The Price of Rapid Exit in Venture Capital-backed IPOs*

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Abstract

This paper proposes an explanation for two empirical puzzles surrounding initial public offerings (IPOs). Firstly, it is well documented that IPO underpricing increases during 'hot issue' periods. Secondly, venture capital (VC) backed IPOs are less underpriced than non venture capital backed IPOs during normal periods of activity, but the reverse is true during hot issue periods: VC backed IPOs are more underpriced than non VC backed ones. This paper shows that when IPOs are driven by the initial investor's desire to exit from an existing investment in order to finance a new venture, both the value of the new venture and the value of the existing firm to be sold in the IPO can be signaled by the investor's choice of underpricing and fraction of shares sold in the IPO. When this is the case, the availability of attractive new ventures increases equilibrium underpricing, which is what we observe during hot issue periods. Moreover, I show that underpricing as a signal is affected by the severity of the moral hazard problem between an investor and the firm's manager. In the presence of a moral hazard problem the degree of equilibrium underpricing is more sensitive to changes in the value of the new venture. This can explain why venture capitalists, which often finance firms with more severe moral hazard problems, underprice IPOs less in normal periods, but underprice more strongly during hot issue periods. Further empirical implications relating the fraction of shares sold and the degree of underpricing are presented.

JEL classification: C72, D82, G24, G31, G32

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1 Introduction

The number of Initial Public Offerings (IPOs) increased dramatically during the period from 1998-2000. At the same time the level of underpricing also increased.[1] These twin occurrences are the distinctive elements of what is called a "hot issue"market. During the same period, venture capitalist backed IPOs were significantly more underpriced than non venture capital backed ones (Ljungqvist (1999) and Franzke (2001)). This phenomenon is puzzling since generally venture capitalist backed firms are less underpriced than non venture capital backed ones (Barry, Muscarella, Peavy, and Vestuypens 1990). This paper shows that these phenomena are related and can be explained through a two-dimensional signaling model.

The existence of hot issue markets is not new (Ibbotson and Jaffe (1975) and Ritter (1984)). Ibbotson and Ritter (1995) report examples of IPOs clustering with higher underpricing for the last 40 years in different countries. The IPO cluster of the early '80s was due to an exceptional investment in the natural resource industry: in that period high oil prices caused an extraordinarily favorable situation in the oil sector, and many natural resources start-up companies were taken public in highly underpriced IPOs (Ritter 1984). A "cold issue" market occurred after the market crash of '87, when the IPO volume fell by almost 80% and average underpricing halved relative to the previous year. In the second half of the '90s, the diffusion of the use of Internet and new communication services triggered an impressive IPO wave, coupled with strong underpricing.

At the same time IPOs are usually the most profitable exit route for the venture capitalist Dai (2005). Although IPOs constitute a small fraction of the total venture capitalist portfolio (between 20% and 35%, according to Cumming and MacIntosh (2001)), they contribute the highest returns (from 30% to more than 50% of total return according to (Gompers and Lerner 1999)).

In early studies, venture capital backed IPOs were found to be less underpriced than non-venture capital backed IPOs (Barry, Muscarella, Peavy, and Vestuypens (1990), Megginson and Weiss (1991) and Lin and Smith (1998)). However, more recently it has been noticed

[1]In August 2000 alone, 66 firms were taken public in the US, the same number as during the whole 2003. In 2000 it was not uncommon to witness 100% first day returns, while in 2003 an initial return above 20% was considered already very high (http://bear.cba.ufl.edu/ritter/ipodata.htm).

that during hot issue markets, venture capital backed IPOs are significantly more underpriced than non venture capital backed IPOs (Francis and Hasan (2001), Franzke (2001), Ljungqvist (1999), Smart and Zutter (2000) and Lee and Wahal (2004)) (Fig.1 summarizes the results of these studies). No theoretical model has yet attempted to explain this cyclical regularity in the underpricing of Venture Capital backed firms.

This paper offers a new explanation both to the hot issue puzzle and to the venture capitalist's underpricing strategy. An early stage investor (or the entrepreneur himself) takes the firm public to exit and raise funds to invest in a new opportunity. [2] Pástor and Veronesi (2003) have shown that hot issue periods are correlated with the raising of fundings for new investment opportunities. Similarly Black and Gilson (1998) found that IPOs are used as a tool to exit from a firm and to raise funds. The early stage investor has private information on both the value of the present firm and the new investment opportunity's profitability. The early stage investors can then choose the stake and (under)pricing of the firm from which he wishes to exit via an IPO. Moreover, although the return on the new investment opportunity does not directly affect the payoff to the outside investors buying into the IPO, it is informative about the exit choice faced by the early stage investor and thus helps to interpret correctly the signal on the value of the IPO firm.[3] We obtain a partially separating equilibrium where the fraction of shares retained signals the present firm value, while the underpricing signals the investment opportunity profitability.[4]

[2]In most IPO models the entrepreneur takes a firm public for either diversification or fund raising. Boot, Gopalan, and Thakor (forthcoming) interpret the IPO decision as the result of a trade off between liquidity and loss of control.

[3]Leone, Rock, and Willenborg (2003) find that the level of information asymmetry on the intended use of IPO proceeds contributes significantly to the determination of the level of underpricing: the higher is the disclosure on the intended use of IPO proceeds, the lower is the underpricing. Berkovitch, Gesser, and Sarig (2004) find that firms decides to go public to overcome asymmetry information problem.

[4]CFOs interpret the selling of large fraction of shares of the firm as negative signals (Brau and Fawcett forthcoming). Allen and Faulhaber (1989), Grinblatt and Hwang (1989) and Welch (1989) have interpreted the underpricing as a signal of the IPO firm value. Empirical studies give contrasting support to these theories. Brennan (1990) and Smith (1986) support the signaling theories, while Garfinkel (1989), Jegadeesh, Weinstein, and Welch (1993) and Michaely and Shaw (1994) reject them. In our model, underpricing actually signals the expected profitability of a different firm (the new investment opportunity) leading to a different set of empirical predictions.

The model predicts that, the higher the profitability of the *new* venture, the more the investor is eager to take the *existing* firm public and to underprice in order to sell more shares and obtain higher proceeds to reinvest. This implies that, in periods of economic expansions with many new investment opportunities, there is more rapid exit and higher underpricing, followed with a delay by many IPOs.[5] In contrast, in periods when there are few and poorly profitable investment opportunities, exiting investors retain a larger fraction of shares and underprice less.[6]

"Hot issue" periods may thus not be triggered by optimism on the demand side, the outside investors, but rather by the supply side, that is when early stage investors have a strong incentive to exit in order to enter new ventures.

In the second part of the paper I extend the model to describe venture capital backed IPOs and to explain how the underpricing strategy of venture capital backed IPOs differs from non venture capital backed IPOs in hot and cold issue markets. Venture capitalists distinguish themselves from an early stage investor (or an entrepreneur) because they invest in projects with a stronger entrepreneurial moral hazard problem (Sahlman (1990) and Gompers (1995)). The contractual solution of the moral hazard problem between entrepreneur of the new venture and the venture capitalist affects the underpricing and the fraction of shares sold at the IPO of the old venture.[7] As in the basic model, exit through IPO by a venture capitalist is triggered by the arrival of a new investment opportunity and the IPO is seen as a fundraising stage. There is no detailed study on the use of IPO proceeds by the venture capitalists; however, the high correlation between proceeds from venture capital backed IPOs and capital invested supports with the results of the model.[8]

[5]Many empirical studies find that during hot issue markets firms taken public are usually younger and less established (see Lowry and Schwert (2002) and Loughran and Ritter (2004) for US firms and Rydqvist and Hogholm (1995) and Giudici and Roosenboom (2002) for European firms. This confirms the model's predictions of waves of quick and costly disinvestment.

[6]The relation between stock offerings and business cycle is not new to empirical literature. Choe, Masulis, and Nanda (1993) find a correlation between growth opportunities and IPOs.

[7]We show in the paper that the contrary does not apply: the venture capitalist-entrepreneur contracting in the new venture is not influenced by the modality of exit from the previous investment.

