&D investments of small and high-tech publicly listed Swedish companies?

It is important to consider that R&D is treated as an expenditure and not as an asset in the accounting system and financial statements of Swedish companies. According to International Accounting Standards (IAS 38), investments in important resources, such as research cannot be recognized as an intangible asset, because of the high level of uncertainty about future economic benefits of these projects (IFRS, 2017). Development costs however, can be capitalized as assets, as they can fulfill the category of intangible assets (Nguyen & Leander, 2012). Debate continues about the fact that intangible spending should not be considered as intangible investments (Haskel, 2015). In this study, I use the notion of R&D investments to underline the fact that R&D expenditures, result in innovation, future profitability and competitive advantages for companies and contribute to economic growth (Verspagen, 2005). Nevertheless, research and development are applied as one value in this paper since they are also reported as one value in the financial statements of selected firms.

The sample of this study is chosen from Swedish listed firms in Stockholm Stock Exchange (Nasdaq Stockholm). It is important to consider that this study is performed in a developed country with a developed stock market. Sweden gross domestic product (GDP) per capita in current prices amounted to approximately 53,217.63 US dollars in 2017, which is higher than GDP per capita in current prices in many European countries such as Germany that has reported 44,769.22 US dollars in 2017 (Statista, 2018, 1 & 2). GDP per capita divides “the total value of all goods and services produced in a country in a year” to the population of that country (Statista, 2018, 1). This indicator increases between 2012 and 2013, however, decreases drastically from 2013 to 2015. It then increases gradually from 2015, which is an implication of economic growth in this country (ibid.).

The results of this study show that small and high tech Swedish listed companies are highly reliant on their internal resources for their R&D investments. Moreover, there is a negative correlation between debt amount and R&D investments of these companies. The correlation between common stocks and R&D investments is also negative, which is in contrast with results of other studies about financing constraints in Sweden such as Brown et al. (2012). Finally, the decreasing trend of R&D investments with the occurrence of financial recession in the period of
this study is completely visible, which is an indicator of pro-cyclicality of R&D investments for both young and mature firms.

Data in this study is extracted from Thomson Reuters Datastream and Stockholm Stock Exchange website. Moreover, this paper follows a classical structure for a thesis report. In the next chapter, by literature review, it is meant to study related papers to build a solid background in innovation, R&D and financing constraints. Chapter 3 presents the method approach and the way of data collection, while the rest of the study express the results and make a discussion based on the generated results. This study ends with the conclusion and suggestions for future studies.

2 Literature review

This chapter offers a broad context to understand innovation and characteristics of R&D investments. It gives an overview of different methods of financing R&D and then continues by providing a short summary of the literature related to financing constraints and R&D investments. This part concludes with a general model that shows the relationship of investments in innovation in companies with different organizations and reflects how innovations create value both for companies and the society.

2.1 Innovation

The notion of innovation is associated with developing new and superior ways of doing things and put them into practice (Fagerberg et al., 2005). In fact, the first step of innovation is related to the creation of new information, which is known as invention (Arrow, 1962), while first attempts to put generated information into practice is innovation (Fagerberg et al., 2005). Invention and innovation are closely related to each other and sometimes it is difficult to separate them. As an example, in biotechnology, it is almost impossible to separate these two concepts. In other instances however, there is usually a significant time lag between these two processes (ibid.). Besides, the invention can take place anywhere, but innovations are mainly performed by firms (ibid.). Innovative firms, as a result, need to apply different kinds of resources, knowledge, and capabilities to be able to succeed in the long procedure of innovation (ibid.). This procedure has been treated as a “black box” for a long time since it was difficult to classify and collect data about firm’s innovations and activities that they undertake in this process (ibid.).
Schumpeter (1934) has developed a popular way to classify different types of innovations. According to this researcher, innovations are classified into five different categories, which are related to producing of new products, developing of new processes for production, discovering of new and better supplies, applying new marketing methods or finding new markets, and at last new ways for running and managing businesses (Schumpeter, first published 1983, Routledge 2017). However, only two first categories of this classification are generally used in economics (Fagerberg et al., 2005).

The mentioned classification has continuously brought up in different literature including Oslo Manual for definitions of innovation (Cruickshank, 2010). This manual firstly issued in 1992 by the Organization for Economic Co-operation and Development (OECD) to collect and apply data about innovations. This organization has the mission to improve the social and economic situation of people all around the world (OECD, 2018). It has also carried out a process of data collection in Europe about innovation activities of different companies through Community Innovation Survey (CIS) every four years since 1993 (OECD, 2005; Cruickshank, 2010, 18). Accordingly, by application of the same standards and equal surveys, OECD has made an evaluation of innovation possible at EU level (Cruickshank, 2010). Later with the second edition of the Oslo Manual in 2005, this organization developed new guidelines and innovation indicators to facilitate comparability of data and assist other countries in evaluating of their innovation activities (OECD, 2005).

2.2 Innovation and economic growth

Different studies have highlighted the important role of technological and organizational innovation in the acceleration of economic growth. In fact, changes in technology accompanied by organizational changes in different levels increase living standards and improve the quality of people’s lives in different regions (Verspagen, 2005). Nowadays, governments pay special attention to the subject of Innovation. As an example, after the global financial crisis, Chinese policy-makers decided to restructure the economy of their country through concentrating on scientific and technological innovations (Lin et al., 2017; Yanrui et al., 2017). Renewed interest of OECD in innovation and the extensive inclusion of this subject in its activities is another example of policy-makers’ attention to innovation at the international level (Cruickshank, 2010).
Ways in which innovation impact economic growth has also been the subject of debate through different economic theories and throughout the time. Economic models developed after the 1950s and 1960s assumed that technology is endogenous and there is a “linear relationship between the growth of labor productivity and the growth of capital per worker” (Verspagen, 2005, 490). Accordingly, these models reflected the fact that investments in human capital increase the productivity of entities and result in economic growth. Endogenous growth models had a different interpretation of the nature of knowledge and innovations, which was in contrast with neoclassical models. According to endogenous growth theory, knowledge is not a public good and knowledge spillover through different sectors and nations have a broad and positive impact and cause further developments (Verspagen, 2005).

Later in 1970, the relationship between technology and economic growth was confirmed one more time by the development of growth accounting models (Verspagen, 2005, 491). These models added “knowledge stock” to the traditional model of technical progress function, which was developed earlier and had only considered factors of labor and capital in the companies. They also suggest that knowledge positively affect productivity at different levels of accumulation, such as companies, industries, and countries. Studies related to these models developed the notion of R&D spillovers, which shows that knowledge produced by firms is not only beneficial for the producer of the knowledge but also benefit other firms in same or different sectors in different regions (Verspagen, 2005). Knowledge also plays an important role as a basis for generating more advanced knowledge in the future (Arrow, 1962). Lastly, the creation of new knowledge is an important prerequisite of innovations. In other words, “all the models assume that R&D is essentially a lottery in which the prize is a successful innovation” (Verspagen, 2005, 502). However, R&D has special characteristics that make its financing different from other sorts of investments. These characteristics are discussed in the next section.

2.3 R&D characteristics

Creation of new information or invention, which discussed by Arrow (1962), can be associated with R&D activities in the companies. Arrow (1962), exemplify the risky process of creating new information as a person, who has the capability to predict different states of nature. This person in the economy can be an entrepreneur that undertake research and have the knowledge of production and demand in a special field. Information, in this case, has an economic value, since it can give great advantages to the people that make effort to gain this knowledge. However, one
can never predict outcomes from the inputs in this procedure. New information produced in the procedure of invention is also underestimated and not always rewarded properly, which reduces the quantity and quality of the research process.

Kerr & Nanda (2015), mention four distinctive characteristics for R&D performances. Firstly, this process is uncertain and uncertainty in this context is basically different from risk. In other words, in these kinds of investment, there is no chance to define any kind of probability about desired outcomes and sometimes potential results of the project are also unknown. Secondly, revenues from an innovation procedure are highly skewed and it is almost impossible to allocate the right amount of returns to the right periods with standard ways of evaluation. Thirdly, although investors and innovators are not fully aware of possible outcomes of R&D projects, the innovators still know more, but it is hard for them to calculate and declare required inputs into the innovation procedure (Kerr & Nanda, 2015). Moreover, in some cases, innovators are reluctant to reveal information about their R&D activities because of confidentiality considerations and they want to hinder information leak to their business counterparts (Lin et al., 2017). At last, with consideration of mentioned characteristics of R&D, agency costs are noticeably higher than the standard agency costs between investors and entrepreneurs (Kerr & Nanda, 2015).

