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Exit timing of venture capitalists in the course of an initial public offering

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Abstract

We analyze the disinvestment decisions of venture capitalists in the course of an IPO of their portfolio firms. The capital market learns of the project quality only in the period following the IPO. Venture capitalists with high-quality firms must choose between immediately selling their stake in the venture at a price below the true value and waiting until the true value is revealed. We show that this choice is facilitated by a reputation-based mechanism in a repeated-game setting. This allows us to explain the phenomenon of "hot-issue market behavior" involving early disinvestments and a high degree of price uncertainty. In a further step, we provide a new rationale for underpricing. We show that young venture capitalists may use underpricing as a device for credibly committing themselves to establishing reputation.

JEL classification: G24; G14; D82

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1. Introduction

One of the key issues in venture capital finance is the exiting process (cf. Gompers and Lerner, 2000). Due to the structure of the venture capital industry, in which often

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closed-end funds are used, and due to their comparative advantage in start-up finance, venture capital firms are engaged in their portfolio firms for only a limited period of time. Unwinding the engagement in the portfolio firm in the course of the exit process is therefore one of the most important determinants of success for venture capital firms. Among the different exit channels, the initial public offering (IPO) of shares in the portfolio firms is often regarded as the most essential one in terms of its contribution to a venture capitalist's return. Therefore, IPOs play a decisive role in venture capital investments (e.g., Black and Gilson, 1998). Surprisingly, however, venture capitalists (VCs) do not always sell (all) their shares at the time of the IPO (Barry et al., 1990). Why is that?

This question is the starting point of our paper. To understand the relevant issues, we first examine the question: what is the optimal exit/disinvestment strategy of the venture capital firm? We address this question by isolating the determinants of the VC's decision to unwind their investment at the time of the IPO and explore potential motives for postponing the disinvestment to a later period. In contrast to the analysis by Gompers (1996), who considers the timing of the IPO, we take the date of the IPO as given and ask whether disinvesting at the time of the IPO or disinvesting later is optimal for the VC. We thereby take into account the fact that VCs, as inside investors, are typically better informed, at least for some period of time, about the quality of their portfolio firms than are outside investors in the capital market. That is, whereas information asymmetries do exist at the time of the IPO, they vanish over time. Therefore, VCs wanting to disinvest a single high-quality portfolio firm face the following trade-off. On the one hand, late disinvestments are associated with large opportunity costs; on the other hand, they may help to overcome information costs, i.e. a low price for such ventures. This trade-off leads to the possibility of an equilibrium with late disinvestment of the most profitable firms.

However, static analysis concentrating only on the single-issue case is inherently limited in its capacity to illustrate these issues, because it does not take into account that VCs are identifiable and repeat players in the IPO market. To take dynamic interactions into account, we model the disinvestment process in a repeated-game framework. We show that such a repeated-game setting allows venture capitalists to establish a reputation for not selling overvalued shares. Because we want to focus on economic consequences rather than build a subtle game-theoretic model, we model reputation in as simple a manner as possible, using an infinitely repeated game with perfectly observable deviant behavior. In models like this (e.g. Klein and Leffler, 1981), reputation is the trust outside investors have in the accuracy of a VC's announcement of project quality. Thus, reputation implicitly influences the pricing of a venture. Therefore, reputation is a binary variable: VCs may or may not have a reputation for correct pricing. This kind of reputation allows VCs to overcome the costs associated with informational asymmetries in the IPO market.[1] The importance of reputation is stressed in many theoretical as well as empirical studies of venture capital (see, e.g., Amit et al., 1998). In our setting, reputation has the potential to serve as a credible commitment to the accurate pricing of issues.

[1] This idea corresponds to the more general "certification hypothesis" on the role of investment bankers in the process of issuing shares in public offerings (e.g., Beatty and Ritter, 1986; Booth and Smith, 1986).

This leads us to our second question: under what circumstances will such a reputational equilibrium emerge? We address this question by examining those "types" of VCs that are most likely able to establish a reputation for credible announcements of the (high) quality of portfolio firms in the course of the IPO, where heterogeneity among VCs may be manifested in market share, experience and portfolio composition. Such kind of reputation will enable VCs to sell their venture at the time of the IPO at the "correct" price. We show that seasoned VCs with a high market share signal the quality of their firms best. This is consistent with empirical research on the timing of disinvestment in the course of an IPO (see Lin and Smith, 1998).

We then extend our basic model by allowing for the possibility of investing in the quality of portfolio firms via advisory services and management support for an additional period. This is a matter of some importance, as the provision of managerial resources is one of the essential tasks of VCs (see Hellmann, 1998). Once again, we isolate the types of VCs willing to invest in their portfolio firms for an additional period and analyze how this option impacts the distribution of disinvestment timing. Finally, we introduce underpricing as an additional device for establishing reputation in the IPO market. Thereby, no overvalued firms are sold. We show that particularly young and unseasoned VCs may underprice their high-quality firms in order to acquire one of the most sought-after goods in the venture capital market: reputation. By underpricing, young VCs are able to overcome (at least to an extent) the inefficiencies in the IPO market.

There are a number of studies that are related to our paper. Gompers (1996) investigates the timing of the IPOs of venture-backed firms and argues that VCs force their firms to go public too early. In an empirical paper, Gompers and Lerner (1998) investigate one very prominent way for VCs to liquidate the positions in their portfolios, namely via the distribution of shares rather than cash to their investors. In doing so, VCs delegate the task of selling shares to their investors.

Our paper complements an empirical study by Lin and Smith (1998), who analyze the disinvestment decision of VCs using US data. However, their study lacks a theoretical framework in which the disinvestment decisions can be analyzed in detail.

