

R&D INDUCED IPO UNDERPRICING

MONEY GLADLY LEFT ON THE TABLE

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R&D Induced IPO Underpricing – Money Gladly Left on the Table

Abstract:

Previous research has found that for firms investing in R&D, asymmetric information between firm insiders and outsiders raises the cost of external capital above the fair level. In this paper, we examine how the presence of R&D activities affects firms' cost of raising capital in a special case of external financing – namely, the IPO. In IPOs, an additional component called IPO underpricing is added to the cost of raising capital for the average firm, a phenomenon presumably driven by asymmetric information. We hypothesize and find support for this component being systematically larger the more R&D activities a firm does. We do this using OLS regressions that model a relationship between R&D activities and IPO underpricing. Furthermore, we test whether two chosen potential quality signals can mitigate the R&D induced asymmetric information, but find no support for this. However, we conclude that although the cost of an IPO is higher for firms doing R&D, the gains they can expect are also larger.

Keywords:

Information asymmetry, IPO underpricing, R&D, Quality signal, External finance

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1. Introduction

It is widely recognized that innovation plays a central role in the economic development. Through innovation, new ideas and technologies are developed that enable productivity to increase. On a societal level, the implication of increasing productivity is that a larger quantity of products is produced, wages rise and consumption increases – i.e. that economic growth occurs (European Central Bank, 2017). In Sweden, the private sector is the largest actor within innovation, accounting for 71 percent of the investment in research and development (R&D) in 2017 (Statistics Sweden, 2017). Therefore, firms that engage in R&D activities are of utmost importance to society and have attracted much attention by the academia. Within this body of research, it has been identified that R&D activities give rise to asymmetric information between firm insiders and firm outsiders. The effect of this is that for firms that do R&D, the cost of external capital is above the fair level (Hall & Lerner, 2010). This means that the risk-adjusted cost of capital is higher for firms doing R&D, relative the average firm.

This paper zooms in on one special case of external capital raising, namely the initial public offering (IPO) of a firm's common stock. In an IPO setting, the average firm experiences a higher cost of capital than their normal level, due to a well-studied phenomenon known as IPO underpricing. One of the most supported explanations for IPO underpricing is that it is driven by asymmetric information. Therefore, there is reason to believe that the R&D induced information asymmetries will magnify the IPO specific increase in cost of capital. If this is the case, firms doing R&D will, in addition to experiencing higher cost of external capital in general, on average be more severely subjected to this cost of going public.

In this paper, we investigate and quantify the effect that the level of R&D activities in a firm has on the level of IPO underpricing. We do this by proxying R&D activities with the ratio of capitalized development expenditures over assets (henceforth also called R&D capital), and then regressing IPO underpricing on this proxy. We then go on to explore whether signals of quality of a firm's R&D activities can mitigate the level of asymmetrical information that the R&D activities give rise to. The chosen signals are presence of venture capital (VC) and information about past R&D outputs, proxied by the existence of patents. To test the effect of the signals, we use regressions to see whether the effect of R&D activities on IPO underpricing is smaller for firms that exhibit these quality signals.

We document the presence of "R&D induced IPO underpricing", defined as the additional IPO underpricing a firm with a certain level of R&D activities experiences in comparison to an identical firm, in respect of all control variables, except it has no R&D activities. When we test the effect of quality signals, we get no statistically significant results.

Our model estimates the effect of R&D induced IPO underpricing to be positive. The size of the effect decreases with higher levels of R&D activities. At the median level of R&D capital among R&D firms, i.e. 20.3 percent, the R&D induced IPO underpricing is 6.6 percent. At the median level of proceeds this effect, translated to monetary values, amounts to 7,914 thousand SEK. For firms with R&D capital at the 90th percentile, the corresponding effect is 12.7 percent R&D induced IPO underpricing, which translates to 15,228 thousand SEK in monetary value. When we adjust the model to include the quality signals, we find that neither the effect of R&D capital nor the effect of the quality signals are statistically significant. Primarily, our interpretation of this is that our model does not support the hypothesis of how the chosen signals can mitigate the R&D induced IPO underpricing. However, the results also raise questions about sample size limitations.

1.1. Research and Development Activities

A commonly used definition of R&D is found in the Frascati Manual, published by OECD. In the 7th edition of the manual, published in 2015, their definition is stated in the following way:

Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of man, culture and society – and to devise new applications of available knowledge (OECD, 2015).

The manual then elaborates on the meaning of the concept by clarifying which types of activities it comprises:

The term R&D covers three types of activity: basic research, applied research and experimental development. **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. **Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improve existing products or processes (OECD, 2015).

All three types of R&D activities can be found in the operations of firms. However, basic research is the one out of the three activities that firms most rarely engage in (Rosenberg, 1989). More commonly, firms carry out applied research, with the aim of developing methods for achieving some predetermined goals or to find applications for knowledge generated through basic research (OECD, 2015). Lastly, firms' development activities consist of creating or improving specific products or processes. However only some stages of the product development process are considered development activities, namely those in which "generic knowledge is actually tested for the specific applications needed to bring such a process to a successful end" (OECD, 2015). The level of uncertainty varies

among the activities – from the highest level of uncertainty in basic research activities to the least uncertainty in development activities (OECD, 2015).

Firms' R&D activities are of interest for analysts, investors and other stakeholders, since they can be an important source of value (Chan et al., 2001). However, these actors cannot directly observe the R&D activities of the firms and thus they must rely on other sources to receive information about the activities (Landsman et al., 2012). The main information source for quantifiable information about firms' R&D activities is their financial statements. The way R&D activities are reported in financial statements depend on which accounting standard the report follows. Since the probability of investments in R&D activities leading to future benefits is more uncertain than for many other investments, it is not conclusive whether these expenditures should be expensed or capitalized. Different accounting standard setters have taken different positions regarding these questions. For example, under the US GAAP, R&D expenditures are exclusionary expensed, while development expenditures are capitalized if they meet certain criteria under the International Financial Reporting Standards (IFRS).

In Sweden, which accounting regulations a firm follows depends on the size of the firm. Firms that go public, i.e. the relevant firms in the context of this paper, almost exclusively follow the regulation frameworks K3 or K4. While K4 contains the IFRS, K3 contains the main Swedish accounting standards. Under K3, firms are to choose one out of two alternative approaches of treating R&D expenditures – the expensing method or the capitalization method. The expensing method prescribes firms to expense all R&D expenditures. The capitalization model contains the same rules for treatment of R&D expenditures as IFRS. Under K4, i.e. IFRS, the treatment of R&D expenditures depends on whether the expenditures derive from research activities or development activities (Verksam.se, 2019). The definitions used for research activities and development activities are based on the Frascati manual definitions. The IFRS definition of research activities cover basic as well as applied research.

IFRS prescribes, in the following quote from IAS 38, that whether the R&D activities should be capitalized is based on the six criteria:

- 1) The technical feasibility of completing the intangible asset so that it will be available for use or sale,
- 2) Its intention to complete the intangible asset and use or sell it,
- 3) Its ability to use or sell the intangible asset,
- 4) How the intangible asset will generate probable future economic benefits.
Among other things, the entity can demonstrate the existence of a market for the output of the intangible asset or the intangible asset itself or, if it is to be used internally, the usefulness of the intangible asset,
- 5) The availability of adequate technical, financial and other resources to complete the development and to use or sell the intangible asset and

- 6) Its ability to measure reliably the expenditure attributable to the intangible asset during its development.

In practice, this means that expenditures that arise in firms' basic research and applied research phases will be expensed, since they can never meet the criteria for capitalization. Expenditures that arise in the development phase, on the other hand, can potentially be capitalized (IAS 38). Thus, firms' R&D activities can be divided into three categories; research, development with lower degree of certainty which does not meet the criteria (uncertain development) for capitalization and development with higher degree of certainty which meet the criteria for capitalization (certain development). Expenditures that arise as a result of the first two types of activities will be expensed and reported on the income statement. Expenditures that derive from activities of the third type will be capitalized and reported on the balance sheet. An overview of this is found in Figure 1.

