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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 drive the investor's choice of price 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 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, who 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.

Keywords: IPO, Venture Capital, Signaling, Exit.

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 capital (VC) backed IPOs were significantly more underpriced than non VC backed ones (Ljungqvist and Habib (2001) and Franzke (2004)). This phenomenon is puzzling since generally VC backed firms are less underpriced than non VC backed ones (Barry, Muscarella, Peavy, and Vestuypens 1990). This paper proposes an explanation to both these phenomena based on an asymmetric information problem and a moral hazard one.

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 VC portfolio (between 20% and 35%, according to Cumming and MacIntosh (2003)), they contribute the highest returns (from 30% to more than 50% of total return according to Gompers and Lerner (1999)).

In early studies, VC backed IPOs were found to be less underpriced than non VC backed IPOs (Barry, Muscarella, Peavy, and Vestuypens (1990), Megginson and Weiss (1991) and Lin and Smith (1998)). However, more recently it has been noticed that during hot issue markets, VC backed IPOs are significantly more underpriced than non VC backed IPOs (Francis

[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).

and Hasan (2001), Franzke (2004), Ljungqvist and Habib (2001), Smart and Zutter (2003), Loughran and Ritter (2004) 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 VC backed firms.

This paper offers a new explanation both to the hot issue puzzle and to the venture capitalist's underpricing strategy. In my model an early stage investor (or the entrepreneur himself) takes the firm public to exit and raise funds for a new opportunity.[2] Pástor and Veronesi (2005) show that hot issue periods are correlated with the raising of funding 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. I assume that 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 the price of the firm from which he wishes to exit via an IPO (the 'IPO firm'). Moreover, although the return on the new investment opportunity does not directly affect the payoff of outside investors buying into the IPO, it affects the pricing strategy of the early stage investor.[3]

I show that the early stage investor's choice of IPO price P and fraction β of shares sold has the following properties. In equilibrium there is a one to one mapping between β and P which can be described by a decreasing function $P(\beta)$.[4] The investor's decision is therefore effectively reduced to choosing a point on the function $P(\beta)$. The point actually chosen depends on how

[2]In most IPO models the entrepreneur takes a firm public for either diversification or fund raising. Boot, Gopalan, and Thakor (2006) 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 decide to go public to overcome asymmetric information problems.

[4]This is consistent with the observation that CFOs interpret the selling of large fraction of shares of the firm as negative signals (Brau and Fawcett 2006). 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 my model, underpricing is related to the expected profitability of a different firm (the new investment opportunity) leading to a different set of empirical predictions.

profitable the new opportunity is compared to the true value of the IPO firm. In equilibrium the point chosen on the function $P(\beta)$ is a signal of the ratio of the new opportunity's profits over the true value of the IPO firm. Hence investors do not learn the precise value of the IPO firm, or the exact profitability of the outside opportunity. I show that for a given value of the IPO firm an increase in the profitability of the outside opportunity leads the early stage investor to sell a larger fraction of shares at a lower price. This leads to a decrease in the equilibrium price to value ratio of the IPO firm. Therefore, as new opportunities become more profitable, equilibrium underpricing increases. This implies that, in periods of economic expansions with many new investment opportunities, there is more exit and higher underpricing, just as observed during hot issue markets. In contrast, in periods when there are few and less profitable investment opportunities, exiting investors retain a larger fraction of shares and underprice less.[5] The idea of waves of quick and costly disinvestment is in line with many empirical studies finding 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 (2004) for European firms).

In the second part of the paper I extend the model to describe VC backed IPOs and to explain how the underpricing strategy of venture capital backed IPOs differs from non VC 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 venture capitalist affects the underpricing and the fraction of shares sold in the IPO of the old venture. 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 fund raising stage. This idea is supported among others by Jeng and Wells (2000) which found that "IPOs are the strongest driver of venture capital investing."

The introduction of a moral hazard problem affects the VC's pricing during the IPO. A venture capitalist has to give the entrepreneur a share in the firm in order to induce him to

[5]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.

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 of 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 profits per share and in addition the VC's ownership augments, 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. This changes the shape of the function $P(\beta)$ from which the VC chooses in equilibrium and this affects the way in which equilibrium underpricing fluctuates in response to changes in the new venture's profitability. Due to the convex relationship between the new venture's profitability and the VC's profits, the degree of underpricing fluctuates more strongly between hot and cold markets compared to firms with no moral hazard problem. I show that the venture capitalist limits his stake in the new venture and then disinvests less during the IPO and underprices less than an early stage investor. The reverse is true during hot issue periods.

The literature on IPOs is very extensive (see Draho (2002), Welch and Ritter (2002) and Jenkinson and Ljungqvist (2001) for a reviews). Among the different explanations offered for IPO underpricing and "hot issue", 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 (2002) 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 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.

Stoughton, Wong, and Zechner (2001) investigate IPO decisions when market pricing conveys information on the product's quality to consumers. A "hot issue"market can then arise when uncertainty about market size is high and consumer preferences exhibit network externalities.

Other papers interpret these anomalies as the result of bounded rationality in the form of over-optimism among investors and analysts (Rajan and Servaes (1997), Ljungqvist, Nanda, and Singh (2006) 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 (1997) 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. I argue that "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.

There are a number of empirical studies that capture how VC underpricing varies over time, but no theoretical models offer an explanation. Empirical papers that find lower IPO underpricing by the VC backed firms interpreted the phenomenon as a result of the certification role of venture capitalists. Lee and Wahal (2004) hypothesize that VC backed IPOs must be more underpriced than non VC 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), Hellmann (forthcoming) and Schwienbacher (2002) provide models of a 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. Hellmann (forthcoming) and Schwienbacher (2002) analyze 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 mine is the first theoretical paper that addresses the issue of time varying underpricing by venture capitalists.

The structure of the paper is as follows. Section 2 describes the IPO exit behavior of a generic (non VC backed) firm. In Section 3, the VC backed IPO model is presented. In Section 4, I compare the results of the two models and derive empirical implications. The final section summarizes and concludes the paper. All proofs are in the Appendix.