Underpricing is one of the most prominent features in the IPO literature, and is often viewed as signaling project quality (e.g., Grinblatt and Hwang, 1989; Allen and Faulhaber, 1989). Alternatively, underpricing may be a compensation for winner's curse in a setting where some of the outside investors have superior information on the value of the firm (Rock, 1986). Furthermore, underpricing may result from moral-hazard problems between the investment banker (agent) and his client (Baron, 1982). Hughes and Thakor (1992) address underpricing from a different angle. They provide conditions under which an underpricing equilibrium based on litigation risk emerges. Underwriters that are concerned with reputation underprice new issues to insure themselves against potential litigation risk. We present an additional rationale for underpricing: Particularly for young VCs, underpricing may serve as a credible commitment to building up a reputation for the accurate pricing of issues.

Finally, there is some relationship between our paper and Stocken (2000), who examines the credibility of a manager's disclosure of privately obtained information to investors in a repeated-game setting. In his model, managers who are sufficiently patient almost always report truthfully, whereas in our paper the credibility of VCs depends on certain attributes.

The paper is organized as follows. In Section 2, we present the basic structure of our model and outline the equilibria emerging for a one-shot game, i.e. for a single issue. The second part of this section contains a detailed analysis of potential reputational equilibria. In Sections 3 and 4, we analyze straightforward extensions of our basic setting. In Section 3, we allow for the option of value-enhancing investments by the VC and examine how this option impacts the exit strategy of the VC. In Section 4, we derive a new explanation for the underpricing exhibited during IPOs. In Section 5, we provide a short conclusion and state testable hypotheses emerging from our analysis.

2. The basic model

2.1. The single-issue case

Let us consider VCs, who want to unwind their investment in one of their portfolio firms in the course of an IPO or at a later point in time. The VC has invested either in a "good" firm or in a "bad" firm.[2] We will refer to the first one as a type G firm and call the second one a type B firm. The value of a G firm is $1 + \Delta$, whereas for type B firms it is normalized to 1. The positive parameter Δ therefore measures the degree of quality heterogeneity between the two types of firms. From the point of view of the uninformed investor, Δ can be regarded as a measure of risk. In order to simplify the setting, we restrict the exit decision of the VC to two periods. Either the VC sells its shares at $t = 1$ during the IPO process or waits a further period and then sells at $t = 2$. There is an informational asymmetry in the sense that the VC already knows the quality of its particular firm at $t = 1$, whereas the outside investors in the capital market are only informed about the average percentage α of good firms.[3] Thus, we assume an informationally efficient secondary market, while the IPO market lacks efficiency. This mirrors the fact that the secondary market is more efficient than the IPO market. Rational investors in the competitive IPO market will pay the average price $\alpha \cdot (1 + \Delta) + (1 - \alpha) \cdot 1 = 1 + \alpha \cdot \Delta$.[4] In the second period, intrinsic values are paid for the firms. Hence, any informational asymmetry has vanished when the VC posts its price at $t = 2$.

Figure 1 displays the sequence of moves in the respective time periods. We explore conditions for the perfect Bayesian equilibrium of the game in which the informed VC moves first. Note that the second period subgame has a trivial outcome as the investors have become fully informed in the mean time. Furthermore, investors will have to pay

[2] This terminology clearly does not describe the quality of the firm overall but rather from a relative point of view, given that the portfolio firms listed via an IPO already depict a positive selection in a VC's portfolio.

[3] Obviously, there are many sources of information about a firm's track record for an external investor, e.g. financial statements and reports. In addition, there are civil as well as criminal sanctions for false statements. But this information and the sanction refer to records on past developments. Assessments of the firm's future prospects are always subjective. Therefore, it is very difficult to sanction wrong assessments of expected future developments. Based on this reasoning we allow for informational asymmetries between the VC and the investors in the capital market.

[4] In order to avoid the need to distinguish between the value of the firm and the value of the VC investment, we focus, without loss of generality, only on that part of the portfolio firm, which is in the VC's possession.

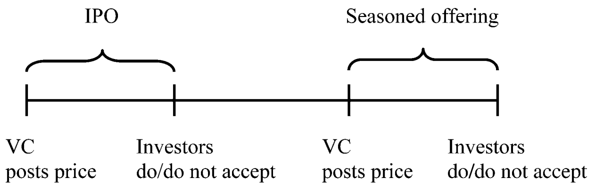

Fig. 1. Sequence of moves in the single-issue case.

the average price, given their expectation of a venture's quality. Therefore, a Bayesian equilibrium is fully described by the VC's type-dependent choice of strategy (sell or wait) and the resulting expectations on the part of the investors.

The VC discounts sales proceeds at $t = 2$ by the factor β ($\beta < 1$). The discount factor of the VC between the two periods is smaller than that of the public, reflecting the typically higher preference for liquidity in the VC industry. In order to save notation, we normalize the discount factor of the general public to unity and consider β the difference in the discount factor between the two groups.[5] The smaller β is, the more pronounced the demand for liquidity on the part of the VC. Given that the VC is typically restricted in its ability to finance new projects, we also can view this discount factor as a measure of the availability of profitable new investments for the VC, i.e., as a measure of the innovative edge of the economy as a whole. Thus, a low β arises with a "hot issue market."

The crucial question of our further analysis concerns the VC's strategy of unwinding their engagement. The VC can either disinvest at $t = 1$ or at $t = 2$.[6] We may distinguish four possible situations. In the first situation, VCs are not willing to sell their shares in the first period, independently of the quality of their portfolio firm. Selling its stake at $t = 2$ enables the VC to always receive a price equal to the true value of the firm. In discounted terms, this yields $P_{B,2} = \beta$ for a type B firm and $P_{G,2} = \beta \cdot (1 + \Delta)$ for a type G firm.