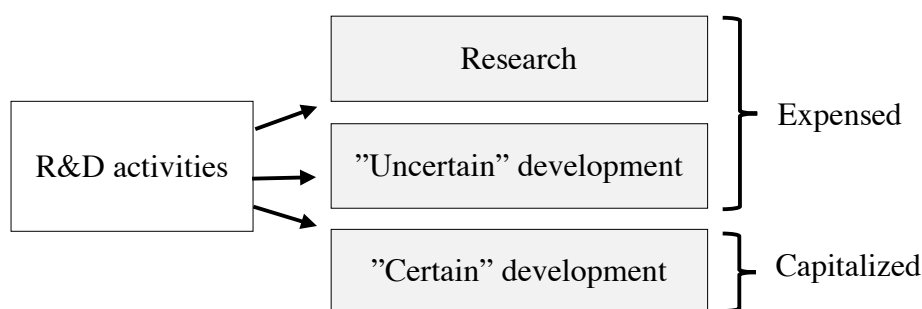


Figure 1. Illustration of accounting treatment of R&D activities under IFRS

2. Literature Review

This paper builds on two different research areas, in which extensive previous research has been performed in the different areas individually. For a more comprehensive understanding of the fundamental concepts our research rests upon, the two bodies of theory are reviewed separately below. Ultimately, our paper enters where these research areas overlap. Namely, as they both advocate the importance of information structures in the context of investing decisions and subsequently the implications it has on capital allocation. There have also been previous efforts to combine the two areas, such as the research done by Guo et al., (2006) investigating the US IPO market in 1980-1995. They present evidence of R&D expenditures having a positive relationship with IPO underpricing. While their results provide validation for our hypothesis, it is not possible to directly translate their results to the today's Swedish IPO market because of differences in the institutional environment as well as firm's reporting of R&D activities.

2.1. Theory on Business R&D and Asymmetric Information

R&D activities are increasingly important aspects of firms' operations. Over the past 30 years, the amount of R&D activities in firms has increased substantially, which can be explained by an increase in the R&D activities of existing firms as well as the growth of R&D-intensive industries (Franzen et al., 2007). Furthermore, for many firms, R&D capital is a major source of firm value (Chan et al., 2002). As highlighted in the introduction, R&D activities are also important for society as a whole. For these reasons, firms' R&D activities have received much attention from the academia.

Influential research within the economics literature has proposed that from a societal perspective, it is underinvested in R&D activities in the private sector (Hall & Lerner, 2010). Hall and Lerner (2010) argue there are two reasons for this. Firstly, the private gains for the firm investing in R&D activities are smaller than the societal gains, since knowledge produced in one firm can be used to create value by other actors in society. Secondly, R&D activities create asymmetric information between firm insiders and firm outsiders and thus, raises the cost of capital above the fair level, which results in lower than optimal allocation of external capital to R&D firms. They further claim the cause of the asymmetrical information problem is due to firm insiders having superior information about the nature of the R&D activities and the probability of success for the R&D projects. The higher than fair cost of capital that R&D intensive firms experience has also been documented empirically (see e.g. Chan et al., 2002; Eberhart et al., 2004)

The relationship between R&D activities and informational asymmetries has been documented in empirical research as well. In a study by Aboody and Lev (2000), the hypothesis that R&D activities are positively correlated with information asymmetry is tested through an investigation of the relationship between R&D-intensity, defined as

R&D expenses over sales, and gains from insider trading. They find support for their hypothesis and draw the conclusion that R&D-intensive firms are subjected to higher levels of information asymmetry than non-R&D-intensive firms. The same conclusion is drawn by Gompers (1995) who finds support for the hypothesis that venture capitalists should invest heavily in R&D-intensive firms. His hypothesis is built on the assumption that R&D-intensive firms' exposure to information asymmetries make the monitoring services that venture capitalists provide more valuable than in other types of firms.

Aboody and Lev (2000) argue there are three reasons investment in R&D gives rise to more information asymmetry than other types of investments. Firstly, R&D activities are unique to a firm and R&D capital can therefore not be valued with the help of the value of R&D capital of other firms in the industry, which is possible for many other types of capital. Secondly, there is no market for R&D capital and therefore no available market prices which valuation can be based on. Thirdly, since Aboody and Lev's study takes place in the setting of American firms that follow the US GAAP accounting standards and therefore expense all R&D expenditures, investors cannot observe value and productivity changes. In contrast, the value of types of capital that are capitalized is updated in quarterly and annual reports. Furthermore, they claim that R&D-intensity increases investors' cost of reducing the information asymmetry between themselves and firm insiders, primarily since analyzing R&D-intensive firms requires the investors to acquire sufficient scientific knowledge to understand the market and the firm's activities. Another circumstance that they suggest further complicates the valuation of R&D-intensive firms is the scarcity of public information on firms' R&D activities. Hall and Lerner (2010) observe the same phenomena and explain this with the fact that revealing information about innovative ideas to competitors can severely reduce the value of those ideas – a problem that is largest for basic research activities and decreases the closer to “certain” development activities that the activity gets.

Some information about firms' R&D activities can however be gathered by studying their past R&D performance, if the observer believes past R&D activities are representative for current and future R&D activities. In a study performed by Cohen et al. (2013), it is examined whether investors take firms' past success at R&D into account in the valuation of R&D-intensive firms. They find that the market fails to distinguish between what the authors categorize as “Good R&D” and “Bad R&D” based on how well previous R&D investments have been translated into future sales, although this distinction is relatively simple to make by analyzing the firms' past performance. Their results thus imply that investors do not take the results of past R&D activities into account when they value current and future R&D activities, either because they do not believe past R&D activities are representative for current and future R&D activities or because they simply fail to utilize the information.

One notable common feature among the mentioned papers is that they have all been carried out in settings in which R&D expenditures are fully expensed. This has two

consequences. Firstly, they have used R&D expenses to proxy R&D activities. Secondly, they have studied the effect of R&D in settings where the reporting of R&D activities carry less information relative to countries that follow IFRS, where investors get access to productivity changes and information about the firm's prediction about the probability of future benefits.

2.2. Theory on IPOs and IPO Underpricing

2.2.1. Why Do Firms Go Public?

To fully understand the implications that IPO underpricing has for the issuer, there is a need for understanding the underlying reasons for choosing to undergo the IPO process. As Brau (2010) notes, the reasons vary widely across firms. Ritter and Welch (2002) mention how some of these explanations revolve around life cycle theories, stating how it for different reasons becomes optimal at a certain stage in a firm's life to go public, e.g. to achieve increased publicity towards future investors and acquirers, following the trend of the industry or to obtain a first-mover advantage. As further discussed by Brau, (2010), theory also identifies reasons connected to corporate finance activities, such as minimizing the firm's cost of capital when bankruptcy costs included in the cost of debt makes a mixture of debt and equity more optimal. The reason can also be that more debt is not obtainable. There is also research investigating explanations more plainly built on raising as much capital as possible at present, whether it be for financing business growth investments, as suggested by the increase in asset sizes post-IPO found by Mikkelsen et al., (1997), or for founders and other business insiders to cash-out of their investment (e.g., Ang & Brau (2003) and Brau et al., (2007)).

2.2.2. Evidence of IPO Underpricing

The phenomenon of how initial public offerings (IPOs) of firms' common stocks, on average, exhibit underpricing is something that has puzzled scholars for decades. IPO underpricing refers to the situation in which the first day closing price after an IPO exceeds the IPO's offer price. For existing shareholders, the consequence of IPO underpricing is that they are 'leaving money on the table' – i.e. not getting fully compensated for the value of the assets that they are selling. Early research by Stoll and Curley (1970), Louge (1973), Reilly (1973), Ibbotson (1975) show convincing evidence of the phenomenon. Since the 70's, the research on IPO underpricing has grown large and within this body of research, one of the major questions raised is why underpricing of IPOs is observed.

One theory of the reason for IPO underpricing is that it is caused by general market conditions. Ritter (1984) shows that during the 80s the IPO underpricing was abnormally high, which could be explained by conditions in certain industries such as the gas and oil industry. Others instead present evidence of underpricing being highly dependent on

fluctuations in IPO market conditions (Ibbotson & Jaffe, 1975) or in the stock market conditions (Butler et al., 2014).