High adjustment cost for R&D smoothing at the firm level is another important characteristic of R&D, which R&D intensive companies need to be aware of and make continuous adjustments to avoid unfavorable consequences of them (Kerr & Nanda, 2015; Sasidharan et al., 2015). These costs are related to salaries of educated employees and scientists, which their performances result in intangible assets for the company and generate profit for it in the future (Hall, 2002; Kerr & Nanda, 2015). Hall (2002, 36), estimated this cost to be about 50 percent of R&D expenditures. In other words, knowledge is rooted in human capital in R&D intensive companies. As a result, these companies need to be aware of the potential losses that generate from laying off or leaving their scientists and assign their R&D spending into appropriate intervals to avoid the high level of adjustment costs in later stages of their projects (Hall, 2002; Kerr & Nanda, 2015).
R&D investments are also more vulnerable to financial shocks resulted from economical instabilities and companies tend to decrease their R&D investments in the situation that their financial resources decrease to save up for their short-term expenditures. However, they increase these investments during economic booms (Brown et al., 2009; Fabrizio & Tsolmon, 2014; Sasidharan et al., 2015). Researchers have used the term of pro-cyclical for R&D investments. Accordingly, firms strategically time their R&D and innovation investments corresponding to the economic situation and market demands. This matter is more visible in financially constraint firms since they face more credit constraints in economic recessions (Fabrizio & Tsolmon, 2014).

2.4 Financing Innovation and R&D

Dividing a firm’s capital between debt and equity as external sources of financing to increase firm value has been the subject of debate through academic financing literature for a long time (Barclay & Smith, 2005). In fact, different firms have different needs for different kinds of financing, since they have distinctive cost structures, different sizes, and they operate in different markets (Kerr & Nanda, 2015, Mazzucato, 2013). Differences between companies accompanied by the fact that they select different sources of financing over their life cycle make their financing decisions diverse and complex (Brown et al., 2009; Mazzucato, 2013). Financing innovation and R&D, however, cannot be discussed effectively through traditional financing discussions, which only consider the optimal level of leverage of companies (Barclay & Smith, 2005). The reason for this difference is the special characteristics of R&D investments that make external financing more expensive for R&D intensive firms (O’Sullivan, 2005). In the following, academic papers related to financing innovation are reviewed to realize which financing methods provide innovation and R&D more appropriately.

2.4.1 Equity financing of R&D

Developed financial markets have an increasingly important role in urging the process of financing technological innovations and accelerate economic growth (Brown et al., 2009; Brown et al., 2012; Kerr & Nanda, 2015). In fact, common stocks solve the resource allocation problem and let different participants of financial markets diversify their portfolio and reduce their risk by obtaining a smaller amount of stocks from different companies to reach their optimal risk level (Arrow, 1962).
Brown et al. (2009), stated several important reasons for priority of equity financing over debt financing in R&D intensive firms. Firstly, there is no need for collaterals in this kind of investment and investors benefit from upside returns. The notion of upside return in this context is related to positive changes in stock prices, which increase stockholders’ equity (Klausner & Litvak, 2001). Secondly, additional equity does not increase problems of financial distresses that bring significant costs and negatively affect debtholders and non-financial stakeholders of companies (Brown et al., 2009). Financial distresses can also impair the availability of credits and increase costs of building relationships with different stakeholders of companies such as non-financial suppliers (Opler & Titman, 1994). For example, an extreme case of financial distress is bankruptcy, in which highly leveraged companies cannot meet their obligations towards their debtholders. Moreover, companies that file for bankruptcy need to bear indirect costs that originate from losing their market value. Even in less severe cases of financial distresses, companies with a higher amount of debt over equity are more likely to put off their valuable investment opportunities or decrease their investments in important projects such as R&D, training, and maintenance (Barclay & Smith, 2005).

At the same time, different researchers argue that market-based financial systems increase the productivity of innovative projects (Brown et al., 2009; Lehmann-Hasemeyer & Streb, 2016). They also believe that this way of financing decreases information asymmetries between investors and recipients since, in bank-based financial systems, only a few people including bank managers make the decision about financing innovative projects (Lehmann-Hasemeyer & Streb, 2016). However, these people might not have adequate information about these projects (ibid.). In fact, market-based financial systems apply widespread information about innovative projects and let everyone to make an investment according to their own prospects. (Lehmann-Hasemeyer & Streb, 2016).

Priority of equity financing over debt financing of R&D has also brought up in literature related to (IPOs) of companies. Through IPOs, companies that have grown appropriately and reached an acceptable size choose to go public for the first time to raise equity capital for their projects (Ritter & Welch, 2002). Lehmann-Hasemeyer & Streb (2016), as an example, consider 474 firms that reached for public equity in Germany in the period of 1892 to 1913 and confirm the important role of IPOs in financing innovations. To date, however, there has been little agreement about the reasons for success in innovative industries in the US and Germany before
the First World War. Lehmann-Hasemeyer & Streb (2016), state that although the US and Germany were popular for different kinds of financial systems during the mentioned period, the financial systems of these two countries were more similar to each other than what stylized fact states. Fear & Kobrak (2010) also illustrate that despite major differences between regulations of the US and Germany, the banking system was playing an important intermediary role for stock markets in the US before the First World War.

Another example in this matter is the study of Prianichnikov (2013), which considers innovative companies in Russia and realize that these companies are highly reliant on their IPOs since loans are expensive. Moreover, innovative companies are mainly formed by intangible assets and do not have sufficient collaterals. As a result, it is impossible for them to rely on debt financing for their innovative projects. Prianichnikov (2013) argues that a successful outcome of the IPOs of innovative companies is a leading cause for further investments of financers in later projects of these companies. Moreover, he states that IPOs have other benefits rather than raising credits for their companies. For example, they can increase the brand’s recognition, facilitate interaction with suppliers and banks and improve the efficiency of companies (Prianichnikov, 2013).

2.4.2 Debt financing of R&D
Results about the role of banks in financing innovations and R&D are contradictory in different studies. These differences are partially related to the country and time spans that different researches have been conducted. For example, the US has a developed market-based financial system and it has experienced significant growth in high-tech industries in the past century. However, Germany with rapid development in innovative industries is popular for its bank-based financial system (Lehmann-Hasemeyer & Streb, 2016). As stated by Kerr & Nanda (2015), banks have an increasing role in financing innovation within a wide range of industries. These researchers also suggest that public equity markets represent their own types of agency costs. On the other hand, according to several case studies in Germany, the banking sector has not always been a good alternative for funding young innovative companies and entrepreneurs (Lehmann-Hasemeyer & Streb, 2016). As an example, German universal banks have focused only on mature industries such as steel and iron, while they neglected new industries such as chemicals throughout the nineteenth century (ibid.).
Recent studies that conducted in Germany show a positive relationship between debt financing and R&D investments in companies. Fryges et al. (2015), as an example, suggests that there is a link between debt financing and R&D activities of newly established firms in this country. Besides, they prove that there is an interdependent linkage between R&D intensity and the proportion of loan financing in the financial structure of these companies. In other words, the higher share of loan financing can increase the R&D intensity of young firms, while higher R&D intensity can reflect better future growth perspectives and increase chances of firms to obtain more loans in the future (Fryges et al., 2015).

Studies that conducted in market-based financial systems, however, show that leverage in the capital structure of R&D intensive firms is typically lower than other firms (Hall, 2002; Barclay & Smith, 2005). Brown et al. (2009), specifies several reasons for undesirability of debt financing for R&D intensive companies, which are related to the uncertainty of projects, volatility of returns, lack of collateral and ambiguity of future performance and growth in these companies. It has been also argued that bank managers in the bank-based financial system may give priority to their own customers over innovative companies to protect them from new competitors (Lehmann-Hasemeyer & Streb, 2016). The controversy about the best way of financing innovation and financial structure of R&D intensive companies has stayed an open question (Fryges et al., 2015). Moreover, different studies show different financing patterns of companies, industries, and countries in different periods. Supply of financial resources by financial institutions is also dissimilar in various countries and over different time spans, which leads to dissimilar results of studies about financing structure of R&D intensive companies (O’Sullivan, 2005).

2.4.3 Financing R&D with internal resources
Different studies have shown that there is a significant relationship between internal resources of financing such as cash holdings and R&D expenditure of companies in different countries (Brown et al., 2009; Brown et al., 2012; Sasidharan et al., 2015). However, internal and external financing are not perfect alternatives in financing innovations (Hall, 2002; Brown et al., 2009) since cash flows of companies have higher sensitivity to economic instabilities. In other words, problems originating from internal or external instabilities, resulting in cutbacks in R&D investments in companies. As an example, economic downturns as an external matter decrease cash flows of companies and result in the reduction of R&D investments (Barclay & Smith, 2005; Lööf & Nabavi, 2016).
The reason for priority of internal resources of financing over external resources is the fact that shifting risk through common stocks is not always a perfect solution for resource allocation in the risky procedure of production of information. Companies, as a result, use their internal resources excessively for their R&D investments. In other words, “The great predominance of internal over external equity financing in an industry is one illustration of the fact that securities do not completely fulfill their allocative role with respect to risk” (Arrow, 1962, 612).

Moreover, internal resources of companies are less expensive and they are not associated with the problems that are resulted from the high level of informational asymmetries between investors and companies (Brown et al., 2012; Sasidharan et al., 2015; Lööf & Nabavi, 2016). Accordingly, this way of financing is known as a stable way of financing R&D all around the world. In other words, special characteristics of R&D investments and some features of high-tech companies, which direct innovative projects make raising external resources harder for them and make them more susceptible to financing constraints (Brown et al., 2012).

