Firm complexity and IPO underpricing

Bachelor Thesis

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May 2016

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Abstract

The purpose of this thesis is to investigate the relationship between information production and firm complexity during initial public offerings.

By studying 528 U.S. IPOs during the time period 2000-2015 we find support for our claim that increased complexity contributes to increased underpricing which may serve to diminish the effect additional underwriting managers have on the level of underpricing present in initial public offerings. Additionally, we find that factors such as age help reduce the amount underpricing, a result which is explained by more public information being available for older firms and the ex-ante uncertainty regarding the firm value is thus reduced. Finally, we find that issuers backed by venture capital do in fact experience a higher degree of underpricing than unbacked firms do.

We suggest that initial public offerings in firms exhibiting high degrees of complexity will generally experience more underpricing.

Key words: complexity, underpricing, initial public offerings, ex-ante uncertainty.

Contents

1. Background and introduction

Underpricing in initial public offerings ("IPO") is a well-known and well documented phenomenon that researchers have been trying to grasp for a long time. Although underpricing has remained relatively stable, with the exception of two large spikes in 1999 and 2003, the resulting amounts of money foregone by owners are staggering. Between 2001 and 2015 a total of $53bn was left on the table as a result of IPO underpricing[1] These vast sums are cause for further research in why IPO underpricing arise.

Corwin and Schultz (2005) and Hu and Ritter (2007) find that an increased number of managing underwriters in an IPO will reduce underpricing. They argue that the reduced underpricing stems from the information production hypothesis, which states that a larger number of managing underwriters will serve to more efficiently produce information in order to accurately price the IPO. However, even though the number of managing underwriters has increased over time, from averaging around one in the early 1980's to averaging around six in 2015, underpricing seems to remain constant, or increase very slightly over time. In addition, over the last five years or so, the number of technology and biotechnology IPOs as a percentage of the total number of IPOs has increased quite significantly.

Figure 1: Money left on the table (underpricing)

This graph plots the aggregate amount of money foregone by investors due to underpricing per year between 2001 and 2015

Aggregate amount left on the table (USDbn)

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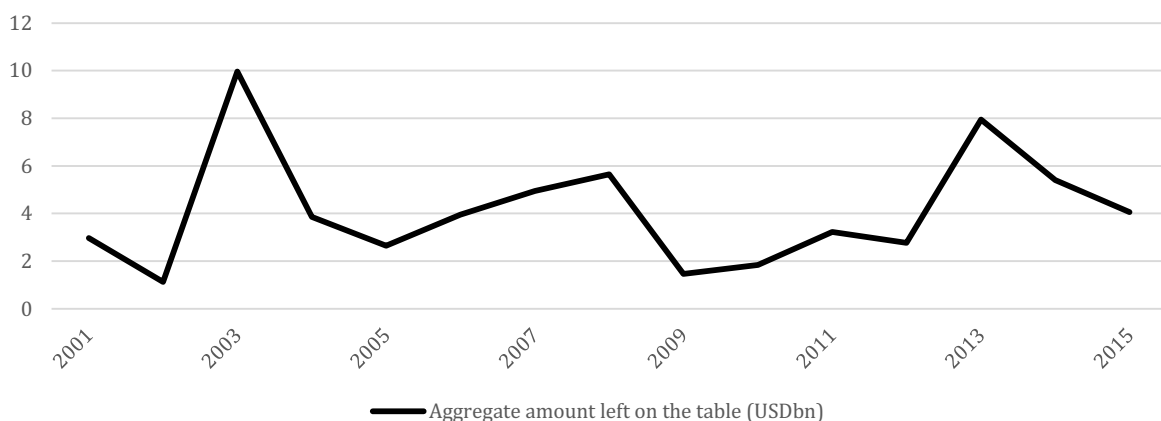
[1] Jay Ritter of the University of Florida has compiled a comprehensive database of IPO and underpricing related statistics. Jay R. Ritter IPO Data 2015, https://site.warrington.ufl.edu/ritter/files/2016/02/IPOs2015Underpricing.pdf

Figure 2: Technology and Biotech IPOs
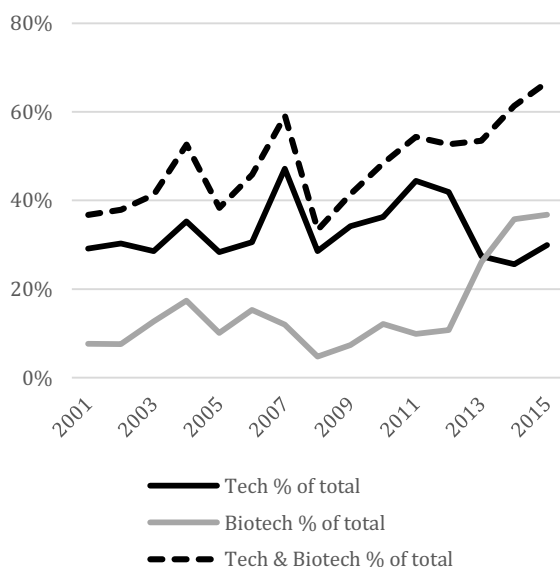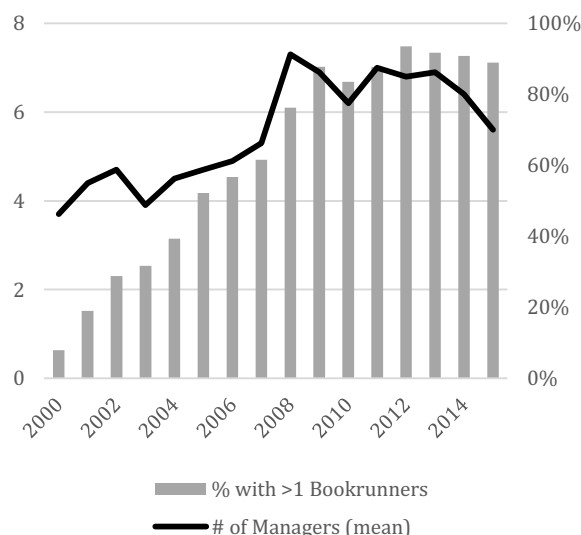This graph plots the share of technology and biotechnology IPOs to total IPOs during the period 2001 to 2015

Figure 3: Number of underwriting managers
This graph plots the number of managers and percentage share of IPOs with more than 1 underwriting manger during the period 2000 and 2015

We argue that the results from previous studies are lacking in explaining why underpricing has not decreased while the average number of underwriting managers in the syndicates has increased. This paper seeks to complement previous research within this area. Although the increased number of managing underwriters, through better information production, will serve to reduce underpricing, earlier findings do not incorporate their *qualitative* ability to produce *accurate* information. We argue that as firms become more complex (e.g. technology and biotechnology companies) it becomes increasingly difficult for managing underwriters, the issuing firms' management and investors to comprehend the firm, its environment and its true value. Increased firm complexity may thus offset the information production benefits of having a larger number of managing underwriters in the IPO syndicate and consequently increase the underpricing relative less complex firms.

By studying 528 U.S. IPOs between 2000 and 2015 we find support for our claim that increased complexity in fact contributes to increased underpricing and may serve to diminish the effect additional underwriting managers have on the amount of underpricing present in

initial public offerings. Additionally, our results indicate that factors such as age help reduce the amount underpricing, a result which is explained by more public information being available for older firms, and thus the ex-ante uncertainty regarding the firm value is reduced. Finally, in contradiction of our hypothesis but in line with findings by Gompers (1996) and Lee and Wahal (2004), we find that issuers backed by venture capital and private equity firms do in fact experience a higher degree of underpricing than do unbacked firms.

1.1 Sources of IPO Underpricing

The listing of a company's shares on a regulated market is a way for firms to raise capital to finance its operations and new projects. These funds are commonly raised through primary and secondary offerings, serving as sources of capital and liquidity to the issuing firm. Assuming that the price agreed by market participants on an open stock exchange represents the true value of the company, large degrees of underpricing indicates that the price at which the shares are sold in the IPO is below the true value of the firm. The sources of underpricing is a controversial area and various theories have been presented in order to explain its existence. Explanations range from theories of adverse selection, discrepancies in incentives between principals and agents (known as moral hazard) and information asymmetries both between different investors and between the issuer and underwriting investment banks. This study will focus on *Information Asymmetry* and *Ex-Ante Uncertainty* as the explanations of why underpricing occurs. Further, complexity inherent in the issuing firms' operations is discussed in order to shed additional light on the existence of uncertainty regarding the issuing firms' true value.

1.1.1 Information Asymmetry

According to Rock's Winner's curse theory, IPO underpricing arises as a result of asymmetric information and rationing. The theory assumes that there are two types of investors: an informed group which possess perfect knowledge about the realized offering value and one group of investors which is uninformed. Due to their superior knowledge of the firm's value, informed investors will only subscribe to issues where the expected aftermarket price surpasses the offering price. Those investors who are uninformed however do not possess superior information and will bid randomly across all issues. Considering a good issue where

the offering price is set below its true value, the informed investors will crowd out the uninformed investors. In the reverse case, the informed investors withdraw from the market leaving the uninformed investors with a disproportionately large amount of overpriced shares. This phenomenon is referred to as the "Winner's Curse". As a result of the information asymmetry, uninformed investors will on average lose money by participating in IPOs and thus leave the IPO market unless they are sufficiently compensated. However, the sole participation of informed investors is not enough to satisfy the supply of the IPO market. Participation by uninformed investors is thus necessary to satisfy the supply of issued shares and the underwriter must discount the issue in the form of underpricing in order to increase the probability of being able to sell the whole issue. This theory has received strong empirical support and is acknowledged by Keloharju (1993) and Koh and Walter (1989).