The majority of the remaining theories explaining the reasons for IPO underpricing can broadly be divided between whether they rely on the assumption of asymmetric information or symmetric information between the different parties involved in the IPO (Ritter & Welch, 2002). For the aim of this paper, explanations on IPO underpricing based on asymmetrical information theories are the main focus. Therefore, theories building on symmetric information are not reviewed.

2.2.3. Explanations for IPO Underpricing Building on Asymmetric Information

One of the main strains of theory aimed at explaining the systematic underpricing of IPOs builds on the idea of information asymmetry prevailing between different parties involved in the IPO. The large body of asymmetric information theory, however, presents a wide range of explanations for where this information asymmetry lies, and between which involved parties.

Rock (1986) presents a model aimed at explaining the paradox of why some investors are willing to obtain costly information of securities if the evidence put forward by Grossman (1976) of how all investors' information is visible and readily available in the equilibrium price of the asset, holds true. Through his model, Rock suggests underpricing is a way for the issuer to ration out shares between well-informed investors and uninformed investors, whereas the latter who are crowded out from good issues and thus, biased towards bad issues, would otherwise drop out of the market. The crowding out effect of uninformed investors is a result of well-informed investors fully subscribing to "good" issues, while only allowing accessibility to uninformed investors in "bad" issues in which they do not want to participate themselves. Namely, Rock argues that only a random group of well-informed investors are aware of the firm's prospects while neither the firm nor the underwriter know the true value of the firm. Underpricing then functions as a way to ensure uninformed investors' participation in new issues by giving them the discount they require in order to on average break-even, resulting in full subscription being secured even in "bad issues". Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990) also conclude that both the issuer and the underwriter lack information about the true value of the firm, and only a small group of investors who frequently interact with the firm, are informed about its just value. However, in contrast to Rock, they argue that underpricing is a way of compensating well-informed investors for revealing their information about the issue to the underwriter, which they do by disclosing the price that they are willing to pay for the issued shares during the book building process.

Building on an assumption of asymmetric information rather prevailing between the issuer and the underwriter, Baron (1982) explains underpricing in an agent-principle context. The agency problem is argued to stem from the fact that the underwriter has

superior information about the capital market, who then advises the issuer on the price level of the unseasoned securities, and ultimately commits to sell them. As the compensation to the underwriting bank is a function of total proceeds and thus, the price of the issue shares, underpricing may be included in the underwriting contract since the underwriter has incentives to set the price at a level that secures full subscription in the issue and hence, increase their sales volume. However, contradicting evidence is put forward by Muscarella and Vetsuypens (1989) who find that when investment banks go public and participate in their own distribution of shares, IPO underpricing is still observed although there should be no underpricing under the assumptions of Baron's model since no asymmetric information exists between the issuer and the share distributor.

A substantial branch within the information asymmetry research argues that the information asymmetry predominantly, instead, prevails between issuer and external investors. Grinblatt and Hwang (1989), Allen and Faulhaber (1989), and Welch (1989, 1992) assume that the only informed party in the IPO is the issuer itself. This assumption is commonly coupled with rational investors fear of unknowingly investing in lemons, as they presume only less-than-average quality issuers are willing to sell their shares at the average price. Underpricing is then the costly signal that high-quality firms choose to differentiate themselves from low-quality firms. It is also argued that firms use underpricing to leave a "good taste in investors' mouths" in order to receive a good price on future issues. Welch (1989), for example, shows that a third of the IPO issuers between the years 1977-1982 had reissued equity by 1986, typically at a price of three times the IPO price. Research also establishes that there are other quality signals, aside from IPO underpricing, that can be used to convey more internal information to externals in an IPO. Booth and Smith (1986) argue how the reputation of chosen underwriter influences external perception of the firm's quality, while Titman and Trueman (1986) state similar effects stem from the firm's choice of auditor. Schenone (2004) similarly, establishes how having a relationship bank taking the firm public can assist in equating any potential unleveled information structures between firm insiders and outsiders. Building on the same certification hypothesis, results by Megginson and Weiss (1991) suggest that VC-backing leads to significantly lower underpricing.

Also based on the conjecture of how investors are less informed about the prospect of an individual issue, Beatty and Ritter (1986) show how greater levels of "ex ante uncertainty", lead to greater levels of expected underpricing in a given IPO. The reasoning builds on the presumption that uninformed investors only are willing to submit purchases orders for offered shares if they, on average, can break-even across IPOs they invest in. With higher levels of perceived uncertainty in the valuation of a preceding issue, then the higher the compensation required from the uninformed investors - i.e. through a higher level of underpricing.

3. Hypothesis Development

The first hypothesis is that a firm's R&D induced asymmetrical information will, in addition to leading to higher cost of capital and thereby setting the market value of its R&D capital to below the fair value, cause the average price for capital sold through an IPO to be more underpriced in relation to the first day market valuation (i.e. the market value based on the first day closing price) than for comparable firms. Furthermore, while much of previous research has drawn conclusion based on differences between 'R&D firms' and 'non-R&D firms', we instead measure the effect of differences in the level of R&D activities, to add nuance to the analysis. We anticipate that the size of the positive effect of R&D activities on IPO underpricing will decrease with higher levels of R&D activities. The assumption is at the same increase in R&D activities will give rise to more asymmetrical information the less R&D activities the firm has prior to the increase.

Hypothesis 1: Firms with relatively higher levels of R&D activities will have relatively higher levels of IPO underpricing.

Secondly, we turn our attention to whether the degree of R&D induced asymmetrical information can be decreased by quality signals. Specifically, the firm quality signal that is commonly viewed as the most important in the IPO context is considered, namely VC backing. It is hypothesized that investors trust that the VC firms are superior within the technical competence and experienced needed to value R&D activities and that firms that have been subjected to screening and monitoring by VC firms are more likely to have high quality R&D activities that will have high future payoff. This would decrease the asymmetrical information between firm insiders and firm outsiders.

Hypothesis 2: Given that a VC-backed firm and a non-VC-backed firm have the same level of R&D activities, the VC-backed firm will experience a relatively lower level of IPO underpricing.

Thirdly, we examine whether information about the output of past R&D activities can reduce the R&D induced information asymmetry. Specifically, we hypothesize that given the same level of current R&D activities, firms that have patents outstanding can show that they have previously been successful in their R&D activities. They should therefore experience lower underpricing.

Hypothesis 3: Given that a firm that has patents outstanding and a firm that does not have patents outstanding have the same level of R&D activities, the firm that has patents outstanding will experience a relatively lower level of IPO underpricing.

4. Data and Methodology

4.1. Data Collection

The sample constitutes a unique data set of IPOs that occurred between January 1, 2012 and March 15, 2019, which was the date that we received the data directly from Nasdaq Nordic's data center. The data was confined to all IPOs during the time period done on any of the three lists under Nasdaq's management, i.e. the Main list, First North and First North Premier. As the research was aimed at examining the Swedish market, offerings on any of Nasdaq Nordic's lists outside of Stockholm were excluded. The initial sample consisted of 450 IPOs carried out on the Stockholm stock exchange during the eight-year period.

Furthermore, offerings stemming from equity carve-outs, rights or unit offerings, direct listings without an attached issue, or from issuers that changed lists or returned to the public market after having been previously delisted, were excluded. Due to differences in traits and trading between common and preferred stocks, offerings of preferred stocks were dropped as well. After these exclusions, 200 IPOs were left in the sample.

As a next step, all firms that use the expensing method allowed under K3 were dropped since these firms expense development costs even though requirements for capitalization are met. These firms thus lack capitalized development expenditures, which we need to construct the proxy for R&D activities in our model. In this step, another 10 observations were dropped, leaving a total of 190 observations in the sample.