[8]In the US the correlation is around 75% and increases if we focus on regional data. In the Silicon Valley for example the correlation between IPO proceeds and the capital invested is 80% (Elaboration from Pricewa-

The introduction of a moral hazard problem affects the VC's signal problem, because a venture capitalist has to give the entrepreneur a share in the firm in order to induce him to exert effort (Sahlman 1990). Crucially, the more profitable the new venture is, the lower is the fraction of shares the venture capitalist has to offer to the entrepreneur. Therefore, the VC's share in the new venture is an increasing function in the profitability of the new venture.

An increase in the profitability of new ventures increases the venture capitalist's profits in a convex way: higher profitability itself increases the VC's per share and in addition VC's ownership increases multiplying the per share profits. When new investment opportunities are very good, i.e. in hot periods, a venture capitalist becomes relatively more eager to invest in the new venture and to raise more capital. He is therefore ready to sell more shares and to accept higher underpricing. Due to the convex relationship between the new venture's profitability and the VC's profits, the degree of underpricing therefore fluctuates more strongly between hot and cold markets compared to firms with no moral hazard problem. In the case of less profitable new investment opportunities, the moral hazard problem is more binding; the venture capitalist limits his stake in the new venture and then disinvests less during the IPO and underprice less than an early stage investor.

The literature on IPO is very extensive (see Draho (2002), Welch and Ritter (2002) and Jenkinson and Ljungqvist (2001) for a review). Among the different explanations offered on IPO underpricing and 'hot issues', Ritter (1984) and Grinblatt and Hwang (1989) suggest underpricing could be driven by risk. However, this hypothesis is rejected empirically by Ritter (1984) himself: underpricing is not higher in periods of high uncertainty.

Benveniste and Spindt (1989) and Loughran and Ritter (forthcoming) argue that underpricing compensates the underwriter for the cost of information collection about the true firm value. While these papers offer an explanation of the variation of underpricing over time, they do not explain the variation in IPO volume and its positive relation with underpricing.

Benveniste, Busaba, and Wilhelm (2002), Benveniste, Ljungqvist, Wilhelm, and Yu (2003) and Lowry and Schwert (2002) using the framework of Benveniste and Spindt (1989), suggest that information spillovers in the learning process associated with an IPO induce firms from the same sector to go public in the same period. Underpricing is the cost to be paid to induce

terhouseCoopers/Thomson Venture Economics/NVCA statistics).

investors to gather information about the sector. Each time a firm is taken public, more information is revealed about the sector, reducing uncertainty over other firms in the same sector. This reduces the cost of going public and hence increases the number of firms that are willing to go public. There is, however, no conclusive evidence on sector clustering: while Helwege and Liang (2004) reject the hypothesis of sector clustering during hot periods, Lewis and Ivanov (2002) find evidence of a positive effect of technological innovation on IPO activity.[9]

Other papers interpret these anomalies as the result of irrationality in the form of over-optimism among investors and analysts (Rajan and Servaes (1997), Ljungqvist, Nanda, and Singh (2001) and Derrien (2005)). In periods of over optimism, high post-IPO prices induce more firms to take advantage of the favorable situation to go public. However, Persons and Warther (2001) and Stoughton, Wong, and Zechner (2001) have shown that cycles in IPO volume and in general financial innovations are consistent with efficient markets and do not necessarily reflect irrational behavior.

There are few studies that investigate how VC underpricing varies over time. Empirical papers that find lower IPO underpricing by the VC backed firms interpreted the phenomena as a result of the certification role of venture capitalists. Lee and Wahal (2004) hypothesize that venture capital backed IPOs must be more underpriced than non venture capital backed IPOs because the IPO is an opportunity to affirm VC reputation and attract additional funds from investors. The effect should become stronger during hot issue periods.

Berglöf (1994) and Schwienbacher (2002) model venture capitalist's exit. Berglöf (1994) describes how control rights of venture capital are allocated as compensation for his capability to sell to a larger company that operates in the same sector, overcoming the entrepreneur's preference of independence. Schwienbacher (2002) analyzes the optimal capital structure when there is an agency conflict between the entrepreneur, who prefers to go public to acquire more control on the management of the firm and the venture capitalist who may prefer to exit through a trade sale (this conflict affects also the level of innovation). To my knowledge this is the first theoretical paper that addresses the issue of IPO underpricing by venture capitalists.

The structure of the paper is as follows. Section 2 describes the IPO exit behavior of a

[9]The different results might be due to the different definition of hot issue and to the sectors included in the sample.

generic (non venture capital backed) firm. In Section 3, the venture capital backed IPO model is presented. In Section 4, we compare the results of the two models and derive some empirical implications. The final section summarizes and concludes the paper.

2 The "hot issue" market model

2.1 The time structure

Consider a risk neutral early stage investor who holds a stake in a firm whose value is $V \in [L, \infty)$ where L is the minimum possible firm value. We assume that there is no agency problem between the early stage investor and the entrepreneur (this case is dealt with in the next section). At $t = 1$ the early stage investor has the opportunity to invest in a new venture whose expected return is $\pi \in [\pi_L, \infty)$, where π_L is the minimum possible expected return. The early stage investor has limited capital or limited capacity in managing companies,[10] and, therefore, needs to exit from the existing firm in order to invest in the new venture.[11] Hence, at date $t = 1$ the early stage investor decides to take the existing firm public in order to reinvest the IPO proceeds in the new venture. He makes a "take it or leave it" offer to outside investors, who are also risk neutral and act in a perfectly competitive market: he fixes the firm price at P and offers to sell a fraction β of it. We define with underpricing, D, the difference between the firm value, V, and the firm price P: $D = V - P$.

Both the value of the existing firm and the expected returns of the new investment opportunity are known to the early stage investor, but not to the outside investors. Outside investors as buyers of the existing firm's shares, care about the firm's value, but they are not directly affected by the early stage investor's new investment opportunity. However, outside investors cannot evaluate the early stage investor's pay off without knowing the new investment opportunity's profitability. Hence a second signal is required to convey the second piece of information. We assume that the early stage investor can signal only via the fraction of shares sold during

[10]The financial constraint, here exogenous, may apply even to a financial institution subject to some agency conflict with its own investors.

[11]The positive relation between IPOs and availability of equity financing is also supported by the empirical findings of Choe, Masulis, and Nanda (1993) and Lowry (2003).

the IPOs, β, and the underpricing discount, D.

One of the requirements for a signaling model to work is the observability of the signals and in particular for IPO signaling models the observability of the degree of underpricing. In the present model we assume that investors are able to observe directly the fraction of shares sold with the IPO and the underpricing. The latter is obviously unrealistic because investors observe the offer price in practice, but not underpricing.

However, it is also known from previous papers that a slightly more complicated model in which only the offer price can be observed would generate identical results. Allen and Faulhaber (1989) and Welch (1989) have shown that in the presence of uncertainty on the price revelation at time 2 there exists a one to one relationship between the offer price and the level of underpricing. It would be straightforward to adapt the model presented here to allow for the true value of the firm to be revealed probabilistically in period 2 and therefore endogenize the relationship between offer price and the level of underpricing. Since this only complicates the model further without adding anything new to the model we chose not to pursue that route.

At date 2, the value of the firm which is now publicly traded becomes known to all investors and the final fraction can be sold at the true value without any further discount.

The time structure of the model is sketched in Fig. 2.

2.2 IPO exit with asymmetric information on the IPO firm value

At time 1 the early stage investor sells through an IPO all or part of his stake in order to be able to invest in the new opportunity. The amount of capital available for investment in the new venture is determined by the IPO proceeds, βP.

The early stage investor maximizes his expected wealth W, which is given by the sum of the expected returns from investing the IPO proceeds at time 1 in the new venture, $\pi\beta P$, and the return from selling the remaining stake, $(1-\beta)\,V$, at time 2. Assuming a zero interest rate, the objective function for the early stage investor is:[12]

$$\max_{\beta,P} W = \max_{\beta,P} \pi\beta P + (1-\beta)\,V \tag{1}$$

[12]The original stake held by the early stage investor in the firm is irrelevant for the maximization problem as it would be only a multiplying factor of the objective function. For this reason inserting it does not affect the results.

As outside investors are price takers, the price set by the early stage investor is equal to the firm value inferred by outside investors given the signals minus the underpricing: $P = V(\beta, D) - D$, where $V(\beta, D)$ is the firm value inferred by outside investors given the two signals, β and D. So the maximization problem of equation (1) becomes:

$$\max_{\beta,D} W = \max_{\beta,D} \beta\pi \left[V(\beta, D) - D\right] + (1-\beta)(V) \tag{2}$$

The problem could be solved simultaneously (Quinzii and Rochet 1985). However for ease of exposition we follow Grinblatt and Hwang (1989) and we first solve the case where there is only one source of asymmetric information before solving the double signaling problem. Thus, initially we assume that outside investors know the expected profitability of the new investment opportunity, but not the value of the firm sold during the IPO.