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. I 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 lowest possible expected return. The early stage investor has limited capital or limited capacity in managing companies,[6] and, therefore, needs to exit from the existing firm in order to invest in the new venture.[7] 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's price at P and offers to sell a fraction β of it. Outside investors observing the price and the fraction of shares tendered decide if they are willing to buy the shares or not.

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

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

[7]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).

structure of the model is sketched in Fig. 2.

2.2 IPO of the early stage investor

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 chooses β and P so as to maximize 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:[8]

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

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

Investors observe the price and the fraction of shares sold in the IPO. They then decide if they are willing to buy shares or not. The problem faced by the early stage investor is a double asymmetric information one and can be solved as proposed by Quinzii and Rochet (1985) and Grinblatt and Hwang (1989).

Proposition 1 *When the new investment opportunity and the firm value are unknown to outside investors, there exists a unique Pareto dominant partially separating equilibrium. When:*

$$\frac{V}{L} \geq \frac{\pi}{\pi_L} \tag{2}$$

[8]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.

the early stage investor sets:

$$P = \frac{\pi_L}{\pi} V \tag{3}$$

$$\beta = \left(\frac{L}{\pi_L} \frac{\pi}{V} \right)^{\frac{\pi_L}{\pi_L - 1}} \tag{4}$$

When $\frac{V}{L} < \frac{\pi}{\pi_L}$*, he sells all the shares,* $\beta = 1$ *at* $P = L$*.*

When condition (2) is satisfied, the price increases in firm value and decreases in the profitability of the new investment opportunity (equation (3)). Moreover, in equilibrium, both P and β are a function of $\frac{\pi}{V}$. There is therefore a one to one equilibrium relationship between β and P, where a point (P, β) is a signal of $\frac{\pi}{V}$. As $\frac{\pi}{V}$ increases P falls and β increases. We can define underpricing, D as the difference between the firm value, V, and the firm's price P, i.e., $D = V - P$. Since $\pi \geq \pi_L$ it follows from (3) that there is always underpricing except when the profitability of the new investment is at its lower bound, π_L. Moreover, it follows directly that for a given level of V an increase in π leads to an increase in underpricing. When the profitability of the new investment increases underpricing increases in a concave way.[9] When $\frac{\pi}{V} = \frac{\pi_L}{L}$, a pooling equilibrium arises and the price is set equal to the minimum value of the firm, L, and the early stage investor sells all the shares, $\beta = 1$. The early stage investor would like to sell more than the total of the shares available. Given, however, that $\beta > 1$ is infeasible, the early stage investor settles with the corner solution of selling everything ($\beta = 1$) and the price then equals the lowest possible firm value ($P = L$).

The implicit relationship between P and β given by (3) and (4) can be written as

$$P = L\beta^{-\frac{\pi_L - 1}{\pi_L}}. \tag{5}$$

A higher fraction β of shares sold therefore comes in equilibrium at a lower price P and total proceeds are given by $\beta^{\frac{1}{\pi_L}}$. In his choice of P and β the early stage investor faces a trade off. On the one hand he would like to raise the price P so as to have more funds to invest in the new opportunity. At the same time doing so forces him to sell a smaller fraction of shares, which reduces his proceeds. Crucially, the trade-off changes with $\frac{\pi}{V}$, because the effective value

[9] This result is in line with Leland and Pyle (1977) and Grinblatt and Hwang (1989). However, in these models the firm is taken public because of risk aversion of the initial owner. Here the early stage investor is risk neutral and chooses to go public as a new investment arises.

of the proceeds raised depends on how good the new opportunity is, and the cost of issuing more shares depends on how underpriced the firm is at the IPO stage. This allows different types of early stage investors (defined by their ratio $\frac{\pi}{V}$) to choose different values of P and β so as to signal $\frac{\pi}{V}$. Otherwise identical high value firms (low $\frac{\pi}{V}$) sell at higher prices (but are more strongly underpriced) and sell fewer shares than low value firms (high $\frac{\pi}{V}$) (see Fig. 5).

In principle, the early stage investor could deviate from the proposed equilibrium in two different ways. Firstly, he could choose a point P and β that is consistent with equilibrium, i.e, that lies on (5) but that does not correspond to his true type, i.e., (3) and (4) are violated. Secondly, he could deviate to a point outside the function (5) in which case the deviation is observed by outside investors.

We now describe why the first type of deviation is not profitable. Consider the early stage investor of a low value firm and compare it to a high value firm with an identical new opportunity. Intuitively, the early stage investor of the low value firm chooses in equilibrium to sell a relatively large fraction of shares at a relatively low price, which gives him relatively high proceeds to reinvest (total proceeds are an increasing function of β). If instead, he mimicked the high value firm by increasing the price and selling a smaller fraction of shares, he would raise less proceeds for 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 and it does not pay a low value firm to mimic this behavior. Moreover, the marginal effect of the signal is greater the higher is the firm value: a further reduction of shares sold and the resulting lower returns is marginally more expensive (i.e. the second derivative is positive).

Similarly, when the early stage investor has a highly profitable new opportunity, he has no incentive to mimic the low profitability investment opportunity even though this would allow him to set a higher price. Doing so would reduce the fraction of shares he can sell and lower the proceeds. This is more costly when the new opportunity is better. An early stage investor with a highly profitable opportunity is therefore willing to incur high underpricing: the loss from investing less in the new investment would be higher than the gain from setting a higher price. Conversely, when the new investment opportunity is not very profitable, the early stage

investor does not gain much from the high proceeds of the IPO: the loss from leaving money on the table is too high and the gain from investing the proceeds is too low to compensate for it.

The outcome is a partially separating equilibrium where the shares sold signal the ratio between firm value and investment profitability. An early stage investor who takes public a very valuable firm would retain many shares and set a high price. However, when in addition he has a very valuable new investment opportunity, he would also like to have high proceeds. He then prefers to set a lower price and sell more shares such that the proceeds are higher. Outside investors observing the amount of shares tendered know that the price is equal or below the true value of the firm taken public, although they cannot quantify the eventual underpricing.[10] They are then willing to buy the shares.