Data on R&D expenditures was collected from annual reports. Attaining the capitalized development expenditures from one, respectively two years preceding the IPO, for the sampled firms was relatively simple. In the majority of the annual reports, capitalized development expenditures were explicitly stated. In some reports, almost exclusively for firms that have very little R&D, the capitalized development expenditures were not separated from other intangible assets. In these cases, the notes were used to interpret how much that can be derived from development activities. On the contrary, it was not possible to get the R&D expenses for many of the sample firms, especially young and small firms, neither in the income statement nor by interpretation of information in the notes. Data on the issuers' total assets and cash was also collected from the last, and second to last annual report leading up to the IPO, which were provided by the database Retriever Business. In some cases there was no data available for two years preceding the individual IPO, either because the firm was not active at that point of time or because of major business restructuring hindering the accessibility of historical consolidated financial statements. This issue was handled by only using the one most recent data point that could be obtained. All balance sheet items were then adjusted for inflation using data from the Swedish Central Bank, benchmarked to 1980s prices. One extreme outlier was

recognized, which had an assets size three times larger than for the observation with the second largest asset size. The extreme outlier was therefore excluded as to not distort the results of the OLS regressions. Retriever Business was also used to obtain data on age of the issuers, which was then cross-checked against information from the firms' websites to retrieve the actual age of the business, instead of the years since the existing private corporation was registered. This was due to the fact that many firms had been subjected to corporate restructuring since the initial inception of the operation and transformed to a newer corporation, which Retriever Business did not always pick up on. Total proceeds from the issue and the offer price was manually collected from the prospectuses published in conjunction with the issue. First day closing prices of the issued stocks as well as data on the market return was collected from Nasdaq Nordic. Whether a firm was classified as research intensive was based on an assessment of the business description in the annual reports.

Furthermore, data on the ownership in the firms prior to the IPO was collected from the prospectus to determine whether the issue was VC-backed or not. For the IPO to be considered VC-backed, a threshold of a minimum of 5 percent VC ownership was applied. Data on the lead underwriter of the issue was also collected from the prospectus. While there are already comprised rankings on top underwriters in other countries, such as the one in the US market comprised by Loughran and Ritter (2004), the same was not obtainable about Swedish underwriters. To still be able to construct a control variable for underwriter reputation, data was collected on annual rankings of the top 5 Swedish Equity advisors published by Kantar Sifo. While not as comprehensive as rankings available on other markets, we assess it is the best available option.

For subsequent hypothesis testing, data on firms' historical patent applications was also needed. This data was collected from the Swedish Patent and Registration Office or the corresponding government agency in specific countries when the issuer had its home market outside of Sweden. These agencies provide databases that record all patent applications submitted in the home country of the firm, as well as all applications that have been submitted on an European level, i.e. providing protection in all member countries at once. The screening of whether patents had been previously applied for by the issuer, also spanned across the issuer's fully owned subsidiaries, if applicable. Our assumption was that if a firm had not applied for patents in its home market nor in any of the other European markets, they have not applied for any patents.

Throughout the additional data gathering for the dependent, independent and control variables, a total of 7 observations was dropped due to missing values, leaving a total of 183 observations.

4.2. Variable Description

4.2.1. Independent Variable

Most research on R&D has used total R&D expenditures to proxy R&D activities. As previously mentioned, our sampled firms follow IFRS rules and for many of them, we do not have access to the R&D expenses (i.e. research and uncertain development expenditures) but only the capitalized development expenditures. Excluding all firms that do not report R&D expenses will create a major selection bias issue. On the other hand, if we include those firms we only have capitalized development expenditures to proxy R&D activities with. We assess that the selection bias issue will be severe enough to make any conclusions invalid, and therefore the firms for which the R&D expenses are missing are kept in the sample.

The question that follows is whether the size of the capitalized development expenditures can serve as a proxy for R&D activities, which depends on two things. Firstly, for this to be true, the fraction of the R&D activities that are classified as certain development activities must be constant across the sample companies. The main source of variation in this fraction is expected to be interindustry differences. Specifically, firms in research intensive industries will have a larger fraction of research activities and presumably higher degrees of uncertainty in development activities. Therefore, we expect that a unit increase in the capitalized development expenditures in a research intense firm will be the result of a relatively larger increase in R&D activities, and that each unit of increase in R&D capital will therefore have a larger effect on IPO underpricing. This difference in effect on IPO underpricing will be allowed for in the model.

Secondly, there cannot be variation in how conservative the firms are when interpreting of the criteria for capitalization. If the interpretations vary, some of the difference in capitalized development expenditures will measure differences in strictness of the interpretation of the criteria rather than differences in R&D activities. Since this is an unobservable characteristic it cannot be controlled for, and it is therefore a potential source of errors in the model.

Capitalized development expenditures are expected to be a good proxy for R&D activities, although it is possible that it is somewhat less precise than total R&D expenditures. The independent variable is thus defined as the average over the two years prior to the IPO for capitalized development expenditures divided by total assets minus cash and equivalents, since these balance sheet items are not considered to be results of value creating activities.

$$RD = 0.5 * \sum_{t=IPO-2}^{IPO-1} \frac{\text{Capitalized development expenditures}_t}{(\text{Total assets}_t - \text{Cash and equivalents}_t)} \quad (1)$$

The purpose of scaling the capitalized development expenditures to the asset size is to get a measure that is comparable for companies of varying sizes and that has an intuitive interpretation. In this paper we call this variable R&D capital.

4.2.1. Dependent Variable

The dependent variable, IPO underpricing, is defined, in line with the vast majority of all previous research, as:

$$IPO\ underpricing = \frac{(First\ day\ closing\ price - Offer\ price)}{Offer\ price} \quad (2)$$

Table 1. Description of control variables

Firm Age	Numbers of years between initial inception of the firm and the date of the IPO, where the natural logarithm is taken from the variable. Older firms are believed to have had longer exposure to investor attention relative to younger firms.
Firm Size	Total assets as stated in the last financial reports leading up to the IPO. Larger firms are believed to have been exposed to more investor attention compared to smaller firms, having a negative correlation with IPO underpricing. [kSEK]
IPO 2015-2017	Dummy for which year the firm's IPO took place where 1 indicates that it occurred during the years 2015-2017. The intent is to control for yearly effects as IPO markets are believed to be exposed to fluctuations over time.
Market Return	Market return proxied by the average daily return on OMX Stockholm 30 during the one month preceding the IPO. The variable is included to control for general market conditions [%-units]
Research Intensity	Dummy of characteristics of firms' main business area where 1 indicates research intensity.
Top Underwriter	Dummy of underwriter of the issue where 1 indicates the top underwriter took the firm public.
VC-backed	Dummy of ownership in the firm leading up to the IPO where 1 indicates firm backed with Venture Capital.

Note: the table shows all variables that are included as control variables in our model, also including their description.

4.2.1. Control Variables

To avoid omitted variable bias issues and isolate the effect of capitalized R&D on IPO underpricing, we need to control for other factors that are believed to have systematic impact on the dependent variable and are correlated with R&D activities. Variables for firm age and firm size are included since older and larger firms are believed to be subjected to less asymmetrical information than younger and smaller firms (see e.g. Bajo et al., 2016). In line with research observing that fluctuations in general market conditions correlate with varying levels of IPO underpricing levels (see e.g. Butler et al., 2014), market return is controlled for in the regressions. Furthermore, as in line with qualification theory, it is also predicted VC-backed, relative non-VC-backed, IPOs will systematically be exposed to lower levels of asymmetric information (see e.g. Megginson & Weiss, 1991). Building on the same certification hypothesis, a control variable for the top underwriter, i.e. the underwriter with the highest average ranking in Kantar Sifo's annual ranking during the period of the sampled IPOs, is also included. This underwriter is Carnegie.

4.3. The Model

The primary model in this paper is an Ordinary Least Squared (OLS) regression, designed to test the effect R&D activities have on IPO underpricing. The model looks as following,

$$IPO\ underpricing_i = \beta_0 + \beta_{RD}\sqrt{RD_i} + \beta_X X_i + \varepsilon_i \quad (3)$$

where *IPO underpricing* is the first day closing price less the offer price divided by the offer price and *RD* is the capitalized development expenditures over total assets excluding cash and equivalents. *X* is a set of control variables for firm characteristics – age, asset size, a high-tech dummy and an interaction term between capitalized development expenditures and a research intensive dummy – and IPO characteristics – market return, a top underwriter dummy, a VC dummy and years effect. Based on Hypothesis 1, β_{RD} is expected to have a positive sign.

