Underpricing of Venture-backed IPOs: a meta-analytic approach

Listing firms are subject to underpricing mainly because of asymmetries of information, but IPOs backed by a venture capitalist are generally found to be subject to less underpricing. Although this condition is commonly verified by the empirical evidence, a consistent number of studies finds contrasting results. This paper aims to answer to the question: do venture capitalists effectively reduce underpricing at IPO? Evidence provides a negative answer, with venture-backed IPOs having higher underpricing especially in US markets. Meta-regression results confirm the different effect of VC between US and European IPOs. Results overall suggest that other explanations on underpricing might hold in US markets.

Keywords: venture capital, underpricing, IPO, meta-analysis, meta-regression

JEL codes: G24, G10, G32

Introduction

Firms that go public are subject to underpricing: the price set for the issue is generally below the price prevailing on the market right after the IPO. This phenomenon has found several explanations in the theory that mainly relate to asymmetries of information (Benveniste and Spindt, 1989; Ibbotson, 1975; Ibbotson and Ritter, 1995; Rock, 1986; Welch, 1992; Ljungqvist, 2007). Firms that go public are not known to the wide public of investors and their valuation by the market might be uncertain. After having considered firm characteristics and market conditions, underpricing might occur when investors want to be compensated for the uncertainty and the opaqueness of the listing firm, i.e. the higher risk perceived. This results in a "loss" for the issuing firms because setting a lower issue price reduces the amount of resources that companies can collect on the market for their investment purposes (often named "money left on the table").

The amount of information is key in the financial markets and especially on primary stock markets. Indeed, other explanations on underpricing provided by the literature include regulatory arrangements that act to improve transparency of issuers (among others, Johnston and Madura, 2009 and Akyol et al., 2014). But underpricing can persist even in transparent and efficient markets, when considerations on the choice of the underwriter by the issuing company depart from a purely pricing perspective and consider other aspects (such as analysts coverage) that yield the issuers to accept a higher underpricing (Cliff and Denis, 2004; Liu and Ritter, 2011).

Venture capital is often found to be able to reduce underpricing at IPO for companies listing on the market because of its ability to reduce asymmetric information and to convey signals on the quality of the issuing firms. The empirical contributions on this issue are numerous and often provide contrasting evidence, also caused by differences in time periods and geographical area considered by the various studies. It is not therefore fully clear if venture capital (VC) is actually able to limit underpricing at IPO as some studies find, or if this is not the case (as other studies find).

This paper aims to answer the following research question: do VC backed IPOs have a lower underpricing compared to their non-VC backed peers?

To answer this question, we use a meta-analytic framework testing the relationship between the presence of VC at IPO and underpricing, measured on the first days of trading as the percentage change in price from the IPO price (or issue price). To enable better comparability of studies, we focus on papers investigating IPOs taking place in European countries and the US after 2000, published after 2001 and available on Scopus as at February 2019.

This paper relates to the stream of studies on the impact of venture capital on underpricing and fits into the meta-analytic approach to evaluate the results of the empirical contributions. Although two previous meta-analyses on either underpricing or VC backed companies have been provided, respectively, by Daily et al. (2003) and Rosenbusch et al. (2013), we differentiate from these two contributions in two aspects. First of all, we focus on more recent studies (both in terms of sample periods and publishing date) and on European and US markets to provide empirical evidence on the differences between these markets. Second, we differentiate from Daily et al. (2003) given that we specifically study the relationship between VC presence at IPO and underpricing, while the authors investigate the determinants of underpricing in general. We also differentiate from Rosenbusch et al. (2013) because we do not investigate various configurations of performance, but rather focus on underpricing. Additionally, we update their evidence, given that their sample studies are published between 1991 and 2010, while we start from 2001 to include all the further contributions up until 2019. This update might also contribute to shed light on the underpricing phenomenon during the financial and economic crises that broke out in 2008 and that had severe effects on the financial markets.

Results show that on average the effect of VC on underpricing is positive and significant and it is around 4.6%. It seems hence that VC backing provides opposite results than what expected, but this evidence is in turn in line with previous meta-analysis provided on the performance of VC backed companies (with performance variously defined) (Daily et al., 2003; Rosenbusch, 2013) and with the hypothesis that some issuers might be prone to accept higher underpricing in change of higher coverage by analysts.

The most relevant result, nevertheless, appears the difference between US and European IPOs. In fact, the strong significant positive result holds for US, while European IPOs on average have an underpricing that is positive, but not statistically different from zero. Differences in institutional background of the two markets can be a possible explanation for this evidence.

When performing meta-regression, results confirm the differences between US and European IPOs backed by VCs, with the latter experiencing lower underpricing.

The paper is organised as follows. Section 1 reviews the main theories on underpricing and on VC contribution to performance at IPO. Section 2 presents the methodology and the data collection. Section 3 presents the results and the last section concludes.

1. Literature Review

The empirical and theoretical literature has been working on the identification of the determinants of underpricing for decades. Underpricing is computed as the difference between the issue price (or IPO price) and the price prevailing at the end of the first trading day (Ibbotson, 1975; Ibboston and Ritter, 1995; Ljungqvist, 2007; Ritter, 2011); that difference is generally positive, as on average the offering price is set below the price that prevails on the first trading day (or days) (Ibbotson and Ritter, 1995). While it is sufficiently clear and established that underpricing exists and that it represents a “loss” for equity owners that list their company on a stock exchange (often named as “money left on the table” - Ritter, 1987) and that this phenomenon is mainly due to asymmetries of information, it is less established what are the driving forces determining the amount of underpricing (Daily et al., 2003; see also Kennedy et al., 2006 who test for competing theories explaining underpricing).

The main theories involving asymmetry of information can be summarised as follows. The first theory by Rock (1986) models a market with two types of investors, one group made of informed and one made of uninformed investors. According to the author, the uninformed investors would receive their full order only when the issue is overpriced as they are left with the stocks not subscribed by informed investors (the so-called “winner’s curse”). To compensate for this mechanism, offering price may be set at a discounted price than what expected to induce uninformed investors to subscribe the issue. Several researchers have then extended Rock’s setting. Among them, Beatty and Ritter (1986) who include a cost to acquire information for the group of uninformed investors and Carter and Manaster (1990) who further develop on risky IPOs.

Benveniste and Spindt (1989) discuss instead the “costly information hypothesis”. In this case, underpricing exists to enable investment banks to obtain private information by investors during the pre-selling period, when the offer price is set. Cascades also might be related to underpricing: when IPO occurs, some investors have to be induced to buy to induce, in turn, other investors to buy. To induce the first move, the issue has to be underpriced (Welch, 1992).

Asymmetries of information also exist between issuer and investors. In this case, the issuer can send signals to the market to convey the expected value of the firm. Signalling theories also represent a key to understand underpricing (Bhattacharya, 1979; Ross, 1977). Much of the empirical literature using information from IPO prospectus is built on this theory (Daily et al., 2003).

Also market regulation can have a relevant role also in influencing the amount of information available on the markets and, as a consequence, the asymmetries of information that affect underpricing. A stream of literature, in fact, finds that a more prescriptive disclosure regulation on financial information is associated with lower levels of underpricing. Among the studies, Johnston and Madura (2009) evaluate the amount of underpricing of IPO listed in the US after the enactment of Sarbanes-Oxley regulation that increased transparency standards for listed companies. Their findings suggest a positive impact of regulation on the reduction of asymmetries of information and, as a consequence, a reduced underpricing for issuing firms. For the European markets, Akyol et al. (2014) find that IPOs taking place on markets with more stringent governance rules and requirements have on average less underpricing, while when issuers are exempted from governance rules, they experience a higher underpricing, with negative effects on the amount of resources they are able to obtain at IPO. This evidence holds also across countries, as testified by the study by Shi et al. (2013) who analyse the relationship between underpricing at IPO and disclosure requirements in 34 different countries. Evidence suggests that more restrictive requirements are beneficial to IPO in the sense that they reduce underpricing. The same result is achieved by Ekkayokkaya and Pengniti (2012) for Thailand. More recently, Colombo et al. (2019) find that the introduction of regulation in Europe (they call it EU-SOX, given it was inspired by the Sarbanes-Oxley principles) diminishes the benefits of affiliation between issuer and reputable venture capitalists for biotech firms, in line with the hypothesis that the new regulation was able to reduce asymmetries of information on the issuers.