Consider now the second type of deviation. If the early stage investor were to deviate from equilibrium and attempted to sell shares at a higher price than that implied by (5), this would violate relation (4) and investors would simply not buy any shares. Setting instead a price lower than that given by relation (4), the early stage investor would be giving up proceeds and then get less profits from the new investment opportunity. He can therefore do better selling the same amount of shares at a higher price and such a deviation would not be profitable. Hence, deviating from (5) is never profitable.

Empirically our results mean that higher value firms are 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 2006). Empirical studies do not agree on the relation between shares retained and firm value. Brennan (1990) and Smith (1986) find a negative relation between shares retained and firm value while Garfinkel (1989), Jegadeesh, Weinstein, and Welch (1993) and Michaely and Shaw (1994) find a positive one. This however does not contradict with my model. The fraction of shares determined is not determined only by the firm value, but also by the outside option of the early stage investor. To the best of my knowledge empirical studies have not controlled

[10] A fully separating equilibrium could be obtained when relaxing the assumption of the full revelation of the firm value in the period 2. Allowing for the revelation of the firm value in the next period would give a fully separating equilibrium as in Allen and Faulhaber (1989) and Welch (1989). At the same time the model would become unduly complicated without adding any new insights.

for this second determinant.

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 value of the new investment opportunity the higher is the first day return (underpricing) and the higher is the fraction of shares sold in the IPO. This allows us to understand the time variation of IPO underpricing over time can be interpreted. Good investment prospects trigger a "hot issue" market: early stage investors take existing firms public, sell 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, i.e. once the "opportunity wave" passed, fewer firms will be taken public and fewer shares will be sold in the IPO and firms will be less underpriced. Empirical studies confirm this idea of quick and costly exits. Not only hot issues are found to be correlated to growth opportunities (Choe, Masulis, and Nanda (1993) and Pástor and Veronesi (2005)), but also during hot issue periods the 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 (2004) for European firms).

3 The Venture Capitalist

In this section I present a model of VC backed IPOs. The comparison of this model with the one of the early stage investor will offer an explanation for why VC backed IPOs show different underpricing across time compared to the non VC backed ones (see next Section).

Gompers (1995, p. 1461) finds that "[v]enture capitalists concentrate investments in early stage companies and high technology industries where informational asymmetries are highest". Such investments are characterized by the lack of tangible assets and by their low or non-existent current cash flows. Agency problems are likely to be particularly severe under those circumstances. As Admati and Pfleiderer (1994) and Kaplan and Stromberg (2003) pointed out, the superior capability in information gathering and monitoring of the venture capitalist helps them to mitigate the agency problems. The exploitation of this comparative advantage induces the venture capitalist to invest in firms where moral hazard problems are more severe.

I distinguish a venture capitalist from an early stage investor by considering a simple model of moral hazard between venture capitalist and entrepreneur. I introduce this element in the IPO framework and analyze how it affects the venture capitalist's pricing strategy. The time structure of the model changes slightly. I now have a cycle subdivided into 3 periods with 4 different players: the venture capitalist, the entrepreneurs of the existing and of the new firm, the outside investors.

At date 0, the venture capitalist wants to invest in a new venture. Its value is stochastic and depends probabilistically on the amount of effort $e \in [0, \overline{e}]$ exerted by the entrepreneur. The effort exerted is unobservable and is costly for the entrepreneur. The cost is set for simplicity equal to e. The marginal productivity of the entrepreneur's effort is $E[\pi'(e)]$.[11]

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 as a function of the effort exerted. I define by $f(\tilde{\pi}_i \mid e)$ the probability distribution for the i- venture to generate return $\tilde{\pi}$ given the entrepreneur's effort, e. Both the venture capitalist and the entrepreneur are risk neutral and have limited liability.

I assume that the venture capitalist has all the bargaining power, but has to give enough incentives to the entrepreneur to exert effort. Assume that the monotone likelihood ratio property (MLRP) is satisfied (Salanié 1999) and therefore $\frac{\partial}{\partial \tilde{\pi}_i}\left[\frac{\frac{\partial f(\tilde{\pi}_i|e)}{\partial e}}{f(\tilde{\pi}_i|e)}\right] > 0$. I also assume that the marginal increase in profitability due to an increase in effort is higher than the marginal cost for the relevant values of effort: $\frac{\partial f(\tilde{\pi}_i|e)}{\partial e} > 1$. This condition implies the optimal effort is a corner solution where optimally the maximum effort is exerted.[12]

In order to mitigate the moral hazard problem, the venture capitalist has to leave a fraction of the shares to the entrepreneur as a compensation for the effort exerted. I define by $\alpha_i \in [a_L, 1]$ the endogenous profit share of the venture capitalist (a_L is an endogenous lower bound which will be discussed below).

At date 1 the firm value, $V \in [V_L, \infty)$, is realized. This firm value can be observed by both

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

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

the venture capitalist and the entrepreneur, but not by outside investors. At the same time the venture capitalist has a new investment opportunity. Given his limits in management capacity he wants to exit and take the firm public to invest the proceeds in the new venture.[13]

The characteristics of the contract between the venture capitalist and the entrepreneur of the new venture are not known to 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.

As in the early stage investor's case, when taking a firm public the venture capitalist makes an offer to the outside investors setting a price, P, and the amount of shares distributed, β. Investors face a double asymmetric information problem: both the existing firm value and the profitability of the new venture are private information. However, contrary to the early stage investor's case, both the value of the firm and the profitability of the new venture are determined by the terms of the contract between the venture capitalist and the respective entrepreneur. Specifically these terms are the capital invested, K, and profit share, α.

At date 2, after the IPO, the firm value is revealed to all players and the venture capitalist sells the remaining shares, $1 - \beta$ on the market. At this point, the cycle repeats itself: the selling of the stake of the new firm at period 1 and 2, the venture capitalist's investment in a new venture, etc. The new time structure is sketched in Fig. 3.

3.1 The Contract between Venture Capitalist and the Entrepreneur

Before solving for the optimal pricing strategy of the venture capitalist when doing the IPO, I first derive the contract between the venture capitalist and the entrepreneur. The interaction between IPO and VC-entrepreneur contract is not trivial. The amount of capital that the venture capitalist invests in the new investment opportunity depends on the outcome of the IPO. The amount of capital that is invested in a firm in turn influences the contract with the entrepreneur and therefore the profitability of the new firm. At the same time the profitability affects the pricing and thus the capital raised during the IPO.