Lemma 1 *When the profitability of the new investement opportunity is common knowledge, the early stage investor signals the value of the existing firm through the choice of the fraction of shares sold.*

Proof. See Appendix. ■

If only the firm value is unknown to outside investors, the early stage investor maximizes his wealth by signaling the firm value through selling fewer shares, rather than selling at a lower price. The missing returns from selling fewer shares is smaller than from setting a lower price and sell all the shares during the IPO.

Hence we can solve the maximization problem with the shares sold as signal and obtain a signaling schedule that gives the unique reactive separating equilibrium (Riley (1979) and Salanié (1999)).

Proposition 2 *The signaling schedule that gives the unique reactive separating equilibrium is:*

$$V(\beta) = \beta^{-1+\frac{1}{\pi}} L \tag{3}$$

where L is the minimum possible firm value.

Proof. See Appendix. ■

As in Leland and Pyle (1977), when the early stage investor sells his entire stake, $\beta = 1$, the firm value signaled to the outside investor is at its minimum, L.[13] Indeed, $V(1) = L$ is always preferred by the early stage investor to any schedules for which $V(1) < L$; as the minimum possible firm value is L, when all shares are sold outside investors are willing to pay at least a price $P = L$. At the same time, the schedules where $V(1) > L$ are not credible: the early stage investor with a firm whose value is L, would always take the firm public and gain the difference $V(1) - L$; hence outside investors would never accept a price above L when all shares are offered.

The fraction of shares sold acts as a signal of firm value in the following way. Firstly, given schedule (3), the more shares are sold, i.e. higher β, the lower is the firm value inferred by the outside investor, $V(\beta)$. Secondly, the early stage investor of a low value firm receives more proceeds (given by $\beta\frac{1}{\pi}L$)) available to invest in the new opportunity than the one of a high value firm.

This constitutes the signaling cost that induces the early stage investor of a low value firm not to mimic the one with high firm value. Intuitively, the early stage investor of a low value firm faces a trade off between sell at the true value and having high proceeds to reinvest, or to mimic the high value firm and reinvest less in the new investment opportunity. The opportunity cost of investing less in the new venture is smaller for a high value firm, because the fraction of shares retained in the first period can be sold at a higher price later on. Hence, only the early stage investor of a high value firm is willing to sell fewer shares in exchange for a higher price. Empirically this means that higher value firms will be sold with a lower free float than low value firms. Practitioners confirm these results: CFOs interpret the amount of shares sold during an IPO as a negative signal on the quality of the firm taken public (Brau and Fawcett forthcoming).

Finally, the marginal effect of the signal is greater the higher is firm value: a further reduction of shares sold and the resulting lower returns is marginally more expensive (i.e. the second derivative is positive).

[13]Here the early stage investor wants to take a firm public to reinvest the proceeds while in Leland and Pyle (1977) he does it because of risk aversion.

2.3 Double asymmetric information

We now derive the signaling schedule when there is asymmetric information both on the value of the firm taken public and on the profitability of the new investment opportunity. Although its profitability does not directly influence the outside investors' pay-offs, it determines the early stage investor's payoff from exiting the existing venture, which is useful information when determining the IPO price. A second signal, the IPO pricing, may therefore be useful. It is worthwhile to notice that the early stage investor maximizes not only over the level of underpricing and the fraction of shares, but indirectly also over the optimal level of capital to invest in the new investment opportunity.

We indicate with $\pi(\beta, D)$, the profitability of the investment opportunity inferred by outside investors given the observed underpricing and the fraction of shares sold.

Proposition 3 *When both the new investment opportunity and the firm value are unknown to the outside investors, there exists a two parameter partially separating signaling equilibrium. When:*

$$\frac{V}{L} \geq \frac{\pi}{\pi_L} \tag{4}$$

the signaling schedule is given by

$$V(\beta, D) = V_L(\beta) + D \tag{5}$$

$$\pi(\beta, D) = \pi_L \left(1 + \frac{\beta^{1-\frac{1}{\pi_L}}}{L} D\right) \tag{6}$$

$$= \pi_L \left(1 + \frac{D}{V_L(\beta)}\right) = \pi_L \left(1 + \frac{D}{V - D}\right) \tag{7}$$

where

$$V_L(\beta) = \beta^{-1+\frac{1}{\pi_L}} L \tag{8}$$

When $\frac{V}{L} < \frac{\pi}{\pi_L}$, all the shares will be sold at $P = L$. This equilibrium is the unique Pareto-dominant schedule.

Proof. See Appendix. ■

When condition (4) is satisfied, the signaling schedules are such that the retained share $(1 - \beta)$ signals the firm value, while the underpricing D, or better the percentage of initial return $\frac{D}{V_L}$, signals the new investment opportunity profitability.

When there is no underpricing, by construction the inferred value of the new investment is the lowest possible, π_L. It increases in a convex way as D increases and approaches infinity, as D equals the total firm value, V.

An increase in the expected profitability of the new investment induces the early stage investor to increase proportionally the percentage of underpricing, but increases the amount of shares sold such that the total proceeds of the IPO increase. More precisely, the level of the discount ($D = \left(\frac{\pi}{\pi_L} - 1\right) V_L$) is proportional to the expected extra gain (above the minimum expected profitability π_L) of the new investment.

For higher values of the new investment opportunity's profitability, it is optimal for the early stage investor to underprice more and sell more shares.

However, when the new investment opportunity is very attractive, $\frac{\pi}{\pi_L} > \frac{V}{L}$, and the firm value is very low, the early stage investor would like to sell more than the total of the shares available at a price lower than the possible firm value ($\beta > 1$). Given that this is infeasible, the early stage investor settle with the corner solution of selling sell everything ($\beta = 1$) at the lowest firm value possible.

We then have a partially separating equilibrium with the following features. When the firm value increases, the fraction of shares sold decreases and underpricing increases. For the early stage investor it is very costly to sell a large fraction of shares of a high value firm at a low price to have higher proceeds to invest in the new venture. Hence he prefers to signal partly with the shares sold and partly with underpricing. On the other hand, the more profitable is the new investment opportunity, the higher the fraction of shares sold and the higher is the underpricing. It is more attractive to sell more of the old firm and invest the proceeds in the new investment, rather than selling less and mimic a higher value firm: the loss from investing less in the new investment would be higher than the gain from overpricing. In the extreme case where the new investment profitability is very high compared to the firm value, we end up in a pooling equilibrium. The early stage investor prefers to sell his stake at the lowest possible firm value, L, rather than sell less at a higher price.

Empirically, underpricing is measured as the first day return relative to the issue price (in our notation $\frac{D}{V-D}$). Therefore we should witness that the higher is the firm value, the lower the fraction of shares sold, while the higher is the value of the new investment opportunity the

higher is the first day return and the higher the fraction of shares sold.

Given these results, we can now interpret the variation of IPO underpricing over time. Good investment prospects, due for example to technological innovation triggers a "hot issue" market: early stage investors take existing firms public, selling more shares at a low price, and invest the proceeds in the new ventures. As firms are taken public, the most profitable opportunities are exploited, and the underpricing tends to decrease over time. When the new firms are mature for exit, if the "opportunity wave"passed fewer firms will be taken public and fewer shares will be sold at the IPO and will be less underpriced.

3 The Venture Capitalist

In this section we present an extension of the basic model by introducing a moral hazard problem between the firm's manager and the outside investor. If venture capitalists invest in firms where agency problems are more prevalent, then this provides us with a way of distinguishing a VC's IPO behavior from that of non-VC backed IPOs. There are strong reasons to believe that venture capitalists tend to invest in firms where moral hazard problems are more important because of their superior information gathering and monitoring capability which may help to mitigate agency problems (Admati and Pfleiderer (1994) and Kaplan and Stromberg (2003)). Gompers (1995, p. 1461) confirms it empirically: "[v]enture capitalists concentrate investments in early stage companied and high techonology industries where informational asymmetries are highest".