In the second situation, both types of firms are sold in the first period. In this case, the uninformed outside investor pays the pooling price:

$$P_1^{\text{pool}} = \alpha \cdot (1 + \Delta) + (1 - \alpha) \cdot 1 = 1 + \alpha \cdot \Delta. \tag{1}$$

In the third (fourth) situation in which only type G (B) projects are sold, outside investors in competitive capital markets will pay $P_{G,1} = 1 + \Delta$ ($P_{B,1} = 1$).

We note that not all four situations can be equilibrium configurations. Due to the fact that all informational asymmetries will have been eliminated in period 2, waiting never pays for VCs with type B firms. Therefore, both the first situation as well as the one in which only type G shares are sold in the initial period can be excluded as candidates for

[5] A perfect substitute for this would be to assume that the value of the firms increases between the two periods in a manner inversely proportional to the discount factor of the outside investor.

[6] Empirical evidence shows (cf., e.g., Lin and Smith, 1998) that VCs typically maintain a certain portion of their ventures' shares at the time of the IPO. If we allow for continuously distributed types of ventures and a choice as to the number of shares sold at the IPO, our model captures this result as well. An exposition of this alternative modeling is given in Appendix A. As our basic model will pave the way for a detailed discussion of more subtle issues, we subsequently use the binary variable in what follows. As a further relaxation of our assumption, we show in Appendix B that all our qualitative results continue to hold if some shares of a "good" venture are sold at $t = 1$, i.e., during the IPO.

a Bayesian equilibrium. Two equilibrium configurations remain.[7] In the *pooling equilibrium*, both types of firms are sold in the first period. In the *separating equilibrium*, type B shares are sold in period 1, whereas type G shares remain in the portfolio of the respective VC until $t = 2$.[8] With the separating equilibrium, both types are sold at their true values.

The pooling situation actually constitutes an equilibrium, if VCs with a good project prefer to wait and sell at a discounted price of $\beta \cdot (1 + \Delta)$ rather than at the pooling price $1 + \alpha \cdot \Delta$ (see Eq. (1)). Given that VCs with a type B project obviously always prefer to sell above the true value at the pooling price in period 1, we obtain the following condition:

$$1 + \alpha \cdot \Delta > \beta \cdot (1 + \Delta). \tag{2}$$

Hence, pooling constitutes an equilibrium if[9]

$$\beta < \beta_P \equiv \frac{1 + \alpha \cdot \Delta}{1 + \Delta}. \tag{3}$$

In contrast, a separating equilibrium requires that a VC with a type G project prefers to wait and sell at the true value of the project rather than at the pooling price. That is,

$$1 + \alpha \cdot \Delta \leqslant \beta \cdot (1 + \Delta) \tag{4}$$

or $\beta \geqslant \beta_P$ must hold.

Using Eq. (3), which describes the separating line between the two types of equilibria,[10] we can summarize our findings as:

Proposition 1. (i) *In the single-issue case, a separating equilibrium with G firms sold in period* 2 *and B firms sold in period* 1 *is obtained for $\beta \geqslant \beta_P$. With $\beta < \beta_P$ early disinvestments of both firm types occurs in the first period.*
(ii) *The pooling equilibrium is more likely the larger the proportion α of high-quality projects, the smaller the difference in value Δ, and the smaller β, i.e., the more pronounced the VC's demand for liquidity is.*

The intuition behind the second part of this result is straightforward. With a high α and a small Δ, subsidization of B firms by G firms via the pooling price is not pronounced, making disinvestment in period 1 at the pooling price rather attractive. A small β, which

[7] Throughout the paper we neglect any equilibria in randomized strategies.

[8] The investors' expectations are easy to check: VCs with a type-B project will choose to immediately sell their stake, anyway. If condition (3) holds, investors will recognize that it is in the best interest of a VC with a type-G venture to sell immediately, too, and the pooling-price will emerge. Otherwise investors will understand that only type B will be sold at the occasion of the IPO.

[9] For the sake of concreteness, we assume for the entire analysis that a separating equilibrium results in the case of indifference.

[10] For certain parameter values, both pooling and separating equilibria constitute a Bayesian equilibrium. In this case of a multiple equilibrium, type G's payoff in a pooling equilibrium exceeds the payoff in the separating equilibrium. Therefore, from an economic point of view, β_P unambiguously separates the two equilibria. Furthermore, with regard to the existence of a reputational equilibrium, the proposed equilibrium selection creates a higher hurdle than any alternative.

might occur in the event of a hot-issue market, makes waiting and hence the separating equilibrium rather unattractive.

In both types of equilibria, VCs with type G firms face costs from either waiting or pooling. We now analyze whether the fact that VCs are repeat players in the IPO market may provide a remedy to this distorting effect.

2.2. A reputational game

Typically, VCs are not engaged in only one IPO during their economic lifetime; typically they play a repeated game in the IPO market. Moreover, VCs are identifiable players in the IPO market. This allows them to build up reputation, which is generally considered essential in this industry with its welter of informational asymmetries (see Black and Gilson, 1998; Sahlman, 1990).[11] With respect to exiting via the IPO market, there are two important aspects to reputation. On the one hand, young VCs have an especially strong incentive to establish a reputation with their investors by means of realizing a successful IPO with high returns as soon as possible. This facilitates refinancing for the VC, especially for first-time funds. We capture this aspect with our discount factor for the VC. On the other hand, when playing the IPO market more than once, VCs may have a strong incentive to establish a reputation for not mispricing the issue. We model this aspect with the help of a repeated game. Additional future profits may serve as a device to commit oneself to a cooperative strategy with outside investors, i.e., VCs may abandon reporting the false type of their own portfolio firm.