An alternative interesting explanation for underpricing at IPO is related to analysts' coverage. An example is provided by Cliff and Denis (2004). The authors maintain that firms might be interested into underpricing an offer in order to gain attention by the analysts. Starting from the consideration of Dunbar (2000) and Clarke et al. (2002), the authors underline how the coverage by an analyst is a way to increase or maintain the share of IPOs assisted for an investment bank or underwriter. They conclude that IPO firms can purchase analysts' coverage by allowing for higher underpricing at the time of the IPO (Cliff and Denis, 2004). In a more recent contribution, Liu and Ritter (2011) maintain that issuers in a given industry choose their underwriter mainly on the basis of the reputation and the expertise of the underwriter analysts in that industry. In other words, issuers may choose the underwriter and expose themselves to a higher underpricing in order to get more attention by those analysts that are specialised in their industry. In their contribution, the rationale for underpricing is mainly related to non-price arrangements, such as differentiated services provided by the underwriters (among them, coverage) and localised competition. Their hypothesis holds also for VC-backed IPOs, that results more underpriced when they receive more attention by top analysts (all-star analysts).

It has to be recalled, in fact, that the presence of VC is generally believed to act as signal of the good quality of the firm and VC backing at IPO is able to limit underpricing (Gompers, 1996; Jain and Kini, 2000; Belghitar and Dixon, 2012) also because of VCs experience and superior information on the issuer (Barry et al., 1990; da Rin et al., 2013).

The presence of venture capitalists enables, in fact, to limit the asymmetries of information between investors and issuer. This is also because of screening activities performed by venture capitalists that yields them to invest only in the best companies, and monitoring activities that further improve target performance (Megginson and Weiss, 1991). This effect is stronger when venture capitalists retain a relevant portion of stocks after the IPO and continue monitoring the firm (Barry et al., 1990). Venture capitalists are also able to limit underpricing thanks to their relationships with investment banks (Chemmanur and Loutskina, 2006).

Despite the above assumptions and empirical evidence, it is still not univocally agreed if VC backed companies actually show a lower underpricing (da Silva Rosa et al., 2003; Brau et al., 2004; Liu and Ritter, 2011).

As a final remark, it has to be stressed that underpricing can be influenced by other factors that do not depend on VC intervention, such the hot or cold markets, general market characteristics (Ritter and Welch, 2002; Coackley et al., 2009; Bessler and Seim, 2012; Rosenbusch et al., 2013) and several firm characteristics, including firm age, size and industry (for a discussion on this issue, the reader might refer to Engelen and van Essen, 2010).

Given the amount of contrasting evidence, other authors already performed meta-analyses to provide clarification on the issues of underpricing and venture capital contribution. A first contribution worth mentioning is provided by Daily et al. (2003) who specifically focus on IPO underpricing determinants. They investigate 74 paper published between 1986 and 2000 to test the determinants of performance at IPO; among these, the authors also include venture capital equity, that is supposed to act towards a reduction of underpricing from a theoretical standpoint, as already discussed. Nevertheless, they find the opposite result when analysing the impact of VC on the return at IPO and hypothesise that a moderator effect exists and that the impact of VC can be correctly read only when analysed in conjunction with other variables. Additionally, the authors claim that the cyclicality of capital markets may influence the impact of VC on underpricing. With specific reference to VC, again, the authors suggest that a non-linear relationship may hold, thus yielding counterintuitive results in the analyses that do not consider this issue.

The second relevant meta-analysis is by Rosenbusch et al. (2013) who instead focus on venture capital and its impact on firm performance, where performance also includes performance at IPO (measured as underpricing). They analyse 48 studies published (or released) between 1991 and 2010. The authors, in general, find that VC contributes positively to performance (defined broadly as stock market, growth or profitability of companies), but when restricting the sample on the papers including industry effects, the contributions to performance becomes negligible from a statistical point of view.

Our study fits in the stream of literature investigating the relation between VC presence at IPO and underpricing and adds to the literature an important contribution in terms of: i) update of the analysis of the literature, by examining papers published between 2001 and 2019, substantially extending the time span covered by the two previous meta-analyses here cited; ii) clarification and isolation of the contribution of VC to underpricing not as one of the determinants, but as the key relationship to investigate; iii) we present first evidence on a meta-analysis on the differences between the US and the European markets.

2. Data and Methodology

2.1 Data Selection

We selected all the papers available on Scopus as of February 2019 and published after 2001 that have the keyword "underpricing" in the abstract, title or keywords in all the scientific areas. We obtained 914 results. We then selected only the empirical papers that have the following characteristics:

- aim: test the relationship between the presence of venture capital and underpricing at IPO, defined as the percentage change of the price on the first day of trading from the IPO price.
- sample: European countries, and/or US. We excluded studies whose sample have IPOs from other countries, even if they include Europe or US countries, but we retained studies with just one or more European countries or US markets.
- sample period: after 2000. If the sample period starts before the year 2000 and ends after, we included the paper if the median of the sample years in the period considered in the study is higher than 2000.
- type of offering: equity IPOs. We excluded SEO, REITS and mixed papers that do not control only for IPOs.

Additionally, we excluded papers not written in English. We ended up with 40 papers and 43 effect sizes.

2.2 Methodology Used

This study applies meta-analytical methods to quantitatively synthesize empirical evidence for the relationship between venture capital and underpricing. The main purpose of this meta-analysis is to make an appropriate aggregation of 'effect sizes' collected in a sample of studies. An example of effect size is the magnitude and sign of a correlation coefficient concerning a relationship of interest (Hunter & Schmidt, 2014). As noted by various scholars (Dalton & Dalton, 2005; Geyskens et al., 2009), it has become increasingly popular in management and financial research to quantitatively integrate research findings across a large number of studies to examine whether there are prevailing relationships among a set of variables.

In the present analysis we perform a meta-analysis and meta-regression on extracting regression slopes from the selected set of studies (Appendix A contains the full list of these studies). Sometimes in the meta-analytic literature this is somehow criticized because incomparability of different effect sizes (among others, due to different model formulations, different measurements, etc.) is allegedly supposed to exist across studies. The alternative to this is to select studies containing correlation coefficients only and synthesize them. However, the philosophy of meta-analysis is to extract as much information as possible from the selected studies. Moreover, evidence for relationships in economics and finance (and more specifically on the stream of literature we are investigating in this study) is much more retrievable from model coefficients rather than from simple correlation coefficients (correlation matrices are seldom reported in published papers on the topic). Finally, methods to transform regression slopes into partial correlation coefficients are widely used. In fact, problems and critics are much more focused on the side of performing meta-analyses of regression coefficients directly in the meta-analysis synthesis, that is using their values without any transformation to other effect sizes (Becker & Wu, 2007). For these reasons, we focus our attention on regression coefficients and their standard error, t-statistic or p-value. We then transform them into partial correlation coefficients as detailed in appendix B.

In our setting, the coefficient to be extracted is the one expressing the effect of VC on underpricing. In the studies on venture capital, the presence of VC is generally identified through a dummy (1 if the IPO is VC backed and 0 otherwise). Rarer are the studies controlling for the stake of VC in the issuing company, especially on the European

IPOs (because of lower availability of information and more difficulties in retrieving the data).

Commonly studies in banking and finance present a number of specification of the model testing the economic relationship. In this case, we take all the coefficients for the widest sample and average them (see appendix B). In most of the cases, there are no strong variations between coefficients in the same model for the different specifications.

With reference to the meta-regression, coefficients transformed into effect sizes are used as dependent variables and other study characteristics are employed as controls. These include the variables listed in Table 1. As said, underpricing might be affected by other characteristics of the IPO even after controlling for VC. For this reason, we control if the study employs a definition of VC that is binary (UnS) and hence the stake of the VC in the issuing firm is unknown, in line with Barry et al. (1990) who claims that the effect of underpricing reduction for VC backed IPOs is stronger for those companies having a higher share of stocks held by VCs and keep it after the IPO. We also control for industry, age and the US market, to see if these features affect the capability of VCs to reduce asymmetries of information. Finally, we control for the crisis years (we expect higher underpricing for those IPOs taking place during the crisis, given more uncertain market conditions), the length of the study sample period and the median year of the sample period. Finally, we control for the quality of the journal as a proxy for the quality of the study and the potential relevance for the academia.