2.5 Background literature related to financing constraints

Debate continues over the financial structure and financing constraints for R&D investments in high-tech companies since these constraints can affect R&D investment decisions and postpone innovative projects (Almeida & Campello, 2007; Kerr & Nanda, 2015). Table 1, shows different literature about financing constraints. These studies were accomplished through different time spans in both developed and developing markets and can give the reader a solid background about the purpose of this paper.

According to table 1, variables and the models that are used in different studies are diverse; some studies apply financial data at the firm-level, while others use surveys. However, both of these ways for gathering data in this subject are not free from limitations (Hall et al., 2016). As stated earlier, projects that are based on R&D in companies can be associated with the creation of new information or invention, which is discussed by Arrow (1962). This researcher, illustrate allocation of resources for an invention to agricultural production models since outputs and results of these models are not predictable from certain inputs.

Agricultural production models apply different variables that are important in agriculture such as rainfalls, number of sunny days or temperature to generate accurate results (Arrow, 1962). Moreover, one can extend these kinds of models by entering other variables to reflect “a formal
description of any kind of uncertainty in production” (ibid., 611). In the topic of financing constraints for R&D investments, different researchers have also employed different variables to predict resource allocation under the uncertain procedure of R&D investments. They have also applied complementary variables to the models in previous studies to examine the effect of financing constraints on R&D investments of the companies in different countries.

Table 1. Studies on R&D investments and financing constraints

<table>
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<th>Authors</th>
<th>Countries</th>
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<th>Data period</th>
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<tr>
<td>Savignac, (2008)</td>
<td>France</td>
<td>Established firms</td>
<td>–</td>
<td>A recursive bivariate probit model</td>
<td>The tendency of the firms for innovation is reduced by financial constraints.</td>
</tr>
<tr>
<td>Lehmann-Hasemeyer &amp; Streb (2016)</td>
<td>Germany</td>
<td>High-tech firms</td>
<td>1892-1913</td>
<td>Fixed Effects (FE) model</td>
<td>Berlin Stock Exchange performed as an efficient market for high-tech firms before the first World War.</td>
</tr>
<tr>
<td>Hall et al., (2016)</td>
<td>Europe</td>
<td>Different groups of firms in different countries in Europe</td>
<td>–</td>
<td>The literature review of seven different studies about R&amp;D investments and financial constraints</td>
<td>This paper confirms that financing constraints have the negative effect on the level of R&amp;D investments. Moreover, it proves that R&amp;D subsidy programs affect R&amp;D activities of firms positively.</td>
</tr>
<tr>
<td>Lin et al., (2017)</td>
<td>China</td>
<td>listed firms that reported R&amp;D</td>
<td>2010-2012</td>
<td>Two tier stochastic frontier model in light of Euler Equation</td>
<td>Financing constraints result in R&amp;D underinvestment, whereas agency costs result in R&amp;D overinvestments.</td>
</tr>
</tbody>
</table>
As stated by Hall et al. (2016), in the literature review of seven different studies about R&D investments and financial constraints, cash flow is a widely-used indicator for identification of financing constraints and existence of financial distresses. According to table 1, the Euler model of investment is also a common approach to examine the relation of financial factors on R&D investments. This approach is developed by Bond & Meghir (1994), to examine the relation of internal resources of companies with their financing decisions. These researchers also performed a formal test to examine the hierarchy of financing in corporate finance. Results from this study show that since internal resources are less expensive than external resources of financing, different firms tend to use internal investment resources in case of financial constraints (Bond & Meghir, 1994).

The model used by Bond & Meghir (1994), however, has transformed in different studies and employed more variables to study how financing decisions of companies affect their R&D investments. As an example, Brown et al. (2009), considered this model in form of regression equation where R&D investments of firms depend on internal and external sources of funds such as cash flow, sales, and stock issues in two consecutive years. These researchers also include R&D investments of the past year, firm and time effects and industry dummies in their model. According to Brown et al. (2009), this method can control for the impacts of future expectations about the profitability of projects from present investments of the companies. As a result, coefficients in this regression can be interpreted in a more direct manner. Results of this study, which considers small and young high-tech firms in the US, shows that there is a significant relationship between R&D investments and volatile sources of financing such as cash flow and stock issues. Moreover, it concludes that R&D investments of small and young high-tech companies form a significant part of aggregate R&D in the US Economy (Brown et al., 2009).

Brown et al. (2012), considers R&D reporting companies in 16 European countries. These researchers use a similar approach to Brown et al. (2009). However, they include changes in cash holding between two consecutive years to control for the R&D smoothing behavior of the companies. They also apply firm effects such as technology, industry and country effect, state of the macroeconomics and additional control for investment demand in their model. The results from this study suggest that the amount of stock issue is substantially high for young firms in countries with a developed stock market such as Sweden and the UK. However, these kinds of firms also keep a high level of cash and cash equivalents to maintain costs of their ongoing R&D
investments. As a result, this study concludes that financial constraints exist in publicly listed European firms since they maintain a high level of liquidity for their R&D activities (Brown et al., 2012).

Sasidharan et al. (2015), applies a similar regression equation to Brown et al. (2009), to study the effect of financing constraints on R&D expenditures of listed manufacturing firms in India. This study, however, is different from studies in countries with a developed stock market such as Sweden and the US, since financial markets are underdeveloped in India. Moreover, the banking sector does not contribute in providing credits to companies. As a result, immature financial systems in this country hinder R&D investments and delay economic growth. This study shows that there is a significant and positive relationship between cash flow and R&D investments in Indian manufacturing firms. However, it is important to consider that results of other studies in developed countries with developed stock markets and banking systems shows the same relationship between internal resources and R&D investment of companies (Mulkay et al., 2001; Lin et al., 2017).

Savignac (2008) uses surveys to gather data about barriers innovative firms confront, which hinder performing or continuing of innovative projects in these companies. Besides, he develops a Probit model to examine the probability of undertaking innovative projects with respect to the probability of encountering financial constraints in French manufacturing firms. He considers three reasons for the existence of financing constraints in potentially innovative firms in his survey which are: deficiency of external financing resources, high-interest rates, and slowness in financing arrangements.

Results of the mentioned study show that financial constraints in potentially innovative manufacturing firms in France basically originate from lack of external financing resources. However, 22% of selected firms in the sample of his study that faced financing constraints declared that high interest rates is the reason of this matter (Savignac, 2008, 555) Most important of all, 45% of the firms declared that they have suffered from slowness in setting up financing for their innovations (ibid.). In fact, financing innovations and R&D are accompanied by heavy scientific estimations (Chowdhury, 1968). In other words, R&D financing decisions are often an outcome of scientific, strategic and financial evaluations and take longer time spans for firms to
process them and put them into practice \textit{(ibid.)}. Savignac (2008) concludes that financing constraints can reduce innovative performances of companies.

As mentioned earlier, agency costs that result from an incomplete alignment of interests between investors and managers (Pawlina & Renneboog, 2005) are noticeably higher in R&D intensive companies (Kerr & Nanda, 2015). Lin \textit{et al.} (2017, 4), examine effects of financing constraints and agency costs on R&D investments of listed firms in China, which is \textit{“the world’s largest developing country with many economic growth problems such as production overcapacity and investment inefficiency”}. Results of this study show that there is a negative correlation between R&D investments and financing constraints, while there is a positive correlation between R&D investments and agency costs. In other words, financing constraints cause R&D underinvestment and agency costs result in R&D overinvestments (Lin \textit{et al.}, 2017).

Lööf & Nabavi (2016), Hottenrott \textit{et al.} (2016) and Lehmann-Hasemeyer & Streb (2016), have drawn attention to quality signals that firms can send to their potential investors. These researchers believe that these signals such as patents and exports of new goods can reduce the effects of financial constraints and assist firms in raising external financing resources for their R&D investments. Accordingly, patents are considered as \textit{“intermediate innovation output”} (Hall \textit{et al.}, 2016, 189), since they show accomplishment of innovative projects. As stated by, Lehmann-Hasemeyer & Streb (2016), patents assist firms in sending positive signals to investors and increase the favorability of their stocks. Moreover, they have characteristics that make unobservable features of firms, such as the potential value of their technological findings more apparent for outsiders (Hottenrott \textit{et al.}, 2016).

Studies about debt financing of R&D activities, which conducted in bank-based financial systems also suggest that patents can play an important role and substitute as collaterals in bank-financing. Accordingly, there is a positive correlation between leverage and the number of new patents in companies. Moreover, companies with higher quality patents access to bank loans with lower interest rates compared to their competitors (Fryges \textit{et al.}, 2015). Application of patents is more essential for young and small firms, as these kinds of firms generally face greater financial constraints (Hall \textit{et al.}, 2016). Nevertheless, exports of new products have also considered as a signal for innovation accomplishments, which can facilitate raising external credits through international markets (Lööf & Nabavi, 2016; Hall \textit{et al.}, 2016).
2.6 A framework for innovation requirements and results

Figure 1, on the next page, shows an overview of how innovations in firms are related to different internal and external financing resources. It also shows how innovations create value for the company and society. This picture, however, does not reflect signals that firms send about their performances such as patents, which reflect the productivity of their R&D projects. Effect of R&D spillovers is also not visible. In other words, although this picture is not a complete indicator of innovation mechanisms, it gives a general outline of different factors, which were discussed in this section.