Since our intention is to capture reputational effects as simple as possible, some remarks on our modeling of reputation are called for. Generally, there are two types of models which capture the notion of reputation. In the first type of model (cf. Milgrom and Roberts, 1982; Kreps and Wilson, 1982), reputation is defined as a belief in unknown characteristics, where the fraction α of good projects might be such a characteristic. Starting from a priori probabilities, beliefs evolve in a Bayesian updating process, taking into account the observation of an imperfect signal as quality parameter. Reputation can then be measured by the a posteriori probability of it being the good type. While these models explicate the process of establishing or losing reputation, they require substantial calculations.

The second type of model (e.g., Klein and Leffler, 1981; Shapiro, 1983) is considerably simpler. Reputation is described as the trust outside investors place in the pricing of a certain VC. If the incentive compatibility constraint is met, investors assume the pricing of a venture to be accurate, unless they observe cheating behavior on the part of the VC. Note that it is perfectly observable ex post whether the VC is playing cooperatively or is deviating from the equilibrium strategy. Under these conditions, a supergame consisting of an infinitely repeated game typically exhibits multiple equilibria. To be more precise, any feasible, individually rational payoff can be enforced as a subgame-perfect equilibrium, if a deviation is punished by playing the equilibrium of the one-shot game and the agents are

[11] The fact that reputation plays a crucial role in the course of an IPO, not only for VCs but for underwriters as well is stressed in empirical studies (e.g., Nanda and Yun, 1997) as well as theoretical work (e.g., Hughes and Thakor, 1992).

sufficiently patient. This famous "folk theorem" was formalized by Friedman (1971). However, among the plethora of equilibria, the truth-telling equilibrium is of major importance, as it eliminates any misallocation of capital.

We focus on the existence of truth-telling equilibria where VCs price ventures accurately and outside investors ascribe a positive reputation to the VC as long as no mispricing is detected. The VC has invested in a number of portfolio firms, some of which periodically go public. The percentage of good firms, i.e., of firms being type G firms, is α. The probability of such a type G project is therefore constant over time from the viewpoint of the individual VC.

We investigate the necessary conditions that ensure that truth-telling is a perfect Bayesian equilibrium of the infinitely repeated game. With the reputational equilibrium, VCs sell their portfolio firms at their respective true values in the initial period. This permits VCs with a type G project to overcome the costs associated with either waiting or pooling.

Since a VC with a type G project always prefers the outcome of such a reputational equilibrium, its individual rationality does not impose any further restrictions on a reputational equilibrium. Instead the crucial question is whether a VC with a type B firm is willing to report the true quality of the portfolio firm. In the event of truthful reporting, the VC is able to stick to the cooperative outcome and can expect to sell a type G firm at the correct price at $t = 1$ in future issue rounds. A cheating VC gains in the initial round by selling a type B project at the value of a type G firm, thus receiving $1 + \Delta$ rather than only 1. The truth-telling strategy yields the VC with a type B firm a discounted value for selling the portfolio firms in the present and all following issues of

$$P_B^{\mathrm{tr}} = 1 + \sum_{t=1}^{\infty} \gamma^t \cdot \big[\alpha \cdot (1 + \Delta) + (1 - \alpha) \cdot 1\big] = 1 + \frac{\gamma}{1 - \gamma} \cdot (1 + \alpha \cdot \Delta), \tag{5}$$

with γ denoting the rate at which VCs discount revenues across two subsequent issues. The discount factor γ reflects the refinancing possibilities of the VC or, almost equivalently, the density with which VCs will enter the IPO market in future. We interpret the latter as the market share of the VC. That is, the closer γ is to one, the better are the refinancing possibilities of the VC and the higher is its market share.

The discount factors β and γ ought not to be confused: β is a measure for the time period between the IPO and the seasoned offering of the shares held by the VC, whereas γ measures the distance between two IPOs of two different ventures of the VC (see Fig. 2).

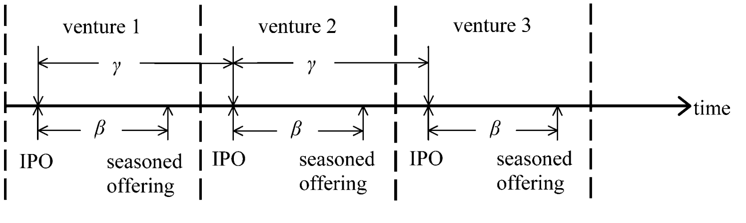

Fig. 2. The distinction between the discount factors β and γ. *Note*. The parameter β represents the discount factor between the two points in time of a single IPO, whereas γ $(< \beta)$ discounts cash-flows stemming from two subsequent IPOs.

The difference between these measures basically captures the fact that the timespan between the IPOs of two different ventures by a VC on the one hand, and that between the IPO and the seasoned offerings of shares by the same venture on the other, may not be the same.[12] To simplify the analysis we do not analyze overlapping ventures, i.e., β is assumed to be larger than γ.