[Insert Table 2 about here]

3. Results

3.1. Meta-analysis results

Meta-analysis results show that, on average, the size of the coefficient associated with the presence of VC at IPO is 4.6 percent (Table 1). VC backed IPOs show a higher degree of underpricing if compared to other IPOs, in contrast with what predicted by the theory on the role of venture capitalists as signal of the good quality of the company: VC backed companies have worse performance than their peers.

Nevertheless, also Rosenbusch et al. (2013) found that VC backing has a negative effect on performance. In their study, performance is measured through various indicators, including underpricing (performance at IPO). Their results, hence, contrast with the theory that maintains that venture capitalists select better companies and are able to boost their performance.

Our result hence agrees with Rosenbusch et al. (2013) overall evidence and it might be consistent with the literature supporting the analysts' coverage hypothesis. In the latter case, companies would choose investment bankers on the basis of other non-economic factors and this would result in companies being prone to accept lower offer prices (and higher underpricing as a consequence) in order to gain additional coverage by analysts.

We report also the chi-squared test for heterogeneity, the I^2 statistic and the significance test for the effect size. The I^2 statistic is a percentage indicating the degree of the between-study heterogeneity (Higgins & Thompson, 2004; Harris et. al., 2008, p. 8;)[1].

The value of I^2 lies between 0 percent and 100 percent, whereby negative values of I^2 are set to zero. This indicator is easily interpretable: the larger the value of I^2 the more heterogeneity can be observed. Although there is no absolute rule, a suggestive indication is that a low degree of heterogeneity is given when I^2 takes a value between 25 percent and 50 percent, a moderate level is achieved when I^2 is between 50 percent and 75 percent and a high degree of heterogeneity is assumed when I^2 is higher than 75 percent (Harris et. al., 2008, p. 18-19). Table 2 shows a value of I^2 equal to 74.5 percent. The value lies between moderate and high thresholds, but it is indeed close to the higher one.

Figure 1 helps in clarifying the contribution of each study to the final result. The plot indicates whether the coefficient arising from each regression is positive or negative. The grey square indicates the size of the sample (also reported in number on the last right-hand side column), that is the representativeness of the sample included in the study, while the length of the horizontal line expresses the confidence interval (also reported in numbers on the next right-hand side column).

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[1] The I^2 is calculated with the following formula, where Q is the Cochran's heterogeneity statistic and df is the degree of freedom:

$$I^2 = \frac{Q-df}{Q} \times 100\%.$$

The diamond at the bottom of the figure represents the average overall coefficient, that is, the expected overall impact of VC on the underpricing of listing companies.

[Insert Table 2 about here]

[Insert Figure 1 about here]

As it is common in the literature, generally US studies in finance are more common than studies completed on other geographical area and also present different results. As confirmed by a recent survey by Tykvová (2018), despite an increase in the focus on regions different than the US, more than 52% of all empirical studies on venture capital covered by the author are solely based on the US markets. Country and institutional characteristics of the US market makes it an interesting case study, especially in relation to some European countries that are traditionally more bank-centric (with the exception of the UK that in many aspects is more similar to the US). The wide and profound development of US financial markets might affect in a different fashion underpricing and, as a consequence, it might highlight a different role of VC backing in the IPO process.

To highlight if the results are influenced by the presence of US market characteristics and to compare the results with the non-US studies, we differentiate the meta-analysis depending on the geographical origin of the sample (Table 3, Figure 2). Results show that the expected sign is positive and significant for US studies, while it is negative, but not significant for studies focusing on other countries (Table 3).

From a statistical point of view, we might conclude that US studies are the ones weighting the most, and hence the final overall result presented above is influenced mostly by US evidence. Similar conclusions can be drawn from the forest plot (Figure 2), where the first block of studies is for US samples and the second for European ones.

[Insert Table 3 about here]

[Insert Figure 2 about here]

For a more theoretical perspective, the differences between US and non-US studies might be attributed to the different features of these markets. In fact, as said US financial markets are well developed and are often presented as an example of well-functioning financial markets[2]. A presence of positive underpricing for VC backed

[2] Historically, as tracked by the World Bank database (https://data.worldbank.org) in the US market there are more listed companies than in the European ones. Additionally, the weight of the market capitalisation of listed companies on GDP is also higher for the USA than for the European countries. Overall, for the US markets as at 2017 it was around 166%, while for the whole Euro Area it was around 77.89%. The data for the European Union is not available at that date.

companies in this market might hence support the hypothesis of analysts' coverage. Many of the most reputable venture capitalists are located in the US[3]. In case of a US IPO, venture capitalists might not act as signal to the market in reducing underpricing because the latter is not caused mainly by asymmetries of information, but rather by specific choices of the debuting company when selecting the investment bank assisting the IPO.

With reference to non-US studies, instead, we find a negative coefficient. In this case, the presence of VC backing at IPO reduces asymmetries of information and, hence, limits the need to underprice the IPO. Nevertheless, the effect is weak from a statistical standpoint.

Another explanation of the divergence between US and European evidence can be the differences in regulatory environments. As found by several authors (e.g. Johnston and Madura, 2009; Akyol et al., 2014 and Shi et al., 2013), markets with more restrictive rules on transparency show a lower underpricing. This would mean that US markets are less stringent in this sense, but the literature has not provided a definitive answer[4].

Additionally, to better evaluate this statement, we would need to differentiate the effects of VC presence before and after the coming into effect of the single transparency rules. While this could be worth doing, in our setting most of the sample periods include the year of the regulatory changes and it is therefore really hard to discriminate between those IPOs occurring before and those after the regulatory changes in this meta-analysis setting, also because, for instance the European Market Directive (MiFID) is dated 2007 and four European studies in our sample have a period of investigation that ends before 2007. Most of the sample periods for the European studies considered in the meta-analysis, start before 2007 and end after.

As further clarification of the results of each empirical investigation, we also build the funnel plot that shows if there is publication bias. Funnel plots are used to show the bias that might arise when small sample studies with no significant effect remain unpublished, while this would be in fact a result and the relative evidence has to be taken into account when analysing the relationship between the dependent and independent variables (Rosenthal, 1979; Iyengar & Greenhouse, 1988; Duval and Tweedie, 2000 for a discussion of funnel methods). Funnel plots are simple scatterplots of the effect sizes

[3] The vast majority of the top-30 venture capitalists in the ranking provided by CB Insigths (a data provider for the private capital markets) are US VCs. See https://www.cbinsights.com/research/top-venture-capital-partners/. The same holds for the list provided by thefunded.com/ .
[4] See for instance Boskovic et al. (2007) on the differences between the European MiFID and the US National Market System.

estimated from individual studies against a measure of study weight, which in general is the inverse of the standard error of the estimates. Therefore, points representing studies with low weight should scatter widely at the bottom of the graph, whereas points representing studies with high weight should lie at the top of the graph and close to the pooled estimate. If the meta-analysis departs from this situation, then the presence of publication bias is suspected. We see from figure 3 that some studies suffer from publication bias.

Non-US studies are shown as circles and US studies as triangles. As it can be observed, the vast majority of studies lies within the two lines and hence we can conclude that there is no publication bias. Those outside the confidence limits are nevertheless very close: 4 US studies and 2 non-US are above the upper bound, while there are also 1 US and 3 non-US studies slightly below the lower bound limit.

Despite this evidence, it has to be noted that the bias might be due to other factors[5]. For instance, we also tested for the so-called small-study bias, that is the presence of systematic differences in the results of large and small studies caused by confounding factors such as differential study quality. The Egger's test (Egger et al., 1997) for small study bias resulted not significant and therefore no small-study bias was present.

[Insert figure 3 about here]

3.2. Meta-regression results

Meta-regression is performed controlling for several study characteristics, described in Table 1. The choice of variables is determined by the level of details provided in the study and by the use of a common set of variables. In fact, while it would be interesting to use a continuous variable to check for the effect of age, most of the studies do not provide a detailed description of the variable employed. This applies also to industry-specific effects, as some studies indicate the model tests for industry fixed effect, without specifying how many industry dummies are introduced in the model.

Additionally, we initially test and then drop the dummy (UnS) for the studies that simply control for the presence of VC at IPO, without providing any more detailed information on the relative weight or importance of the venture capitalist as stakeholder in the company (for instance, measuring the percentage of shares held or the

[5] See Sterne and Egger (2001) for a discussion on asymmetric bias in funnel plots.

countervalue). We drop the variable because most of the studies do not employ the explicit stake of VC but just the dummy, and this improves the significance of the linear model.