We introduce a simple model of moral hazard to highlight its effect on the IPO's underpricing behavior of the venture capitalist. The time structure of the model changes slightly. We have now a cycle subdivided into 3 periods with 5 different players: the venture capitalist, the entrepreneurs of the existing and of the new firm, the outside investors and the financiers of the venture capitalist activity.

At period 0, the venture capitalist wants to invest in a new venture. Its value is stochastic and depends probabilistically on the amount of effort exerted by the entrepreneur, $e \in [0, \overline{e}]$. The effort exerted is unobserved by the venture capitalist and determines a cost for the entrepreneur, which is set for simplicity equal to e. The marginal productivity of the en-

trepreneur's effort is $\pi'(e)$.

Hence, the objective functions of the venture capitalist and the entrepreneur, do not coincide and a moral hazard problem arises.[14] In order to mitigate this problem, the venture capitalist gives away a fraction of the shares as a payment to the entrepreneur for the effort exerted. We define with $\alpha_i \in [a_L, 1]$ the profit share of the venture capitalist endogenous (a_L is the minimum possible share of the venture capitalist).

The characteristics of the contract between the entrepreneur and the venture capitalist are not known to the outside investors: outside investors know only that the venture capitalist finances the new venture through equity, but they do not know the size of the investment, K, the share participation of the venture capitalist, α_i, and the quality of the entrepreneur.

At date 1 the firm value, $V \in [V_L, \infty)$, is realized and can range from V_L to infinity. This firm value can be observed by both the venture capitalist and the entrepreneur, but not by the outside investors and the financiers.

At date 1 the venture capitalist wants to take the firm public for two reasons. First, at period 1 the venture capitalist has a new investment opportunity whose features are known only to him. To take advantage of it, the venture capitalist is forced to disinvest from the firm because as before he has a limited capacity in managing the financing activity.[15]

Second, an IPO can be a tool for the venture capitalist to facilitate the subsequent distribution of proceeds to his own financiers: as Gompers and Lerner (1999) have shown, profit distribution usually happens through allocation of shares of firms the venture capitalist has invested in and an IPO constitutes a prerequisite to ease the subsequent financiers' exit.

The venture capitalist incurs a double asymmetric information problem when taking a firm public: both the existing firm value and the profitability of the new venture are private information. This time, however, the profitability of the new venture is determined by the terms of the contract between venture capitalist and entrepreneur (i.e. capital invested and profit share) that are not observable to others. Again, we assume that the venture capitalist

[14] In addition to providing capital, a venture capitalist is said to provide useful managerial input into its portfolio firms. For simplicity we ignore this additional dimension of interaction.

[15] VC uses IPO not only as an exit tool, but also as a mechanism to raise funds to finance new projects (Gompers 1995). While we do not model this aspect, the introduction of the IPO as a signal to raise further capital would reinforce our conclusions.

can use as signals only pricing and quantity of the shares sold, i.e. the underpricing, D, and the stake sold, β.

At date 2, after the IPO, the firm value is revealed to all players and the venture capitalist transfers the remaining shares, $1-\beta$, to his own financiers. At this point, the cycle repeats itself: with the selling of the stake of the new firm at period 1 and 2, the venture capitalist has the possibility to finance further investment opportunities, etc. The new time structure is sketched in Fig. 3.

Studying this cycle allows us to see the influence of the past and future decisions of the venture capitalist on the investment and disinvestment decisions.

3.1 The Contract between Venture Capitalist and the Entrepreneur

Before solving for the full equilibrium, let us first derive the incentive contract for the entrepreneur. After the venture capitalist has invested in the firm in period 0, he disinvests in period 1 through an IPO in order to be able to invest in the new opportunity and to later distribute the remaining share to the financiers. The amount of capital that the venture capitalist is investing in the new investment opportunity is not solely determined by the outcome of the IPO, but is chosen so as to take into account the entrepreneurial moral hazard problem.

The degree of moral hazard depends on the productivity of entrepreneurial effort, which may reflect either the quality of the entrepreneur or of his idea. Entrepreneurial productivity is a function of effort exerted and is defined as the change in profitability of the firm on the base of the effort exerted. $f\left(\tilde{\pi}_i \mid e\right)$ is the probability distribution for the i- venture to have $\tilde{\pi}$ return given entrepreneur's effort, e.

We assume that the venture capitalist has all the bargaining power, but has to give enough incentives to the entrepreneur to exert effort. Assume that $\frac{\partial}{\partial \tilde{\pi}_i}\left[\frac{\frac{\partial f(\tilde{\pi}_i|e)}{\partial e}}{f(\tilde{\pi}_i|e)}\right]$ is positive and therefore the monotone likelihood property (MLRP) is satisfied (Salanié 1999). We also assume that the marginal increase in profitability due an increase in effort is higher than the marginal cost for the relevant values of effort: $\frac{f(\tilde{\pi}_i|e)}{\partial e} > 1$. This condition allows us to focus only on the corner solution where the maximum effort is eserted.[16]

[16]Relaxing this assumption and considering a concave productivity function of the entrepreneur's effort would complicate the analysis unnecessarily.

The venture capitalist can induce the entrepreneur to exert effort by increasing his stake, i.e. diminishing his own equity stake, α_i. The higher is the stake of the entrepreneur, the greater is his incentive to exert effort and so to increase expected profits.

We assume that returns are verifiable and the firm enjoys limited liability. All agents are risk neutral.

Proposition 4 *The optimal equity stake of the venture capitalist is such that the entrepreneur exerts the maximum effort, $\overline{e}$ and is equal to:*

$$\alpha_i = 1 - \frac{1}{\int_0^{\infty} \frac{\partial f(\tilde{\pi}_i|\overline{e})}{\partial \overline{e}} \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i} \tag{9}$$

and the expected return of the investment is given by:

$$\int_0^{\infty} f\left(\tilde{\pi}_i \mid \overline{e}\right) \tilde{\pi}_i, \mathrm{d}\tilde{\pi}_i = \frac{\overline{e}}{\left(1-\alpha_i\right) K} \leq \pi_L \tag{10}$$

Proof. See Appendix. ■

The venture return depends on the effort exerted by the entrepreneur relative to his capital involvement. The entrepreneurial stake, $1-\alpha_i$, depends on his marginal productivity: the higher the entrepreneur's quality, the smaller the necessary financial participation of the entrepreneur.

The cost to exert the maximum effort is constant for entrepreneur $(\overline{e})$ and hence the higher the entrepreneur's quality, the higher the expected return and the lower the fraction of shares that the venture capitalist has to concede to the entrepreneur to induce him to exert effort.

How this venture will be taken public, namely the level of underpricing and the amount of shares sold, influences the expected profits of the venture capitalist. These profits increase with the expected fraction of the firm sold during the IPO, with the expected value of the future investment opportunity and decrease with the percentage of underpricing.

However, as we can see from equations (9) and (10), the structure of the IPO does not influence the contract between the venture capitalist and the entrepreneur. Intuitively, there is no conflict between the venture capitalist's objective during the contracting and the IPO phase: the higher the firm value in the first period, the more valuable the subsequent IPO and the higher the venture capitalist profits.

The venture capitalist-entrepreneur contract in the existing firm is therefore not relevant for the IPO structure. Hence, the recursive element of the model vanishes and we can focus

only on how the IPO structure is affected by moral hazard in the subsequent venture. For consistency in the notation, we indicate with α_{i+1} the participation of the venture capitalist in the subsequent venture, with $\pi_{i+1}(e) = \int_0^\infty f(\tilde{\pi}_{i+1} \mid e)\, \tilde{\pi}_{i+1}\, \mathrm{d}\tilde{\pi}_{i+1}$ its expected return, and with $\pi'_{i+1}(e)$, the marginal expected productivity of the entrepreneurial effort of the new venture, $\int_0^\infty \frac{\partial f(\tilde{\pi}_{i+1}|e)}{\partial e} \tilde{\pi}_{i+1} K\, \mathrm{d}\tilde{\pi}_{i+1}$. Then, the results of Proposition (4) can be expressed as:

$$1 - \alpha_{i+1} = \frac{1}{\pi'_{i+1}(\overline{e})\, K} \tag{11}$$

$$\pi_{i+1}(\overline{e}) = \frac{\overline{e}}{(1-\alpha_{i+1})\, K} \geq \pi_L \tag{12}$$

From equation (12), it follows that the venture capitalist invests in the new venture only if he is going to have a share of the profits larger than $\frac{L-e}{L}$. This value is the minimum venture capital share participation that we defined as α_L.