1.1.2 Ex-Ante Uncertainty

Another widely acknowledged hypothesis put forth by Beatty and Ritter (1986) states that an increase in the ex-ante uncertainty regarding the issuing firm's true value, as determined by the closing price on the first day of trading following the offering, increases the required underpricing. The model acts as an extension of Rock's "winner's curse"-theory of underpricing.

The choice made by an outside investor to engage in information production of the issue can be regarded as an investment in a call option on the IPO. The investor will exercise if the information production indicates an estimated true value exceeding the strike price i.e. the offered share price. The value of exercising the option increases with the uncertainty regarding the valuation which motivates more investors to be informed. Consequently, an increase in the number of informed investors exacerbates the "winner's curse" and thus the underpricing.

Considering the imperfect allocation of information, uninformed investors face the risk of receiving a disproportional allocation of overpriced IPO's and issuers intentionally underprice in order to ensure participation and full subscription. An increase in ex-ante uncertainty will thus result in a higher degree of downside risk for the uninformed investor, raising the required underpricing accordingly.

1.2 Firm complexity

The information production hypothesis predicts that a larger number of managing underwriters included in the underwriting syndicate will serve to reduce IPO underpricing. However, information production as a means to reduce underpricing ultimately depends on the underwriting managers' ability to comprehend the issuer and its environment. This understanding is necessary in order to produce information which adequately reflects the true nature of the issuer and will ultimately lead to an accurate valuation of the issuing firm. Increased firm complexity makes it increasingly difficult for underwriting managers as well as investors to evaluate the issuer, reducing the effectiveness of information production as a mitigating factor to underpricing. Taken into account that firms exhibit different degrees of complexity, the prevalence of underpricing should differ between issuers depending on their respective complexity. In other words, a higher degree of issuer complexity increases the ex-ante uncertainty related to the issuer's value. This consequently results in a larger pricing discount demanded in the primary market in the form of underpricing.

Cohen and Lou (2012) find that when firms become more complex, investors fail to process available information as quickly and to the same extent as they would when evaluating less complex firms. The frictions to incorporate available information into the firm's value thus grow more pronounced with firm complexity. The authors' results are found by studying how the same piece of information affect the share price development of public firms of differing complexity. It is therefore *not* a case of *information asymmetry* but rather a result of how different firm characteristics (*viz.* complexity) affect the ability of investors to relate to available information. This in turn affects the investors' ability to form an opinion regarding how the information should be translated into firm value. Essentially, it is this characteristic of firm complexity that affects the ex-ante uncertainty surrounding the value of the firm. Analogous to these findings, we argue that the higher ex-ante uncertainty stemming from higher firm complexity will affect investors' view on companies prior to going public. Ultimately the difficulty in incorporating available information in the evaluation of the firm will lead investors to require a greater discount on the offer price of more complex firms in comparison to the offer price of a less complex firm. Hence, more complex firms will experience a greater degree of underpricing.

1.2.1 Internal vs external complexity

There are numerous dimensions in which an issuer can be considered complex. Markarian and Parbonetti (2007) make the distinction between internal and external complexity of firms. These two sources of complexity and their respective implications are discussed below.

Internal complexity

The internal complexity of an issuing firm refers to the business itself and the internal organizational processes. More complex firm structures and processes make the firm harder to understand and to evaluate from a valuation perspective. Additionally, as the issuer's products and services become more technologically advanced, the difficulty in understanding the business grows, resulting in higher complexity. Markarian and Parbonetti (2007) argues that higher internal complexity results in difficulties to communicate firm-specific information to outsiders, in relation to board of director composition. Following the same reasoning, the investors who are considered outsiders in this respect should be unable to accurately evaluate the business, processes and value of the issuer as the internal complexity of the same issuer increases.

In this paper R&D-intensity, the percentage of intangible assets to total assets, and a selection of Standard Industry Classification (SIC) codes, are used as proxies for internal complexity.

External complexity

External complexity refers to factors affecting the firm from the outside, i.e. the complexity of the firm's external environment. More sophisticated customers with rapidly changing demands increases the difficulty in evaluating the firm's ability to meet these demands in the future and thus the general prospects of the business. Also, more diversified firms with comprehensively challenging competitive structures and operational and geographical scopes exhibit increasing external complexity. (Rose and Shephard, 1997, Hermalin and Weisbach, 1988 and Yermack, 1996). Increased external complexity makes it more difficult for both underwriting managers and investors to evaluate the firm which results in increased ex-ante uncertainty and thus underpricing.

For the purpose of this study we choose to focus on the internal complexity of firms. As previously noted, external complexity occurs as a result of market forces where the issuer operates. However, information regarding market conditions and characteristics should be readily available for outsiders (investors and underwriting managers) as well as insiders. Thus, the ability to form an opinion of market forces as well as evaluate probabilities of success in a specific market should not differ considerably between insiders and outsiders. Internal complexity, on the other hand, stems from firm characteristics that may only be observable to insiders and increased internal complexity results in difficulties to communicate firm-specific information to outsiders. Therefore, the ex-ante uncertainty should be higher given a higher level of internal complexity in comparison to external complexity. Indicators of internal rather than external complexity will thus be utilized to identify complex firms.

1.3 Theories on how to reduce uncertainty regarding firm value

1.3.1 Certification

The process of bringing a highly complex firm public is associated with significant difficulties regarding communication of firm quality to investors. As the literature recognizes information asymmetry among investors where one group has access to more information than another group regarding the firm's true value, the presence of venture capital and private equity firms could be perceived as a signal of quality as capital markets recognizes their monitoring roles. Private equity and venture capital firms are considered active owners and act as a third party certification of the issuing firm's true value, thus reducing information asymmetry and underpricing (Megginson and Weiss, 1991 and Barry et al., 1990). However, subsequent literature on the area presented by Rossetto (2008), Gompers (1996) and Lee and Wahal (2004) argue that venture capital backed IPO's experience a higher degree of underpricing in comparison to non-venture capital-backed IPO's. The venture capital firms are willing to bear higher costs of underpricing since venture capital returns and their abilities to raise future funds depend on the firms' abilities to take their companies public.

Gompers (1996) provide two explanations to the observed results. Firstly, the establishment of reputation is of considerable importance in order to raise capital for subsequent funds. Relatively young venture capital firms which have not yet established a reputation have an incentive to bring their portfolio companies public early since it acts as a signal of quality. Consequently, less mature companies are brought public and venture capital firms face a higher degree of underpricing.

Secondly, investors recycle capital between different assets. By taking the portfolio companies public earlier, venture capital firms return cash to investors which can be used to invest in newly established funds. The recycling of assets thus motivates early IPOs since it allows venture capital firms to raise capital for later investments.

In addition to private equity and venture capital sponsorships as potential sources of certification, the age of the issuing firm may serve to alleviate some of the uncertainty regarding firm value experienced by outsiders. Although privately held, firms that have been present in the market during a longer period of time are more likely to have proven their business concept to outsiders and possible investors. In addition, the amount of media coverage and other publically available information about the company increases as firms grow older (Ljungqvist, 2007 and Chemmanur, 1993). Thus, as firms age, outsiders have a greater possibility to assess the future prospects of the firm in question. Therefore, increased age should serve to reduce the uncertainty surrounding the firm and the discount demanded by investors to acquire shares.

1.3.2 Monitoring

Theoretically, the concentration of ownership may directly affect the value of a firm as a result of improved corporate governance. An ownership structure characterized by larger and more concentrated shareholders should have an effect of reducing the free rider problem associated with firm monitoring (Shleifer and Vishny, 1986 and Demsetz and Lehn, 1985). This theory is generally referred to as the monitoring hypothesis. However, a more concentrated shareholder structure also contributes with a higher incentive among the respective owners to provide valuable advice and potentially improve the firm's utilization of corporate resources. This aspect of the monitoring theory might prove particularly helpful in complex firms. Investors who are larger, more experienced and more inclined to provide

useful advice and insights could serve to alleviate some uncertainty regarding firms that exhibit higher complexity. As investors are uncertain regarding the value and prospects of the firm, the presence of experienced owners could serve as a sign of quality.

The notion that there exists a positive relationship between the benefit of monitoring and the firm's size has received empirical support (Hertzel and Smith, 1993 and Vishny, Morck, Shleifer, 1988). Firms of smaller size tend to be relatively more illiquid, exhibit higher growth rates and have a more managerial ownership structure in comparison to larger firms. In this case, when investors are more concerned about the firm's ability to satisfy its future growth prospect, the certification signaling effects should be stronger than the monitoring effects. In contrast, the relative importance of monitoring should be higher in larger firms as they are more liquid and have a more dispersed ownership structure. Taken this into account, venture capital firms could be seen as active investors contributing to the monitoring of the firm and thus reducing the information asymmetry.