Finally, as JCR and SJR are highly correlated (86 percent), we use them one at a time. For the sake of synthesis, we present only results for SJR as this has a wider coverage of journals. Results do not change substantially.

Results are summarised in Table 4. Evidence shows a significant effect of US studies. This implies that studies using the US as sample area yield a greater effect size, i.e. the coefficient linked to VC impact on underpricing is positive and higher than for non-US samples. This is in accordance with the results of the meta-analysis. In some specifications, also industry takes positive and significant sign, suggesting that when studies control for industry, the effect is larger (VC backed IPOs have larger underpricing).

Evidence provides hints for the evaluation of the effect of VC presence at IPO, suggesting that the ability of VC to limit underpricing does not emerge for US markets. On this markets, alternative explanations for underpricing of VC-backed IPOs could be valid, in line with evidence provided by Colombo et al. (2019) and Liu and Ritter (2011) among others. As further research hints, it would be interesting to evaluate if and how companies listing on US market are different (in size, industry, age) than the average company listing in Europe, where markets (with UK exception) are less mature. But, when controlling for other study characteristics, such as age, IPO years, etc., no striking significant effect emerges.

[Insert Table 4 about here]

4. Conclusions

This study evaluates the empirical evidence on the effect of the presence of a venture capitalist at IPO on the performance of the first trading day. The latter is commonly found to be high and positive, generating the so-called underpricing and producing a negative effect on the amount of resources that listing companies are able to collect on the markets. VC backed companies are believed to be subject to less underpricing because of the signalling presence of the venture capitalist. Nevertheless, other theoretical explanations also provide support for positive underpricing, when companies listing on a stock exchange choose their investment bankers according to criteria beyond the economic conditions of the issue. For instance, they might choose a reputable financial intermediary for the coverage that its analysts provide. In this case, the presence of VC would not be helpful in reducing underpricing.

In some empirical studies VC eventually appears to increase the amount of money left on the table. As it would probably be unfeasible to retrieve data for all the studies performed on this topic to control for the overall effect of VC at IPO, we investigate the effect of the presence of a VC at IPO on performance using a meta-analytic framework. We focus on papers on VC backed IPOs taking place on European and US markets since 2001 to find if the relationship arising from the studies is negative, as predicted by the theories, that is VC backing limits underpricing. Departing from previous meta-analytic studies (Daily et al., 2003 and Rosenbusch et al., 2013), we focus on more recent studies that specifically investigate the link between the presence of VC at IPO and underpricing.

Results show that on average VC backing increases underpricing. The effect is in contrast with what predicted by the theories on the ability of venture capitalists to reduce asymmetries of information for issuing companies. The evidence is however consistent with the hypothesis of "analysts coverage" developed by the literature. Additionally, it agrees with previous results provided in the literature (Daily et al., 2003; Rosenbusch et al., 2013) that propose the existence of a non-linear relationship between the two variables or that other factors influence the size effect.

Country and institutional features can severely affect underpricing and the effectiveness of VC backing at IPO. To check for this, we isolate the US studies and find that on average, companies listing in US markets backed by VC have a higher underpricing than their peers. European ones, instead, show a slightly negative coefficient, which however has no statistical significance. Results on the overall sample are hence influenced by the effect sizes of US studies.

When proceeding with the meta-regression, we find again that US samples drive substantially the results towards a positive and higher underpricing for VC backed IPOs. Among the other variables, only the variable "industry" shows seldom statistical significance.

Evidence provided by this study supports the view that VC is not always beneficial to underpricing, especially if companies choose their advisors and counterparts in the IPO process according to other criteria. Additionally, specific institutional features, such as regulatory differences in the level of transparency requested on the financial markets between countries, might be able to affect underpricing. These two aspects appear to be interesting hints for future research.

References

*Akyol, A. C., Cooper, T., Meoli, M., & Vismara, S. (2014). Do regulatory changes affect the underpricing of European IPOs?. Journal of Banking & Finance, 45, 43-58.

*Alhadab, M. M. (2016). IPO underpricing and audit quality: Evidence from the alternative investment market in the UK. Corporate Board: Role, Duties and Composition, 104.

*Bajo, E., & Raimondo, C. (2017). Media sentiment and IPO underpricing. Journal of Corporate Finance, 46, 139-153.

*Banerjee, S., Güçbilmez, U., & Pawlina, G. (2016). Leaders and followers in hot IPO markets. Journal of Corporate Finance, 37, 309-334.

Barry, C. B., Muscarella, C. J., Peavy, J. W., & Vetsuypens, M. R. (1990). The role of venture capital in the creation of public companies: Evidence from the going-public process. Journal of Financial Economics, 27(2), 447-471.

Beatty, R. P., & Ritter, J. R. (1986). Investment banking, reputation, and the underpricing of initial public offerings. Journal of financial economics, 15(1-2), 213-232.

Becker, B.J., & Wu, M.J. (2007). The synthesis of regression slopes in meta-analysis. Statistical Science, 22(3), 414–429.

Belghitar, Y., & Dixon, R. (2012). Do venture capitalists reduce underpricing and underperformance of IPOs?. Applied Financial Economics, 22(1), 33-44.

*Bennouri, M., Falconieri, S., & Kooli, M. (2017). Single versus multiple banking: lessons from initial public offerings. The European Journal of Finance, 23(10), 841-858.

*Benson, D. F., Brau, J. C., Cicon, J., & Ferris, S. P. (2015). Strategically camouflaged corporate governance in IPOs: Entrepreneurial masking and impression management. Journal of Business Venturing, 30(6), 839-864.

Benveniste, L. M., & Spindt, P. A. (1989). How investment bankers determine the offer price and allocation of new issues. Journal of Financial Economics, 24(2), 343-361.

Bessler, W., & Seim, M. (2012). The performance of venture-backed IPOs in Europe. Venture Capital, 14(4), 215-239.

Bhattacharya, S. (1979). Imperfect information, dividend policy, and “the bird in the hand” fallacy. Bell journal of economics, 10(1), 259-270.

*Boeh, K. K., & Dunbar, G. (2016). Underwriter deal pipeline and the pricing of IPOs. Journal of Financial Economics, 120(2), 383-399.

*Boone, A. L., Floros, I. V., & Johnson, S. A. (2016). Redacting proprietary information at the initial public offering. Journal of Financial Economics, 120(1), 102-123.

Boskovic, T., Cerruti, C., & Noel, M. (2009). Comparing European and US securities regulations: MiFID versus corresponding US regulations. The World Bank.

*Bradley, D., Kim, I., & Krigman, L. (2015). Top VC IPO underpricing. Journal of Corporate Finance, 31, 186-202.

Brau, J. C., Brown, R. A., & Osteryoung, J. S. (2004). Do Venture Capitalists Add Value to Small Manufacturing Firms? An Empirical Analysis of Venture and Nonventure Capital-Backed Initial Public Offerings. Journal of Small Business Management, 42(1), 78-92.

*Brau, J. C., Cicon, J., & McQueen, G. (2016). Soft strategic information and IPO underpricing. Journal of Behavioral Finance, 17(1), 1-17.

*Bruton, G. D., Chahine, S., & Filatotchev, I. (2009). Founders, private equity investors, and underpricing in entrepreneurial IPOs. Entrepreneurship Theory and Practice, 33(4), 909-928.

*Capizzi, V., Giovannini, R., & Pesic, V. (2011). Does Corporate Governance really matter for firms performance? Evidence from Italian IPOs market. Corporate Ownership and Control, 9(1 G), 569-586.

Carter, R., & Manaster, S. (1990). Initial public offerings and underwriter reputation. The Journal of Finance, 45(4), 1045-1067.

*Chahine, S., Filatotchev, I., & Zahra, S. A. (2011). Building perceived quality of founder-involved IPO firms: Founders' effects on board selection and stock market performance. Entrepreneurship Theory and Practice, 35(2), 319-335.

*Chahine, S., & Filatotchev, I. (2011). The effects of corporate governance and audit and non-audit fees on IPO Value. The British Accounting Review, 43(3), 155-172.

*Chahine, S., & Goergen, M. (2011). The two sides of CEO option grants at the IPO. Journal of Corporate Finance, 17(4), 1116-1131.

Chemmanur, T. J., & Loutskina, E. (2006). The role of venture capital backing in initial public offerings: certification, screening, or market power?.