3.2 Venture capitalist-entrepreneur contracting and the IPO

Having solved for the optimal contract between venture capitalist and entrepreneur, we can now study which is the optimal combination of price and shares retained for a venture capitalist when taking a firm public. The steps are similar to the ones in Section 2. However, the venture capitalist has to take into account how the proceeds of the IPO invested in the venture influence the profitability of the new venture via managerial incentives.

As before, the value of the existing venture and the profitability of the new venture (which is now endogenous) are not known to outside investors. In particular outside investors do not know the marginal productivity of the entrepreneur of the new venture, and cannot observe the stakes that the venture capitalist will have in the new venture.

In the presence of entrepreneurial moral hazard the IPO outcome changes for two reasons. First, the return of the new investment opportunity is now a function of the venture capitalist's stake (expressed by equation (12)) and hence the venture capitalist's maximization problem becomes:

$$\max_{\beta,P} W = \max_{\beta,P}\ \beta \frac{\overline{e}}{(1-\alpha_{i+1})\, K} P + (1-\beta)\, V \tag{13}$$

Second, the capital invested by the venture capitalist in the new firm, $\alpha_{i+1}K$, is given by the capital raised during the IPO, βP.

As in the basic model, we initially solve the problem for one level of asymmetry: the quality of manager, and then the contracting conditions between venture capitalist and entrepreneur, are common knowledge, while the value of the firm taken public is signaled by the share sold.

Proposition 5 *When the contract between the entrepreneur and the venture capitalist in the new venture is common knowledge, the unique reactive separating equilibrium is given by:*

$$V(\beta) = \frac{\overline{e}\alpha_{i+1}L}{\beta\left(\overline{e}\alpha_{i+1} - L(1-\alpha_{i+1})\ln[\beta]\right)} \tag{14}$$

Proof. See Appendix. ■

The signaling schedule has qualitatively the same features of the one dimensional signaling schedule of the early stage investor. Note that the schedule is not affected by the total amount of capital needed for the new investment, but only by the stake of the venture capitalist, α_{i+1}.

When the profit share of the venture capitalist is not known to outside investors, the venture capitalist has to signal it trough underpricing, D. If the venture capitalist acquires the minimum stake in the new venture, α_L, he gains the minimum possible level of profitability and so he is not willing to incur any underpricing, $D = 0$. Hence, the signaling schedule, of no underpricing should indicate the minimum possible participation of the venture capitalist in the new venture.

We can therefore define $V_L(\beta)$ as the solution to (14) when $\alpha_{i+1} = \alpha_L$.

Proposition 6 *When both the IPO firm value and the characteristics of the next venture are unknown to outside investors, there exists a two parameter partially separating signaling equilibrium. When:*

$$\frac{V}{L} \geq \frac{\alpha_{i+1}(1-\alpha_L)}{\alpha_L(1-\alpha_{i+1})} \tag{15}$$

the signaling schedule is given by:

$$V(\beta, D) = V_L(\beta) + D \tag{16}$$

$$\alpha_{i+1}(\beta, D) = 1 - \frac{\overline{e}(1-\alpha_L)L}{\overline{e}(L + \alpha_L\beta D) - DL(1+\alpha_L)\beta\ln[\beta]} \tag{17}$$

$$= \alpha_L\left(1 + \frac{(1-\alpha_L)D}{V(\beta, D) - (1-\alpha_L)D}\right) \tag{18}$$

otherwise, all the shares will be sold at $P = L$. This is the unique Pareto dominant equilibrium.

Proof. See Appendix. ■

The resulting double signaling schedule is such that the shares sold signals the IPO firm value, while underpricing signals indirectly the marginal profitability of the new venture.

The signaling behavior of the venture capitalist is similar to the early stage investor. Given the new venture's profitability, for higher firm value, the venture capitalist distributes the costs of signaling between reducing the amount of shares sold, β, and increasing the degree of underpricing. On the other hand, given the firm value, when the venture capitalist has a more profitable new venture, he tends to underprice more so he can sell more shares and obtain higher proceeds in the new venture. The equilibrium is partially separating and when the new venture's profitability is very high the venture capitalist sells the shares at the minimum price possible to obtain the maximum proceeds to reinvest.

4 Analysis of the results and empirical implications

So far, we have presented two types of IPO exits. In the basic model, an early stage investor wants to take a firm public to reinvest the proceeds in a new investment opportunity (Section 2). In the extended model, a venture capitalist takes a firm public, but when reinvesting the proceeds he faces a moral hazard problem with the entrepreneur. Hence we have two types of IPO structures: the early stage investor signals the firm value and the expected profitability in the new investment opportunity, while a venture capitalist must signal the firm value and the characteristic of the contract in the new venture, which indirectly identifies its profitability.

In this section we analyze the difference in the signaling behavior of these two investors, and identify empirical implications. In particular we show how the moral hazard problem explains the puzzle on the changing underpricing behaviour of venture capital and early stage investor in hot and cold issue market. We first conduct a comparative static analysis of the signaling schedules with respect to the profitability of the new investment and derive a condition for the existence of a separating equilibrium. Subsequently, we conduct comparative statics with respect to the value of the firm that is taken public.

4.1 Signaling the profitability of the new venture

This section explores how a change in the new venture's profitability affects the degree of underpricing depending on wether the IPOis or is not venture capital backed.

We rewrite the schedules (7) and (17) in terms of percentage of underpricing with respect to the IPO price, d_{ESI} for the early stage investor and d_{VC} for the venture capitalist. Furthermore we rewrite venture capitalist signaling in terms of new venture profitability

Proposition 7 *For a given value of the firm to be sold, there exists a $\pi^* > \pi_L$ such that when $\pi > \pi^*$ the percentage underpricing of the venture capital backed IPO is higher than that of the early stage investor and when $\pi < \pi^*$ it is lower.*

Proof. See Appendix. ■

Fo a sufficient high underpricing and shares retained, there exists a critical profitability value for which the venture capitalist underprices more than the early stage investor.

Hence a venture capitalist is more eager than an early stage investor to disinvest from the existing venture when he sells a very promising new venture, i.e., he sells more shares and at a higher discount. This is also reflected in the fact that he tends to end up in a pooling equilibrium for a wider range of parameters (see equation (4) and (15)). When instead the venture capitalist has a less profitable new venture he underprices less than an early stage investor.

The explanation of this result lies in the convex relation between the profitability of the new venture and the profits that the venture capitalist derives from them. An increase in the profitability of the new investment opportunity has a linear effect on the profits of the early stage investor, while for the venture capitalist this effect is more than proportional: an increase in the new venture's profitability not only increases the venture capital profits in a direct way, but also softens the moral hazard and increases his profit share.

When the new investment opportunity is less profitable, the venture capitalist has to give a large fraction of shares to the entrepreneur to induce him to exert effort. For this reason he is not willing to sell the existing firm more cheaply than the early stage investor with an investment opportunity with similar profitability.

As the new venture becomes more profitable, the venture capitalist becomes more eager to invest at an increasing rate. His willingness to underprice the IPO increases more quickly than that of the early stage investor. Hence he wants to invest more in the new venture and sell more shares of the existing firm than the correspondent early stage investor. At the same time in order to avoid mimicking by the venture capitalist with a less profitable investment, he has to increase the signaling much more than the early stage investor.

This result can explain the empirical evidence on the underpricing of venture capital backed IPOs (Lee and Wahal 2004). On one hand, Barry, Muscarella, Peavy, and Vestuypens (1990), Megginson and Weiss (1991) and Lin and Smith (1998) find that venture capital backed IPOs are less underpriced than non venture capital backed IPOs during normal IPO periods. The opposite happens during hot issue periods studied in Francis and Hasan (2001), Smart and Zutter (2000), Franzke (2001).

The papers which find less underpricing for venture capital backed firms, refer to periods of relatively stable markets or very long periods where the hot issue markets are not investigated separately. Barry, Muscarella, Peavy, and Vestuypens (1990) and Megginson and Weiss (1991) study IPOs between '83-'87, where there were no hot issue markets and the venture capitalist was underpricing less than the early stage investor (7% instead of 8%).

Lin and Smith (1998) instead consider a long time series ('79-'90) without distinguishing the hot market periods and find that the venture capital underpricing is 12% while the early stage investor one is 17%.