A cheating VC with a type B firm will gain now, but may experience lower returns in the future due to loss of reputation. Future returns without reputation are identical to those in the one-shot game. If condition (3) holds, the pooling equilibrium is the outcome of the one-shot game. In this case, the discounted value with cheating is

$$P_B^{\mathrm{ch}}(pool) = 1 + \Delta + \sum_{t=1}^{\infty} \gamma^t \cdot (1 + \alpha \cdot \Delta) = 1 + \Delta + \frac{\gamma}{1-\gamma} \cdot (1 + \alpha \cdot \Delta). \tag{6}$$

Comparing Eqs. (5) and (6) reveals that $P_B^{\mathrm{tr}} < P_B^{\mathrm{ch}}(pool)$, i.e., cheating always pays. This merely reflects the fact that, on average, the true prices of the projects are paid in the pooling equilibrium. Hence, the costs of cheating are zero. Given the costs of truth-telling in the initial period, cheating is obviously the optimal strategy. As a result, no reputational equilibrium exists if $\beta < \beta_{\mathrm{P}}$.

Matters are different if a separating equilibrium is obtained in the one-shot game. Then, the expected discounted sum of revenues for a cheating VC with a type B firm amounts to

$$\begin{aligned} P_B^{\mathrm{ch}}(sep) &= 1 + \Delta + \sum_{t=1}^{\infty} \gamma^t \cdot \big[\alpha \cdot \beta \cdot (1 + \Delta) + (1 - \alpha) \cdot 1\big] \\ &= 1 + \Delta + \frac{\gamma}{1-\gamma} \cdot \big[(1 + \alpha \cdot \Delta) - \alpha \cdot (1 - \beta) \cdot (1 + \Delta)\big]. \end{aligned} \tag{7}$$

Once again, the latter part of the right-hand-side expression reflects the expected discounted revenues occurring after the cheating period.

We state:

Proposition 2. (i) *A reputational equilibrium is obtained if $\beta_{\mathrm{P}} \leqslant \beta < \beta_{\mathrm{R}}$, with*

$$\beta_{\mathrm{R}} = 1 - \frac{1-\gamma}{\alpha \cdot \gamma} \cdot \frac{\Delta}{1+\Delta}.$$

For $\beta < \beta_{\mathrm{P}}$, a pooling equilibrium results, whereas with $\beta \geqslant \max\{\beta_{\mathrm{R}}, \beta_{\mathrm{P}}\}$ we find a separating equilibrium.
(ii) *The reputational equilibrium prevails for a larger set of exogenous parameter values the larger γ and Δ. It results if β and α take on intermediate values.*

[12] An alternative representation to ours is to use a common discount factor for a given period of time and to allow for two different time variables. In order to save notation, we have chosen the above procedure and decided to use two "different discount factors."

Proof. (i) Comparing (7) and (5) yields the necessary condition for a reputational equilibrium

$$\beta \leqslant \beta_R \equiv 1 - \frac{1-\gamma}{\alpha \cdot \gamma} \cdot \frac{\Delta}{1+\Delta}. \tag{8}$$

Taking into account the non-existence of a reputational equilibrium in the presence of pooling and using condition (3) shows that a reputational equilibrium prevails if and only if $\beta_P \leqslant \beta < \beta_R$. Hence, a pooling equilibrium exists with $\beta < \beta_P$, whereas a separating equilibrium is obtained for $\beta \geqslant \max\{\beta_R, \beta_P\}$.

(ii) The range of the reputational equilibrium is non-empty if $\beta_R > \beta_P$, or

$$\beta_R - \beta_P = \frac{\Delta}{1+\Delta} \cdot \frac{(1-\alpha) \cdot \alpha \cdot \gamma - (1-\gamma)}{\alpha \cdot \gamma} > 0. \tag{9}$$

This holds if[13]

$$\gamma > \gamma^* \equiv \frac{1}{1+\alpha-\alpha^2}. \tag{10}$$

That is, a larger γ makes a reputational equilibrium more likely. Since $\partial(\beta_R - \beta_P)/\partial\Delta > 0$ (see Eq. (9)), a larger Δ enlarges the parameter range of the reputational equilibrium, rendering it more likely. The condition $\beta_P \leqslant \beta < \beta_R$ requires intermediate β-values. Since $\partial\gamma^*/\partial\alpha < (>)\ 0$ for $\alpha < (>)\ 0.5$ (see Eq. (10)) the reputational equilibrium will be obtained for intermediate α-values only. □

Figure 3 illustrates the different equilibrium configurations which may be obtained. The intuition behind our comparative static results is quite straightforward. Graphically speaking, a higher discount factor γ shifts line B upwards, while leaving line A unaffected. A VC with a larger γ has more to lose in the event of deviation from a truth-telling strategy. That is, a VC appearing more often in this issue market has a stronger incentive to build up reputation, since it is of greater benefit to sell the future type G firms at their true value in the initial period of the IPO process. An immediate corollary of this point is that established venture capitalists find it much easier to signal their own credibility.

The non-monotonic impact of α on the likelihood of a reputational equilibrium results from the two opposite effects on the incentive to adhere to a cooperative strategy. On the one hand, a very large α leads to a pooling equilibrium, since the inherent subsidies of type B firms that come with the pooling price become less important. This, in turn, makes pooling relatively less unattractive. Since there are no sanctions on the cheating VC with a pooling equilibrium, in the event of a sufficiently high α we will not observe a reputational equilibrium. On the other hand, a sufficiently small α implies that, on average, VCs expect very few type G investments in future, which also reduces the cost of the cheating strategy. Therefore, it is apparent that a reputational equilibrium is only feasible for intermediate values of α.

The third parameter affecting the likelihood of a reputational equilibrium is the discount factor β for the two periods of one particular issue. With a low β, VCs with a type G firm

[13] While β_R might generally be negative, (10) implies that β_R is positive.