To test Hypothesis 2, the model is extended to allow for the effect of R&D capital on IPO underpricing to differ depending on whether the firm is VC backed,

$$IPO\ underpricing_i = \beta_0 + \beta_{RD}\sqrt{RD_i} + \beta_{VCRD}(VC_i * RD_i) + \beta_X X_i + \varepsilon_i \quad (4)$$

where $VC * RD$ is an interaction term between VC backing and R&D capital. The effect of a unit increase in RD on IPO underpricing depends on β_{RD} and β_{VCRD} for a VC-backed firm and only on β_{RD} for a firm that is not VC-backed. Under Hypothesis 2, β_{VCRD} is expected to have a negative sign.

To test Hypothesis 3, the model is modified to allow for firms that have outstanding patents to be systematically less underpriced given the same level of R&D activities,

$$IPO\ underpricing_i = \beta_0 + \beta_{RD}\sqrt{RD_i} + \beta_P Patents_i + \beta_X X_i + \varepsilon_i \quad (5)$$

where *Patents* is a dummy variable that measure whether the firm has any patents outstanding. Under Hypothesis 3, β_P is expected to have a negative sign.

4.4. Potential Issues

There are a few potential issues that our model could have, which we have discussed in this chapter. There are two main potential issues that the reader should be aware of. Firstly, the design of the independent variable could be less efficient in proxying R&D activities than we expect it to be. This issue can result in estimated effects that are not precise and therefore, some caution should be used in the interpretation of the sizes of the predicted effects.

Secondly, there is a risk that the model suffers from omitted variable bias. This issue is typical for studies within IPO underpricing, since it is commonly accepted that the cause and the drivers of the phenomenon are not fully understood.

4.5. Descriptive Statistics

Presented below are summary statistics intended to allow the reader to better understand the characteristics of the underlying sample. Table 2 reports the number of IPOs in the sample for each year between 2012 and 2019, including data on the yearly average IPO underpricing given in percent. As can be observed in the table, the average underpricing during the full period is 10.02 percent, while the individual observations range between an overpricing of 58.52 percent to a maximum of 147.3 percent underpricing. The last column also shows the distribution of the total 183 observations of IPOs across the different years.

Table 2. IPO underpricing across years [%]

Year of IPO	mean	min	max	sd	N
2012	-7.84	-32.35	16.67	34.66	2
2013	13.87	-13.33	72.73	29.85	6
2014	-1.52	-58.52	17.50	18.19	20
2015	13.38	-24.00	94.12	26.40	38
2016	13.09	-39.23	147.53	32.92	37
2017	14.88	-34.78	123.20	25.58	55
2018	1.67	30.33	77.14	23.42	23
2019	-26.51	-52.51	-0.05	36.78	2
Total	10.0	-58.5	147.5	27.3	183

Note: descriptive statistics of IPO underpricing, given in %-units, across years. N indicates the number of observations for a given year.

Table 3 further gives an overview of the distributions of the continuous variables included in the model. We conclude that R&D capital average at 19.72 percent, with ratios ranging from 0 to 96.56 percent for the total sample. The average assets size is 477.55 million SEK. While the age parameter is given by the logarithm of firm age, the actual ages for our sampled firms span between firms less than one year, to the oldest firm at an age of 139 years.

Table 3. Descriptive statistics of continuous variables

Variable	mean	median	min	max	sd	N
Underpricing	10.02%	6.20%	-58.52%	147.33%	27.26%	183
R&D Capital	19.72%	1.67%	0%	96.56%	28.44%	183
Assets	477.55	29	0.75	1227.94	8136.41	183
Ln(Age)	2.53	2.49	0	4.93	0.88	183
Market Return	0.02%	0.02%	-0.45%	0.05%	0.15%	183

Note: Underpricing indicates the level of IPO underpricing, R&D Capital represents the ratio of capitalized development expenditures over total assets less cash and equivalents. Assets, given by the firms' total assets one year preceding the IPO, are presented in million SEK. Ln(Age) is the logarithm of numbers of years of age of firms. Market Return is given as the average daily return on OMX Stockholm 30.

Table 4 illustrates how the sampled observations are distributed between the different discrete variables included in our model by the number of firms in each sub-group.

Table 4. Distribution of observations between groups in categorical variables

Variable		N
VC-backed	<i>yes</i>	84
	<i>no</i>	99
Top Underwriter	<i>yes</i>	39
	<i>no</i>	144
Research Intensity	<i>yes</i>	72
	<i>no</i>	111
Patents	<i>yes</i>	77
	<i>no</i>	106

Note: VC-backed takes the value "yes" for all IPOs performed by a VC-backed firm. Top Underwriter takes the value "yes" if the IPO is backed by the top underwriter. Research Intensity takes the value 'yes' if the firm is research intensive. Patents takes the value "yes" if the firm has patents outstanding at the time of the IPO.

Below, a correlation matrix of our different variables is presented. From Table 5, we get an indication that multicollinearity is unlikely to be a problem in our model. The variable Research Intensity shows high degree of correlation with the R&D-variable which is not surprising since firms that carry out research activities will also be likely to carry out development activities. Furthermore, as in line with our conjectures, assets size and firm

age show a positive relationship. From the matrix we can also conclude that including the variable for time-fixed effects for year 2015-2017 is useful as its controlling effect is not captured by any of the other variables in the model.

Table 5. Correlation matrix

	RD	RI	Age	Assets	VC	MR	Top UW	Y2015- 2017	Patent
RD	1								
RI	0.40	1							
Age	-0.27	-0.18	1						
Assets	-0.26	-0.27	0.35	1					
VC	0.11	0.13	0.08	0.02	1				
MR	0.005	0.05	0.08	0.09	-0.02	1			
Top UW	-0.30	-0.15	0.26	0.19	0.16	0.14	1		
Y2015 -2017	-0.03	-0.10	-0.03	0.05	-0.04	0.01	0.01	1	
Patent	0.30	0.51	0.04	-0.09	0.17	0.11	0.02	-0.02	1

Note: every data point presents the pairwise correlation between the row variable and the column variable. Included variables in the correlation matrix are; R&D capital (RD), Research intensity (RI), Ln(Age) (Age), VC-backing (VC), Market Return (MR), Top Underwriter (Top UW), Years of IPO 2015-2017 (Y2015-2017), Patents (Patent).

5. Results

5.1. Type of Regression

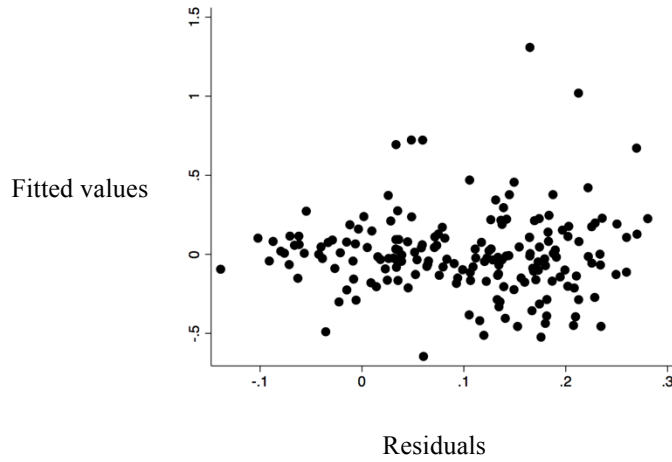
We start out by investigating whether the Ordinary Least Squares (OLS) assumptions are met. A variance inflation factor (VIF) test confirms what the correlation matrix implied, by showing that none of the variables have VIF values above 10 and that the model thus does not have multicollinearity issues. Furthermore, the standard errors are approximately normally distributed.