The studies that find higher venture capital underpricing, instead focus on hot issue market periods and find more underpricing for venture capital backed firms. For example Ljungqvist (1999) for the US and Franzke (2001) for Germany find that at the end of the nineties during the Internet hot issue market venture backed firms were more underpriced than non venture capital backed firms. Lee and Wahal (2004) find that the underpricing of the VC backed IPO is higher or lower depending on the period considered.

According to our model, these empirical results originate from different economic conditions. When the economy is expanding due for example to technological innovation, and there are many new profitable investment opportunities; investors want to exit quickly from the existing firms taking them public. In particular the venture capitalists exit more quickly than the rest

of the investors and are ready to incur heavier costs in order to be able to exploit new investment opportunities. The opposite occurs when there are fewer and less profitable investment opportunities. Investors, and the venture capitalists in particular, are not willing to disinvest from the existing firms and incur the heavy costs of taking them public.

4.2 Signaling the IPO firm value

The comparison of the signaling schedules of the value of the firm taken public for the early stage investor and for the venture capitalist has to take into account the fact that the underpricing indicates the new venture profitability in the first case and the venture capital participation for the new venture in the second case. For this reason we first study the case of no moral hazard in the venture capitalist then the case of no underpricing and subsequently we see how the signaling schedule changes adding the underpricing.

When there is no moral hazard, the venture capitalist is not giving up part of his capital returns to the entrepreneur as compensation for the effort's exertion, $\alpha_{i+1} = 1$. In this case the signaling schedule of the firm taken public of the venture capitalist coincide with the one of the early stage investor.

When there is moral hazard and there is no underpricing, the new investment profitability is at the minimum and the venture capitalist concedes part of the profits to the entrepreneur to induce effort exertion, and hence his profitability is reduced to $\alpha_{i+1}\pi$. Hence for the same level of new investment profitability, the venture capitalist is gaining less and therefore prefers to less fewer during the IPO. It follows that the venture capitalist tends to sell less shares for the same firm value and the same investment profitability.

When the new venture profitability is low and the venture capitalist underprices less than the early stage investor, the amount of shares retained is even higher: not only does the venture capitalist tend to retain more shares because he has a smaller fraction of the new investment opportunity, but as he underprices less (as we saw above), he retains more shares because he has to signal a higher price.

For higher new venture profitability, the venture capitalist underprices more than the early stage investor; however given that he gets only a fraction of the profits he still holds more shares. In the extreme case, for very high new venture profitability, the venture capitalist underprices

much more than the early stage investor and has to hold fewer shares than the early stage investor.

These empirical predictions are new and no study to date focused on the differences in the amount of shares retained by the venture capitalist versus the early stage investor over time. There is however a general consensus in literature that the amount of shares retained by the venture capitalist is generally higher than the one retained by the early stage investor and this is in line with the predictions of the model (Gompers and Lerner 1999).

5 Conclusions

This paper models the exit strategy from existing investments by investors who have a reinvestment opportunity. Our model can contribute to explain some features of "hot issue markets". It also explains some puzzling results of the empirical literature on IPO underpricing behavior of venture capital and non-venture capital backed firms.

In our model a firm is taken public to exploit new investment opportunities. In periods when there are many new investment opportunities, the model predicts faster exit, thus more IPOs, and more underpricing. In periods with few investment opportunities, there should be fewer IPOs and less underpricing.

This model distinguishes between two kinds of investors who take the firm public: the early stage investor and the venture capitalist, where the latter specializes in firms with more severe moral hazard problems. We show that the difference may be crucial to explain differing IPO underpricing behavior. The contractual solution to the moral hazard problem induces the venture capitalist to retain more shares during the IPO. He also tends to underprice more than an early stage investor when the new opportunity is very profitable. When instead it is not very profitable, the venture capitalist underprices less than an early stage investor.

This is consistent with the evidence that during boom periods venture capitalists underprice more than other investors; while in other periods the VC backed firms are less underpriced.

The model makes new predictions regarding the level of underpricing and the shares sold during hot and cold issue market periods, and distinguishes between venture capital and non venture capital backed firms.

Appendix

Proof of Lemma 1.

When the firm value is signaled through underpricing, the optimal schedule has to satisfy the following first order condition:

$$\frac{\partial W}{\partial D} = \pi\beta\left(\frac{\partial V(D)}{D} - 1\right) = 0 \tag{19}$$

To obtain an informationally consistent price function, we impose the self-fulfilling belief condition, that is we impose that the beliefs on the firm value of the outside investors are correctly formed (Salanié (1999)), reflecting the true firm value:

$$V(D) = V \tag{20}$$

It follows that the family of the optimal candidate as signaling schedule is the equation that solves the above differential equation.

The generic solution is given by:

$$V(D) = D + A \tag{21}$$

where A is an arbitrary constant.

In order to find the Pareto optimal schedule, the constant of integration has to be such that when the traditional investor does not underprice the firm value is equal to the minimum firm value of the investment, L. Indeed, the schedules where $V(0) < L$ allow for arbitrages and those where $V(0) > L$ are Pareto dominated by $V(0) = L$. So the Pareto-dominant price schedule is:

$$V(D) = D + L \tag{22}$$

In this case the amount of fraction sold during the IPO is determined by the maximization of the wealth. Given the result of the separating equilibrium when the investor signal with underpricing the wealth is given by:

$$W = \pi\beta L + (1-\beta)V \tag{23}$$

The first derivative in respect of β is given by:

$$\frac{\partial W}{\partial \beta} = \pi L - V \tag{24}$$

The optimal fraction sold is 1 when $\pi L > V$ and is 0 when $\pi L < V$. The investor wealth is given by the $\max[\pi L, V]$. Comparing this result with the wealth in case of signaling with the fraction sold (see Proposition 2), it results that signaling through underpricing is inferior to signaling through retained shares.

■

Proof of Proposition 2.

In order to proof Proposition 2, we first find the informationally consistent Pareto dominating schedule and subsequently we demonstrate that this is the unique reactive equilibrium.

The informationally consistent Pareto-dominant price schedule must satisfy the following first order condition:

$$\frac{\partial W}{\partial \beta} = \pi V(\beta) + \pi \beta V'(\beta) - V = 0 \tag{25}$$

To obtain an informationally consistent price function, we impose the self fulfilling belief condition:

$$V(\beta) = V \tag{26}$$

Substituting equation (26) in equation (25) and rearranging, the first order condition becomes:

$$(-1 + \pi) V(\beta) + \beta \pi V'(\beta) = 0 \tag{27}$$

It follows that the family of optimal candidates as signaling schedule is the equation that solves the above differential equation. The generic solution is given by:

$$V(\beta) = \beta^{-1+\frac{1}{\pi}} A \tag{28}$$

where A is an arbitrary constant.

In order to find the Pareto optimal schedule, the constant of integration has to be such that when the traditional investor sells all his holding the firm value is equal to the minimum firm value of the investment, L. Indeed, the schedules where $V(1) < L$ allow for arbitrages and those where $V(1) > L$ are Pareto dominated by $V(1) = L$. Hence, $V(1) = A = L$.

So the Pareto-dominant price schedule is:

$$V(\beta) = \beta^{-1+\frac{1}{\pi}} L \tag{29}$$

This price schedule verifies also the second order condition[17] and its first and second derivatives are respectively given by:

$$\frac{\partial V(\beta)}{\partial \beta} = \beta^{-2+\frac{1}{\pi}} \left(-1+\frac{1}{\pi}\right) L < 0 \tag{31}$$

$$\frac{\partial^2 V(\beta)}{\partial \beta^2} = \beta^{-3+\frac{1}{\pi}} \left(-1+\frac{1}{\pi}\right)\left(-2+\frac{1}{\pi}\right) L > 0 \tag{32}$$

Now that we found the informationally consistent Pareto dominating schedule we demonstrate that this is the unique reactive equilibrium.

Riley (1979) demonstrates there is a unique reactive equilibrium if 6 conditions are satisfied.[18] Using the notation of this paper we restate the 6 hypothesis and we verify that they are satisfied:

1. The first hypothesis is satisfied as by assumption $V \in [L, \infty]$;
2. W and $V(\beta)$ are differentiable in all the arguments;
3. The maximizing function, W, is strictly increasing in the market price of the firm;
4. Hypothesis 4 is satisfied because:
   - Given the condition on the integration constant the firm value has always positive value ($V(\beta) > 0$);
   - $\frac{\partial V(\beta)}{\partial \beta} < 0$(see equation (31)).
5. Single-crossing property is satisfied as:

$$\frac{\partial}{\partial V}\left(-\frac{\partial W}{\partial \beta}/\frac{\partial W}{\partial P}\right) = \frac{1}{\beta\pi} > 0 \tag{33}$$

6. From how we constructed the price schedule it derives that the maximazing function in terms of firm value has a unique β that maximizes W.