1.3.3 The role of underwriting syndicates in IPOs

Information production

In the process of an initial public offering, it is the task of the underwriting managers to value and assign a price to the issuing firms' offered shares. The information production hypothesis as presented in Corwin and Schultz (2005) is founded on the idea that underwriting managers during the IPO process receive and then relate to information from the market regarding the issuing firm. During the period from the IPO filing date to the determination of the final offering price, the underwriting managers engage in conversations with their respective customer base in order to determine the market interest and demand for the shares offered. Information uncovered by syndicate member underwriters is then communicated to the lead manager. As underwriters differ in both customer bases (e.g. private or institutional investors) and geographical markets, the inclusion of additional underwriting managers with different customer bases and geographical markets help to increase the information gathered in preparation for the final pricing of the shares offered in the IPO. With additional information, the offering is likely to be more accurately priced and thus reducing the amount of money "left on the table" as a result of underpricing. An

increased syndicate size therefore implies improved information production and more efficiently priced IPOs. Most benefits of having larger syndicates therefore comes from adding syndicate members with complementary attributes.

Another aspect of information production is the information flow that goes in the opposite direction; information about the issuing firm might be conveyed by the underwriting managers to the investors during "investor education". By going on roadshows, the issuing firms' management present the company and the context of the IPO. Information is passed to investors which may help to alleviate investor uncertainty regarding the true value and future prospects of the issuing firm. A larger number of underwriting managers may thus contribute to a more exhaustive information base and presentation material about the issuing firm. Therefore, if a greater number of syndicate members are included to produce this material, investors may be better positioned to make well-informed decisions about the issuing firm's true value, leading to less uncertainty and a lower required discount. This has a counteracting effect on the underpricing stemming from ex-ante uncertainty.

Underpricing of shares in IPOs may be of more or less importance to the selling shareholders. Depending on how much they stand to lose, the propensity of previous owners to counteract underpricing varies. As put forward by Habib and Ljungqvist (2001) the level of underpricing can be affected by the extent of the issuing firm's promotion. Employing more reputable underwriters, lawyers and accountants as well as conducting more extensive investor education in the form of longer management roadshows or listing the shares on stock exchanges with investors of "higher quality" all constitute increased promotion. The aforementioned actions are all costly, but might decrease the level of underpricing in the IPO. Thus, there exists a trade-off between the level of underpricing and the promotion of the issue. Regarding more complex firms, it might be the case that they experience higher promotional costs due to the difficulties of investors to incorporate relevant information into the value of the firm, and thus need more promotion. Given the above mentioned trade-off it is possible that complex firms' optimal allocation of promotional costs and costs incurred due to underpricing results in a level of underpricing which is above that of less complex firms.

Competition between underwriters

Even after being selected as a member of the underwriting syndicate, competition amongst the underwriting managers is a possibility. The competition between syndicate members arises due to the managers' desire to secure more senior roles in subsequent offerings by the same issuer and to advance their respective industry reputation. This will help them reserve better positions in future transactions. By "whispering in the ear" of the issuing firm, syndicate members try to convey the picture that they might have done a better job than the lead manager at securing a more accurate (often higher) issue price in the IPO. Issuers receiving this positive pricing information are likely to pressure the book manager to revise the target price upwards. Consequently, additional syndicate members participating in intense intra-syndicate competition will likely result in IPO prices being pushed upward which reduces underpricing in comparison to issues characterized by a smaller amount of syndicate members.

2. Hypotheses

As argued above, different levels of complexity inherent in different issuers will result in different levels of underpricing. Due to the increased ex-ante uncertainty stemming from higher firm complexity we thus arrive at our first and most central hypothesis:

H1 – Increased firm complexity will lead to more underpricing.

Firm complexity as a source of IPO underpricing ultimately results in ex-ante uncertainty as well as underwriting managers' and investors' inability to accurately comprehend and price the issuing firm. We argue that firms of greater age have had a longer time to prove their business on the respective market and simultaneously provide investors with a longer time to understand and evaluate the company. These firms will most likely experience less underpricing in a potential IPO and the second prediction regarding IPO underpricing is therefore:

H2 – Because of less time to alleviate any ex-ante uncertainty regarding their business prospects, younger firms should suffer more underpricing than older firms.

Following the line of the certification theory and the uncertainty resulting from complex firms, in the presence of complexity, potential investors might want some indication of the issuers' worth. When investors face difficulties in evaluating the issuing firm, they may look elsewhere for clues indicating whether the investment is sound. Well renowned existing owners who have previously been successful might in these cases serve as assurance to new investors that the issuing firm does indeed constitute an attractive investment proposition. Thus, our third hypothesis will be:

H3 – Due to certification and monitoring, venture capital and private equity-backed firms should experience less underpricing than do unbacked firms.

Previous studies have focused on the effect of *quantitatively* greater information production and, to some extent, disregarded the *qualitative* aspects of the underwriting syndicate's ability to produce accurate information. A larger number of managers included in the syndicate has been proven to reduce underpricing. However, we argue that more ex-ante uncertainty derived from increased firm complexity will inhibit the benefit of including additional underwriting managers and its decreasing effect on underpricing. Consequently, the fourth and final hypothesis is:

H4 – *Because of the increased difficulty for underwriters, as well as investors, to evaluate complex firms, the benefit of additional underwriting managers is lower in more complex firms than in less complex firms.*

3. Data collection and summary statistics

3.1 Data collection

The data sample consists of IPO data for 3,542 U.S. IPOs being completed in the time period of 2000-2015. The primary data has been acquired from Thomson Reuter's Security Data Company's (SDC) Global New Issues Database. The collected data consists of observations on offer price, issue size, underwriting syndicate characteristics, firm specific information such as Standard Industrial Classification ("SIC") codes and historical stock price data.

Research and Development Expenditures as a percentage of Net Sales has been collected from Bloomberg's database on company financials. Information regarding firm incorporation dates (used to calculate firm ages at the time of the IPO) has been acquired from Bloomberg as well.

A total number of 704 observations had missing information on stock price performance after issue and were thus excluded from the sample. Another 1,957 observations were excluded due to missing information on firm specific and accounting information at the time of the IPO, such as firm age, total assets, intangible assets and R&D Expenses. Finally, after the exclusion of issues on other exchanges than NYSE and NASDAQ, the remaining data set consists of 528 IPOs. These IPOs, issued between 2000 and 2015 serve as the final data sample used in our regression analysis.

3.2 Summary statistics

Table 1 below displays an overview of the sample characteristics for our 528 observations. The average underpricing among the sample IPOs is 19 percent and the median is 10 percent. Some outliers are present as the maximum and minimum observed values of underpricing is 326 percent and -80 percent respectively.

The age of the sampled firms varies from newly formed firms to firms that have been around for almost a century. The average age of our sample firms is 6 years while the median is 5 years.

The average size of the funds raised in the IPO is USD 274 million and the average firm size measured by total assets is USD 1,2bn. However, we do see some variation in these measures as well.

The mean and median values for Intangible assets as a percentage of total assets are 28 percent and 20 percent respectively among our sample firms. The corresponding values for R&D Expenditures as a percentage of net sales are 204 percent and 5 percent respectively. The considerably high maximum value, which also influences the mean value, reported for the R&D variable might seem surprising at first glance. However after considering the nature of the firms exhibiting these numbers, they seem less odd. A number of the sample firms constitute biotechnology firms in a relatively early stage of their lives. It is not uncommon for firms within this industry to not yet have any marketable products since many of these firms are still in the product developing phase. These products have to be approved before they can be offered to consumers, resulting in these firms exhibiting neglectable sales and notably high Research and Development costs.

Lastly, the number of managers in the IPO syndicates vary between 1 and 45 managers, with mean and median values of 8 percent and 6 percent respectively.

Table 1.
Sample descriptive statistics.

This table illustrates the mean, minimum, 25th percentile, median, 75th percentile and maximum values of underpricing (defined as the percentage change in price from the offer price to the closing price after the first day of trading), age in years (measured as the number of years from the incorporation date of the company until the date of the IPO), total assets measured in USD at the last balance day before the IPO, intangible assets as a percentage of total assets, R&D intensity (measured as total R&D expenditures as a percentage of net sales) and the number of managing underwriters included in the underwriting syndicate for our sample of 528 U.S. firms completeing an IPO between the years 2000 and 2015.

	Mean	Min	25th percentile	Median	75th percentile	Max
Underpricing (%)	19	-80	0	10	27	326
Age (Years)	6	0	1	5	9	90
Offer size (USDm)	274	3	72	112	232	16,007
Total assets (USDm)	1,195	1	60	179	721	137,238
Intangible assets (% of total assets)	28	0	5	20	48	98
R&D intensity (R&D exp. % of Net Sales)	204	0	0	5	19	74,182
# of managers	8	1	4	6	9	45

Table 2 below displays summary statistics of our sample's underpricing development during the time period 2000 and 2015. Table 3 displays a summary of our sample in terms of IPO activity broken down per period.

Table 2.
Overview of underpricing per year.

This table illustrates the mean, minimum, 25th percentile, median, 75th percentile and maximum values of underpricing per year for our sample of 528 U.S. firms completing an IPO between the years 2000 and 2015.