Figure 1, A simplified framework for innovation requirements and results (based on the literature review in this study)

This picture shows the innovation requirements and results according to what I have discussed in this section. The solid box, which separates the firm from its environment, illustrates the fact that there is not the same level of knowledge about R&D and innovative projects inside and outside of R&D intensive firms. High level of information asymmetries and uncertainties increase the cost of external resources and lead to financing constraints for these projects (Savignac, 2008; Kerr & Nanda, 2015). Accordingly, firms are excessively dependent on their internal resource such as their cash holdings for financing innovation (Brown et al., 2012; Sasidharan et al., 2015). Moreover, they may put off their valuable investment opportunities in situations that they do not have sufficient internal resources or when the cost of external financing resources is quite high (Myers & Majluf, 1984).
This picture also reflects the fact that innovations result in the creation of new knowledge and new technologies that have positive effects at different levels of accumulation such as companies, industries, and countries (Verspagen, 2005). Innovations also result in the production of newer and better products and processes and create value for companies among their competitors and bring higher profitability and more cash flows for firms that can be used for their future R&D investments (ibid.).

3 Methodological considerations and data description

In this chapter, I develop a regression model, which is based on the literature related to financing constraints for R&D investments. Besides, I describe choices related to the variables that I selected for this model. This chapter ends with the description of the sample and the selected data in this study.

3.1 R&D regression as an empirical approach

As stated by Hall et al. (2016), effects of financing constraints on innovations in high-tech companies can be directly recognized from financing choices they make in relation to their R&D investments. Accordingly, the regression equation of this study identifies how financing decisions of companies in raising external funds or using internal resources in two consecutive years affect their R&D investments. Some of the variables in this regression have been used by different researchers about financing constraints and R&D investments (Brown et al., 2009; Brown et al., 2012; and Sasidharan et al., 2015). The regression equation in this study is an ordinary least squares (OLS) regression that examines the effect of financial constraints on R&D investments in high-tech Swedish publicly listed companies.

In this study, I assumed that cash holdings of the companies are resulted from operating activities, while common stocks and debt are indicators of external financing resources. Moreover, applying lagged values of R&D investment and other independent variables in this regression help to create a rational model (Brown et al., 2009). In fact, R&D projects are normally performed in the longer time spans (Hall, 2002). They are also riskier and need more funds in the primary stages of a project (ibid.). Bringing the financing decisions of the past year in this model, as a result, can give us a better understanding of the financing procedure of R&D investments in selected companies. The regression equation used in this study is as follows.
Where $RD_{j,t}$ is R&D investments of the firm $j$ in the period of $t$ and $RD_{j,t-1}$ is the indicator of R&D investments of the firms in the previous financial period. The effect of financial constraints in this study is captured by companies’ dependence on their internal resources of financing. This assumption is based on two different approaches, which were used in previous studies about financing constraints. First, investments-cash flow sensitivity, which is one of the most common approaches for the identification of financing constraints and the existence of financial distresses (Hall et al., 2016). This approach examines the sensitivity of investments to the availability of internal resources. Consequently, high investment-cash flow sensitivity reflects the higher costs of external resources of financing, such as debt and equity in comparison with internal resources of companies (Fazzari et al., 1988; Sasidharan et al., 2015). The second approach is related to cash flow sensitivity of cash in R&D intensive companies. According to the latter approach, effects of financing constraints are recognized by the higher tendency of companies in saving cash out of cash flows (Almeida et al., 2004). This issue is directly visible in R&D intensive industries, as they need to maintain a higher level of liquidity to secure their future investments (Brown et al., 2012).

3.2 Investment-cash flow sensitivity and its limitations

While investment-cash flow sensitivity has been widely used in the literature related to financing constraints in both developed and developing markets, it has been disapproved by many researchers (Sasidharan et al., 2015). The reason for these disapprovals is related to the possible endogeneity of cash flows (Hall et al., 2016). Moreover, the results of some studies show contradictory findings about this approach and state that investment-cash flow sensitivity is not theoretically enough for proving financing constraints in companies (Chen & Chen, 2012).

Recent studies about financing constraints that are discussed in the literature review of this paper such as Brown et al. (2009), Brown et al. (2012), and Sasidharan et al. (2015), have transformed this approach to overcome its deficiencies. Accordingly, they entered the variable of cash holdings beside cash flows in their model to reflect R&D smoothing behaviors of companies. They also use generalized methods of moments (GMM) for the estimation of their equations. This estimator uses lagged values of different explanatory variables to overcome measurement
errors while it also considers potential endogeneity of financial variables that are employed in these models (Sasidharan et al., 2015).

3.3 Description of the variables

As stated by Brown et al. (2012) and Hall et al. (2016), cash and cash equivalents in R&D intensive companies are best resources for smoothing and maintaining high adjustment costs of R&D investments. Moreover, they are better indicators for financial constraints in European firms. Adjustment costs in this context are mainly related to the wages of professional employees, which their knowledge is considered as intangible assets in R&D intensive companies. According to Brown et al. (2012), the presence of strict labor regulation in many European countries and high costs of training and hiring of professional employees call for a higher amount of internal liquidity in high-tech companies. In other words, these companies need to have a higher amount of cash or other cash equivalents to be able to complete their projects in case of external shocks and economic instabilities (Brown et al., 2012).

Common stocks and debt amount in this regression accompanied by their lagged values are the indicators of the quantity of external financing in selected firms. Common stocks in the balance sheet of companies represent stated value or par value of stocks. As a result, increase or decrease in its amount indicates share issue or share repurchases by companies, while it excludes changes in market value of shares. Moreover, debt is the indicator of long-term and short-term liabilities of companies. At last, in this model industry dummies are represented by $v_t$, while $d_t$ is representing year dummies and $\beta_0$ is the constant in this regression.

Sales and cash flows are important variables in the regression analysis of previous studies about financing constraints since they can reflect the results of operational activities in companies (Brown et al., 2009; Brown et al., 2012, Sasidharan et al., 2015). However, these variables are not applied in the regression equation of this study. The reason behind the absence of these variables is the endogeneity of these variables at the firm level. As stated earlier, R&D procedures take a longer time to be accomplished in comparison with other projects of companies and it also takes a long time before they can bring profitability for firms. Preliminary investigation in the selected data also shows that amount of cash flow to sales of many companies in the sample of my study often take negative values for many years. Moreover, sales and cash flows of companies in Europe and all around the world are considerably volatile from
2008 to 2017. As stated by European Commission Press Release Database in December 2014, R&D investments and sales of R&D intensive sectors have been the subject of drastic changes after 2008 and the global financial crisis. This matter is more visible in the following figure.

![Figure 2](image)

**Figure 2. Annual growth rates of R&D investment and sales (European Commission Press Release Database, 2014)**

Figure 2 shows the annual growth rate of R&D investments and sales in R&D intensive sectors in the EU, the US, and Japan. It also reflects these trends globally between 2006 and 2013. According to this figure, although R&D investments and sales indicate a recovery in 2010 and 2011, this recovery slows down significantly from 2011 to 2013. US firms, however, appear to be more resistant to changes after 2011 in comparison to their EU counterparts.

### 3.4 Data source and sample characteristic

Some studies related to financing constraints such as Brown *et al.* (2009), Lööf & Nabavi (2016), and Sasidharan *et al.* (2015), have drawn attention to small R&D intensive companies, since these kinds of firms are more susceptible to financing constraints (Hall *et al.*, 2016). According to Hall (2002), and Fryges *et al.* (2015), larger firms have a better possibility to use their internal resources for investing in R&D projects. These companies often have extra cash holdings in addition to their demand for their financing activities; hence, they do not depend on debt or stock financing (Brown *et al.*, 2009). Moreover, they have stronger relationships with lenders and external investors, so they have fewer problems in raising external resources. At last, these kinds
of firms can easily compensate for their extra costs by selling additional units of their products (Fryges et al., 2015).

In this study, it was intended to choose small firms among high-tech publicly listed Swedish firms. It is important to consider that small firms have a distinctive definition according to the European Commission (EC), which defines a certain number of employees and maximum level of annual turnover for this group of firms. As stated in commission recommendation of 6 May 2003, “within the SME category a small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed Euro 10 million” (EUR-Lex, 2003). OECD (2011), on the other hand, has a distinctive classification for high-tech industries. This classification is based on R&D intensity level, which is derived from the latest R&D activities of industries and varies across different countries. Consideration of R&D intensity is very important for this classification, otherwise many manufacturing activities can be considered as “high-technology” (ibid.). According to OECD (2011), high-tech manufacturing industries, which can produce both high-tech and low-tech products are aircraft and spacecraft, pharmaceuticals, office, accounting and computing machinery, radio, TV and communication equipment, and medical, precision and optical instrument. The rest of the manufacturing industries are categorized into medium high, medium low and low technology industries by mentioned classification (OECD, 2011).