Another issue our model could potentially exhibit is heteroscedasticity. In Figure A, the residuals are plotted against the fitted values to facilitate a visual inspection. The model shows a tendency for generating larger residuals at larger fitted values. Therefore, we carry out a Breusch-Pagan test for heteroscedasticity, which gives the result that the null hypothesis of homoscedastic error terms is rejected at all significance levels above 0.02 percent. The low level of the p-value is however largely driven by outliers. The preferable approach to handle the heteroscedasticity would be to use a Weighted Least Squares (WLS) regression. However, since we are unaware of the heteroscedasticity's exact form, we would need to use the Feasible Generalized Least Squares (FGLS) method to model the heteroscedasticity (Wooldridge, 2015). There are a range of opinions regarding the sample size required for FGLS estimators to be more reliable than OLS estimators and while some argue that a sample size of 200 could be enough, influential papers have suggested that sample sizes of at least 1,000 observations are required (Moshagen & Musch, 2014; Olsson et al., 2000). Due to our time consuming method for collecting data, we are unable to meet the requirement of 1,000 observations. In addition, there is a high probability that omitted variables are the source of the heteroscedasticity, since it is commonly accepted within the field that the causes of IPO underpricing are not fully mapped out, which would limit the effectiveness of FGLS estimators. Therefore, we choose another way to handle the heteroscedasticity, namely using robust standard errors. Considering that when the outliers are not considered the heteroscedasticity issue is not severe, robust standard errors should be a sufficient measure.

Following these tests, we conclude the OLS regression is the most suitable method to use for testing our hypotheses.

5.2. Results from Regressions

We start out the hypotheses testing by running a simplified version of the model, in which we include R&D activities through a dummy variable that takes the value 1 for all firms that have R&D capital above 5 percent. Thus, for now, we do not take the potential effect



Note: scatter plot with fitted values from our model on the y-axis and the residuals on the x-axis.

Figure 2. Graph facilitating visual inspection for heteroscedasticity

of the level of R&D activities into account. The cut-off value of 5 percent is included to ensure that the dummy variable captures the firms in which R&D activities are a large enough part of the business to be relevant in investors' valuation of the firm. The results are shown in Table 6 as Regression 1. The R&D dummy has a p-value of 2.8 percent which means that the estimated difference in IPO underpricing between the R&D firms and non-R&D firms is statistically significant. The interpretation of the estimated effect is that R&D firms, on average, are 9.27 percentage points more underpriced than comparable firms without R&D activities. This result indicates R&D activities have a large and systematic impact on IPO underpricing, which suggests further investigation of the relationship between the two is called for.

In Regression 2, the result of the full model including all control variable, is presented. The results show how the level of R&D capital does not have a statistically significant effect on IPO underpricing and that the effect of the level of R&D capital on IPO underpricing is not statistically different between research intensive firms and non-research intensive firms. Given our sample size constraint, it is reasonable to question whether the reason for the insignificant results could be that the real effect is small rather than that no effect exists. Therefore, we believe some useful insights can still be gained from studying the results of Regression 2. Firstly, the sign of the estimated effect of the R&D capital variable is in line with our hypothesis and the p-value is just above a significant level, which indicates there may be a real effect the model in its current form is not able to capture, e.g. because there are too few observations to estimate the effect with. The inclusion of the interaction term between research intensive firms and R&D capital could contribute to the difficulty in estimating the effect. Secondly, the results give us no reason to suspect a real difference exists in the effect of an increase in R&D capital between research intense and non-research intensive firms, since the p-value for

the interaction term is 51.9 percent and the sign of the estimated effect is the opposite of what we expected. Following these two insights, we will next respecify the model by excluding the discussed interaction term.

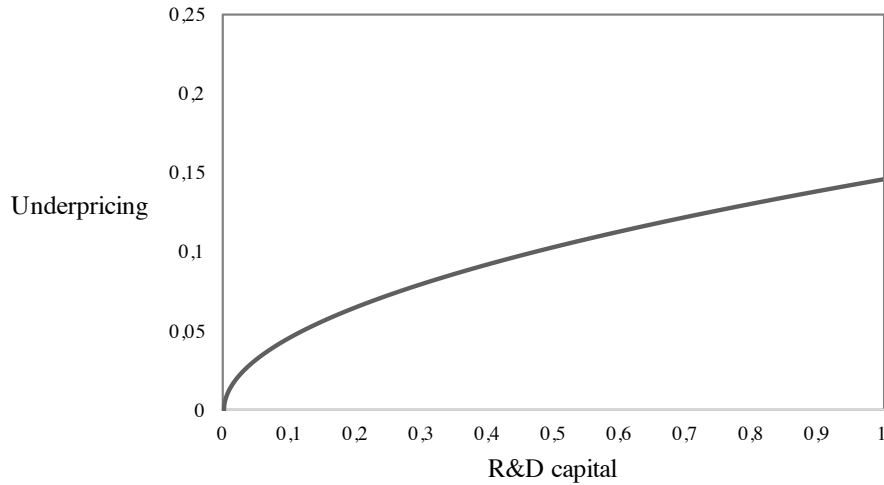
Table 6. Regression outputs

VARIABLES	Regression 1	Regression 2	Regression 3 (Base regression)	Regression 4	Regression 5	Patents 6
RDsqrt		0.215 (0.142)	0.146** (0.0720)	0.197** (0.0964)	0.103 (0.100)	0.115 (0.0723)
RI_RDsqrt		-0.0980 (0.152)				
Ln(Age)	0.00730 (0.0210)	0.0114 (0.0197)	0.00841 (0.0208)	0.0361 (0.0318)	0.00759 (0.0206)	0.00446 (0.0206)
Assets	2.85e-06 (7.80e-06)	9.09e-07 (7.82e-06)	1.67e-06 (7.95e-06)	-7.60e-06 (1.15e-05)	1.57e-06 (7.70e-06)	3.16e-06 (7.77e-06)
VC	-0.0636 (0.0402)	-0.0656 (0.0404)	-0.0686* (0.0396)	-0.0670 (0.0572)	-0.0942*** (0.0356)	-0.0766* (0.0400)
Market Return	31.93*** (11.93)	32.07*** (11.85)	30.33*** (11.60)	36.23** (16.10)	29.96** (11.65)	28.21** (11.90)
Top UW	0.0444 (0.0313)	0.0467 (0.0320)	0.0502 (0.0311)	0.0394 (0.0430)	0.0551* (0.0307)	0.0451 (0.0323)
Y201567	0.134*** (0.0401)	0.128*** (0.0409)	0.135*** (0.0400)	0.156*** (0.0587)	0.133*** (0.0398)	0.135*** (0.0401)
RDYN	0.0927** (0.0419)					
VC_RDsqrt					0.0839 (0.143)	
Patents						0.0642 (0.0416)
Constant	-0.0435 (0.0656)	-0.0531 (0.0648)	-0.0476 (0.0642)	-0.160 (0.111)	-0.0334 (0.0628)	-0.0511 (0.0630)
Observations	183	183	183	120	183	183
R-squared	0.115	0.123	0.117	0.113	0.120	0.129

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

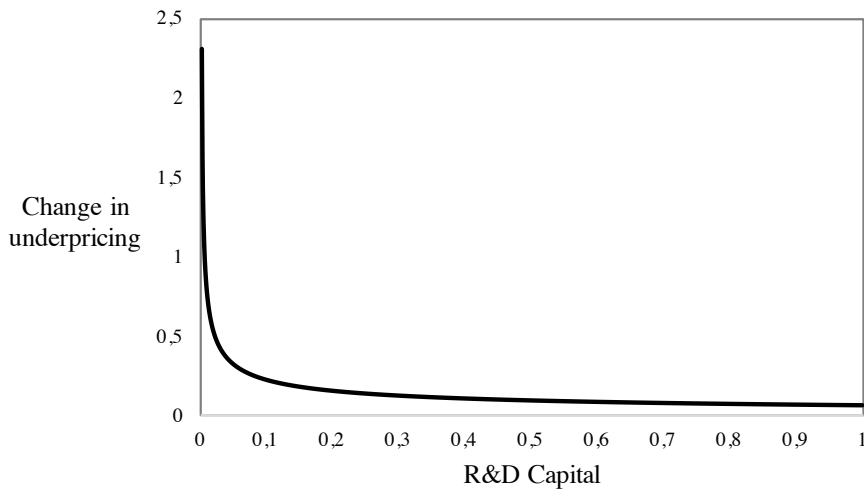
Note: results from 6 slightly different versions of our model. Regression 1-4 test hypothesis 1, Regression 5 tests hypothesis 2 and Regression 6 tests hypothesis 3. Included variables are; the square root of R&D capital (RDsqrt), an interaction term between the research intensity dummy and RDsqrt (RI_RDsqrt), the logarithm of firm age (Ln(Age)), asset size (Assets), a dummy for VC-backing (VC), average daily market return 30 days prior to the IPO (Market Return), a dummy for IPOs underwritten by the top ranked underwriter (Top UW), a dummy for IPOs during the years 2015-2017 (Y201567), a dummy for firms with R&D capital>5% (RDYN), an interaction term between the VC-backing dummy and RDsqrt (VC_RDsqrt), a dummy for firm that have patents outstanding (Patents).