Year	Mean	Min	25th Percentile	Median	75th Percentile	Max
2000	73	-19	1.56	39	115	326
2001	11	-32	0.10	9	23	71
2002	7	-3	0.00	2	16	20
2003	20	9	8.93	23	28	28
2004	14	-6	0.86	6	20	52
2005	9	-13	0.00	7	17	51
2006	11	-14	0.00	6	18	60
2007	22	-15	0.83	18	31	99
2008	4	-20	-3.78	0	17	23
2009	11	-15	0.28	9	17	57
2010	8	-18	-0.50	5	15	39
2011	18	-12	0.22	13	29	107
2012	16	-80	0.40	16	29	100
2013	22	-29	0.05	14	35	122
2014	18	-28	0.00	10	21	212
2015	14	-49	-1.89	12	29	72

Table 3.
Overview of no. of IPOs and offer size.

This table illustrates the number of IPOs and the average offer size of our sample of 528 U.S. firms completing an IPO between the years 2000 and 2015, divided by the periods 2000-2002, 2003-2005, 2006-2008, 2009-2011 and 2012-2015.

Year	No. of IPOs	Average offer size (USDm)
2000-2002	53	145
2003-2005	51	168
2006-2008	67	171
2009-2011	103	419
2012-2015	254	291
Total	528	274

4. Methodology

4.1 Dependent and independent variables

The stated hypotheses are tested by a regression analysis using an Ordinary Least Squares (OLS) regression. Possible sources of underpricing is the target of investigation and thus the observed underpricing constitutes our dependent variable. This variable is defined as the return (percentage change in price) between the offer price in the IPO and the closing price after one day of trading.

Equation 1: Underpricing definition

$$Underpricing = \frac{P_{close,t=1} - P_{offer}}{P_{offer}}$$

The analysis employs eleven independent variables in order to explain differences in underpricing between the observed issuing firms. Out of these eleven explanatory variables R&D Expenditures as a percentage of net sales is identified as the primary indicator of high complexity. The argument is based on to two reasons. Firstly, the main usage of reported R&D expenditures may in several cases be nearly impossible to identify by firm outsiders. Secondly, the task of evaluating the prospects of products, currently in the R&D phase and their probability to reach the market is a considerably difficult task even for the firm's management. Outsiders with limited insight into privately held firms will thus face even greater difficulty in appropriately evaluating the prospects of the firms' products currently being developed. We do acknowledge that R&D Expenditures is in no way an exhaustive measure of complexity in a firm. Other indicators such as the length of the management roadshow and management participation on the roadshow in connection with the IPO might be included and prove to complement R&D intensity as an indicator of complexity. We do, however, view R&D intensity as a straightforward and appropriate indicator for the purpose of this study. Additionally, previous research (e.g. Markarian and Parbonetti, 2007) has found that R&D-related measures are good proxies for firm complexity.

In addition to the R&D intensity variable two other independent explanatory variables are added: Intangible assets as a percentage of total assets and industry classification codes (SIC-codes)[2]. A summary of the SIC-codes used in this study is displayed in Table 4.

Table 4.
3-digit SIC Codes for Sampling of High-Tech Firm.

This table illustrate the eleven 3-digit Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as most appropriate for sampling hihg-technology firms.

SIC-Code	Industry name
283	Drugs
357	Computer and office equipment
366	Communication equipment
367	Electronic components and accessories
382	Laboratory, optic, measure, control instruments
384	Surgical, medical, dental instruments
481	Telephone communications
482	Miscellaneous communication services
489	Communication services, NEC
737	Computer programming, data processing, etc.
873	Research, development, testing services

Firm size has in many cases been shown to exhibit a negative relationship to underpricing. Smaller and unestablished firms often cause more uncertainty regarding the firms' prospects and value. In order to control for this well-known source of underpricing total assets of the firm (in USD) is included in the regression model. In addition, the size of the offering (i.e. the offer price multiplied by the offered amount of shares) has been found to have a positive relationship with underpricing (e.g. Loughran and Ritter, 2002). Therefore, we also include a variable measuring the size of the offering (measured in USD).

Furthermore, intertemporal differences in underpricing are controlled for by the creation of two additional variables. The first representing the year in which the IPO was completed and the second a dummy variable for IPOs completed during the internet bubble.

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[2] Kile and Phillips (2009) investigate the SIC-codes most commonly used to identify firms as being "high-technology firms". Their study develops a procedure which reduces the sampling errors when selecting samples of high-technology firms and finally results in a recommendation of eleven SIC-codes the authors consider optimal when sampling high-technology firms.

To answer the full range of our hypotheses, an additional four variables are included: the age of the firm, the number of managers included in the underwriting syndicate, a venture capital dummy and a private equity dummy.

Outlined below is a detailed description of the respective independent variables used in the regression:

RD_Dummy – Is a dummy variable measuring firm complexity in terms of the proportion of R&D Expenditures to Net Sales. The variable takes the value of one (1) if the firm has a proportion of R&D Expenditures to Net Sales in excess of the median value, and zero (0) otherwise.

Int_Assets – Is a continuous variable measuring firm complexity in terms of the proportion of intangible assets to total assets.

SIC_11_Dummy – Is a dummy variable indicating if the firm belongs to any of the eleven three digit SIC-codes identified by Kile and Phillips (2009) as being optimal for sampling high-technology firms. We have chosen to look at high-technology firms because of their high internal complexity characteristics stemming from the high R&D nature of the offered products and the complications of managing the highly educated people necessary to carry out the complex tasks undergoing in a high-technology business (Moornan and Swaminathan, 2003)

Ln_Offer_Size – Is the natural logarithm of the total amount of proceeds raised in the IPO, measured as the product of the offer price and the number of shares offered in the IPO.

Ln_Total_Assets – Is the natural logarithm of the sample firms' total assets at the last balance day before the IPO.

Year – Is simply the year in which the IPO was completed. This variable is included to control for any variations over time, which historically have been significant.

Internet_Bubble_Dummy – The large amounts of underpricing during the internet stock bubble of the late 1990s and early 2000s is documented by Ljungqvist and Wilhelm (2003) and cause for concern when looking at causes for underpricing in a sample period spanning these years. Due to this anomaly a dummy variable is constructed to control for the effect. Since our sample starts in the year 2000, the dummy variable takes the value of one (1) if the sample firm completed the IPO before the year 2001, and zero (0) otherwise.

Ln_age – Is the natural logarithm of the sample firms' age at the time of their respective IPOs. Age is measured as the number of days between the firm's incorporation date and the firm's IPO. The variable is commonly utilized as a proxy for information asymmetry as older firms are assumed to have provided the market with more information.

VC_Dummy – Is a dummy variable indicating whether or not the issuing firm is backed by a venture capital-firm in the IPO.

PE_Dummy – Is a dummy variable indicating whether or not the issuing firm is backed by a private equity-firm in the IPO.

No_Of_Mngrs – Is the total number of underwriting managers included in the underwriting syndicate of the IPO. Both Corwin and Schultz (2005), and Ritter and Hu (2007) found evidence that an increased number of managing underwriters included in an IPO syndicate will contribute to decrease underpricing. We therefore include this variable to account for the effect on underpricing from the number of underwriters in the syndicate.

Our main regression constructed for carrying out the tests of our hypotheses thus looks like follows:

Equation 2: Ordinary Least Squares Regression

$$Underpricing = \alpha + \beta_1(RD\_Dummy) + \beta_2(Int\_Assets) + \beta_3(SIC\_11\_Dummy)$$
$$+ \beta_4(Ln\_Offer\_Size) + \beta_5(Ln\_Total\_Assets) + \beta_6(Year)$$
$$+ \beta_7(Internet\_Bubble\_Dummy) + \beta_8(Ln\_Age) + \beta_9(VC\_Dummy)$$
$$+ \beta_{10}(PE\_Dummy) + \beta_{11}(No\_Of\_Mngrs)$$

The final sample contains a number of outliers with regards to underpricing. As shown in Table 5, the mean and median underpricing in our sample is 19 percent and 10 percent respectively, with minimum and maximum values of -80 percent and 326 percent respectively. This is graphically illustrated in Figure 4. In order to correct for these discrepancies the variable *Underpricing* is winsorized, by replacing values in the 1st and 99th percentiles respectively. This procedure yields the marginally altered regression displayed below.

Equation 3: Ordinary Least Squares Regression with winsorized dependent variable

$$Underpricing\_Win$$
$$= \alpha + \beta_1(RD\_Dummy) + \beta_2(Int\_Assets) + \beta_3(SIC\_11\_Dummy)$$
$$+ \beta_4(Ln\_Offer\_Size) + \beta_5(Ln\_Total\_Assets) + \beta_6(Year)$$
$$+ \beta_7(Internet\_Bubble\_Dummy) + \beta_8(Ln\_Age) + \beta_9(VC\_Dummy)$$
$$+ \beta_{10}(PE\_Dummy) + \beta_{11}(No\_Of\_Mngrs)$$

Table 5.
**Underpricing sample characteristics.**
This table illustrates the mean, minimum, 25th percentile, median, 75th percentile and maximum values of underpricing for our sample of 528 U.S. firms completing an IPO between the years 2000 and 2015.