*Chemmanur, T. J., Hu, G., & Huang, J. (2010). The role of institutional investors in initial public offerings. Review of Financial Studies, 23(12), 4496-4540.

Chua, A. & Nasser, T., (2016). Insider sales in IPOs: Consequences of liquidity needs, Journal of Corporate Finance, Elsevier, vol. 39(C), pages 1-17.

Clarke, J., Dunbar, C. G., & Kahle, K. M. (2002). All-star analyst turnover, investment bank market share, and the performance of initial public offerings.

Cliff, M.T., Denis, D.J. (2004). Do Initial Public Offering Firms Purchase Analyst Coverage with Underpricing? The Journal of Finance, 59(6), 2871-2901.

Coakley, J., Hadass, L., & Wood, A. (2009). UK IPO underpricing and venture capitalists. The European Journal of Finance, 15(4), 421-435.

Colombo, M.G., Meoli, M., Vismara, S., 2019. Signaling in science-based IPOs: The combined effect of affiliation with prestigious universities, underwriters, and venture capitalists. Journal of Business Venturing 34, 141–177.

*Cole, R. A., Floros, I. V., & Ivanov, V. I. (2018). US exchange upgrades: Reducing uncertainty through a two-stage IPO. Journal of Financial Intermediation.

da Rin, M., Hellman, T.F., & Puri M. (2013). A survey of venture capital research. In Constantinides G., Harris M., Stulz R. (eds.), 2013, Handbook of the Economics of Finance, Volume 2, Part A, Chapter 8, 573–648.

da Silva Rosa, R., Velayuthen, G., & Walter, T. (2003). The sharemarket performance of Australian venture capital-backed and non-venture capital-backed IPOs. Pacific-Basin Finance Journal, 11(2), 197-218.

Daily, C. M., Certo, S. T., Dalton, D. R., & Roengpitya, R. (2003). IPO underpricing: A meta-analysis and research synthesis. Entrepreneurship Theory and Practice, 27(3), 271-295.

Dalton, D. R., & Dalton, C.M. (2005). Strategic Management Studies are a Special Case for Meta-Analysis, in David J. Ketchen, Donald D. Bergh (ed.) Research Methodology in Strategy and Management, Vol. 2, Emerald Group Publishing Limited, 31 – 63.

Dunbar, C.G. (2000). Factors affecting investment bank initial public offering market share. Journal of Financial Economics 55, 3–41.

Duval, S. & Tweedie, R. (2000). Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. Biometrics 56 , 455-463

Egger, M., Davey-Smith, G., Schneider, M. & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. British Medical Journal, 315: 629–634.

Ekkayokkaya, M., Pengniti, T. (2012). Governance reform and IPO underpricing. Journal of Corporate Finance 18, 238–253.

Engelen, P. J., & van Essen, M. (2010). Underpricing of IPOs: Firm-, issue-and country-specific characteristics. Journal of Banking & Finance, 34(8), 1958-1969.

*Falconieri, S., & Tastan, M. (2018). The role of admission documents on the pricing of UK fixed priced IPOs. Economics Letters, 173, 44-46.

*Ferretti, R., & Meles, A. (2011). Underpricing, wealth loss for pre-existing shareholders and the cost of going public: the role of private equity backing in Italian IPOs. Venture Capital, 13(1), 23-47.

Field, A.P. (2001). Meta-analysis of correlation coefficients: a Monte-Carlo comparison of fixed- and random-effects methods. Psychological Methods 6(2), 161–180.

*Geranio, M., Mazzoli, C. & Palmucci, F. (2017). The effects of affiliations on the initial public offering pricing, International Review of Economics & Finance, 51, 295-313.

Geyskens, I., Krishnan, R., Steenkamp, J.B. & Cunha, P. V. (2009). A Review and Evaluation of Meta-Analysis Practices in Management Research, Journal of Management, 35(2), 393-419.

Gompers, P. A. (1996). Grandstanding in the venture capital industry. Journal of Financial economics, 42(1), 133-156.

*Gounopoulos, D., Kallias, A., Kallias, K., & Tzeremes, P.G. (2017), Political money contributions of U.S. IPOs, Journal of Corporate Finance, 43, 19-38

*Guo, Y., Wang, T., Seng, J.-L., & Hung, S.-S. (2017). The effect of disclosure patterns of risk factors in prospectus on the relation between strategic alliances and underpricing of biotechnology IPOs. Journal of Applied Business Research, 33(3), 509-520.

*Hanley, K. W., & Hoberg, G. (2010). The information content of IPO prospectuses. Review of Financial Studies, 23(7), 2821-2864.

*Hanley, K. W., & Hoberg, G. (2012). Litigation risk, strategic disclosure and the underpricing of initial public offerings. Journal of Financial Economics, 103(2), 235-254.

*Harris, O. (2018). The impact of industrial districts on the pricing of IPOs. The Quarterly Review of Economics and Finance, 69, 274-285.

Harris, R.J., Bradburn, M.J., Deeks, J.J., Harbord, R.M., Altman, D.G. & Sterne, J.A. (2008). metan: fixed- and random-effects meta-analysis. The Stata Journal, Vol. 8, No. 1, pp. 3-28

Hedges, L.V., & Olkin, I. (1985). Statistical Methods for Meta-Analysis. Academic Press, Inc.: Orlando, FL.

Higgins, J.P.T. & Thompson, S.G. (2004). Controlling the risk of spurious findings from meta-regression. Statistics in Medicine 23: 1663–1682.

*Hoque, H. (2014). Role of asymmetric information and moral hazard on IPO underpricing and lockup. Journal of International Financial Markets, Institutions and Money, 30, 81-105.

Hunter, J.E., & Schmidt, F.L. (2014). Methods of Meta-Analysis: Correcting Error and Bias in Research Findings (3rd ed.). Sage: Thousand Oaks, CA

Ibbotson, R. G. (1975). Price performance of common stock new issues. Journal of financial economics, 2(3), 235-272.

Ibbotson R.G., & Ritter J.R., (1995), Initial Public Offerings, chapter 30, 993-1016, in Jarrow R. et al, Eds, Handbook in OR & MS, vol. 9.

Iyengar, S. and Greenhouse, J. B. (1988). Selection models and the file drawer problem. *Statistical Science* 3: 109–135.

Jain, B. A., & Kini, O. (2000). Does the presence of venture capitalists improve the survival profile of IPO firms?. Journal of Business Finance & Accounting, 27(9-10), 1139-1183.

Johnston, J., Madura, J. (2009). The pricing of IPOs post-Sarbanes–Oxley. Financial Review 44, 291–310

*Johnson, W. C., & Sohl, J. E. (2012). Initial public offerings and pre-IPO shareholders: angels versus venture capitalists. Journal of Developmental Entrepreneurship, 17(04), 1250022.

Kennedy, D. B., Sivakumar, R., & Vetzal, K. R. (2006). The implications of IPO underpricing for the firm and insiders: Tests of asymmetric information theories. Journal of Empirical Finance, 13(1), 49-78.

*Krigman. L, & Jeffus, W. (2016). IPO pricing as a function of your investment banks' past mistakes: The case of Facebook. Journal of Corporate Finance, 38, 335-344.

Li, B., & Liu, Z. (2017). The oversight role of regulators: evidence from SEC comment letters in the IPO process. Review of Accounting Studies, 22(3), 1229-1260.

Liu, X., Ritter, J.R. (2011). Local underwriter oligopolies and IPO underpricing. Journal of Financial Economics, 102, 579–601.

Ljungqvist, A. (2007). IPO underpricing, Handbook of corporate finance: Empirical corporate finance, 1, pp. 375-422.

*Matanova, N., Steigner, T., Yi, B., & Zheng, Q. (2018). Going concern opinions and IPO pricing accuracy. Review of Quantitative Finance and Accounting, 1-44.

Megginson, W. L., & Weiss, K. A. (1991). Venture capitalist certification in initial public offerings. The Journal of Finance, 46(3), 879-903.

*Migliorati, K., & Vismara, S. (2014). Ranking underwriters of european ipos. European Financial Management, 20(5), 891-925.

*Mogilevsky, V., & Murgulov, Z. (2012). Underpricing of private equity backed, venture capital backed and non-sponsored IPOs. Investment Management and Financial Innovations, 9(3), 47-59.

*Morricone, S., Munari, F., Oriani, R., & de Rassenfosse, G. (2017). Commercialization Strategy and IPO Underpricing. Research Policy, 46(6), 1133-1141.