Note: the y-axis states different levels of IPO underpricing. R&D capital, i.e. capitalized R&D expenditures over total assets less cash, are given on the x-axis.

Figure 3. Estimated R&D induced IPO underpricing at different R&D capital levels

The respecified model is shown in Table 6 as Regression 3, which we also call our Base regression. This regression shows the level of R&D capital has a positive statistically significant effect on IPO underpricing with a p-value of 4.4 percent, which subsequently stagnates with increasing levels of R&D capital. Hence, results from Regression 3 supports our hypothesis 1. The total R&D induced IPO underpricing, defined as the additional IPO underpricing a firm with a certain level of R&D activities experiences in comparison with an identical firm in respect of all control variables except that it has no R&D activities, at different levels of R&D capital is shown in Figure 3. The estimated effect of a percentage point increase in R&D capital on IPO underpricing at different levels of R&D capital is presented in Figure 4.



Note: y-axis shows percentage point changes in IPO underpricing and x-axis shows level of R&D capital.

Figure 4. Estimated effect of a unit increase in R&D capital on IPO underpricing

From these figures, we learn how at the median R&D capital among R&D firms, 20.3 percent, the estimated R&D induced IPO underpricing is 6.6 percentage points and a one percentage point increase in R&D capital is estimated to lead to a 0.15 percentage point increase in IPO underpricing. To express the results in economic terms, we evaluate the effect of R&D induced underpricing at the median IPO proceeds level, which is 119,905 thousand SEK at the current price level. The economic implication of the estimated R&D induced IPO underpricing at the median level of R&D capital, evaluated at the median IPO proceeds, is that the proceeds will be 7,914 thousand SEK less than for a comparable firm without R&D activities, given that the capital raised in the IPO will have the same first day market valuation. The same calculations have been carried out for the level of R&D capital at the 25th, 75th and 90th percentiles, which is presented in Table 7. For the full calculations, see Appendix A.

Table 7. Economic effect of R&D induced IPO underpricing

Percentile	R&D Capital	R&D Induced underpricing	Loss in in proceeds
25 th	1.7%	1.9%	2,278 tSEK
50 th	20.3%	6.6%	7,914 tSEK
75 th	57.3%	11.1%	13,309 tSEK
90 th	76.2%	12.7%	15,228 tSEK

Note: the economic effect of R&D induced IPO underpricing at the 25th, 50th, 75th and 90th percentile of R&D capital among R&D firms. The effect of the R&D induced IPO underpricing is evaluated at the median proceeds level, to capture the economic implications.

Regression 3 further gives interesting estimated effects for some of the control variables. Neither asset size nor firm age has a statistically significant effect on IPO underpricing for the sampled firms. This result is surprising, since virtually all previous research on IPO underpricing has shown that these two variables are good proxies for the level of asymmetrical information in a firm. This could imply asset size and firm age are less important on the Stockholm stock exchange than on other stock exchanges. The effect of the top underwriter dummy variable is not statistically different from zero, with a p-value of 10.9 percent, and has the opposite sign from our expectations. Our results thus do not support the IPO underpricing theories which suggest underwriter reputation is a quality signal. In contrast, the VC dummy has a statistically significant estimated effect with a coefficient of -0.069 which, in line with our expectations, implies that ceteris paribus, VC-backed firms are estimated to experience 6.9 percentage points less underpricing than non-VC-backed firms. Market return also has a statistically significant effect with the expected predicted sign, with a coefficient of 30.33. Since the market return values range between 0.01 percent and 0.05 percent, the interpretation is made in terms of a 0.01

percentage points increase. A 0.01 percentage point increase in market return is estimated to increase IPO underpricing 0.3 percentage points.

In Regression 4, we observe that the positive effect of R&D capital on IPO underpricing remains statistically significant with a p-value of 4.3 percent when all firms which do not have any R&D activities are excluded from the sample. The estimated coefficient increases slightly, from 0.146 to 0.197. A possible explanation for this increase is that as the sample is biased towards the type of firm that does R&D, some omitted variable bias now has a bigger effect. Moreover, while the estimated effect of the VC-backing dummy barely changes, its p-value jumps to 24.4 percent which indicates that among R&D firms, the certifying effect of VC-backing is not as evident. The fact that the effect of the level of R&D capital on IPO underpricing remains strong and statistically significant in this regression provides further validation for our hypothesis that there are substantial differences in the effect on IPO underpricing within the R&D firms group as well as between the R&D firms group and non-R&D firms group.

In Regression 5, we shift focus from examining the effect of R&D capital on IPO underpricing (Hypothesis 1) to investigating whether VC-backing can act as a certifier of quality for a firm's R&D activities (Hypothesis 2), by including an interaction term between the R&D capital variable and the VC-backing dummy (henceforth called the VC-RD variable). The result is that the effect of R&D capital on IPO underpricing is neither statistically different from zero for VC-backed firms, as the VC-RD variable has a p-value of 56.0 percent, nor for non-VC-backed firms, as the p-value for the R&D variable is 30.7 percent. These results could possibly partly be explained by sample size limitations in the sense that the insignificance stems from the fact that there are too few observations to base the estimation of the effect on. Therefore, we are careful to draw any decisive economic conclusions based on the results. The estimated effect of the VC-RD variable is positive which indicates that in our sample, the R&D induced IPO underpricing per percentage point increase in R&D capital is larger for VC-backed firms than for non-VC-backed firms. Although this is not a significant result, it can explain the insignificant effect of VC-backing in Regression 4. Since the sample in Regression 4 is biased towards firms with higher levels of R&D capital, the negative effect VC-backing has on IPO underpricing because of its the firm certifying effect is diluted by the positive effect that VC-backing has on R&D induced IPO underpricing in our sample, since these two forces go in opposite directions. In Regression 5 these two effects are separated, which causes the estimated effect of the VC-backing dummy to drop to -9.4 percent compared to -6.9 percent in the Base regression and the p-value to drop to 0.9 percent compared to 8.5 percent.

In Regression 6, we turn our attention to whether the existence of information about successful outcomes from previous R&D activities can mitigate the R&D induced information asymmetry (Hypothesis 3). In the results from this regression, we observe that the R&D capital variable is no longer statistically different from zero and that its

estimated coefficient decreases from 0.146 in the Base regression to 0.115, which signals that some effect of the patents variable was picked up in the R&D capital variable in the Base regression. This seems logical, since the existence of patents almost certainly means that R&D activities have taken place at some point, which makes it likely that the firm is still engaging in R&D activities. The patents dummy variable has a statistically insignificant effect, and an estimated effect that is the opposite sign of what we expected. Therefore, we find no support for our Hypothesis 3. We see two possible ways to interpret of this result. Either the existence of patents is not considered a quality signal by investors, or the patents variable does not measure what we intended it to but rather picks up some dimension of the R&D activities that our R&D capital variable is not able to pick up. The second interpretation is supported by the fact that the R² value is 1.2 percent higher in Regression 6 than in the Base regression, which suggests that more variation in IPO underpricing can be explained when the existence of patents is controlled for.