The venture capitalist can induce the entrepreneur to exert effort offering shares, i.e. di-

[13]This is in line with findings of Gladstone (1987) and Quindlen (2000).

minishing his own equity stake, α_i. The higher is the stake of the entrepreneur, the greater is his incentive to exert effort and therefore increase the firm's expected profits.[14]

Proposition 2 *The optimal equity stake of the venture capitalist is*

$$\alpha_{i+1} = 1 - \frac{1}{\pi'_{i+1}(\overline{e})\, K} \tag{6}$$

The entrepreneur exerts the maximum effort, $\overline{e}$ *and the expected profitability of the venture is:*

$$\pi_{i+1}(\overline{e}) = \frac{\overline{e}}{(1-\alpha_{i+1})\, K} \geq \pi_L \tag{7}$$

The entrepreneur's optimal stake, $1-\alpha_i$, depends on his marginal productivity. The higher is the entrepreneur's quality, the lower the fraction of shares that the venture capitalist has to concede to the entrepreneur to induce him to exert maximum effort.

This result captures an important feature of the VC industry: the better is the firm's quality, the higher is the venture capitalist's stake. In practice the venture capitalist tends to finance new ventures through convertible debt or convertible preferred stock. When the firm turns out to be more successful the venture capitalist exercises the options and increases his cash flow rights (Sahlman (1990), Gompers (1999), Baker and Gompers (1999) and Kaplan and Stromberg (2003)).

The contract between the venture capitalist and the entrepreneur is not influenced by how the venture capitalist will exit from the firm, i.e. the pricing at the IPO stage (see equation (6) and (7)). Intuitively, the outcome of the IPO does not affect the moral hazard problem between the venture capitalist and the entrepreneur and hence the objective at the contract stage remains the same, to maximize firm value: the higher the firm value in the first period, the more valuable the subsequent IPO and the higher the venture capitalist's profits. Due to this property, the recursive element of the model vanishes and the analysis boils down to the static problem of how moral hazard in the subsequent venture affects IPO structure.

On the other hand, the outcome of the IPO, namely the level of pricing and the amount of shares sold, influences the expected profits of the venture capitalist. The IPO determines the amount of capital invested in the firm, K, and hence the profitability of the venture.

[14]We do not solve for the optimal contract as it is beyond the scope of the paper.

Finally, we can derive the lower bound of the participation of the venture capitalist, α_L. This occurs when the expected profitability of the new venture is at the minimum, $\pi = \pi_L$, and the venture capitalist invests the maximum possible proceeds ($K = L$). From equation (7), the venture capitalist invests in the new venture only if his participation is larger than $\frac{\pi_L L - e}{\pi_L L}$.

3.2 Venture capitalist-entrepreneur contracting and the IPO

Having solved for the contract between venture capitalist and entrepreneur, I consider now 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 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 stake 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 (7)). The venture capitalist's maximization problem becomes:

$$\max_{\beta,P} W = \max_{\beta,P} \beta \frac{\overline{e}}{(1-\alpha_{i+1})\,K} P + (1-\beta)\,V \tag{8}$$

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, $K = \beta P$.

Proposition 3 *There exists a unique Pareto dominant partially separating equilibrium. When:*

$$\frac{V}{L} \geq \frac{\alpha_{i+1}\,(1-\alpha_L)}{\alpha_L\,(1-\alpha_{i+1})} \tag{9}$$

the venture capitalist sets:

$$P = \frac{V\,(1-\alpha)\,\alpha_L}{\alpha\,(1-\alpha_L)} \tag{10}$$

and β as the unique solution of the following equation:

$$P = \frac{\bar{e} L \alpha}{\beta\,(\bar{e}\alpha - L\,(1-\alpha)\ln\beta)} \tag{11}$$

When condition (9) is not satisfied, all the shares are sold at $P = L$.

The pricing strategy of the venture capitalist has qualitatively the same features as the early stage investor's. Given the value of the firm taken public, the venture capitalist has to weight the costs of selling the firm cheaply and giving up part of the profits from the new venture. When the firm is very valuable relative to the new venture, he prefers to set a higher price and to distribute few shares. This implies lower proceeds to invest in the new venture. When the profitability of the new venture is high the venture capitalist is ready to accept a lower price (higher underpricing) in order to have more capital to invest in the new venture. When the profitability of the new venture is very high he ends up selling all his shares at the minimum price.

The result is consistent with the empirical findings of Cumming and MacIntosh (2003). They analyze the exits through IPO of venture capitalists in the US and Canada. They find that asymmetric information on the value of the firm taken public affects the amount of shares retained by the venture capitalist. In particular in sectors where the asymmetric information problem is more severe venture capitalists tend to retain more shares (see Fig. 5).

The pricing schedule of the venture capitalist, though qualitatively similar, it differ in an important way from the one of the early stage investor. This is due to the moral hazard problem the venture capitalist has with the entrepreneur of the new venture. In the next section I compare these two schedules and draw implications on how underpricing of a VC backed IPO differs from a non VC backed one.

4 Analysis of the results and empirical implications

So far, two types of IPO exits have been presented. 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 two types of IPO structures arise: the early stage investor faces asymmetry of information on the firm value and the expected profitability in the new investment opportunity, while a venture capitalist faces it on the firm value and the characteristic of the contract in the new venture, which indirectly identifies its profitability.

In this section I analyze the difference in the pricing behavior of these two investor types, and identify empirical implications. In particular I show how the moral hazard problem explains the puzzle on the changing underpricing behavior of venture capitalist and early stage investor in hot and cold issue markets. I first analyze how the profitability of the new investment affects underpricing and shares retained in VC and non VC backed IPOs. I then analyze the effect of firm value on the exit strategy of the early stage investor and of the venture capitalist.

4.1 Underpricing of VC and non VC backed IPOs

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

I focus on percentage underpricing relative to the IPO price $d \equiv \frac{D}{V-D}$. I denote by d_{ESI} the percentage underpricing of the early stage investor derived from equation (3) and d_{VC} the percentage underpricing of the venture capitalist where D is derived from equation (10).