*Park, H. D., & Patel, P. C. (2015). How Does Ambiguity Influence IPO Underpricing? The Role of the Signalling Environment. Journal of Management Studies, 52(6), 796-818.

*Pennacchio, L. (2013). The role of venture capital in Italian IPOs. Economics Bulletin, 33(4), 2528-2539.

*Pennacchio, L. (2014). The causal effect of venture capital backing on the underpricing of Italian initial public offerings. Venture Capital, 16(2), 131-155.

*Qing, H. (2011). Securities litigation, withdrawal risk and initial public offerings. Journal of Corporate Finance, 17(3), 438-456.

Rindquist, E. (2013). Meta-Analysis for Public Management and Policy. Wiley.

Ritter, J. R. (1987). The costs of going public. Journal of Financial Economics, 19(2), 269-281.

Ritter, J. R. (2011). Equilibrium in the initial public offerings market. Annual Review of Financial Economics, 3(1), 347-374.

Ritter, J. R. and Welch, I. (2002), A Review of IPO Activity, Pricing, and Allocations. The Journal of Finance, 57: 1795–1828. doi:10.1111/1540-6261.00478

Rock, K. (1986). Why new issues are underpriced. Journal of financial economics, 15(1-2), 187-212.

Rosenbusch, N., Brinckmann, J., & Müller, V. (2013). Does acquiring venture capital pay off for the funded firms? A meta-analysis on the relationship between venture capital investment and funded firm financial performance. Journal of Business Venturing, 28(3), 335-353.

Rosenthal, R. (1979). The ‘file drawer problem’ and tolerance for null results. Psychological Bulletin.

Ross, S. (1977). The Determinants of Financial Structure: The Incentive Signaling Approach. Bell Journal of Economics, 8(1), 23-40.

Shi, C., Pukthuanthong, K., Walker, T. (2013). Does disclosure regulation work? Evidence from international IPO markets. Contemporary Accounting Research 30, 356–387.

*Song, K., Choi, Y. S., & Lee, J. E. (2012). Revisiting The Certifying Role Of Financial Intermediaries On IPOs. Journal of Applied Business Research (JABR), 28(5), 1017-1034.

Stanley, T.D, & Jarrell S.B. (1989). Meta-regression analysis: a quantitative method of literature surveys, Journal of Economic Surveys 19(3), 299–308.

Sterne, J. A., & Egger, M. (2001). Funnel plots for detecting bias in meta-analysis: guidelines on choice of axis. Journal of clinical epidemiology, 54(10), 1046-1055.

Tykvová, T. (2018). Venture capital and private equity financing: an overview of recent literature and an agenda for future research. Journal of Business Economics, 88(3-4), 325-362.

*Wang, X. A., & Wan, W. P. (2013). Explaining the Variance in Underpricing among Venture Capital-Backed IPOs: A Comparison Between Private and Corporate VC Firms. Strategic Entrepreneurship Journal, 7(4), 331-342.

Welch, I. (1992). Sequential sales, learning, and cascades. The Journal of finance, 47(2), 695-732.

** indicates the papers included in the meta-analysis and meta-regression.*

Tables

Table 1: variables used in the meta-regression and their brief description

Variable name	**Description**
(UnS) Unknown Stake	A dummy equal to 1 for those studies for which the stakes of VC is not known, i.e. for the studies that do not verify the countervalue or the weight of the VC presence in the capital of the VC-backed firm, that commonly use a binary variable to check for VC presence at IPO
Industry	A dummy equal to 1 if the study controls for industry effects
Age	A dummy equal to 1 if the study controls for the age of firms at IPO
US	A dummy equal to 1 for US samples
Crisis	A dummy identifying studies that include the years from 2007 onwards
Length	Length of sample period, in years
Median	Median of sample period
SJR	Score obtained by the Scientific Journal Ranking – Scimago. If the journal is not available in the ranking, the value of the variable is 0
JCR	Score obtained by the Journal Citation Report – Web of Science. If the journal is not available in the ranking, the value of the variable is 0

Table 2: meta-analysis results and effect sizes for all the studies considered

Study	**ES**	**95% confidence interval**		**Weight (%)**
1	0.093	0.047	0.138	3.400
2	0.063	-0.006	0.131	1.510
3	-0.016	-0.048	0.016	6.720
4	-0.219	-0.366	-0.072	0.330
5	-0.006	-0.037	0.026	6.900
6	-0.236	-0.376	-0.096	0.360
7	-0.219	-0.366	-0.072	0.330
8	0.011	-0.020	0.041	7.640
9	-0.053	-0.172	0.066	0.500
10	-0.052	-0.154	0.049	0.680
11	0.029	-0.082	0.140	0.570
12	0.037	-0.057	0.131	0.790
13	0.005	-0.062	0.071	1.580
14	-0.144	-0.308	0.020	0.260
15	-0.228	-0.390	-0.066	0.270
16	0.095	0.048	0.142	3.200
17	0.077	0.028	0.126	2.960
18	0.060	0.018	0.102	4.000
19	0.142	0.066	0.218	1.210
20	0.025	-0.023	0.073	3.000
21	0.018	-0.030	0.067	3.000
22	0.008	-0.091	0.107	0.720
23	-0.036	-0.152	0.080	0.520
24	0.113	-0.063	0.289	0.230
25	0.126	-0.050	0.302	0.230
26	-0.061	-0.158	0.036	0.740
27	0.061	0.018	0.104	3.840
28	0.152	0.088	0.216	1.700
29	0.060	-0.033	0.153	0.810
30	0.151	-0.022	0.325	0.230
31	0.109	-0.087	0.305	0.180
32	0.186	0.109	0.262	1.200
33	0.116	0.028	0.204	0.910
34	0.056	0.012	0.100	3.650
35	0.075	-0.103	0.252	0.220
36	0.088	-0.013	0.188	0.690
37	0.046	0.002	0.090	3.700
38	0.121	0.048	0.194	1.310
39	0.076	0.048	0.103	9.160
40	0.141	0.036	0.246	0.640
41	0.052	0.029	0.075	13.240
42	0.080	0.039	0.122	4.110
43	0.060	0.010	0.111	2.740
I-V pooled ES	**0.046**	0.037	0.054	100.000

Heterogeneity chi-squared=164.98(d.f.=42)p=0
I-squared (variation in ES attributable to heterogeneity) = 74.5%
Test of ES=0 : z= 10.71 p = 0.000

Table 3: meta-analysis differentiating between US and non-US studies.

Sample	Number of studies	Number of effect sizes	ES	95 percent Confidence Interval		percent Weight
US						
I-V pooled ES	28	29	0.060	0.051	0.0570	80.09
non-US	13	14				
I-V pooled ES			-0.012	-0.031	0.007	19.91
Significance test(s) of ES=0						
US		z= 12.59		p = 0.000		
non-US		z= 1.26		p = 0.209		
Overall		z= 10.71		p = 0.000		

Only summary statistics per group of studies are reported.

Table 4: meta-regression results using the effect size as dependent variable and study characteristics as explanatory variables

Variable	Model 1		Model 2		Model 3		Model 4	
sjr	0.003		0.003		0.003			
UnS	-0.049							
Industry	0.041		0.054	*	0. 053		0.052	*
Age	-0.074		-0.087		-0.086		-0.078	
US	0.069	**	0.087	***	0.087	***	0.093	***
Crisis	0.025		0.012		0.014		0.005	
Median	0.002		0.005		0.004		0.005	
Length	-0.000		0.00					
Constant	-4.397		-9.70		-8.886		-9.230	
N	40		43		43		43	
Adj R^2	29.67%		37.30%		42.68%		44.80%	
F Stat	1.68		2.48		2.97		3.43	

In the table, *, ** and * indicate, respectively, significance at 10%, 5% and 1%.**

Figures

Figure 1: forest plot of the studies that show the coefficient for the VC effect on underpricning and the confidence level of the coefficient.