At the same time, as stated by Savignac (2008), it is necessary to precisely define the sample of firms that wish to innovate in studying of financing constraints. Otherwise, firms that do not want to innovate and do not meet financial constraints, induce a positive correlation and generate biased results. Previous literature about financing innovation, such as Brown et al. (2009, 152), considered “drugs, office equipment and computers, electronic components, communication equipment, scientific instruments, medical instruments, and software” as high tech industries. This classification, however, is different on the Stockholm Stock Exchange website. Accordingly, manufacturing companies in sectors of industrials, healthcare, technology, telecommunication, oil and gas, and utilities are selected in this paper. However, Companies in the sectors of basic material, consumer goods, consumer services, and financial sectors are excluded in this study. In this level, 179 companies were selected from listed companies in Stockholm Stock Exchange website. Companies’ profiles were studied afterward to exclude companies that do not necessarily need R&D investments and innovation for their activities. As
an example, companies provide staffing services were classified in the industrial sector, which were excluded from this study.

To achieve a homogeneous sample, the companies that have their headquarters in other countries are also omitted. Accordingly, companies in this study are managed under Swedish rules and regulations. Besides, it is important to control for the technological environment in studying financing constraints for investments in innovation, since technological opportunities are dissimilar in different countries (Fryges et al., 2015). In other words, financing constraints influence investments and performances of companies differently in different environments (Hall et al., 2016). Lehmann-Hasemeyer & Streb (2016), also observed that geographical distances to the stock market affect initial returns of companies. However, based on technological improvements in communication channels, especially in the Stockholm Stock Exchange, this problem cannot be considered as an important matter in this paper.

In the next stage of sample selection, the number of employees and basic information for all listed companies is extracted from the Stockholm Stock Exchange website. This choice helped me to obtain a preliminary idea about Swedish listed firms based on their latest disclosure. Moreover, it made me able to double-check some important financial data of companies in further steps. The balance sheet information of companies is extracted from Thomson Reuters Datastream. This time series database with a large amount of financial data and variety of capabilities make different financial analysis possible for different purposes from examining the correlations of different financial factors to gain overviews about different markets (Thomson Reuters, 2018).

In this level, I found out that only a small group of firms, which fulfill the characteristics of small firms of EC, have reported their R&D investments from 2008 to 2017. Accordingly, I select the firms that their number of employees is less than the median value of employees for all high-tech publicly listed firms. The median value is about 700, while because of not reaching enough data, firms with less than 1000 employees that have reported at least two consecutive values for their R&D investments in the period of 2008-2017 were chosen as sample firms. Moreover, extracted values from Datastream are randomly checked with financial statements of related companies, whereas the difference between reported values by firms and extracted data from Datastream was negligible.
I did not consider the condition of annual turnover or annual balance sheet total of EC. Asset value that has been used by other researchers such as Sasidharan et al. (2015), for categorizing of small companies is also disregarded in this study since the consideration of this condition would narrow down the number of selected firms one more time. Accordingly, the number of employees is the only factor that is considered for classification of smaller firms in this paper. Moreover, based on the literature about financing constraints, I assumed that larger listed firms that the number of their employees is above 1000 have better opportunities to use their internal resources and less or no hardships in raising external financing. Accordingly, the sample of this study includes forty-nine manufacturing high-tech Swedish firms from four industries. Table 2 shows the number of selected firms in each of these industries.

Table 2: Number of selected companies in the high-tech industries (High-tech industries based on classification of Stockholm Stock Exchange website)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Healthcare</th>
<th>Industrials</th>
<th>Technology</th>
<th>Oil and gas</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of firms</td>
<td>25</td>
<td>15</td>
<td>8</td>
<td>1</td>
<td>49</td>
</tr>
<tr>
<td>Percent</td>
<td>51</td>
<td>30.6</td>
<td>16.4</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

In the last stage, I prepared a dataset considering balance sheet information of selected firms between the years of 2010 to 2016. As a result, this study has the format of balanced panel data with 343 firm-year observations. However, missing values reduce the number of these observations in regression analysis of this paper. Missing values are the variables that are not reported by firms or by Datastream database. Some of missing values are also related to the firms that joined the Stockholm Stock Exchange later and at the end of my observation period. Table 3, shows the descriptive statistic of the selected companies with coverage in the Thomson Reuters Datastream database and include values, which reported at the end of each financial year.

Table 3: Descriptive statistics

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R &amp; D expenditure (’000 SEK)</td>
<td>268</td>
<td>74,456</td>
<td>110,275</td>
<td>0</td>
<td>773,720</td>
</tr>
<tr>
<td>Debt, total (’000 SEK)</td>
<td>305</td>
<td>96,334</td>
<td>189,749</td>
<td>0</td>
<td>1,187,000</td>
</tr>
<tr>
<td>Common Stock (’000 SEK)</td>
<td>303</td>
<td>37,672</td>
<td>56,886</td>
<td>0</td>
<td>364,964</td>
</tr>
<tr>
<td>Cash (’000 SEK)</td>
<td>265</td>
<td>136,644</td>
<td>183,793</td>
<td>56</td>
<td>1,162,000</td>
</tr>
</tbody>
</table>
4 Results

In this chapter, generated results from OLS regression equation of this paper is reported to examine the effect of financing constraints on R&D investments of high-tech publicly listed Swedish firms. Explanatory graph and table are also provided to give the reader a better view about the results of this study.

4.1 R&D investment in high-tech publicly listed firms

In this paper, it was aimed to select homogeneous group of firms, which are smaller than the rest of the Swedish publicly listed firms in the Stockholm Stock Exchange and consequently are more susceptible to financing constraints. Smaller firms are chosen based on the number of their employees since accessibility to R&D investments of companies was limited. Figure 3, shows the aggregated amount of the variables that are applied in the regression analysis of this paper from 2010 to 2016.

![Figure 3](image)

*Figure 3. Aggregated amount of R&D, cash holdings, debt, and common stocks for selected firms in the period of 2010 to 2016*

This figure shows aggregated amount of R&D in the selected firms accompanied by other financial variables that are used as indicators of internal and external financing resources of R&D investments in this study. According to this figure, these variables are increasing slightly from 2010 to 2014, while they increase sharply from 2014 to 2016. This result is in line with figure 2 in this paper, which shows that R&D growth rate in Europe slows down from 2012 to 2013 after a period of recovery in 2010 to 2011 in aftermath of the global financial crisis.
Table 4 shows the correlation between different variables of regression analysis of this study. Statistically significant correlations are showed by three asterisks and according to this table (at the significance level of 0.01), all independent variables of this study have significant correlation with R&D investments of companies at the time $t$. As a result, all selected variables are applied in regression analysis in this paper.

Table 5 shows result of regression with three different assumptions, but before we get to each assumption, it is important to notice that the coefficient of the lagged value of R&D ($R&D_{t-1}$) is around one and statistically significant in all assumptions. This value reflects the persistence in R&D, which is in line with previous studies about R&D investments (Brown et al., 2012; Sasidharan et al., 2015). Persistence in this context is related to the fact that there is a relationship between earlier and current R&D investments (Woerter, 2014). R&D projects take a long time to be accomplished, while these accomplishments can lead to production of advanced products or processes and increase the profitability of companies (O’Sullivan, 2005; Verspagen, 2005). Persistency in such activities, as a result, is the key success factor in these companies. At last, in this table, standard errors are showed in parenthesis and statistically significant correlations are showed by three asterisks at the significance level of (0.01).

As mentioned before, each column in table 5 represent different models based on different assumptions about the relation of financial variables presented in the literature with R&D investments. These assumptions are as follows, firstly, for all selected firms in the sample, I assumed that R&D investments of the current year are related to the selected variables for internal and external resources of financing in the same year. Secondly, it is assumed that R&D investments are related to internal and external financing resources of company in the previous year. At last, all the variables in two consecutive years are selected. Mentioned assumptions are also divided to 4 different regressions by including and excluding year and industry dummies.

The purpose of dividing the model into different assumption was helping the reader to understand how different variables behave by adding or eliminating other regressors. This way of classification and providing different models for one sample also assist me to perform a robustness check since similar signs and values of coefficients in different assumptions is an indication of the fact that these coefficients can be interpreted reliably. Core variables in this context are the variables that their coefficients should be credible in the model and they are
chosen based on the structure of the original data. In other word, all coefficient in a model cannot make economic sense, however usually a subset of regressors can be selected for robustness check. Nevertheless, it is important to consider that even in single linear regressions, there are chances of many pitfalls that should be recognized and corrected before further checks and interpretations (Lu & White, 2014).