Proposition 4 *When condition (2) is satisfied, and for a given value of the firm to be sold, there exists a* $\pi^* > \pi_L$ *such that:*

$$d_{VC} \leq d_{ESI} \quad for \quad \pi \leq \pi^* \tag{12}$$

$$d_{VC} > d_{ESI} \quad for \quad \pi > \pi^* \tag{13}$$

When the profitability of the new venture is low, the venture capitalist underprices less than an early stage investor. When the profitability of the new venture, π, exceeds the threshold π^*, the venture capitalist underprices more than the early stage investor. When π increases further, the venture capitalist chooses the maximum amount of underpricing, $\frac{V-L}{L}$ selling all his shares (condition (9) is violated). The early stage investor reaches the case where he sells all his shares for the minimum price for higher levels of π, i.e. condition (2) is violated only when π is very high and when condition (9) is already violated.

The intuition for 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 VC 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 as his profits increase more quickly. Hence he wants to invest more in the new venture and sell more shares of the existing firm than the correspondent early stage investor. He sells more shares at a cheaper price than the early stage investor.

This result can explain the empirical evidence on the underpricing of VC backed IPOs (Lee and Wahal 2004). On the one hand, Barry, Muscarella, Peavy, and Vestuypens (1990), Megginson and Weiss (1991) and Lin and Smith (1998) find that VC backed IPOs are less underpriced than non VC backed IPOs during normal IPO periods. The opposite happens during hot issue periods studied in Francis and Hasan (2001), Smart and Zutter (2003), Franzke (2004).

The papers which find less underpricing for VC 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, when there was no hot issue period and venture capitalists underpriced less than early stage investors (7% instead of 8%). Lin and Smith (1998) consider a long time series ('79-'90) without distinguishing the hot market periods and find that VC underpricing is 12% while the early stage investor one is 17%.

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

According to the model presented here, these empirical results can be explained by 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 and do so by taking them public. The opposite occurs when there are fewer and less profitable investment opportunities. Investors, and venture capitalists in particular, are not very eager to disinvest from existing firms and IPO activity is lower.

4.2 Shares retained in VC and non VC backed IPOs

I have analyzed so far how the profitability of the new investment opportunity affects the IPO and in particular the underpricing. The next step is to study how the value of the firm taken public influences the IPO and especially the shares retained. The comparison is not trivial as the underpricing is determined differently in the early stage investor's case and in the venture capitalist's.

Consider the case where the new investment profitability is at the minimum and thus there is no underpricing. 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 sell fewer shares into the IPO. It follows that the venture capitalist tends to sell fewer shares for the same firm value and the same investment profitability than the early stage investor.

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 wants to set 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 an investor's exit strategy from a private equity investment, when exit is driven by the need to free up funds for new investment opportunities. It thus links the availability of new investment opportunities to IPO decisions of early stage and VC investors. In doing so, the model addresses two unresolved empirical puzzles surrounding IPOs, namely that (i) IPO underpricing tends to increase during hot issue periods, and (ii) VC backed IPOs are underpriced less than non-VC backed ones during normal periods, but surprisingly, are underpriced more during hot issue periods. Neither of the two phenomena have been explained in a satisfactory manner and this paper provides a single explanation for both.

Firstly, it is shown that the widely observed increase in IPO underpricing during hot issue periods can be explained by the arrival of highly profitable new investment opportunities. When such opportunities arise, an early stage or VC investor is more eager to raise funds by exiting from existing investments through an IPO. He is therefore willing to underprice the offering more strongly compared to a situation in which new investment opportunities are only moderately profitable. Secondly, the paper draws a distinction between early stage investors and VC investors based on Gompers (1995)'s finding that VCs tend to invest in companies with more severe moral hazard problems. This paper shows that underpricing in the presence of a moral hazard problem between the venture capitalist and its portfolio firm becomes more sensitive with respect to the profitability of the new investment opportunity. This is because the stake that the VC can invest in such an opportunity depends itself on its profitability: when profitability is high, the entrepreneur's moral hazard problem can be resolved by giving him a small stake in the company. This stake has to become larger when the firm's profitability decreases. The effect of the new venture's underlying profitability is thus compounded by the fact that the VC can invest larger amounts in more profitable projects while still satisfying the

entrepreneur's incentive compatibility constraint. As a result, the VC is keen to raise a lot more funds to invest when the profitability of new ventures increases - essentially the VC's payoff from the new investment becomes a convex function of its underlying profitability. This affects the VC's underpricing strategy in the IPO. When new investments are very profitable, i.e., during a hot issue market, the VC is extremely eager to raise funds via an IPO of an existing company and therefore underprices the offering more than an early stage investor with a similar investment opportunity. Conversely, when new investment opportunities are only moderately profitable, the VC would only invest a small stake in the new venture and therefore have a reduced need to raise funds through an IPO. He therefore underprices an IPO less than an early stage investor during normal periods.

In this model the early stage or VC investor has superior information than the market along two dimensions: the underlying value of the firm to be sold in the IPO and the profitability of the new investment opportunity. While the latter has no direct impact upon the value of buying shares in the IPO, it is informative about how eager the early stage or VC investor is to exit from his existing firm. It therefore becomes an important piece of information that can be partially conveyed by the terms of the IPO. These include the price and the fraction of shares sold in the IPO. Because the early stage investor has two choice variables, the model is able to make novel predictions about the relationship between IPO underpricing and the fraction of shares sold in the IPO, both as a function of whether or not the issue market is hot, and whether an IPO is or is not VC backed. This contrast with much of the literature on IPOs in which the early stage investor can choose the price. I predict that during hot issue markets when underpricing is higher, the amount of shares tendered increases. Moreover, a larger fraction of shares are sold in VC backed IPOs compared to non-VC backed ones during hot issue periods, but the opposite is true during normal periods.

Appendix

Proof of Proposition 1. The proof proceeds in 3 steps.

1. I first prove that when the profitability of the new investment opportunity is common knowledge, the early stage investor chooses to signal the firm through the fraction of

shares sold.