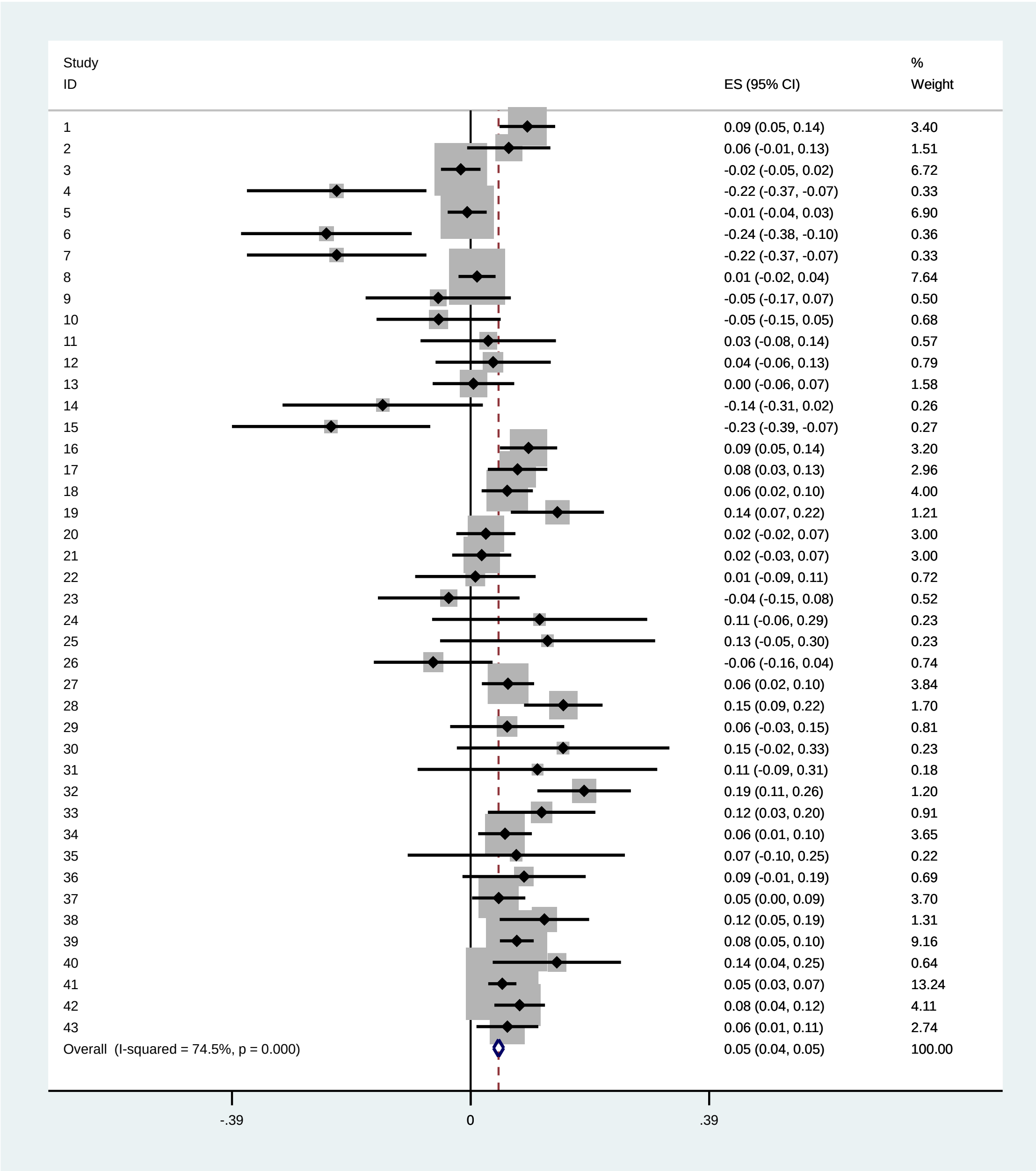


Figure 2: forest plot differentiating between non-US (upper part) and US (lower part) studies that show the coefficient for the VC effect on underpricning and the confidence level of the coefficient.

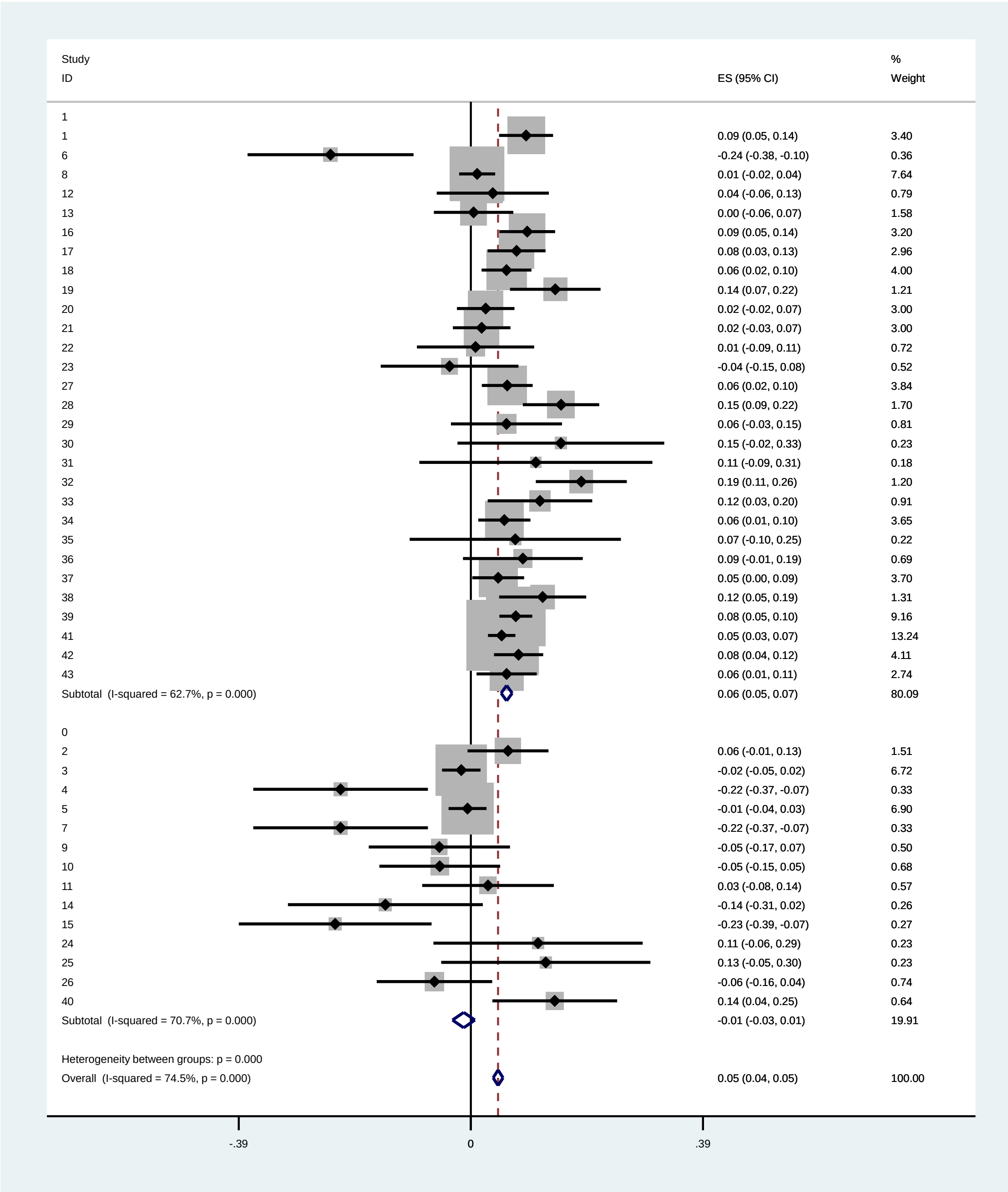
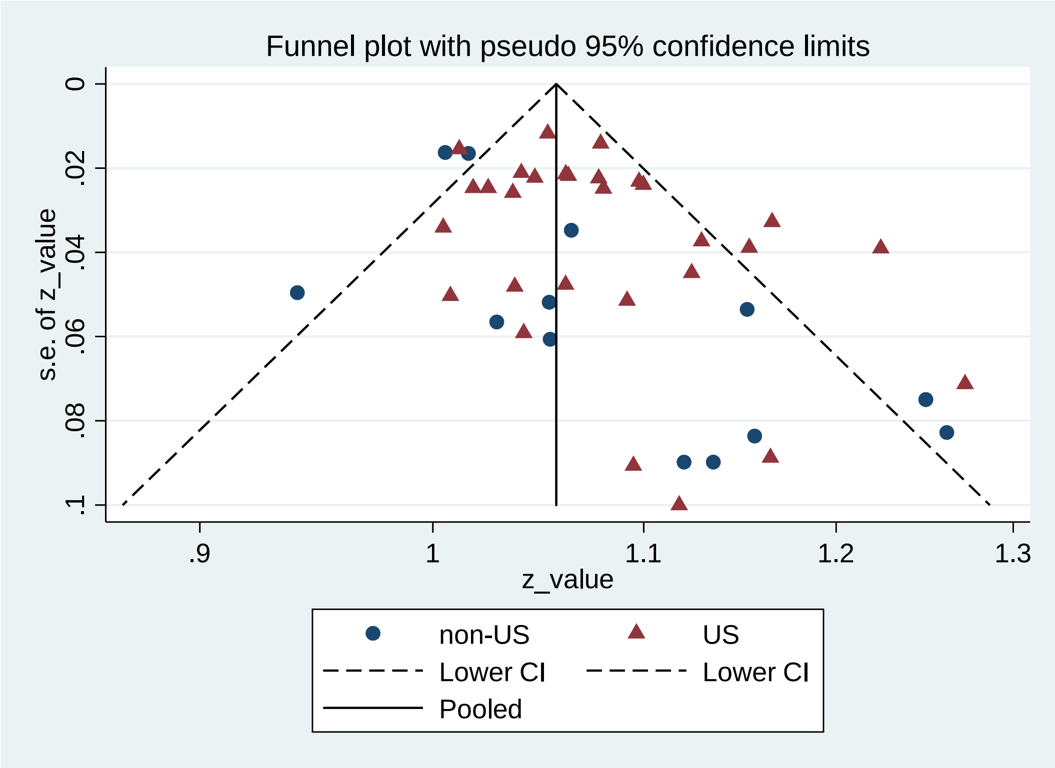