In this study based on the data structure and literature review of different studies about financing constraints, cash holdings of the companies in the current year was chosen as a core variable. This variable is robust in several alternative assumption and equations of table 5. As an example, the coefficients of this variable in the first four model of this table, which only include financial variable of the current year is quantitatively important and statistically significant. At the same time, in four last models of this table by adding the financial variables of the previous year, one can recognize that changes in amount of this coefficients is negligible, while they are still quantitatively important and statistically significant.
Table 4: Correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>(R &amp; D)ₜ</th>
<th>(Debt)ₜ</th>
<th>(Cash)ₜ</th>
<th>(CommonStock)ₜ</th>
<th>(R &amp; D)ₜ₋₁</th>
<th>(Debt)ₜ₋₁</th>
<th>(Cash)ₜ₋₁</th>
<th>(CommonStock)ₜ₋₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R &amp; D)ₜ</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Debt)ₜ</td>
<td>0.3772</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cash)ₜ</td>
<td>0.6095</td>
<td>0.1384</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.024)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CommonStock)ₜ</td>
<td>0.4661</td>
<td>0.1999</td>
<td>0.2452</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.001)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R &amp; D)ₜ₋₁</td>
<td>0.8932</td>
<td>0.4221</td>
<td>0.5638</td>
<td>0.5794</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Debt)ₜ₋₁</td>
<td>0.4493</td>
<td>0.7888</td>
<td>0.2435</td>
<td>0.2582</td>
<td>0.5403</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cash)ₜ₋₁</td>
<td>0.5826</td>
<td>0.1607</td>
<td>0.7411</td>
<td>0.35</td>
<td>0.5748</td>
<td>0.207</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.018)**</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.002)***</td>
<td>(0.002)***</td>
<td></td>
</tr>
<tr>
<td>(CommonStock)ₜ₋₁</td>
<td>0.4548</td>
<td>0.1599</td>
<td>0.2213</td>
<td>0.9584</td>
<td>0.5839</td>
<td>0.2262</td>
<td>0.3404</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(0.000)***</td>
<td>(0.011)**</td>
<td>(0.001)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
</tr>
</tbody>
</table>

Note: p-values are in parentheses; *** p<0.01 (significance at 1%), ** p<0.05 (significance at 5%), * p<0.1 (significance at 1%)
Table 5: OLS regression results considering different variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
<th>(12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(R &amp; D)_{t-1}$</td>
<td>1.004***</td>
<td>0.984***</td>
<td>1.011***</td>
<td>0.996***</td>
<td>1.080***</td>
<td>1.070***</td>
<td>1.089***</td>
<td>1.087***</td>
<td>1.019***</td>
<td>0.994***</td>
<td>1.026***</td>
<td>1.007***</td>
</tr>
<tr>
<td></td>
<td>(0.0554)</td>
<td>(0.0607)</td>
<td>(0.0562)</td>
<td>(0.0622)</td>
<td>(0.0632)</td>
<td>(0.0719)</td>
<td>(0.0637)</td>
<td>(0.0728)</td>
<td>(0.0645)</td>
<td>(0.0739)</td>
<td>(0.0656)</td>
<td>(0.0759)</td>
</tr>
<tr>
<td>$(Debt)_t$</td>
<td>-0.0179</td>
<td>-0.0138</td>
<td>-0.0213</td>
<td>-0.0179</td>
<td>-0.0143</td>
<td>-0.0138</td>
<td>-0.0193</td>
<td>-0.0188</td>
<td>-0.0096</td>
<td>-0.0086</td>
<td>-0.0039</td>
<td>-0.0038</td>
</tr>
<tr>
<td></td>
<td>(0.0209)</td>
<td>(0.0215)</td>
<td>(0.0213)</td>
<td>(0.0220)</td>
<td>(0.0313)</td>
<td>(0.0315)</td>
<td>(0.0323)</td>
<td>(0.0325)</td>
<td>(0.0331)</td>
<td>(0.0302)</td>
<td>(0.0307)</td>
<td>(0.0314)</td>
</tr>
<tr>
<td>$(Cash)_t$</td>
<td>0.109***</td>
<td>0.115***</td>
<td>0.102***</td>
<td>0.107***</td>
<td>0.105***</td>
<td>0.109***</td>
<td>0.101***</td>
<td>0.104***</td>
<td>0.133</td>
<td>0.116</td>
<td>0.108</td>
<td>0.0953</td>
</tr>
<tr>
<td></td>
<td>(0.0220)</td>
<td>(0.0231)</td>
<td>(0.0230)</td>
<td>(0.0244)</td>
<td>(0.0296)</td>
<td>(0.0302)</td>
<td>(0.0307)</td>
<td>(0.0314)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>$(CommonStock)_t$</td>
<td>-0.146**</td>
<td>-0.127*</td>
<td>-0.143*</td>
<td>-0.127*</td>
<td>-0.137</td>
<td>-0.137</td>
<td>-0.137</td>
<td>-0.137</td>
<td>0.133</td>
<td>0.116</td>
<td>0.108</td>
<td>0.0953</td>
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<tr>
<td></td>
<td>(0.0722)</td>
<td>(0.0754)</td>
<td>(0.0728)</td>
<td>(0.0761)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>$(Debt)_{t-1}$</td>
<td>-0.0187</td>
<td>-0.0159</td>
<td>-0.0227</td>
<td>-0.0220</td>
<td>-0.0113</td>
<td>-0.00501</td>
<td>-0.0086</td>
<td>-0.0039</td>
<td>0.133</td>
<td>0.116</td>
<td>0.108</td>
<td>0.0953</td>
</tr>
<tr>
<td></td>
<td>(0.0264)</td>
<td>(0.0280)</td>
<td>(0.0266)</td>
<td>(0.0284)</td>
<td>(0.0364)</td>
<td>(0.0376)</td>
<td>(0.0373)</td>
<td>(0.0385)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>$(Cash)_{t-1}$</td>
<td>0.0824***</td>
<td>0.0857***</td>
<td>0.0720**</td>
<td>0.0728**</td>
<td>0.00916</td>
<td>0.0142</td>
<td>0.00451</td>
<td>0.00824</td>
<td>0.133</td>
<td>0.116</td>
<td>0.108</td>
<td>0.0953</td>
</tr>
<tr>
<td></td>
<td>(0.0290)</td>
<td>(0.0311)</td>
<td>(0.0297)</td>
<td>(0.0320)</td>
<td>(0.0356)</td>
<td>(0.0365)</td>
<td>(0.0363)</td>
<td>(0.0373)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>$(CommonStock)_{t-1}$</td>
<td>-0.232***</td>
<td>-0.228***</td>
<td>-0.225***</td>
<td>-0.223***</td>
<td>-0.347</td>
<td>-0.314</td>
<td>-0.315</td>
<td>-0.289</td>
<td>0.133</td>
<td>0.116</td>
<td>0.108</td>
<td>0.0953</td>
</tr>
<tr>
<td></td>
<td>(0.0801)</td>
<td>(0.0837)</td>
<td>(0.0808)</td>
<td>(0.0845)</td>
<td>(0.245)</td>
<td>(0.250)</td>
<td>(0.252)</td>
<td>(0.258)</td>
<td>(0.235)</td>
<td>(0.237)</td>
<td>(0.242)</td>
<td>(0.244)</td>
</tr>
<tr>
<td>Constant</td>
<td>-415.9</td>
<td>4,334</td>
<td>2,044</td>
<td>6,184</td>
<td>4,260</td>
<td>4,930</td>
<td>-1,844</td>
<td>-1,210</td>
<td>888.0</td>
<td>3,971</td>
<td>3,475</td>
<td>6,192</td>
</tr>
<tr>
<td></td>
<td>(4,961)</td>
<td>(8,511)</td>
<td>(13,664)</td>
<td>(15,020)</td>
<td>(5,434)</td>
<td>(9,370)</td>
<td>(14,339)</td>
<td>(16,050)</td>
<td>(5,512)</td>
<td>(9,074)</td>
<td>(14,801)</td>
<td>(16,181)</td>
</tr>
<tr>
<td>Observations</td>
<td>199</td>
<td>199</td>
<td>199</td>
<td>199</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>185</td>
<td>181</td>
<td>181</td>
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<td>181</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.824</td>
<td>0.825</td>
<td>0.827</td>
<td>0.827</td>
<td>0.803</td>
<td>0.804</td>
<td>0.808</td>
<td>0.808</td>
<td>0.820</td>
<td>0.821</td>
<td>0.823</td>
<td>0.823</td>
</tr>
<tr>
<td>AIC</td>
<td>4877.56</td>
<td>4880.72</td>
<td>4884.59</td>
<td>4888.00</td>
<td>4562.88</td>
<td>4566.78</td>
<td>4568.52</td>
<td>4572.52</td>
<td>4454.42</td>
<td>4457.86</td>
<td>4462.03</td>
<td>4465.69</td>
</tr>
<tr>
<td>BIC</td>
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<td>4903.77</td>
<td>4917.53</td>
<td>4927.52</td>
<td>4578.98</td>
<td>4589.32</td>
<td>4600.73</td>
<td>4611.16</td>
<td>4480.01</td>
<td>4489.84</td>
<td>4503.62</td>
<td>4513.67</td>
</tr>
<tr>
<td>$F$-statistic</td>
<td>227.71***</td>
<td>151.02***</td>
<td>100.39***</td>
<td>81.56***</td>
<td>183.98***</td>
<td>121.37***</td>
<td>81.86***</td>
<td>66.21***</td>
<td>112.76***</td>
<td>87.02***</td>
<td>64.91***</td>
<td>55.10***</td>
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<td>Year dummies</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry dummies</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: Standard errors in parentheses; *** $p<0.01$ (significance at 1%), ** $p<0.05$ (significance at 5%), * $p<0.1$ (significance at 10%)
Changes in financial variables in different models that are presented in table 5 are as follows. In the first assumption, R&D investments are positively correlated with cash holdings of the companies. Cash holding coefficients are near (0.10) and statistically significant in all four regressions of this assumption (p-values of 0.01 or smaller). However, this coefficient reaches its maximum amount (0.115) with including industry dummies. Common stocks, on the other hand, have a negative correlation with R&D investments. At last, the correlation of debt with R&D investment is negative, but it is quantitatively unimportant and statistically insignificant in this specification.