2. I find the unique reactive separating equilibrium when there is only asymmetry of information on the firm value.

3. I find the optimal price and shares retained in case of double asymmetry of information.

Proof of Part 1. When early stage investor chooses to price, it implies choosing the degree of underpricing. Hence, the optimal schedule has to satisfy the following first order condition:

$$\frac{\partial W}{\partial D} = \pi\beta\left(\frac{\partial V(D)}{D} - 1\right) = 0 \tag{14}$$

To obtain an informationally consistent price function, I impose the self-fulfilling belief condition, $V(D) = V$. It follows that the family of the optimal candidate signaling schedules is the equation that solves the above differential equation.

In order to find the Pareto optimal schedule, the constant of integration has to be such that when the traditional investor does not underprice, firm value is equal to the minimum firm value, L. The Pareto-dominant price schedule is:

$$V(D) = D + L \tag{15}$$

and the optimal fraction sold is 1. The investor's wealth is given by $\max[\pi L, V]$. Comparing this result with the wealth in case of signaling with the fraction of shares sold (see Part 2 of the proof), it follows that signaling through underpricing is inferior to signaling through retained shares. ■

Proof of Part 2. The informationally consistent Pareto-dominant price schedule must satisfy the following first order condition:

$$\frac{\partial W}{\partial \beta} = \pi V(\beta) + \pi\beta V'(\beta) - V = 0 \tag{16}$$

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

$$V(\beta) = V \tag{17}$$

Substituting equation (17) in equation (16) and rearranging, the first order condition becomes:

$$(-1 + \pi) V(\beta) + \beta\pi V'(\beta) = 0 \tag{18}$$

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

$$V(\beta) = \beta^{-1+\frac{1}{\pi}} A \tag{19}$$

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, L. Indeed, the schedules where $V(1) < L$ allow for arbitrage 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:

$$V(\beta) = \beta^{-1+\frac{1}{\pi}} L \tag{20}$$

This price schedule satisfies also the second order condition[15] and its first and second derivatives are respectively given by:

$$\frac{\partial V(\beta)}{\partial \beta} = \beta^{-2+\frac{1}{\pi}} \left(-1 + \frac{1}{\pi}\right) L < 0 \tag{22}$$

$$\frac{\partial^2 V(\beta)}{\partial \beta^2} = \beta^{-3+\frac{1}{\pi}} \left(-1 + \frac{1}{\pi}\right)\left(-2 + \frac{1}{\pi}\right) L > 0 \tag{23}$$

This is the informationally consistent Pareto dominant schedule. It is straightforward to verify that it satisfies the conditions of Riley (1979). Hence this is the unique reactive equilibrium.

■

Proof of Part 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 20, the signaling schedule in this case is:

$$V_L(\beta) = \beta^{-1+\frac{1}{\pi_L}} L \tag{24}$$

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

$$\frac{\partial^2 E[W]}{\partial \beta^2} = 2\pi V'(\beta) + \beta\pi V''(\beta) = V'(\beta) < 0 \tag{21}$$

When no shares are retained, the optimal pricing has to satisfy the first order condition and the constraint given by the case of no underpricing:

$$\frac{\partial W}{\partial D} = \beta\pi\left(V'\left(D\right) - 1\right) = 0 \tag{25}$$

$$V\left(0\right) = V_L\left(\beta\right) \tag{26}$$

Solving this differential equation, I obtain $V\left(D\right) = V\left(L\right) + D$.

Applying this result to the objective function, I can write:

$$\max_{\beta} W = \max_{\beta} \beta\pi\left(V_L\left(\beta\right) + D - D\right) + \left(1 - \beta\right)V \tag{27}$$

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

$$\frac{\partial W}{\partial \beta} = -\frac{\beta\pi_L D - \beta^{\frac{1}{\pi_L}}\left(\pi\left(\beta, D\right) - \pi_L\right)}{\beta\pi_L} = 0 \tag{28}$$

Solving this equation and rearranging I obtain equations (3) and (4). This is the unique Pareto dominant equilibrium as it satisfies the 6 conditions of Engers (1987).

As $\beta \leq 1$, this equilibrium 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 2. The maximization problem of the venture capitalist is:

$$\max_{\alpha_i} \int_0^{\infty} f\left(\tilde{\pi}_i \mid e\right)\alpha_i\left[\pi_{i+1}\beta\left(\tilde{\pi}_i K - D\right) + \left(1 - \beta\right)\tilde{\pi}_i K\right]\mathrm{d}\tilde{\pi}_i - K \tag{29}$$

$$\text{s.t. } \max_{e} \int_0^{\infty} f\left(\tilde{\pi}_i \mid e\right)\left(1 - \alpha_i\right)\tilde{\pi}_i K\,\mathrm{d}\tilde{\pi}_i - e \tag{30}$$

$$\int_0^{\infty} f\left(\tilde{\pi}_i \mid e\right)\left(1 - \alpha_i\right)\tilde{\pi}_i K\,\mathrm{d}\tilde{\pi}_i \geq e \tag{31}$$

$$\int_0^{\infty} f\left(\tilde{\pi}_i \mid e\right)\alpha_i\left(\pi_{i+1}\beta\left(\tilde{\pi}_i K - D\right) + \left(1 - \beta\right)\tilde{\pi}_i K\right)\mathrm{d}\tilde{\pi}_i \geq K \tag{32}$$

$$0 \leq \alpha_i \leq 1 \tag{33}$$

where equation (30) is the maximization of the entrepreneur in terms of effort exerted, condition (31) is the individual rationality constraint of the entrepreneur and condition (32) is the individual rationality constraint of the venture capitalist himself. This condition is relevant only in terms of venture selection: the venture capitalist wants to invest only if the rate of return is greater than 1.