[17]The second derivative given the informative consistent price schedule is given by:

$$\frac{\partial^2 E[W]}{\partial \beta^2} = 2\pi V'(\beta) + \beta\pi V''(\beta) = V'(\beta) < 0 \tag{30}$$

[18]Alternatively we could verify the uniqueness of the reactive equilibrium verifying the satisfaction of the 6 conditions of Engers and Fernandez (1987), as they demonstrate the uniqueness with less stringent assumptions.

■

Proof of Proposition 3. When the new opportunity's profitability is lowest, $\pi = \pi_L$, the early stage investor has no reason to incur any cost to signal its profitability, i.e. $D = 0$. In this case the solution of the signaling problem can be reduced to the case of known profitability. Applying the results of Proposition 2, the signaling schedule in this case is:

$$V_L(\beta) = \beta^{-1+\frac{1}{\pi_L}} L \tag{34}$$

If the firm value is signaled via underpricing we have that the optimal schedule has to satisfy the first order condition and the constraint given by the case of no underpricing:

$$\frac{\partial W}{\partial D} = \beta\pi\left(V'(D) - 1\right) = 0 \tag{35}$$

$$V(0) = V_L(\beta) \tag{36}$$

Solving this differential equation we obtain equation (5).

Applying this result to the objective function, it becomes:

$$\max_{\beta} W = \max_{\beta} \beta\pi\left(V_L(\beta) + D - D\right) + (1-\beta)V \tag{37}$$

The first order condition together with the self-fulfilling belief condition, $V = V(\beta, D)$ and $\pi = \pi(\beta, D)$, is:

$$\frac{\partial W}{\partial \beta} = -\frac{\beta\pi_L D - \beta^{\frac{1}{\pi_L}}\left(\pi(\beta, D) - \pi_L\right)}{\beta\pi_L} = 0 \tag{38}$$

Solving this equation and rearranging we obtain equation (7).

Equations (16) and (17) are the unique Pareto dominant schedule as the following 6 conditions are verified Engers (1987):

1. V and π is compact space;
2. β and D are compact and convex schedules;
3. The value function for the outside investors is continuous and non increasing in β and non increasing in D;
4. Equations (16) and (17) is differentiable in the signals;

5. The marginal cost of signaling vector and the value of the firm are negatively related;

6. The signaling schedule do not include all the possible combinations of π and V. For this reason the equilibrium is partially separating.

As $\beta \leq 1$, this schedule applies only when $\frac{L}{V} \leq \frac{\pi_L}{\pi}$. When this condition does not apply, the traditional investor will sell all the shares at $P = L$.

■

Proof of Proposition 4. In this Appendix we are going to find the optimal share distribution given the moral hazard problem between the entrepreneur and the venture capitalist. We rewrite the maximizing problem of the wealth of equation (1) subject to different kind of constraint: the maximization of the entrepreneur utility in terms of effort exerted, the incentive compatibility constraint, the individual rational constraint of the entrepreneur (that is always satisfied as the incentive compatibility constraint is more stringent). Finally there is the individual rational constraint of the venture capitalist himself that is relevant only in terms of venture selection: the venture capitalist wants to invest only if the opportunity return is greater than 1. Formalizing this, we obtain:

$$\max_{\alpha_i} \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \alpha_i \left[\pi_{i+1} \beta \left(\tilde{\pi}_i K - D\right) + \left(1 - \beta\right) \tilde{\pi}_i K\right] \mathrm{d}\tilde{\pi}_i - K \tag{39}$$

$$\text{s.t. } \max_{e} \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \left(1 - \alpha_i\right) \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i - e \tag{40}$$

$$\int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \left(1 - \alpha_i\right) \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i \geq e \tag{41}$$

$$\int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \alpha_i \left(\pi_{i+1} \beta \left(\tilde{\pi}_i K - D\right) + \left(1 - \beta\right) \tilde{\pi}_i K\right) \mathrm{d}\tilde{\pi}_i \geq K \tag{42}$$

$$0 \leq \alpha_i \leq 1 \tag{43}$$

where π_{i+1} is the expected profitability of the subsequent venture.

Letting μ and λ denote the (nonnegative) multipliers of the constraints and transforming the first constraint with the first order condition, the relative Lagrangian becomes:

$$\begin{aligned} \mathcal{L} = & \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \alpha_i \left[\pi_{i+1} \beta \left(\tilde{\pi}_i K - D\right) + \left(1 - \beta\right) \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i\right] - K + \\ & + \lambda \int_0^\infty \frac{\partial f\left(\tilde{\pi}_i \mid e\right)}{\partial e} \left(1 - \alpha_i\right) \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i - \lambda + \\ & + \mu \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \left(1 - \alpha_i\right) \tilde{\pi}_i K \, \mathrm{d}\tilde{\pi}_i - \mu e \end{aligned} \tag{44}$$

The solution of the maximization problem is given by the solution of the following system of equations:

$$\frac{\partial \mathcal{L}}{\partial \alpha_i} = \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \pi_{i+1} \beta \left(\tilde{\pi}_i K - D\right) + f\left(\tilde{\pi}_i \mid e\right)(1-\beta)\,\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i -$$
$$-\lambda \int_0^\infty \frac{\partial f\left(\tilde{\pi}_i \mid e\right)}{\partial e} \tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i - \mu \int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i = 0 \tag{45}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \int_0^\infty \frac{\partial f\left(\tilde{\pi}_i \mid e\right)}{\partial e} (1-\alpha_i)\,\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i - 1 = 0 \tag{46}$$

$$\frac{\partial \mathcal{L}}{\partial \mu} = \int_0^\infty f\left(\tilde{\pi}_i \mid e\right)(1-\alpha_i)\,\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i - e = 0 \tag{47}$$

As the venture capitalist wants the maximum effort exerted, $\overline{e}$, the solution is then given by:

$$\alpha_i = 1 - \frac{1}{\int_0^\infty \frac{\partial f(\tilde{\pi}_i|\overline{e})}{\partial \overline{e}} \tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i} \tag{48}$$

$$\int_0^\infty f\left(\tilde{\pi}_i \mid \overline{e}\right)\, \tilde{\pi}_i \mathrm{d}\tilde{\pi}_i = \frac{\overline{e}}{(1-\alpha_i)K} \geq \pi_L \tag{49}$$

■

Proof of Proposition 5. In this Appendix we are going to find the optimal signaling schedule of the firm of the venture capitalist when the new investment opportunity features are known.

As for the early stage investor, it is more attractive for the venture capitalist to signal trough the fraction of share sold rather than with underpricing.

So the first order condition is given by:

$$\frac{\partial W}{\partial \beta} = -V + \frac{\overline{e}}{K\left(1-\alpha_{i+1}\right)} \pi\left(\beta, D\right) V\left(\beta\right) + \frac{\overline{e}}{K\left(1-\alpha_{i+1}\right)} \beta V'\left(\beta\right) = 0 \tag{50}$$

Adding the self full-filling condition, $V = V\left(\beta\right)$, and the financing condition, $K = \frac{\beta V(\beta)}{\alpha_{i+1}}$, the above equation becomes:

$$\frac{-\overline{e}\alpha_{i+1} V\left(\beta\right) + \beta\left(1-\alpha_{i+1}\right) V\left(\beta\right)^2 - \overline{e}\alpha_{i+1}\beta V'\left(\beta\right)}{\left(1-\alpha_{i+1}\right)\beta V\left(\beta\right)} = 0 \tag{51}$$

The solution of this differential equation with the constraint that

$$E\left[V \mid 1\right] = L \tag{52}$$

is given by:

$$V\left(\beta\right) = \frac{\overline{e}\alpha_{i+1} L}{\beta\left(\overline{e}\alpha_{i+1} - L(1-\alpha_{i+1})\ln[\beta]\right)} \tag{53}$$