6. Discussion

6.1. R&D Activities and IPO Underpricing

Our results confirm our hypothesis 1 by showing that increases in a firm's level of R&D activities, proxied by R&D capital, have a positive effect on IPO underpricing. We have also presented results showing that there are statistically significant differences in the effect on IPO underpricing between R&D firms and non-R&D firms, yet that statistically significant differences can also be found within the R&D firms group. Based on these results, we believe that we have validated that the observed effect of the level of R&D activities on IPO underpricing is not driven by differences between the R&D firms and non-R&D firms and that we have developed a detailed understanding of the effect. These results are in line with the main findings in previous literature on R&D and the asymmetrical information theories of IPO underpricing.

Our results have economic value, since the size of the estimated effect of R&D activities on IPO underpricing in economic terms is substantial enough to have real implications for the issuing firm, especially for the firms with the highest levels of R&D activities.

We do not find any support for our hypotheses 3 and 4. It must however be kept in mind that statistical issues related to sample size limitations have likely contributed to these results. Further discussion of hypotheses 3 and 4 is found in section 6.3 Quality Signals.

6.2. Measuring R&D Activities

Next, we go into the question of how well capitalized R&D expenditures proxy R&D activities. While our interpretation of the results is that capitalized R&D expenditures capture the effects that we intended it to, since its estimated effect on IPO underpricing is in line with previous literature and our hypotheses, two observations regarding the proxy are worth pointing out.

Firstly, to our surprise, our results indicate that the effect of R&D capital on IPO underpricing is not statistically different between research intensive and non-research intensive firms. There are a number of possible explanations to this. It could be due to research intense firms having higher levels of R&D activities at which fluctuations have minor impact on IPO underpricing. This means that the difference in the effect on IPO underpricing between the estimated level of R&D activities based on capitalized R&D expenditures and the real level of R&D activities is small, and it could be that it is too small for our model to pick up and estimate with statistical significance since we have a relatively small sample size. Alternatively, it could be that research activities give rise to less information asymmetries than development activities since they are not perceived to be as value relevant, either because potential future benefits will materialize too far off in

the future or because the ideas produced in the research activities must go through a development phase before they can be utilized to create value.

Secondly, the results from Regression 6, in which we tested hypothesis 3, raises the question of whether there is some dimension of R&D activities that the R&D capital variable is unable to capture, since the patents variable seemed to pick up some dimension of R&D activities that the R&D capital variable was not able to.

6.3. Quality Signals

Our results do not provide support for our hypotheses that the quality certification of VC-backing (Hypothesis 2) or information about the quality of past R&D performance conveyed through patents (Hypothesis 3), can level out the information structure between firm insiders and firm outsiders and thereby increase investors' level of certainty in valuing R&D activities. Before we discuss these results further, we stress it is possible that the results are affected by sample size limitations. We chose these two signals since they can easily be attained by investors at a low cost. Yet, their lack of statistically significant effects in our sample raises questions of whether only signals with higher degrees of informational intensity can convey information that is value relevant enough to over bridge the information asymmetries. Considering the complex nature of R&D activities, this would be reasonable.

Another way to interpret the absence of significant effects of the signals is that from an investor's perspective, firms' R&D activities are perceived as 'black boxes' in the sense that a qualitative evaluation of the internal processes and technologies is considered too complex and time consuming to be feasible. Instead, investors base their valuation of the firm's R&D activities on the quantitative measurements of inputs to R&D activities that can be found in the firm's financial statements. It is unlikely that analysts' attitudes will be similar to an extreme type of the 'black box' attitude, however it is reasonable to believe that some degree of this kind of view of R&D activities can be found among analysts. This interpretation of our results is in line with the findings of Cohen et al. (2013), who find that investors do not utilize information about past success in R&D projects when valuing current and future R&D activities, although this information is easily attainable.

6.4. The Implication of R&D Induced Asymmetrical Information

The implication of our results for an R&D intensive firm is that relative to comparable firms, the capital they raise through an IPO will be more costly. However, we must remember that the gains from going public should also increase with the level of R&D activities a firm carries out. The reason for this is that public companies are more intensely followed by analysts and potential investors, which means that on an aggregated level

more information is produced about a public firm than about a private firm. This will decrease the level of asymmetrical information between firm insiders and firm outsiders. Since asymmetrical information is the reason that R&D intensive firms experience cost of external capital that is higher than the fair level, they will have a lot to gain from the reduced information asymmetries that going public leads to. The difference between an R&D intensive firm's private and public cost of capital should thus be larger than for other firms. Since both the costs and the gains from going public are higher for R&D intensive firms than for other firms, we cannot say that our results show that IPOs are more unfavorable for R&D intensive firms.

How much a R&D firm's cost of external capital is decreased when it goes public will be related to our previous discussion regarding quality signals. If we imagine that R&D activities are looked upon as 'black boxes', the increased analyst coverage will only lower the cost of external capital a minor bit closer to the fair level. If, instead, we think the investors take all available quality signals into account to be able to value the R&D activities with a higher degree of certainty, it is possible that the post-IPO cost of external capital of R&D firms will be close to the fair level.

Another implication of the R&D induced asymmetrical information concerns the fact that an IPO can be a strategy for founders and early investors to cash-out their investments. In R&D intensive firms, firm insiders that wish to exit through the IPO will not realize the future benefits but only bear the cost of leaving money on the table. This could make founding and investing early in R&D intensive firms less attractive relative to other types of firms. However, the size of this effect depends on to what extent founders and early investors take this into consideration.

7. Conclusion

In this paper, we have presented evidence showing that in the setting of an IPO, the higher level of R&D activities a firm has, the higher discount its capital will be sold-out at. Here, discount refers to the difference between the raised proceeds and the market value of the capital raised on the first day of trading. While the cost of the capital that is raised in an IPO increases as a firm's level of R&D activities increases, so does the value of the future benefits from going public. Therefore, the results should not necessarily be interpreted as if the decision to go public is relatively costlier for R&D intensive firms. However, we propose that it is plausible that R&D intensive firms' higher exposure to IPO underpricing puts a downward pressure on the incentives to found and invest early in R&D intensive firms.

We do not find any support for our hypotheses that the two easily attainable signals of high quality R&D activities should mitigate R&D induced asymmetric information between firm insiders and firm outsiders. The two tested quality signals are VC-backing and the existence of patents. These insignificant results may however be explained by the signals carrying too low levels of information.

Moreover, we want to emphasize that there are limitations of this paper, especially regarding the proxy that we have used for R&D activity. While we are confident that our proxy has captured the intended effects, we are hesitant to claim that the estimated effects are precise. We therefore see potential for future research in developing a more precise proxy for R&D activities, potentially using a combination of variables, that can be used in countries in which total R&D expenditures are unobtainable.

Furthermore, we see major potential in further research regarding investors' ability or desire to contextualize firms' R&D activities, by which we mean the act of utilizing all attainable sources of information to reduce the uncertainty in the estimation of the firm's expected future benefits. Specifically, we encourage further attempts at identifying quality signals that can overbridge the asymmetric information structure between firm insiders and firm outsider which stems from the firm's R&D activities.

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Appendix A

We start out by imagining the IPO of a non-R&D firm, in which the proceeds raised equal our sample's median proceeds size.

Median proceeds raised (inflation adjusted, base year 1980): 36,223 tSEK

Median proceeds raised (Feb 2019 prices) 119,905 tSEK

Next, we image the IPO of a firm that is identical in terms of asset size, firm age, VC-backing, top underwriter backing that takes place in the same year as the non-R&D firm at a time with the same average market return during the previous 30 days. The first day market valuation, i.e. the valuation based on the first day closing price of the shares, of the two firms are identical. This firm, however, has some level of R&D activities. In this setting, the differences in proceeds raised between the two firms are the following:

At R&D capital X%: $0.146 \cdot 119,905$ tSEK

where is the R&D induced IPO underpricing at the R&D capital level X%.

At 25th percentile R&D capital, 1.7%: 2,278 tSEK (current prices)

At 50th R&D capital, 20.3%: 7,914 tSEK (current prices)

At 75th R&D capital, 57.3%: 13,309 tSEK (current prices)

At 90th R&D capital, 76.2%: 15,228 tSEK (current prices)