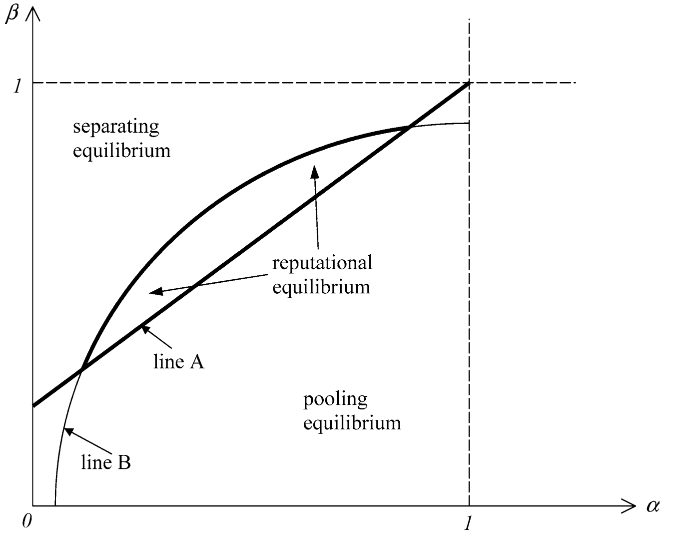

Fig. 3. An overview of the different type of equilibria emerging for different α–β combinations. *Note*. Line A depicts Eq. (3), whereas line B represents Eq. (8). A reputational equilibrium occurs in the area between line A and line B.

prefer the pooling equilibrium, making the cooperative outcome unfeasible. With a high β, designating a low preference for liquidity, the reputational equilibrium is unsustainable because the cost of cheating—the cost of selling type G projects in future issues in $t = 2$ rather than at $t = 1$ at their true value—is small. Therefore, a reputational equilibrium is obtained for intermediate β values only.

Finally, the value difference between the two types of projects simultaneously influences the likelihood of a reputational equilibrium in a positive way. This stems from the fact that a larger Δ makes a pooling equilibrium less likely. It also increases the range of the separating equilibrium. However, since the latter effect is dominated by the second, the range of the reputational equilibrium increases with Δ.

The following numerical examples illustrate, once more, the overall situation and the likelihood of a reputational equilibrium (Table 1).

Table 1
Examples for parameter values, which support a reputational equilibrium

Examples	Parameters			Critical values	
	α	γ	Δ	$\beta_{\min} = \beta_{\mathrm{P}}$	$\beta_{\max} = \beta_{\mathrm{R}}$
1	0.2	0.9	0.9	0.9273	0.9495
2	0.5	0.9	0.9	0.9545	0.9798
3	0.8	0.9	0.9	0.9333	0.9537
4	0.5	0.9	0.9	0.9167	0.9630
5	0.9	0.95	0.95	0.9833	0.9903

Note. A reputational equilibrium occurs for β being in the interval between $\beta_{\min}$ and $\beta_{\max}$. If this interval is empty, no reputational equilibrium exists.

Up to now, we have assumed that the role of VCs as active investors does not have an impact on the exit decision. In the next section, we focus on this crucial role of VCs by allowing for potential value-enhancing investments of the VC in the aftermath of the IPO. We investigate the impact of this investment possibility on the disinvestment process.

3. Investments in project quality and the decision to disinvest

In this section we explicitly take into account that VCs act as permanent consultants to their portfolio firms. We concentrate on the circumstances under which a VC with a type B project is willing to invest in order to secure an increase in value in the aftermath of the IPO. The VC with a type B project faces a trade-off between investing management resources at cost I in the venture, which causes this venture to become a type G project after one period with probability π $(0 < \pi < 1)$, and not investing. We will analyze the conditions under which a VC has an incentive to undertake a value-increasing investment, as well as the impact this has on the overall disinvestment strategy.

A value-increasing investment clearly excludes an immediate disinvestment in period 1. Hence, and in contrast to the preceding section, it is not always preferable to sell type B ventures immediately in period 1; rather, it may pay to invest and wait for another period to disinvest. We pursue our analysis by analyzing the single-issue case first. We then consider the option of a reputational equilibrium during ongoing issues.[14]

3.1. Value-increasing investments and disinvestment in the single-issue case

We encounter three equilibrium candidates. First, there is a pooling situation at $t = 1$ if both types of ventures are sold in the initial period. Second, the separating equilibrium with type B firms sold in period 1 and type G firms sold in period 2 remains a viable equilibrium. Third, due to the investment option, both firms selling at $t = 2$ becomes a feasible equilibrium candidate. We call the latter a "late-pooling" equilibrium.

With a pooling equilibrium prevailing at $t = 1$, an investment at $t = 1$ in type B firms never pays. This can be shown in the following manner. With a pooling equilibrium at $t = 1$, investment takes place only if $1 + \alpha \cdot \Delta \leqslant -I + \beta \cdot (1 + \pi \cdot \Delta)$, or

$$\beta \geqslant \beta_I(pool) \equiv \frac{1 + \alpha \cdot \Delta + I}{1 + \pi \cdot \Delta}. \tag{11}$$

Since $\beta_I(pool) > \beta_{\mathrm{P}}$ (see Eqs. (3) and (11)), the pooling condition is always more restrictive than the investment criterion. This is quite intuitive. With a pooling equilibrium, it does not pay to wait until $t = 2$ with type G firms. Hence, investing in costly value enhancements leading to a type G with a probability of less than one can never make sense.

An immediate corollary of this is that pooling implies underinvestment in value enhancement. In contrast to a symmetric information setting in which type B firms yield a price of 1, we find that in the Bayesian pooling equilibrium type B firms are subsidized

[14] At period 1, the investment is not observable to outside investors. Otherwise, observing a non-investment decision might have informative content for outsiders.

by the amount $\alpha \cdot \Delta$, leading to a level of investment that is too low. This distortion is the more pronounced, the higher the VC's proportion of type G projects. Tracing this back to a superior project selection, we obtain an explanation for the specialization by different VCs in different investment stages. VCs with a comparative advantage in the early stage—those having a high α—have a low incentive to invest heavily in later stages.