	Mean	Min	25th percentile	Median	75th percentile	Max
Underpricing (%)	19	-80	0.03	10	27	326

Figure 4: Underpricing per firm

This graph illustrates the distribution of underpricing among our 528 U.S. sample IPOs between 2000 and 2015
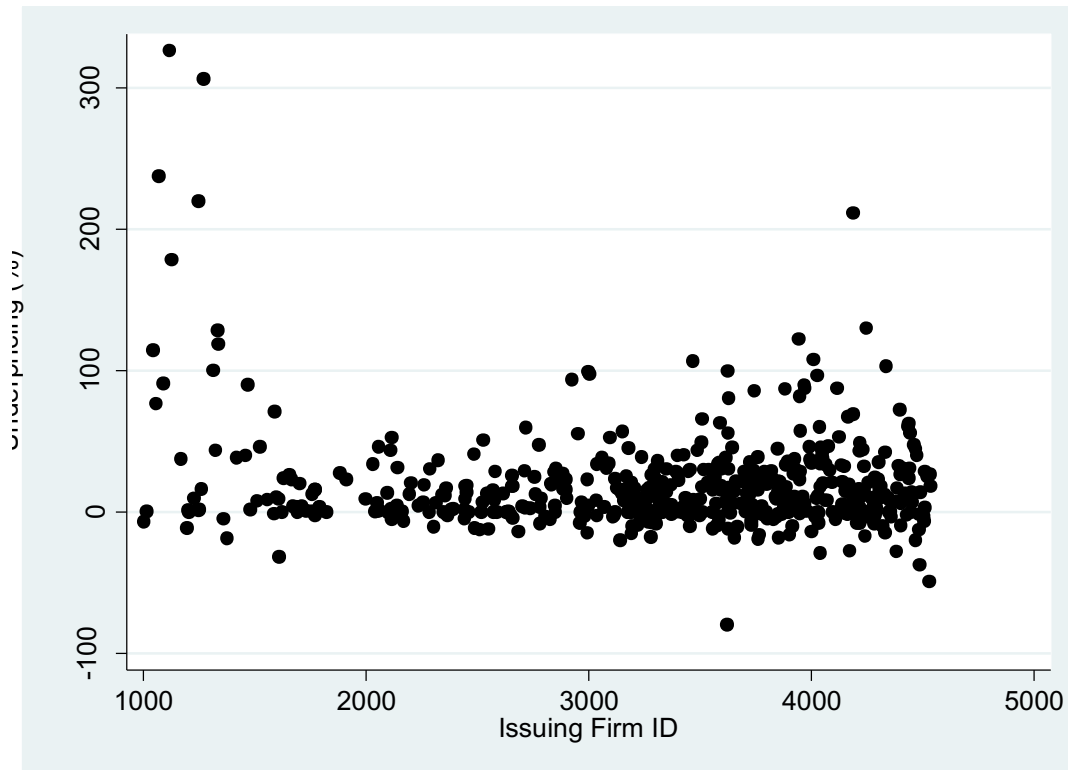
However, the area of particular interest in this study is the interaction between information production and ex-ante uncertainty stemming from increased complexity. Therefore, tests are carried out in order to resolve whether more complex firms exhibit less benefits with regards to the observed underpricing from including additional managers in the underwriting syndicate. Additionally, it is tested whether increased information production has a mitigating effect on the amount of underpricing derived from increased ex-ante uncertainty and firm complexity.

4.2 Interaction between information production and firm complexity

In order to discern the effects of increased firm complexity on underwriting managers' ability to produce accurate information, two variables representing information production and firm specific complexity are interacted. Information production is proxied by the amount of managers included in each syndicate and the degree of complexity in the respective firms is

proxied by R&D Expenditures to Net Sales. For the purpose of testing the above mentioned interaction, the term *RD_Infoprod* is constructed by multiplying the dichotomous variable *RD_Dummy* with the continuous variable *No_Of_Mngrs*. The coefficient of the interactive term will thus represent the additional effect on underpricing of adding more underwriting managers when a firm is classified as being complex. By including the interaction term in the original regression analysis, the following equation is yielded:

Equation 4: Ordinary Least Squares Regression with interactive term

$$Underpricing\_Win$$
$$= \alpha + \beta_1(RD\_Dummy) + \beta_2(No\_of\_Mngrs) + \beta_3(RD\_Infoprod) + \beta_4(Int\_Assets)$$
$$+ \beta_5(SIC\_11\_Dummy) + \beta_6(Ln\_Offer\_Size) + \beta_7(Ln\_Total\_Assets) + \beta_8(Year)$$
$$+ \beta_9(Internet\_Bubble\_Dummy) + \beta_{10}(Ln\_Age)$$

To draw further conclusions regarding the effects that information production has on the reduction of underpricing, stemming from increased firm complexity, the main regression (Equation 2) is carried out on two separate groups. The groups are separated by the amount of information production present in each IPO. Due to the lack of any appropriate absolute measure of information production, the number of underwriters included in the respective syndicates will serve as a proxy. The usage of this proxy has empirical support by Corwin and Schultz (2005) as well as Ritter and Hu (2007) who note that a greater number of underwriters leads to increased information production and thus reduced underpricing.

Group 1 consists of firms with low information production and Group 2 with firms exhibiting high information production. The firms in Group 1 have an amount of underwriters less than or equal to the 33rd percentile, which in our sample represents five underwriters. Group 2 consists of firms that have an amount of underwriters greater than the 67th percentile, which in our sample amounts to eight underwriters. Summary statistics for each of the two groups are displayed in Table 6 below.

Table 6.
Sample subgroup descriptive statistics.

This table illustrates the mean, minimum, 25th percentile, median, 75th percentile and maximum values of underpricing (defined as the percentage change in price from the offer price to the closing price after the first day of trading), age in years (measured as the number of years from the incorporation date of the company until the date of the IPO), total assets measured in USD at the last balance day before the IPO, intangible assets as a percentage of total assets, R&D intensity (measured as total R&D expenditures as a percentage of net sales) and the number of managing underwriters included in the underwriting syndicate for two subgroups of our sample of 528 U.S. firms completeing an IPO between the years 2000 and 2015. Group 1 includes firms with less than or equal to the 33rd percentile number of managers included in the underwriting syndicates, in our sample this number corresponds to five managers. Group 1 includes firms with more than or equal to the 67th percentile number of managers included in the underwriting syndicates, in our sample this number corresponds to eight managers.

Group 1 - No. of Managers ≤ 5

N=228	Mean	Min	25th percentile	Median	75th percentile	Max
Underpricing (%)	15	-80	0	7	24	212
Age (Years)	7	0	2	6	10	36
Offer size (USDm)	90	3	45	79	111	495
Total assets (USDm)	154	1	34	78	202	1,291
Intangible assets (% of total assets)	25	0	4	16	43	90
R&D intensity (R&D exp. % of Net Sales)	433	0	1	10	29	74,182
# of managers	4	1	3	4	5	5

Group 2 - No. of Managers ≥ 8

N=186	Mean	Min	25th percentile	Median	75th percentile	Max
Underpricing (%)	23	-32	1	10	26	326
Age (Years)	5	0	1	4	7	90
Offer size (USDm)	548	20	122	257	477	16,007
Total assets (USDm)	2,760	9	222	874	3,001	137,238
Intangible assets (% of total assets)	31	0	5	24	55	90
R&D intensity (R&D exp. % of Net Sales)	37	0	0	0	7	3,805
# of managers	13	8	9	11	14	45

The purpose of the test is to observe whether differences in information production, proxied by the number of managers included in the underwriting syndicate, affects the observed underpricing derived from increased firm complexity.

5. Results

The following section discusses the obtained empirical results in relation to our hypotheses stated in part 2. Initially, the results from the main regression and overall findings are presented in section 5.1. Section 5.2 and 5.3 treats results relating to possible mitigating factors of underpricing in the face of increased complexity. Section 5.2 will discuss how increased firm age at the time of the IPO might decrease underpricing as ex-ante uncertainty is reduced with a more extensive track record of the firm. Section 5.3 discusses how the backing of a venture capital of private equity sponsor might contribute with certification and monitoring in order to reduce IPO underpricing when investors are faced with increased uncertainty resulting from increased firm complexity. The results obtained by including the interactive term in the regression is described in section 5.4 where we strive to identify some explanatory factors to the occurrence of underpricing despite the presence of larger underwriting syndicates. Finally, in section 5.5 and 5.6 we perform tests for multicollinearity and check the robustness of our regression model, respectively.

5.1 Main regression results

In order to test the main hypothesis H1 outlined in part 2, we run an Ordinary Least Squares (OLS) regression. The indicators of higher firm complexity (R&D-intensity and percentage of intangible assets to total assets) show varying effects on the experienced underpricing for our sample firms. The results from the main regression are illustrated in Table 7.

In line with hypothesis H1 we find support that increased R&D Expenditures as a percentage of net sales does increase the amount of underpricing. The regression coefficient of the variable *RD_Dummy* exhibits a strongly positive value, significant at the one percent level.

Firms with a higher percentage of intangible assets to total assets experience a lower degree of underpricing as our Intangible Assets Dummy variable exhibits a negative coefficient value. The result contradicts hypothesis *H1* which implies that increasing the value of a complexity indicator should increase underpricing. However, the coefficient is not significant as it exhibits a P-value of approximately 0.3. The conclusion that firms with a high degree of intangible assets experience more underpricing can thus not be drawn.