Figure 3: funnel plot with US studies (red triangles) and non-US studies (blue dots) that investigates the presence of small sample study bias.



Appendix A

Table a1: List of papers (ordered alphabetically and according to the publishing year) used for the meta-analysis with main characteristics on sample and period of study.

N	Authors	Year	Sample area	Sample period begins	Sample period ends
1	Bruton et al.	2009	UK	2000	2003
3	Chemmanur et al.	2010	US	1999	2004
4	Hanley & Hoberg	2010	US	1996	2005
5	Capizzi et al.	2011	Italy	1998	2008
6	Chahine & Filatotchev	2011	UK	1999	2003
7	Chahine & Goergen	2011	US	1997	2004
2	Chahine et al.	2011	UK	2000	2003
8	Ferretti & Meles	2011	Italy	1998	2008
9	Qing	2011	US	1996	2005
10	Hanley & Hoberg	2012	US	1996	2005
11	Johnson & Sohl	2012	US	2001	2007
12	Mogilevsky & Murgulov	2012	US	2000	2009
13	Song et al.	2012	US	2000	2011
14	Pennacchio	2013	Italy	1999	2012
15	Wang & Wan	2013	US	2000	2007
16	Akyol et al.	2014	Europe	1998	2012
17	Hoque	2014	UK	1999	2006
18	Migliorati & Vismara	2014	France, Germany, Italy, UK	1995	2010
19	Pennacchio	2014	Italy	1999	2012
20	Benson et al.	2015	US	1995	2011
21	Bradley et al.	2015	US	1994	2011
22	Park & Patel	2015	US	1998	2007
23	Alhadab	2016	UK	1998	2008
24	Banerjee et al.	2016	US	1975	2012
25	Boeh & Dunbar	2016	US	2002	2013
26	Boone et al.	2016	US	1996	2011
27	Brau et al.	2016	US	1996	2008
28	Chua & Nasser	2016	US	1997	2010
29	Krigman & Jeffus	2016	US	2008	2013
30	Bajo & Raimondo	2017	US	1995	2013
31	Bennouri et al.	2017	US	1998	2008
32	Geranio et al.	2017	US	1997	2010
33	Gounopoulos et al.	2017	US	2005	2011
34	Guo et al.	2017	US	1997	2012
35	Li & Liu	2017	US	1998	2013
36	Morricone et al.	2017	US	1996	2007
37	Falconieri & Tastan	2018	UK	2004	2012
38	Harris	2018	US	1990	2016
39	Matanova et al.	2018	US	2001	2012
40	Cole et al.	2019	US	1996	2013

Appendix B

Consider for simplicity (the extension to other types of models is straightforward) a multiple linear regression model of the form:

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k + \cdots \beta_p X_p + \epsilon \qquad \text{(eq. 1)}$$

and suppose that for a given study we have to convert the estimate $\hat{\beta}_k$ into the partial correlation coefficient for the variables X_k, r_{YX_k}. Suppose that together with the value of this estimate we have also its standard error $SE_{\hat{\beta}_k}$, or the correspondent t-statistic $t_{\hat{\beta}_k}$, or, directly, the p-value $p_{\hat{\beta}_k}$. Suppose also that we have the overall degrees of freedom $d = n - p - 1$ (n is the number of observations, p the number of independent variables). Then the partial correlation coefficient is obtained as follows.

- Partial correlation coefficient when coefficient estimates with their standard errors are extracted. In this case, we have:

$$r_{YX_k} = \sqrt{\frac{\left(\frac{\hat{\beta}_k}{SE_{\hat{\beta}_k}}\right)^2}{\left(\frac{\hat{\beta}_k}{SE_{\hat{\beta}_k}}\right)^2 + d}} \text{ (eq. 2).}$$

The sign of $r_{YX_k}$is the same of the regression coefficient.

- Partial correlation coefficient when exact *p*-values are extracted (Thompson et al., 2011).

In this case, the normality assumption is assumed, and therefore the *z*-score corresponding to the *p*-value is computed.

- Partial correlation coefficient when t-statistics are extracted. Similarly to (2) in this case we have:

$$r_{YX_k} = \sqrt{\frac{\left(t_{\hat{\beta}_k}\right)^2}{\left(t_{\hat{\beta}_k}\right)^2 + d}} \text{ (eq. 3).}$$

- Coefficient estimates with their significance levels.

In this case, following Rindquist (2013), we set $t_{\hat{\beta}_k}$ equal to the value of the *t*-statistic corresponding to the significance threshold and given degrees of freedom. For example, if an original study reports $\hat{\beta}_k = 1.5$ with $n = 54$, $p = 3$ and a (two-sided) significance level given by $**p < 0.05$, we get $t = 2.01$, that is the t value corresponding to $p = 0.05$. Then we use formula (3) to get the partial correlation coefficient. If a parameter estimate is reported not significant (with no other information than its value), we simply set $r_{YX_k} = 0$. This assumption is quite restrictive and tends to over-represent 0-valued partial correlation coefficients in the overall results.

The following pooling exercise to meta-analyse the partial correlation coefficients is performed through a random-effect analysis, according to the following steps. First, each r_{YX_k} is converted into a Fisher-transformed *z*-score:

$$z_{r_{YX_k}} = \frac{1}{2} ln\left(\frac{\left(1+r_{YX_k}\right)}{\left(1-r_{YX_k}\right)}\right) \text{ (eq. 4)},$$

which has an approximate normal distribution with standard error $SE\left(z_{r_{YX_k}}\right) = \sqrt{\frac{1}{n-3}}$ (eq. 5).

Second, each computed $z_{r_{YX_k}}$ is averaged across studies with weight w equal to:

$$w = \frac{1}{SE\left(z_{r_{YX_k}}\right)+\hat{v}} \text{ (eq. 6)}$$

where $\hat{v}$ is the estimated random-effect variance (see Field, 2001 or Hedges & Olkin, 1985).

The final average $\bar{z}_{r_{YX_k}}$ is obtained as a weighted average of the values of $z_{r_{YX_k}}$ computed for each estimate in the studies.

After this pooling exercise, the Fisher transform average $\bar{z}_{r_{YX_k}}$ is back-transformed to the average of the partial correlation coefficients by using the inverse of (4).

As for the meta-regression analysis, we use a standard meta-regression model as follows (Stanley & Jarrell, 1989):

$$r_{YX_k,i} = \beta_0 + \sum_{k=1}^{K} \beta_k D_{ik} + \varepsilon_i \text{ (eq. 7)}$$

where $r_{YX_k,i}$ is the effects size in study i, ($i = 1,\ldots, n$), D_{ik} are K variables for study characteristics, and ε_i is an error term.