Investment in value enhancement may only occur with $\beta \geqslant \beta_P$.[15] VCs with a type-B firm face two alternatives. Either they sell their shares immediately at the price given in the prevailing separating equilibrium, i.e., 1. Alternatively, they can bear the investment costs I, and receive an expected payoff of $1 + \pi \cdot \Delta$. Hence, investments are profitable if and only if $1 \leqslant -I + \beta \cdot (1 + \pi \cdot \Delta)$, or

$$\beta \geqslant \beta_I \equiv \frac{1+I}{1+\pi \cdot \Delta}. \tag{12}$$

Using our above discussion and Eq. (12), we can state:

Proposition 3. *Allowing for value-enhancing investments in type B firms leads to late pooling with both types of firms sold in period 2 at their true value if $\beta \geqslant \max\{\beta_I, \beta_P\}$. A separating and a pooling equilibrium both without investment occur if $\beta \in [\beta_P, \beta_I)$ and $\beta < \beta_P$, respectively.*

The intuition behind the comparative static results is as follows. VCs with a comparative advantage in late-stage financing—those with a large success probability π and low investment costs I—are the ones most willing to incur the risk of investing. With a large β, these investments are most likely to pay off in discounted terms. In contrast to the pooling equilibrium, the investment decision is efficient in the two remaining parameter ranges.[16]

3.2. Reputational equilibrium in the presence of profitable investments

Even in the presence of the investment option at $t = 1$, type G ventures are never sold at their true value at $t = 1$ in the single-issue case. This implies inefficiently low returns from this type of venture for the VC, resulting in an underincentive to engage in start-up firms. Hence it is, once again, important to ask whether this shortcoming can be resolved via a reputation mechanism. In particular, we want to determine whether the investment opportunity makes such a solution more or less likely.

We focus only on situations where the investment turns out to be profitable from the point of view of the individual VC, i.e., with $\beta \geqslant \beta_I$. This condition is equivalent to a positive net present value (NPV) of the investment. In any other situation, the investment option will not be exercised and our results in the previous subsection remain unchanged. With $\beta \geqslant \beta_I$, VCs that deviate from the cooperative strategy anticipate "late pooling."

[15] There exist sets of parameters where (12) and (3) hold simultaneously. Again, in this case, the early pooling equilibrium dominates the late pooling equilibrium for a VC with a type G project. Therefore, as stated above, investment in value-enhancement may only occur if $\beta \geqslant \beta_P$.

[16] With a separating equilibrium and a potential price of a type B venture equal to 1 (the true value), the investment incentives are not distorted. In other words, Eq. (12) is equivalent to a positive net present value of the investment.

Thus, the cooperative strategy yields the following discounted cash flow for the VC:

$$
\begin{aligned}
P_B^{\mathrm{tr}}(inv) &= \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right] \\
&\quad + \sum_{t=1}^{\infty} \gamma^t \cdot \left\{\alpha \cdot (1 + \Delta) + (1 - \alpha) \cdot \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right]\right\} \\
&= \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right] \\
&\quad + \frac{\gamma}{1 - \gamma} \cdot \left\{\alpha \cdot (1 + \Delta) + (1 - \alpha) \cdot \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right]\right\}.
\end{aligned} \tag{13}
$$

The RHS of (13) consists of two parts: the revenues from selling the bad firm during the current offering and the discounted cash flow for all future periods.

In the event of cheating, the VC loses the advantage of immediately divesting type G projects in future issues. The present value of revenues therefore amounts to

$$
\begin{aligned}
P_B^{\mathrm{ch}}(inv) &= 1 + \Delta + \sum_{t=1}^{\infty} \gamma^t \cdot \left\{\alpha \cdot \beta \cdot (1 + \Delta) + (1 - \alpha) \cdot \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right]\right\} \\
&= 1 + \Delta + \frac{\gamma}{1 - \gamma} \cdot \left\{\alpha \cdot \beta \cdot (1 + \Delta) + (1 - \alpha) \cdot \left[-I + \beta \cdot (1 + \pi \cdot \Delta)\right]\right\}.
\end{aligned} \tag{14}
$$

Comparing Eqs. (13) and (14) gives us the following condition for a reputational equilibrium:

$$
\beta \leqslant \beta_{\mathrm{R},I} \equiv 1 - \frac{1 - \gamma}{\alpha \cdot \gamma} \cdot \frac{\Delta - NPV}{1 + \Delta}, \tag{15}
$$

where the NPV of the investment is given by

$$
NPV = -(1 + I) + \beta \cdot (1 + \pi \cdot \Delta).
$$

Obviously, condition (15) is weaker than inequality (8), because $\beta_{\mathrm{R},I} > \beta_{\mathrm{R}}$, which in turn reflects the fact that a positive NPV is a necessary condition for late pooling. Given an incentive to engage in a value-enhancing investment, the credibility of the VC increases. While the costs of cheating are not altered by the investment option, the possible gains of cheating decrease by the amount of the NPV. As the NPV itself is positively correlated with β, there is an additional second-order effect.

An overview on the different equilibria with the investment option is given in Fig. 4.

We can summarize our findings in

Proposition 4. *A reputational equilibrium with profitable value-enhancing investments may be obtained. VCs with type G firms will exit early at the true value, while VCs with type B firms and a comparative advantage in managing portfolio firms in later stages remain invested in their portfolio firms, trying to increase the latter's value with the help of management support.*

This result is opposite to our basic model in Section 2.1 in one aspect: Reputational effects enable a VC to sell type G firms early without incurring losses, whereas the investment option provides an incentive to a VC with a type B firm to improve the firm's value and to postpone selling.