Results in the second assumption, which consider lagged values of financial variables, are slightly different from the first assumption. The coefficients of cash holdings stay positive and statistically significant, but their value decreases to around (0.07) in different specifications of this assumption. The negative correlation of common stocks with R&D investment increases. This correlation is statistically significant (p-value of 0.01 or smaller). Debt coefficients with negative values stay quantitatively unimportant and statistically insignificant.

Finally, in the last assumption with including of all financial variables and their lagged values in the regression, the coefficients of cash holdings of the current year are still positive, quantitatively important and statistically significant. However, the coefficients of the lagged value of this variable decrease and get close to zero and become statistically insignificant. Moreover, in this assumption, common stocks of the current year have a positive correlation with R&D investments. The coefficient of the lagged value of this variable, on the other hand, is negative and it increases significantly in every specification of this assumption. Accordingly, the estimated coefficient of the common stock is negative. Debt coefficients accompanied by their lagged value remain quantitatively unimportant and statistically insignificant, while coefficients of (Debt)_{t-1} is getting closer to zero, about (-0.00863) in one specification of this assumption.

As stated by Burnham & Anderson (2004), before selecting the best model among a set of models, it is important to develop a primary data analysis. As a result, before selecting the most fitted model or the model with the least uncertainty, I compare the results of my regression equation with previous studies about financing constraints. In the next stage, Akaike’s information criterion (AIC) and Bayesian information criterion (BIC) are used to choose a single best model between different models (assumptions) in table 5. Mathematical computation of
these two approaches is complex for this paper. However, a short description of these approaches is provided in the following to give the reader an overview about the reason of using these two estimates.

Good approximating models, which are selected by application of AIC and BIC have the following characteristics. Firstly, they are simple, meaning that they do not have too few or too many variables since both situations can result in misleading precision. Secondly, these models do not have null hypotheses. Accordingly, empirical data can support several hypotheses or models, while models with less empirical supports would be eliminated gradually. The last feature of these estimations is the strength of evidence that clarifies the fact that these models are an outcome of quantitative information, unlike the estimations with null hypotheses, which is based on arbitrary dichotomies such as “significant vs. nonsignificant” (Burnham & Anderson, 2004, 266). It is important to consider that these two approaches do not have a meaning by themselves and they are only used to compare different models. AIC and BIC are calculated as follows for least square (LS) estimations in linear models (Burnham & Anderson, 2004).

\[
1- AIC = n \cdot \ln \left( \frac{RSS}{n} \right) + 2K \\
2- BIC = n \cdot \ln \left( \frac{RSS}{n} \right) + K \cdot \ln(n)
\]

Where \( n \) is the number of observations, \( K \) is the number of parameters, and \( RSS \) is the residual sum of squares in OLS regression. Accordingly, the smallest amount of AIC and BIC shows the best model. According to the table 5, the model (assumption) 9, which does not consider the year and industry dummies, is the best approximating model.

In the last step, based on generated results, the variable of common stock of the selected firms studied closely one more time. The year that selected firms join the Stockholm Stock Exchange was also considered for further discussions about negative correlation of common stock with R&D investments in regression analysis of this paper. Table 6, classify the selected firms based on their presence on the Stockholm Stock Exchange, while the year 2017 is assigned as the last year of this observation.
According to this table, about 42 percent of selected firms have been on the market for less than 10 years, while 68 percent of these firms have been on the market for more than 11 years. I did not divide the sample of this study for running separate regressions for young and mature firms since the data in this study were not adequate. However, firms age as an important differentiating factor in relation to investment decisions (Hall et al., 2016), is discussed more in detail in the next chapter.

5 Discussion

This chapter aims to evaluate the generated results to answer the research question of this paper. Accordingly, background literature about different methods of financing R&D and financing constraints are aligned with results of this study to recognize in what ways financing constraints affect high-tech publicly listed Swedish firms, with the smaller amount of employees. Limitations of this study are also discussed in this chapter.

5.1 financing of R&D in small high-tech Swedish firms

According to the results of this study, high-tech publicly listed Swedish firms that have fewer employees in comparison to their counterparts in high-tech industries mainly depend on their internal resources and specifically on their cash holdings for financing their R&D activities. This dependence was expected in this study and it is in line with previous studies about financing constraints in European countries such as the study of Brown et al. (2012). Nowadays, firms are more reliant on their internal resources for their R&D investments in both developed and developing countries (Lin et al., 2017). This issue is also proved by many case studies in recent decades, which reflect that R&D investments are very sensitive to cash flows in high-tech sectors (Brown et al., 2009; Brown et al., 2012; Sasidharan et al., 2015). Accordingly, R&D investments are "customer-financed" (Lööf & Nabavi, 2016) and are highly dependent on the economic performances of the companies (Savignac, 2008). Dependence of R&D investments to internal resources originates from several factors such as general characteristics of R&D investments,
especially it's pro-cyclicality in this study and firms characteristics, which are discussed in the following.

5.1.1 General characteristics of R&D investments
Certain characteristics of R&D activities and hardships that high-tech companies face to access external resources of financing, lead to dependence of these companies to their internal resources (Hall, 2002). Some of these characteristics are high level of information asymmetries between different parties, which cause adverse selection and moral hazard problems (Brown et al., 2012; Kerr & Nanda, 2015). Increasing uncertainties about desired outcomes and potential results of R&D projects, and high level of adjustment and agency costs at the firm level (Kerr & Nanda, 2015; Sasidharan et al., 2015) are also important characteristics of R&D investments that make high-tech firms more susceptible to financing constraints (Hall et al., 2016). It is important to consider that high-tech firms have a higher level of R&D intensity (OECD, 2011). They are also extremely dependent on their R&D projects for the success of their businesses (ibid.). Accordingly, financing constraints caused by special features of R&D, need to be recognized and controlled by firms since they negatively affect R&D investments in these companies (Lin et al., 2017).

5.1.2 R&D pro-cyclicality in aftermath of the global financial crisis
Another important characteristic of R&D investment is its cyclicality, which is related to the vulnerability of these kinds of investments to financial shocks (Brown et al., 2009; Fabrizio & Tsolmon, 2014; Sasidharan et al., 2015). This matter is followed in the generated results of this study since the period of this study is between 2010 and 2016 and in aftermath of global financial crisis. As disclosed by European Commission Press Release Database in December 2014, R&D investments have decreased drastically in 2008 in Europe. Moreover, the recovery trend of these kinds of investments in 2010 and 2011 was accompanied by another sharp decrease from 2011 to 2013. This matter is reflected in figure 2 in the method section. Aggregated amount of R&D investments and other financial variables of the sample of this study also reflect the same results. Accordingly, aggregated amount of R&D for the selected firms increases slightly from 2010 to 2014, while it increases sharply after 2014. This matter is observable in figure 3 in the results section, which confirms the cyclicality of R&D investments in the sample of this study. In other words, selected companies in this study decrease their R&D investments during the period of economic recession and it took several years for them to be able to increase their R&D investments after the global economic recession.
According to the study of Lööf & Nabavi (2016), Swedish exporting companies tend to use their internal resources for financing their R&D activities during the financial crisis. In fact, the financial crisis results in decreasing amount of R&D investments, while it also increases the effects of financing constraints for firms (Fabrizio & Tsolmon, 2014). In this situation, firms put off their valuable R&D opportunities to save up for their short-term expenditure (Brown et al., 2009; Fabrizio & Tsolmon, 2014; Sasidharan et al., 2015). The selected firms in this study, also use their cash holdings as the main way of financing for their R&D investments. Moreover, they had hardships to access external resources of financing such as debt and equity during the global financial recession and several years after this event. This matter is observable from the aggregated amount of common stock and debt which increase sharply with the aggregated amount of R&D investments after 2014. The amount of (GDP) per capita in Sweden increases gradually after 2015 (Statista, 2018, 1). The increasing trend of (GDP) per capita reflects the economic growth (ibid.) parallel with the growing trend of R&D investments in this country.

5.1.3 Firms age
As stated by different researchers, firms mainly use their internal resources for their R&D investments (Brown et al., 2012; Sasidharan et al., 2015; Lin et al., 2017). However, firms size and age are also important differentiating factors in relation to their investments decisions (Hall et al., 2016), because firms use different sources of financing over their life cycle (Brown et al., 2009; Mazzucato, 2013). This matter is also observable in the study of Brown et al. (2012). These researchers reveal considerable differences in the results of their study by dividing their sample into two categories of young and mature firms. Accordingly, they show that in countries such as Sweden and the UK with the developed stock market, R&D intensity and cash holdings are substantially high in younger firms. They also reveal that young companies in these countries rely on volatile stock issues for financing their R&D investments (Brown et al., 2012).