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

$$\begin{aligned}\mathcal{L} = &\int_0^\infty f\left(\tilde{\pi}_i \mid e\right) \alpha_i \left[\pi_{i+1}\beta\left(\tilde{\pi}_i K - D\right) + \left(1-\beta\right)\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i\right] - K + \\ &+ \lambda \int_0^\infty \frac{\partial f\left(\tilde{\pi}_i \mid e\right)}{\partial e}\left(1-\alpha_i\right)\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i - \lambda + \\ &+ \mu \int_0^\infty f\left(\tilde{\pi}_i \mid e\right)\left(1-\alpha_i\right)\tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i - \mu e \end{aligned} \tag{34}$$

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

$$\alpha_i = 1 - \frac{1}{\int_0^\infty \frac{\partial f(\tilde{\pi}_i|\overline{e})}{\partial \overline{e}} \tilde{\pi}_i K \,\mathrm{d}\tilde{\pi}_i} \tag{35}$$

$$\int_0^\infty f\left(\tilde{\pi}_i \mid \overline{e}\right)\, \tilde{\pi}_i \mathrm{d}\tilde{\pi}_i = \frac{\overline{e}}{(1-\alpha_i)K} \geq \pi_L \tag{36}$$

■

Proof of Proposition 3. I follow the same steps as in the proof of Proposition 1. Similarly it can be verified that where there is asymmetry of information on the firm value, the venture capitalist chooses to signal trough the fraction of shares sold rather than with underpricing. In this case the signaling schedule can be found imposing the first order condition:

$$\frac{\partial W}{\partial \beta} = -V + \frac{\overline{e}}{K\left(1-\alpha_{i+1}\right)} V\left(\beta\right) + \frac{\overline{e}}{K\left(1-\alpha_{i+1}\right)} \beta V'\left(\beta\right) = 0 \tag{37}$$

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

$$\frac{-\overline{e}\alpha_{i+1} V\left(\beta\right) + \beta\left(1-\alpha_{i+1}\right) V\left(\beta\right)^2 - \overline{e}\alpha_{i+1}\beta V'\left(\beta\right)}{\left(1-\alpha_{i+1}\right)\beta V\left(\beta\right)} = 0 \tag{38}$$

The solution of this differential equation considering the constraint $E\left[V \mid 1\right] = L$ is:

$$V\left(\beta\right) = \frac{\overline{e}\alpha_{i+1} L}{\beta\left(\overline{e}\alpha_{i+1} - L(1-\alpha_{i+1})\ln\beta\right)} \tag{39}$$

As for the proof of Proposition 20, the six conditions of Riley (1979) need to be satisfied. The first three conditions and the sixth are naturally satisfied. The fourth condition is satisfied for $\alpha > \frac{L}{L+\overline{e}}$. The fifth condition is always satisfied, as:

$$\frac{\partial}{\partial V}\left(-\frac{\partial W}{\partial \beta} \Big/ \frac{\partial W}{\partial P}\right) = \frac{\left(1-\alpha_{i+1}\right)K}{\overline{e}} > 0 \tag{40}$$

Considering the asymmetry of information on both terms, I first solve the optimization problem with respect to D considering the constraint that when there is no underpricing, the level of participation of the venture capitalist is at the minimum, $\alpha_{i+1} = \alpha_L$. Hence, $V(D, \beta) = V_L(\beta) + D$ Inserting this in the maximization problem, it becomes:

$$\max_{\beta} W = \beta \left(\frac{\overline{e}}{(1 - \alpha_{i+1}) K} \right) V_L(\beta) + (1 - \beta) V \tag{41}$$

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

$$\frac{\partial W}{\partial \beta} = -D + \frac{\overline{e} L(\alpha_{i+1} - \alpha_L)}{(1 - \alpha_{i+1})\beta(\overline{e}\alpha_L - L(1 - \alpha_L)\ln\beta)} = 0 \tag{42}$$

This yields to:

$$\alpha_{i+1}(\beta, D) = 1 - \frac{\overline{e}(1 - \alpha_L) L}{\overline{e}(L + \alpha_L \beta D) - DL(1 + \alpha_L)\beta \ln\beta} \tag{43}$$

$$= \alpha_L \left(1 + \frac{(1 - \alpha_L) D}{V - (1 - \alpha_L) D} \right) \tag{44}$$

Given the construction of the two schedules, this is the unique Pareto dominant equilibrium. Rearranging equations (39) and (44), equation (10) and (11) are obtained.

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

$$d_{VC} = \frac{\alpha_{i+1} - \alpha_L}{\alpha_L (1 - \alpha_{i+1})} \tag{45}$$

Denote with β_π the β the venture capitalist chooses given π and β_{π_L} the β chosen by the venture capitalist when $\pi = \pi_L$. Using equation (7) and considering that for α_L there is no underpricing, the above expression becomes:

$$d_{VC} = \frac{\bar{e} - 2V\beta_{\pi_L}\pi_L + \sqrt{\bar{e}^2 - 4V\beta_\pi + 4V^2\beta_{\pi_L}\beta_\pi\pi\pi_L}}{2V\beta_\pi\pi_L - 2\bar{e}} \tag{46}$$

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

$$d_{ESI} = \frac{\pi - \pi_L}{\pi_L} \tag{47}$$

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

$$\pi > \pi_L \frac{V\beta_\pi - \bar{e}}{V\beta_{\pi_L}\pi_L - \bar{e}} \tag{48}$$

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 and Habib (2001)
('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 (2004)
('79-'90) underpricing VC 12% NVC 17%	('97-'00)underpricing VC 64% NVC 61%
Time variation of underpricing	
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%
Loughran and Ritter (2004)	('80-'89) underpricing VC 8% NVC 7.1%
	('90-'98) underpricing VC 16.1% NVC 13.8%
	('99-'00) underpricing VC 82.2% NVC 38.5%
	('01-'03) underpricing VC 15% NVC 9.4%