Inconsistent with our predictions, the remaining complexity variable (SIC – codes) is negative, indicating that firms in these high-technology industries exhibit decreased underpricing. The negative value of the High-Technology coefficient is further puzzling since it contradicts our predictions as well as the results found by Loughran and Ritter (2004). However, the coefficient is insignificant and the discrepancies in the slope might be explained by sampling differences of high-technology firms.

Ln_Offer_Size which measure the amount offered in the issue is in line with predictions. The coefficient of the offer size variable exhibits a positive value of 8.24 and a significance level of one percent. This result indicates that larger offers tend to exhibit more pronounced underpricing and is in line with previous findings by e.g. Loughran and Ritter (2002).

The notion that larger, better established firms exhibit less underpricing is in line with previous literature. The negative relationship between total assets and underpricing could be explained by investors being more comfortable investing in a firm that has been able to reach a profitability level allowing them to accumulate a larger amount of capital and thereof signal higher quality than a smaller firm. Investors should thus be less uncertain about the value of a larger firm.

Table 7.

Ordinary Least Squares Regression of Underpricing on an R&D Dummy, Intagible Assets as a percentag of total assets, Industry Classification Dummy, Ln(Offer Size), Ln(Total Assets), Year of the IPO, Internet Bubble Dummy, Ln(Age), VC Dummy, PE Dummy and Number of Managers Included in the Underwriting Syndicate.

The dependent variable is underpricing, defined as the percentage change in price from the offer price to the closing price after the first day of trading. The R&D Dummy takes the value of one if the percentage of R&D expenditures to net sales exceeds the median, and zero otherwise. Int. Assets (% of total assets) is the percentage of intangible assets of total assets at the last balance day before the IPO. The SIC Dummy takes the value of one if the firm is classified in accordance with any of the eleven Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as the most appropriate to sample high-technology firms, and zero otherwise. Ln(Offer Size) is the natural lograithm of the dollar value of the total offer in the IPO. Ln(Total Assets) is the natural lograithm of the dollar value of total assets on the last balance day before the IPO. Year indicates the year in which the IPO was completed. Internet Bubble Dummy is a dummy variable controlling for the large amounts of underpricing observed during the internet bubble of 1999 and 2000. The dummy variable takes the value of one if the IPO was completed in the year 2000, and zero otherwise. Ln(Age) is the natural lograithm of the age of the firm at the time of the IPO, measured as the number of years between the firm incorporation date and the IPO. VC Dummy takes the value of one if the firm was backed by a venture capital firm at the time of the IPO, and zero otherwise. PE Dummy takes the value of one if the firm was backed by a private equity firm at the time of the IPO, and zero otherwise. No. of Managers is the number of underwriting manger included in the underwriting syndicate.

	(1)	(2)	(3)	(4)	(5)	(6)
R&D Dummy	15.93***	12.61***	12.56***	9.551***	9.708***	9.867***
	(3.316)	(3.387)	(3.378)	(3.687)	(3.678)	(3.694)
Int. Assets (% of total assets)	-0.0828*	-0.0555	-0.0555	-0.0345	-0.0471	-0.0453
	(0.0470)	(0.0450)	(0.0450)	(0.0457)	(0.0458)	(0.0463)
SIC Dummy	-3.668	-3.691	-3.745	-4.523	-4.477	-4.414
	(3.140)	(3.237)	(3.271)	(3.226)	(3.244)	(3.272)
Ln(Offer Size)	7.364**	7.397**	7.448**	6.589**	6.545**	8.242***
	(3.109)	(3.009)	(2.997)	(2.942)	(2.940)	(3.049)
Ln(Total Assets)	-2.009	-2.148	-2.177	-1.625	-1.973	-1.327
	(1.740)	(1.707)	(1.699)	(1.683)	(1.737)	(1.755)
Year		0.629**	0.624**	0.691**	0.726***	0.601**
		(0.272)	(0.273)	(0.269)	(0.275)	(0.285)
Internet Bubble Dummy		47.15***	47.17***	48.00***	48.70***	56.02***
		(12.07)	(12.08)	(11.95)	(12.01)	(12.85)
Ln(Age)			0.147	-0.158	-0.229	-0.355
			(0.850)	(0.851)	(0.854)	(0.859)
VC Dummy				7.434**	10.09***	9.015**
				(3.167)	(3.746)	(3.578)
PE Dummy					5.085*	4.291
					(3.015)	(2.939)
No. of Managers						-0.915**
						(0.383)
Constant	-10.45	-1,276**	-1,268**	-1,400***	-1,470***	-1,222**
	(8.787)	(544.7)	(546.0)	(538.5)	(549.9)	(569.1)
Observations	528	528	528	528	528	528
R-squared	0.080	0.176	0.176	0.184	0.187	0.200

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2 Age effects on underpricing

The second hypothesis concerns the firm age's effect on underpricing. In line with the findings by Ljungqvist (2007) and Chemmanur (1993) a negative slope of the age coefficient is observed. The result indicates the existence of a negative relationship between firm age at the time of the IPO and the observed amount of underpricing. The coefficient value is insignificant but the findings indicate a similar relationship to that stated by the theory that uncertainty regarding firm value is negatively related to the age of the firm. The amount of publically available information regarding the firm increases with firm age which in turn enhances outsiders' ability to assess the firm's quality and prospects.

5.3 Venture capital and private equity backing as sources of certification and monitoring

The third hypothesis relates to the certification and monitoring effects of venture capital and private equity sponsors backing the issuing firm. Megginson and Weiss (1990) found a negative relationship between venture capital backing and IPO underpricing. Our results however contradict these findings as we observe a positive slope of the venture capital dummy, significant at the five percent level. This indicates a positive relationship between venture capital sponsorship and IPO underpricing. Our results are thus more in line with Gompers (1996) and Lee and Wahal (2004) which find that venture capital backed IPOs experience larger amounts of underpricing in relation to non-sponsored IPOs. Gompers (1996) provide two explanations to the observed results. Firstly, the establishment of reputation is considerably important in order to raise capital for subsequent funds. Relatively young venture capital firms which have not yet established a reputation thus have an incentive to bring their portfolio companies public early since it acts as a signal of quality. Consequently, less mature companies are brought public and venture capital firms face a higher degree of underpricing. Secondly, investors recycle capital between different assets. By taking the portfolio companies public earlier, venture capital firms return cash to investors which can be used to invest in newly established funds. The recycling of assets thus motivates early IPOs since it allows venture capital firms to raise capital for later investments.

The private equity variable is positive as well (although not significant) which indicates the possibility of a similar relationship between private equity-backing and underpricing as that found for venture capital backed firms. This result contradicts our hypothesis and the theories of certification and monitoring. Although there exists little (to our knowledge) research on the subject, a similar explanation as to the higher underpricing exhibited by venture capital backed firms might be presented also for private equity backed IPOs. Similar to venture capital firms, private equity firms have an interest in establishing a reputation as a successful investor and thus an incentive to complete successful IPOs of their portfolio companies. Also capital recycling can be argued to be a concern for private equity firms which, in line with Gompers (1996), provide an additional explanation as to the tendencies of increased underpricing for private equity-backed firms observed in our data.

Furthermore, a t-test is conducted on the differences in mean values between i) venture capital-backed and unbacked IPOs, and ii) private equity-backed and unbacked IPOs. The purpose of this test is to clarify if there exists a significant difference in underpricing between the groups. The results obtained from the t-test are illustrated in Table 8 and indicate similar results as our OLS regression. No significant difference in underpricing between private equity backed IPOs and non-backed IPOs can be determined, although the results indicate that private equity-backed firms experience more underpricing than unbacked IPOs do.

The results obtained from the t-test on venture capital-backed IPOs confirm the results generated from the OLS regression. The average amount of underpricing for venture capital backed IPOs is approximately 26 percent in relation to approximately 11 percent for non-sponsored IPOs. These results are significant at the one percent level which corresponds to the findings of Gompers (1996) and Lee and Wahal (2004).

Table 8.
T-test of differences in means of underpricing between Venture Capital backed IPOs and non-backed IPOs, as well as the differences in means of underpricing between Private Equity backed IPOs and non-backed IPOs.