In the current study, we can see a drastic increase in aggregated R&D and other financial variables only after 2014. However, the aggregated amount of cash holdings of the selected companies increases more drastically than the aggregated amount of variables such as debt and common stocks. As a result, I looked at firms' age in the sample of this study, since this factor has a determinative role in financing decisions of companies (Hall et al., 2016). About 50 percent of firms in the sample of this study have been on the Stockholm Stock Exchange for more than 15 years. This duration for classification of young and mature firms is comparable with the study of Brown et al. (2012), which consider firms with maximum 12 years of non-
missing sales report in Compustat Global database as young firms and separate them from mature firms. I also found out that some of the selected firms have been active for many years before they join the stock market. Accordingly, the high dependence of these firms to their cash holdings for financing their R&D investments originates from the fact that the sample of this study includes many mature firms. These firms have better opportunities to use their retained earnings (Mazzucato, 2013) in comparison with young firms that rely on volatile stock issues in countries such as Sweden with the developed stock market (Brown et al., 2012).

5.2 Financing constraints and R&D investments

Dependence of R&D investments of the selected companies in this study to their internal resources such as cash holdings is in line with other studies about financing constraints in Sweden such as Brown et al. (2012) and Lööf & Nabavi (2016). The negative correlation between common stocks and R&D investments is also explainable by firms’ age. The sample of this study is mainly composed of mature firms, while generally young firms rely on stock issues in early stages of their life cycle (Brown et al., 2012). This issue is also true for investments in R&D activities and innovation in young high-tech companies (ibid.). The correlation of debt financing with R&D investments of selected companies is also negative, but this relationship is quantitatively unimportant and statistically insignificant. Moreover, the negative correlation between these two variables was predictable in this study, since Sweden has an equity-based financial system. In fact, the high dependence of companies to the banking sector for financing their innovative projects is only observable in Germany, which has a bank-based financial system.

Mentioned findings from the regression analysis of this paper do not fully support the view that smaller high-tech Swedish publicly listed firms are financially constrained over the entire period of 2010 to 2016. In other words, it cannot be concluded that selected firms choose internal resources over external resources of financing since the cost of external capital is higher for their R&D investments. However, the decreasing trend of the aggregated amount of R&D investments along with the result of the regression, support the fact that financial recession decreased R&D investments in selected firms in the period of 2010 to 2014. R&D investments and sales are typically low in this period in high-tech sectors in Europe and all around the world (European Commission Press Release Database, 2014). This matter is also reflected by the study of Lööf & Nabavi (2016), which shows that Swedish companies tended to offset the negative effects of
economic recession by using their internal resources. Accordingly, the lower amount of cash flows and cash holdings and the fact that firms need to save up for their short-term expenses instead of investing in R&D projects, reflect the presence of financial constraints for R&D investments of the selected firm in aftermath of global financial crisis.

As mentioned earlier, financial constraints, which is imposed by the global financial recession had a negative effect on R&D investments of the selected firms. This issue is visible from the lower amount of aggregated R&D during these years. Moreover, it took several years for these firms to recover from the negative effects of financial constraints and be able to invest in their R&D projects. In this study, details about these investments are not available and mentioned conclusion is suggested from the increasing amount of aggregated R&D after 2014.

The result of this study about the presence of financial constraints can be generalized to the firms in high-tech industries in Sweden between 2010 and 2014. As stated earlier, aggregated amount of R&D investments and cash holdings of the selected firms raise simultaneously and sharply after 2014, which coincide with the constant increase of the amount of GDP per capita in current prices in Sweden (Statista, 2018, 1). This coincidence confirms the important role of R&D investments and innovation in economic growth of this country.

5.3 Role of firms and other institutions in reducing financing constraints

Governments play an important role in the primary stages of financing R&D and innovations since they tolerate more risks (Arrow, 1962; Fryges et al., 2015). Financial institutions such as banks and equity markets also play an important role in reducing the effects of financing constraints (Lerskullawat, 2018). As an example, Lehmann-Hasemeyer & Streb (2016) shows that the Berlin Stock Exchange directed funds from less innovative firms to more innovative ones in Germany before the first world war. The important role of equity markets for financing innovations in young firms has also presented in recent studies such as Brown et al. (2012). More recently however, researchers have shown that R&D intensive firms are highly dependent to their internal resources for their R&D investments all over the world (Lin et al., 2017). This dependence is more visible in the mature firms which have better possibilities to finance their R&D investments by selling additional amount of products or services to their customers (Savignac, 2008).
The results of regression analysis of this paper also reflect the dependence of R&D investments to cash holdings in Swedish high-tech publicly listed firms. It also shows that the selected firms are very vulnerable to the situation of their environment such as economic recession. At the same time, R&D investments have special characteristics such as high level of uncertainties and higher agency costs, which make them susceptible to financing constraints. Although these characteristics are not verified as the reason of financing constraints in this paper, they cannot be neglected and they underline the need for controlling role of different institutions in complex procedure of R&D investments. Accordingly, different literature stated different reasons for the importance of external supervisions of external institutions.

The role of firms in reducing financing constraints for R&D investments is also very important. R&D activities are performed through complex procedures. To date however, there has been little agreement about reliable ways for measuring these activities in different companies (Hannon et al., 2015). R&D departments do not provide clear information about tangible outflows for their projects (ibid.). Moreover, conventional approaches such as R&D expense to revenue ratio or time needed before a new product reach the market do not fully reflect how these projects are performing (ibid.). Many R&D projects might also fail unexpectedly even though they had reported success for many years (ibid.). Accordingly, different financing literatures consider signals, which can improve the relation of investors and firms and reflect the productivity of R&D investments such as patents (Hall et al., 2016).

5.4 limitations of the study

Apart from methodological limitations, there are other limitations that can affect accuracy of the results in this study. This study is based on a model and models are not free from limitations, since they simplify the real world situation and they are exposed to mistakes and flaws. This model uses financial variables that are applied in previous paper. However, it only applies variables from balance sheet information of the firms, while it does not consider the macroeconomic factors that influence the firms such as overall economic situation of the country. Moreover, I faced hardships in choosing the sample of this study, since many small high-tech Swedish listed companies do not report their R&D investments in their financial reports. This situation made me to consider high-tech companies with less than 1000 employees that have reported at least two consecutive values for their R&D investments in the period of
2010-2016. As a result, I was not able to select smaller firms among high-tech Swedish publicly listed firms based on the description of small firms by European Commission.

In this study, I assumed that the selected firms use internal and external resources of financing for their R&D investments, while these resources might be used for physical investments of the companies, since this study is accomplished from 2010 to 2016 and in aftermath of the global financial recession. In this period, R&D intensive sectors experienced drastic decrease in their sale and R&D investments all around the world (European Commission Press Release Database, 2014). Moreover, firms tend to decrease their R&D investments to save up for their short-term expenditures, when they face economic instabilities (Brown et al., 2009; Fabrizio & Tsolmon, 2014; Sasidharan et al., 2015).

Finally, this study cannot be generalized to different countries and to different time spans, since different countries have different financial systems. Technological environment also varies in different countries (Fryges et al., 2015). As stated by O’Sullivan (2005), in order to achieve a complete picture about finance and innovation in a country, we need to consider the historical data about financing patterns in companies and financing supplies by financial institution. There are also chances for presence of different patterns of supply by financial institutions, while firms, industries and countries might tend to use different resources of financing in different periods of time (O’Sullivan, 2005).

6 Conclusion

This paper set out to study effects of financing constraints on R&D investments and innovative performances of high-tech publicly listed Swedish companies, which are smaller than their counterparts. The aim was to provide an overview about financing decisions of companies, which have access to a developed stock market such as Stockholm Stock Exchange. Accordingly, by using balance sheet data of companies and regression analysis, effects of financing constraints on R&D investments of the selected firms was captured from 2010 to 2016 and in aftermath of global financial crisis.

The result of this study showed that there is a significant relationship between cash holdings and R&D investments, however, debt amount and common stock had negative correlation with R&D investments of the selected companies. Relation of debt amount with R&D investment was
expected since Sweden unlike Germany has market-based financial system, while the relation of common stocks with R&D investments is not in line with former studies in Sweden. The reason of this contradiction is associated to several reasons. Firstly, the time span that this study is accomplished is different from other studies. Secondly, selected sample is also different in this study and it mainly composed of mature firms that generally depend to their internal resources for financing their innovative activities. At last, this result can be associated to the characteristics of financial markets, which may provide different patterns of supply over different periods of time.

This study reflect the vulnerability of R&D investments to macroeconomic recessions and shows that economic recessions such as global financial recession in 2007 and 2008 created financing constraints for R&D investments of the mature high-tech firms. This issue is in contrast with the fact that previous literatures mainly consider young and small firms as the main subjects for financing constraints. It also brings the importance role of financial institution and firms in increasing productivity of R&D projects into front. It is important to consider that financial management and R&D management have an increasing importance nowadays since they lead to profitability for the companies and economic growth all over the world.
References