Figure 1: VC underpricing across empirical studies

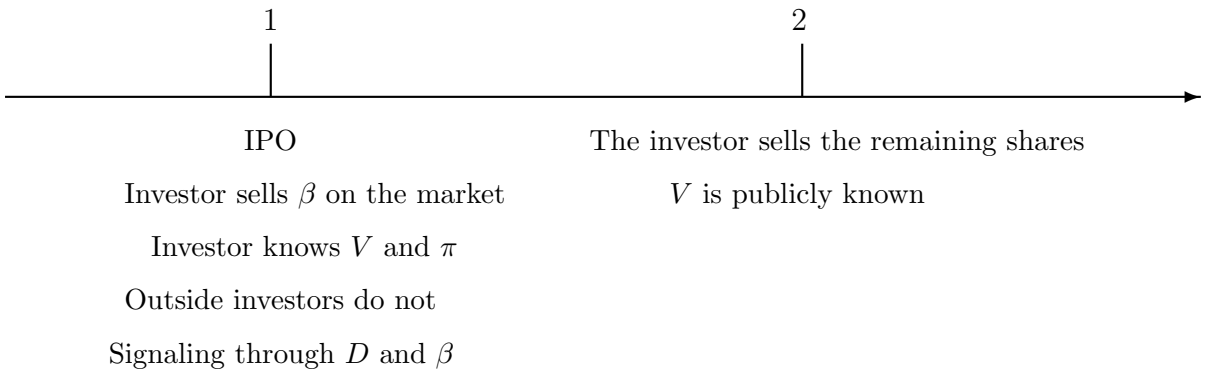

Figure 2: Time Structure of the "Hot Issue" Market Model

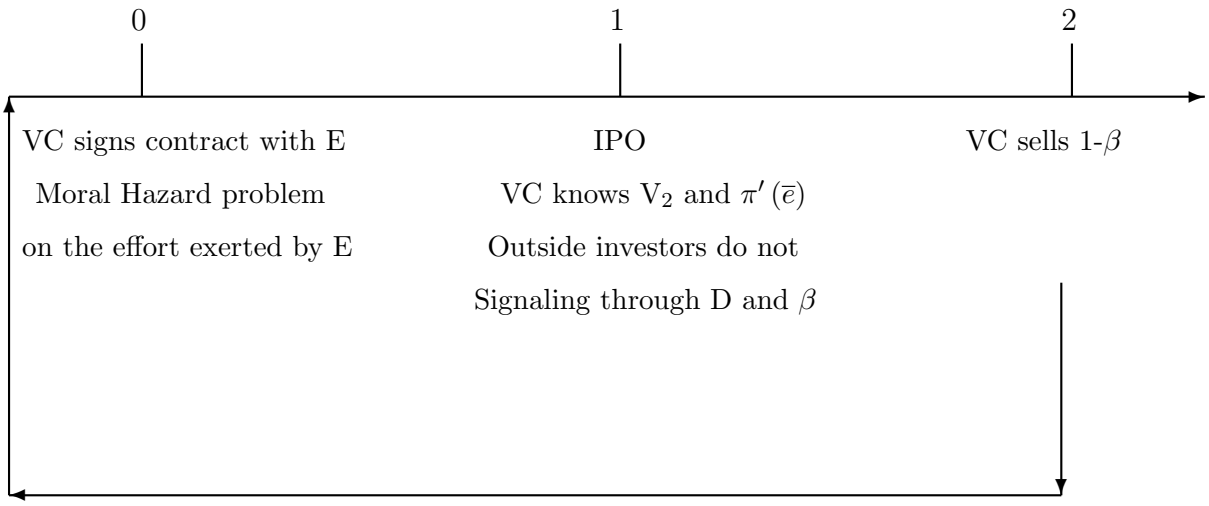

Figure 3: Time Structure of the Venture Capital Model

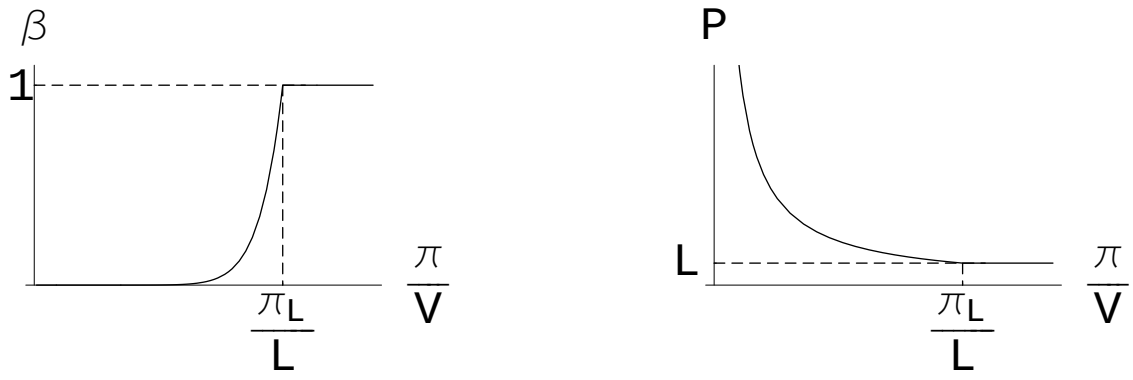

Figure 4: Price and shares sold during IPO by the early stage investor. (L=1,$\pi_L = 1.05$)

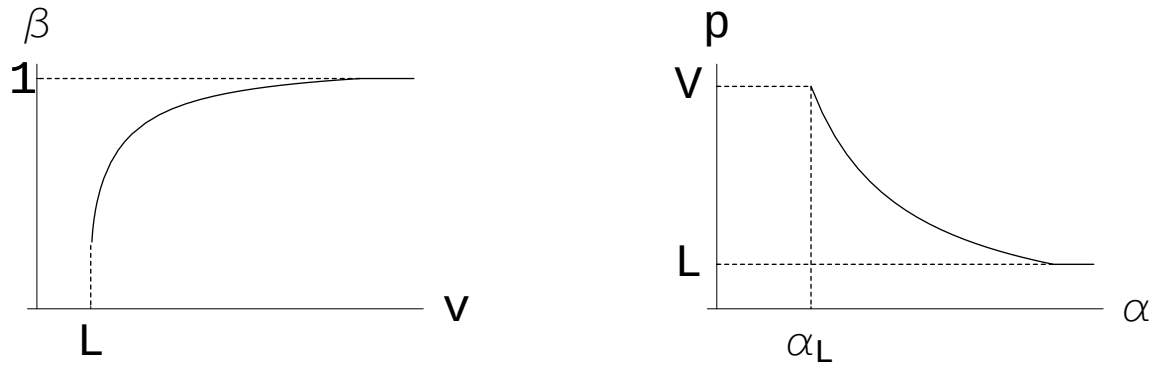

Figure 5: Price and shares sold during IPO by the venture capitalist.($\alpha_L = 0.1$, $\bar{e} = 0.1$, L=1. First graph $\alpha = 0.4$. Second graph $V = 5$)