As for the proof of Proposition 2, we verify that the six conditions of Riley (1979) are satisfied. The first three conditions and the sixth are naturally satisfied. The fourth condition is satisfied for $\alpha > \frac{L}{L+\overline{e}}$. The proof of the fifth condition, the single crossing one, is always satisfied, as:

$$\frac{\partial}{\partial V}\left(-\frac{\partial W}{\partial \beta}/\frac{\partial W}{\partial P}\right) = \frac{(1-\alpha_{i+1})\,K}{\overline{e}} > 0 \tag{54}$$

■

Proof of Proposition 6. The maximizing problem can be simplified as:

$$\max_{\beta,D} W = \max_{\beta,D}\ \beta\left(\frac{\overline{e}}{(1-\alpha_{i+1})\,K}\right)(V(D)-D) + (1-\beta)\,V \tag{55}$$

As we did in the first part of the paper, we solve the optimization problem in respect of D considering the constraint that when there is no underpricing, the level of participation of the venture capitalist is at the minimum, $\alpha_{i+1} = \alpha_L$, and the signaling of the firm value is given by the solution of equation (14). The maximum is then equal to:

$$V(D,\beta) = V_L(\beta) + D \tag{56}$$

Inserting this in the maximization problem, we obtain:

$$\max_{\beta} W = \beta\left(\frac{\overline{e}}{(1-\alpha_{i+1})\,K}\right)V_L(\beta) + (1-\beta)\,V \tag{57}$$

Adding the conditions that $V = V_L(\beta) - D$ and that $K = \frac{\beta V_L}{\alpha_{i+1}}$, the first order condition becomes:

$$\frac{\partial W}{\partial \beta} = -D + \frac{\overline{e}L(\alpha_{i+1}-\alpha_L)}{(1-\alpha_{i+1})\beta(\overline{e}\alpha_L - L(1-\alpha_L)\ln\beta)} = 0 \tag{58}$$

This brings to:

$$\alpha_{i+1}(\beta,D) = 1 - \frac{\overline{e}\,(1-\alpha_L)\,L}{\overline{e}(L+\alpha_L\beta D) - DL(1+\alpha_L)\beta Log[\beta]} \tag{59}$$

$$= \alpha_L\left(1 + \frac{(1-\alpha_L)\,D}{V-(1-\alpha_L)\,D}\right) \tag{60}$$

Given the construction of the two schedules, this is the unique Pareto dominating equilibrium.

However, given the fact that $\beta \leq 1$, this schedule applies only when $\frac{V}{L} \geq \frac{\alpha(1-\alpha_L)}{\alpha_L(1-\alpha)}$. When this condition does not apply, the traditional investor will sell all the shares at $P = L$.

■

Proof of Proposition 7. The percentage underpricing with respect to the IPO price of the venture capital is given by:

$$d_{VC} = \frac{\alpha_{i+1} - \alpha_L}{\alpha_L (1 - \alpha_{i+1})} \tag{61}$$

Using equation (12) and considering that for α_L there is no underpricing, we can rewrite the above expression as:

$$d_V C = \frac{\bar{e} - 2V\beta_{\pi_L}\pi_L + \sqrt{\bar{e}^2 - 4\bar{V}\beta_\pi + 4V^2\beta_{\pi_L}\beta_\pi\pi\pi_L}}{2V\beta_\pi\pi_L - 2\bar{e}} \tag{62}$$

The percentage underpricing with respect to the IPO price of the early stage investor is given by:

$$d_{ESI} = \frac{\pi - \pi_L}{\pi_L} \tag{63}$$

It follows that $d_{VC} > d_{ESI}$ if and only if:

$$\pi_> \pi_L \frac{V\beta_\pi - \bar{e}}{V\beta_{\pi_L}\pi_L - \bar{e}} \tag{64}$$

Note that the fraction on the right hand side is always bigger than one because $\beta_\pi > \beta_{\pi_L}$. ■

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Less underpriced	**More underpriced**
Barry, Muscarella, Peavy, and Vestuypens (1990)	Ljungqvist (1999)
('78-'87) underpricing VC 7% NVC %8	('96-'98) underpricing VC 18% NVC 17%
Megginson and Weiss (1991)	Francis and Hasan (2001)
('83-'87) underpricing VC 7% NVC 12%	('90-'93) underpricing VC 13% NVC 10%
Lin and Smith (1998)	Franzke (2001)
('79-'90) underpricing VC 12% NVC 17%	('97-'00)underpricing VC 64% NVC 61%
	Lee and Wahal (2004)
	('80-'00) underpricing VC 27% NVC 19%
	('80-'89) underpricing VC 8% NVC 9%
	('90-'98) underpricing VC 16.17% NVC 16.70%
	('99) underpricing VC 89% NVC 42%
	('00) underpricing VC 68% NVC 36%

Figure 1: VC underpricing across empirical studies

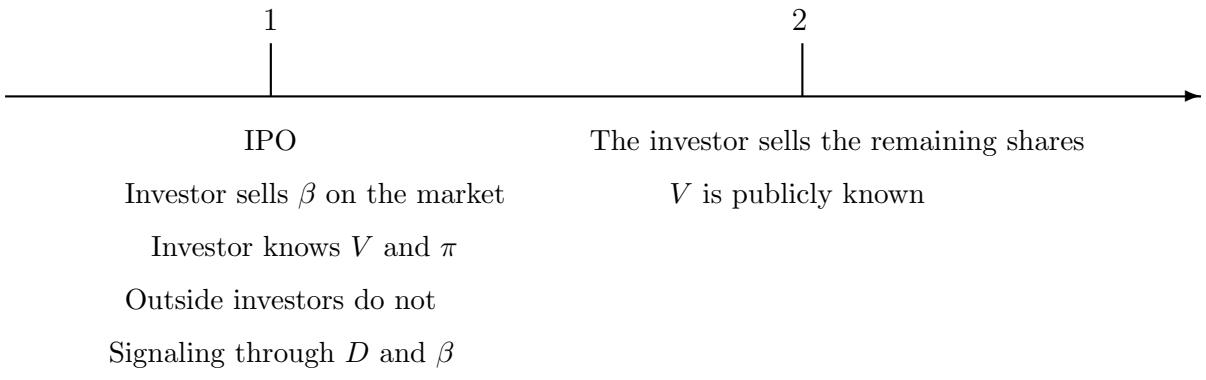

Figure 2: Time Structure of the "Hot Issue" Market Model

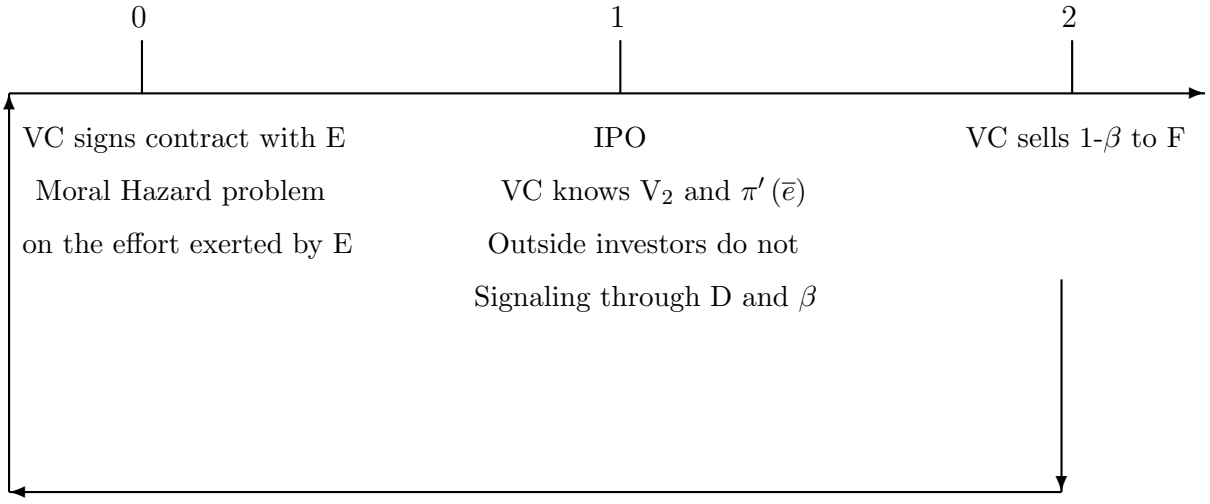

Figure 3: Time Structure of the Venture Capital Model