Venture Capital Backed IPOs	Mean	Std. Error	Std. Dev.	[95% Conf. Interval]	
Non-backed IPOs	11.25	2.50	25.24	6.29	16.20
Venture Capital Backed IPOs	25.75	2.61	38.14	20.59	30.90
Combined	21.05	1.98	35.12	17.16	24.94
Difference	####	4.16		-22.67	-6.32

H0: Mean (Non-Backed) - Mean (VC Backed) = Diff = 0

Ha: diff < 0	Ha: diff != 0	Ha: diff > 0
Pr(T < t) = 0.0003	Pr(|T| > |t|) = 0.0006	Pr(T > t) = 0.9997

Private Equity Backed IPOs	Mean	Std. Error	Std. Dev.	[95% Conf. Interval]	
Non-backed IPOs	11.25	2.50	25.24	6.29	16.20
Private Equity Backed IPOs	13.89	1.52	22.12	10.90	16.88
Combined	13.04	1.31	23.17	10.47	15.60
Difference	-2.64	2.79		-8.13	2.85

H0: Mean (Non-Backed) - Mean (PE Backed) = Diff = 0

Ha: diff < 0	Ha: diff != 0	Ha: diff > 0
Pr(T < t) = 0.1721	Pr(|T| > |t|) = 0.3443	Pr(T > t) = 0.8279

5.4 Interaction between firm complexity and information production

Our fourth and final hypothesis aims to unravel what effects firm complexity has on the information production in underwriting syndicates in IPOs. Although previous research of Corwin and Schultz (2005) and Hu and Ritter (2007) find a negative relationship between the number of underwriters and the amount of underpricing in IPOs, we believe that increasing complexity in the issuing firm will diminish the effect that additional managers in the underwriting syndicate has on underpricing. The results of including an interactive term between complexity and information production in the regression is illustrated in Table 9. We observe that information production, proxied by the number of managers included in the syndicate, exhibits a negative relationship with the amount of underpricing and the slope of the coefficient is significant at the one percent level. A greater number of underwriters results in a higher degree of information production which reduces underpricing. Our results are thus consistent with the findings of Corwin and Schultz (2005) and Hu and Ritter (2007). The interactive term, however, has a positive slope (although not significant) which indicates that the net effect is somewhat smaller. The interpretation of the interactive term's effect on information production is thus that including additional underwriting managers will reduce underpricing. However, the benefit of including additional managers in the underwriting syndicate experiences diminishing returns when complexity is introduced. This is in line with our hypothesis and confirms that the reduction in underpricing, derived from increased information production, is in fact diminished by more complexity inherent in the firm.

Table 9.

Ordinary Least Squares Regression of Underpricing on an R&D Dummy, the number of managers included in the underwriting syndicate, Interaction Term Between R&D Dummy and the number of managers included in the underwriting syndicate, Intangible Assets as a percentage of total assets, Industry Classification Dummy, Ln(Offer Size), Ln(Total Assets), Year of the IPO, Internet Bubble Dummy and Ln(Age). Information Production is proxied by the amount of underwriting managers included in the underwriting syndicate.

The dependent variable is underpricing, defined as the percentage change in price from the offer price to the closing price after the first day of trading. The R&D Dummy takes the value of one if the percentage of R&D expenditures to net sales exceeds the median, and zero otherwise. No. of managers measures the amount of information being produced by the underwriting syndicate. The interactive term is the product of the R&D Dummy and the number of managers included in the underwriting syndicate. Int. Assets (% of total assets) is the percentage of intangible assets of total assets at the last balance day before the IPO. The SIC Dummy takes the value of one if the firm is classified in accordance with any of the eleven Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as the most appropriate to sample high-technology firms, and zero otherwise. Ln(Offer Size) is the natural lograithm of the dollar value of the total offer in the IPO. Ln(Total Assets) is the natural lograithm of the dollar value of total assets on the last balance day before the IPO. Year indicates the year in which the IPO was completed. Internet Bubble Dummy is a dummy variable controlling for the large amounts of underpricing observed during the internet bubble of 1999 and 2000. The dummy variable takes the value of one if the IPO was completed in the year 2000, and zero otherwise. Ln(Age) is the natural logarithm of the age of the firm at the time of the IPO, measured as the number of years between the firm incorporation date and the IPO.

	(1)
R&D Dummy	9.792*
	(5.411)
No. of Managers	-1.188***
	(0.369)
Interaction Term Between R&D Dummy and Information Production	0.417
	(0.661)
Int. Assets (% of total assets)	-0.0563
	(0.0457)
SIC Dummy	-3.910
	(3.280)
Ln(Offer Size)	9.183***
	(3.129)
Ln(Total Assets)	-1.372
	(1.693)
Year	0.508*
	(0.288)
Internet Bubble Dummy	53.54***
	(13.96)
Ln(Age)	-0.0236
	(0.851)
Constant	-1,037*
	(574.2)
Observations	528
R-squared	0.192

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We believe however that there is significant merit to the information production theory. Therefore, two additional regressions are carried out to identify any differences in severity of the effect from increased firm complexity on underpricing, based on the degree of information production. The regression summarized in Table 10 is run in two separate groups, one with a low degree of information production (group 1) that has an amount of underwriters less than or equal to the 33rd percentile and one with a high degree of underpricing (group 2) which has an amount of underwriters greater than the 67th percentile.

Group 1's R&D Dummy exhibits a positive slope of 14.34 at one percent significance level which is slightly higher than that of the total sample. In line with the information production theory, the slope in group 2 has dropped down to 5.25, although not significant.

Our results indicate a similar relationship to earlier findings that an increased number of managers included in the underwriting syndicate reduces IPO underpricing and mitigates the effect of increased complexity on underpricing. This result is in line with the information production hypothesis.

Table 10.

Ordinary Least Squares Regression of Underpricing on an R&D Dummy, Intagible Assets as a percentage of total assets, Industry Classification Dummy, Ln(Offer Size), Ln(Total Assets), Year of the IPO, Internet Bubble Dummy and Ln(Age).

The dependent variable is underpricing, defined as the percentage change in price from the offer price to the closing price after the first day of trading. The R&D Dummy takes the value of one if the percentage of R&D expenditures to net sales exceeds the median, and zero otherwise. Int. Assets (% of total assets) is the percentage of intangible assets of total assets at the last balance day before the IPO. The SIC Dummy takes the value of one if the firm is classified in accordance with any of the eleven Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as the most appropriate to sample high-technology firms, and zero otherwise. Ln(Offer Size) is the natural lograithm of the dollar value of the total offer in the IPO. Ln(Total Assets) is the natural lograithm of the dollar value of total assets on the last balance day before the IPO. Year indicates the year in which the IPO was completed. Internet Bubble Dummy is a dummy variable controlling for the large amounts of underpricing observed during the internet bubble of 1999 and 2000. The dummy variable takes the value of one if the IPO was completed in the year 2000, and zero otherwise. Ln(Age) is the natural logarithm of the age of the firm at the time of the IPO, measured as the number of years between the firm incorporation date and the IPO. Regression (1) includes firms with N≤ 33rd percentile number of managers incldued in the underwriting syndicate. Regression (2) includes firms with N≥ 67th percentile number of managers incldued in the underwriting syndicate.

	(1)	(2)
R&D Dummy	14.34***	5.248
	(4.852)	(6.271)
Int. Assets (% of total assets)	-0.108	-0.0227
	(0.0713)	(0.0869)
SIC Dummy	-10.30*	3.824
	(5.226)	(6.123)
Ln(Offer Size)	8.638*	5.300
	(5.125)	(5.654)
Ln(Total Assets)	-0.563	-2.082
	(2.307)	(3.321)
Year	0.539	1.844***
	(0.395)	(0.547)
Internet Bubble Dummy	-17.20***	88.58***
	(4.390)	(33.39)
Ln(Age)	1.805*	-1.936
	(1.024)	(1.860)
Constant	-1,116	-3,693***
	(792.6)	(1,092)
Observations	228	151
R-squared	0.146	0.244

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.5 Tests for multicollinearity between the explanatory variables

Although we have run VIF checks after each regression and found no cause for concern, we complement the multicollinearity checks by testing for severe correlation between our explanatory variables. Table 11 below illustrate the results from this check. As can be seen, the variables for total assets and the size of the offering experience quite strong correlation of approximately 0.81. This magnitude of correlation between two of our explanatory variables is large enough for us to alter our regression model somewhat in order to see if the quality of the results can be improved upon. In section 5.6 a robustness check in relation to this possible multicollinearity is conducted.

Table 11.
Test of collinearity between the explanatory variables used in the main OLS regression model.

The table illustrate the collinearity between the explanatory variables used in our regression model. The R&D Dummy takes the value of one if the percentage of R&D expenditures to net sales exceeds the median, and zero otherwise. Int Assets (% of total assets) is the percentage of intangible assets of total assets at the last balance day before the IPO. The SIC Dummy takes the value of one if the firm is classified in accordance with any of the eleven Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as the most appropriate to sample high-technology firms, and zero otherwise. Ln(Offer Size) is the natural lograithm of the dollar value of the total offer in the IPO. Ln(Total Assets) is the natural lograithm of the dollar value of total assets on the last balance day before the IPO. Year indicates the year in which the IPO was completed. Internet Bubble Dummy is a dummy variable controlling for the large amounts of underpricing observed during the internet bubble of 1999 and 2000. The dummy variable takes the value of one if the IPO was completed in the year 2000, and zero otherwise. Ln(Age) is the natural logarithm of the age of the firm at the time of the IPO, measured as the number of years between the firm incorporation date and the IPO. VC Dummy takes the value of one if the firm was backed by a venture capital firm at the time of the IPO, and zero otherwise. PE Dummy takes the value of one if the firm was backed by a private equity firm at the time of the IPO, and zero otherwise. No. of Managers is the number of underwriting mangers included in the underwriting syndicate.

(obs=528)	R&D Dummy	Int. Assets Dummy	SIC Dummy	Ln (Offer Size)	Ln (Total Assets)	Year	Internet Bubble Dummy	Ln(Age)	VC Dummy	PE Dummy	No. of Managers
R&D Dummy	1										
Int. Assets Dummy	-0.2652	1									
SIC Dummy	0.6781	-0.1706	1								
Ln(Offer Size)	-0.3562	0.1201	-0.242	1							
Ln(Total Assets)	-0.5228	0.2393	-0.3944	0.8092	1						
Year	-0.1531	0.1228	-0.1172	0.1286	0.1956	1					
Internet Bubble Dummy	0.1973	-0.1136	0.1365	-0.0824	-0.1275	-0.543	1				
Ln(Age)	0.1551	0.0181	0.1644	-0.1291	-0.0609	0.0946	-0.0459	1			
VC Dummy	0.5938	-0.2787	0.4782	-0.1798	-0.3795	-0.1577	0.115	0.1785	1		
PE Dummy	-0.5181	0.339	-0.4022	0.3455	0.5179	0.1357	-0.1518	-0.0821	-0.6762	1	
No. of Managers	-0.19	0.0624	-0.139	0.5349	0.486	-0.2077	0.3559	-0.1385	-0.1558	0.1808	1

5.6 Robustness checks by dropping Total Assets due to high correlation and insignificant results

Since the total assets variable is insignificant and highly correlated with the offer size (0.8092) we re-run our main OLS regression after dropping the variable Ln(Total Assets) in order to see if our results change. As can be seen in Table 12 below, the coefficients change somewhat in magnitude, however the overall findings and interpretation of the results do not change.

Table 12.

Robustness test of main Ordinary Least Squares Regression after dropping variable Ln(Total Assets). Regression of Underpricing is run on an R&D Dummy, Intagible Assets as a percentag of total assets, Industry Classification Dummy, Ln(Offer Size), Year of the IPO, Internet Bubble Dummy, Ln(Age), VC Dummy, PE Dummy and Number of Managers Included in the Underwriting Syndicate.

The dependent variable is underpricing, defined as the percentage change in price from the offer price to the closing price after the first day of trading. The R&D Dummy takes the value of one if the percentage of R&D expenditures to net sales exceeds the median, and zero otherwise. Int. Assets (% of total assets) is the percentage of intangible assets of total assets at the last balance day before the IPO. The SIC Dummy takes the value of one if the firm is classified in accordance with any of the eleven Standard Industry Classification (SIC) codes identified by Kile and Phillips (2009) as the most appropriate to sample high-technology firms, and zero otherwise. Ln(Offer Size) is the natural logarithm of the dollar value of the total offer in the IPO. Year indicates the year in which the IPO was completed. Internet Bubble Dummy is a dummy variable controlling for the large amounts of underpricing observed during the internet bubble of 1999 and 2000. The dummy variable takes the value of one if the IPO was completed in the year 2000, and zero otherwise. Ln(Age) is the natural logarithm of the age of the firm at the time of the IPO, measured as the number of years between the firm incorporation date and the IPO. VC Dummy takes the value of one if the firm was backed by a venture capital firm at the time of the IPO, and zero otherwise. PE Dummy takes the value of one if the firm was backed by a private equity firm at the time of the IPO, and zero otherwise. No. of Managers is the number of underwriting mangers included in the underwriting syndicate.

	(1)	(2)	(3)	(4)	(5)	(6)
R&D Dummy	17.34***	14.11***	14.12***	10.39***	10.65***	10.49***
	(3.054)	(3.109)	(3.106)	(3.524)	(3.491)	(3.508)
Int. Assets (% of total assets)	-0.0983**	-0.0713*	-0.0713*	-0.0438	-0.0555	-0.0508
	(0.0454)	(0.0433)	(0.0432)	(0.0442)	(0.0450)	(0.0454)
SIC Dummy	-3.126	-3.125	-3.108	-4.139	-4.036	-4.122
	(3.230)	(3.319)	(3.361)	(3.301)	(3.322)	(3.346)
Ln(Offer Size)	5.048***	4.938***	4.931***	4.689***	4.328***	6.886***
	(1.624)	(1.600)	(1.593)	(1.561)	(1.564)	(1.945)
Year		0.568**	0.570**	0.659**	0.681**	0.564**
		(0.272)	(0.272)	(0.269)	(0.273)	(0.283)
Internet Bubble Dummy		46.66***	46.66***	47.71***	48.22***	56.11***
		(12.09)	(12.09)	(11.94)	(12.00)	(12.83)
Ln(Age)			-0.0540	-0.332	-0.420	-0.487
			(0.865)	(0.869)	(0.875)	(0.876)
VC Dummy				8.158***	10.41***	9.164**
				(3.130)	(3.745)	(3.570)
PE Dummy					4.072	3.585
					(2.824)	(2.741)
No. of Managers						-0.966**
						(0.378)
Constant	-10.55	-1,154**	-1,157**	-1,334**	-1,378**	-1,148**
	(8.653)	(542.7)	(543.8)	(537.0)	(546.0)	(564.8)
Observations	528	528	528	528	528	528
R-squared	0.076	0.171	0.172	0.182	0.184	0.198

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

The purpose of this study is to further investigate the effects of information production on underpricing in initial public offerings. Corwin and Schultz (2005) and Hu and Ritter (2007) find that a larger number of underwriting managers included in the syndicate will serve to reduce underpricing. These results, it is argued, stems from the increased information production present in underwriting syndicates with a larger number of underwriting managers.

Our contribution to the theory is the inclusion of an additional factor, which we argue will work in opposite direction and increase the level of underpricing – firm complexity. By looking at a sample of 528 U.S. initial public during the time period of 2000-2015 we find support that initial public offerings completed by firms that exhibit a higher degree of complexity suffer from larger amounts of underpricing than less complex firms do. Our main hypothesis H1 is thus confirmed.

Cohen and Lou (2012) find that higher complexity inherent in a firm will serve to increase the frictions in the processing of information relating to the firm in question. Due to limited resources and capabilities, investors evaluating a more complex firm will experience greater difficulties in understanding and processing information regarding the firm. Consequently, updating and incorporating the information into the valuation of the firm will be more time consuming and will not be done at same extent relative to the valuation of a less complex firm. This characteristic of complexity contribute to increasing the uncertainty regarding firm value and thus results in higher underpricing.

Our findings can thus be explained by complexity's association with a higher degree of ex-ante uncertainty. This reasoning is in line with the findings of Beatty and Ritter (1986) regarding the firm's business, future prospects and value. If investors cannot understand or adequately evaluate the firm's business, they will require a discount on the price at which they invest.

We do however find strong support that some firm characteristics may work as mitigating factors of underpricing which confirms our hypothesis H2. When adding a variable representing firm age at the time of the IPO, the results show that older firms tend to experience less underpricing than younger firms. In accordance with Ljungqvist (2007) and

Chemmanur (1993) we argue that a firm's ability to prove their business model to the public and the amount of publically available information regarding the company increases with firm age. These factors contribute to reduce ex-ante uncertainty regarding firm value and consequently underpricing.

No support is found for the hypothesis that venture capital and private equity firm backed firms should experience less underpricing in comparison to unbacked firms. In fact, we find that firms sponsored by venture capital firms experience a higher degree of underpricing relative unsponsored firms. This could potentially be explained by the findings presented by Gompers (1996) and Lee and Wahal (2004). In order for young venture capital firms to establish a track record they are willing to underprice the offering if it results in successfully completing the IPO quickly. Furthermore, venture capital firms may use an IPO as a way to recycle the capital tied up in their current portfolio companies. By taking the firm public, they return cash to their investors who are then able to provide capital in subsequent capital raisings. Similar tendencies are found for firms backed by private equity sponsors in our regression model. These tendencies however are not significant.

Finally, our concluding remarks are regarding the joint effects of information production and firm complexity on IPO underpricing. In line with our hypothesis H4 we observe that the negative relationship between the number of underwriters and IPO underpricing diminishes in the face of high firm complexity. The quality of the information produced by the underwriting syndicate is thus adversely affected by higher complexity. Furthermore, we find that complex firms do benefit from including additional underwriting managers in the syndicate, in line with the information production theory. Accordingly, increased firm complexity has a lesser impact on firms with a higher degree of information production. Our findings are thus in line with Corwin and Schultz (2005) and Hu and Ritter (2007) who argue that a greater number of underwriting managers serve to produce better information which consequently reduces ex-ante uncertainty and thereby limits the underpricing in the respective firm.

7. Limitations and future research

As mentioned earlier, we have chosen to focus on indicators of internal complexity as possible explanatory variables for underpricing. It would be interesting for further research to include the effects of external complexity and compare the two to see which has the greatest impact on underpricing.

Furthermore, R&D Intensity, Intangible assets and SIC-codes have been selected as indicators of internal complexity. It might be valuable to add more indicators for complexity such as the length of management road shows and management participation on road shows. However, our applied proxies for complexity are recognized and most commonly utilized in previous research.

Lastly, Habib and Ljungqvist (2001) mention that the level of underpricing can be affected by the extent of issuing firm's promotion of the issue and there exists a trade-off between the level of underpricing and the promotion of the issue. Given this trade-off, it is possible that the optimal allocation of promotion costs and costs incurred due to underpricing results in a level of underpricing which is above that of less complex firms. This might explain our findings that firms exhibiting more complexity generally experience greater underpricing. Although we do not have any support for this claim it would be an interesting area for further research to study the optimal allocation of these costs in accordance with the trade-off theory. It could provide additional insights into the causes of underpricing of complex firms.

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