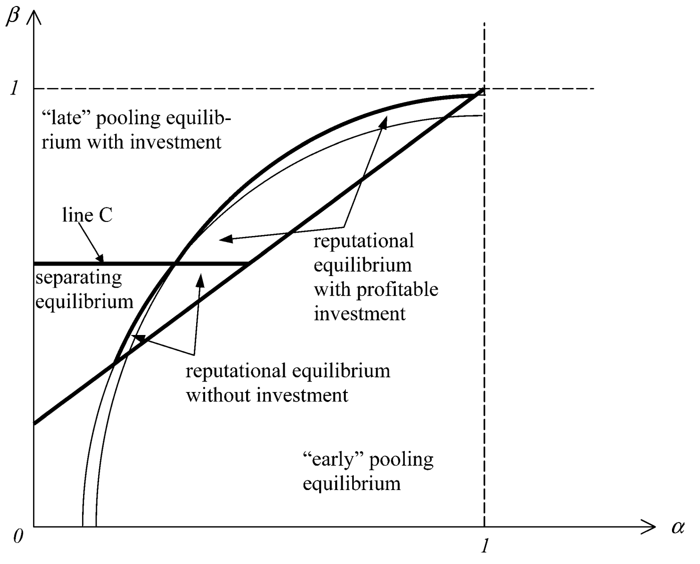

Fig. 4. An overview of the different type of equilibria emerging with potential value-enhancing investment in the repeated-game set-up. *Note*. Line C is defined in condition (12).

4. Underpricing as a reputational device

In the preceding sections, we assumed that the characteristics of VCs do not change over time. Constant parameters over time, however, imply that all learning effects and advantages associated with experience are completely neglected. In this section, we aim to incorporate these aspects by allowing the parameters that characterize VC to change. More precisely, we model the incentives that young VCs have to build up reputation capital. This is done against a background of the often-mentioned argument that in a market characterized by such a high degree of informational asymmetries as the VC market, establishing reputation is crucial (see, e.g., Megginson and Weiss, 1991). Allowing for changing parameters over time also allows us to distinguish different VCs: younger ones with little or no track record and a small number of potential IPO candidates; and older VCs with a long history of successful investments as well as a constant flow of IPOs.

We build this into our model by assuming that a young venture capital firm starts with a low γ, since the timespan between two potential IPOs is long and uncertain. Over time, as the VC grows older, this parameter grows too, reflecting the fact that the VC has more successful firms in its portfolio to be sold via an IPO. In order to model this basic idea in as simple a manner as possible, we allow for two different γ: a low γ_1 in the first time period; and a higher γ_2 for all future periods in which the VC has grown to maturity.

Our basic framework has shown that a low γ is definitely a disadvantage in the realization of a reputational equilibrium. Initially, therefore, it is difficult for a young VC to build up reputation capital. Our main argument in this section is that a young VC may use underpricing as an instrument to compensate for this disadvantage and to build up reputation. Underpricing type G projects enables VCs to commit themselves in a credible manner to the reputational equilibrium. We show that young VCs have an incentive to underprice IPOs, whereas established VCs do not need to pursue this strategy. This is in line with empirical research showing that IPOs with a mature VC as lead investor do not show any signs of significant underpricing, whereas this is the case when the VC is young (see Gompers, 1996). Our explanation of the often-observed phenomenon of underpricing differs from other explanations in the literature. In other papers, underpricing serves as a signal of project quality (e.g., Grinblatt and Hwang, 1989; Allen and Faulhaber, 1989) or as compensation for winner's curse (Rock, 1986), whereas in our scenario it is simply a device for building up reputation.

In order to focus on our argument, we neglect the possibility of value-increasing investments and consider only situations in which young VCs cannot credibly commit themselves to a reputational equilibrium, whereas experienced ones can. Taking the two different values of γ into account, we obtain a modified condition under which a young VC is excluded from a reputational equilibrium:

$$\beta > \beta_{\mathrm{R},y} \equiv 1 - \frac{1-\gamma_2}{\alpha \cdot \gamma_1} \cdot \frac{\Delta}{1+\Delta}. \tag{8$'$}$$

At the same time, an experienced VC will adhere to the reputational equilibrium if

$$\beta \leqslant \beta_{\mathrm{R},e} \equiv 1 - \frac{1-\gamma_2}{\alpha \cdot \gamma_2} \cdot \frac{\Delta}{1+\Delta}. \tag{8$''$}$$

Since $\gamma_1 < \gamma_2$, there is always a parameter constellation for which (8′) and (8″) hold simultaneously. In order to make our point as strongly as possible, we focus only on situations where a separating equilibrium is obtained in the single-issue case, i.e., $\beta \geqslant \beta_\mathrm{P}$.

At first glance, only the separating scenario is a feasible equilibrium for the inexperienced VC. An alternative device of compensating for the low level of experience of a young VC is to underprice type G firms in period 1 to the extent U, implying a price $1 + \Delta - U$.[17] For a young VC with a type G project, this device is associated with lower costs than in the case of non-occurrence of an immediate reputational effect.

For a reputational equilibrium with underpricing, two additional requirements must be fulfilled. First, it should be in the self-interest of a young VC with a type G project to participate in the scheme by underpricing. Second, a young VC with a type B project must have an incentive to stick to the cooperative equilibrium without cheating.

Due to (8″) we know that the experienced VC will remain with the reputational equilibrium if cheating has not taken place with the first issue. Hence, VCs with type G firms only have to compare their payoff stemming from the present issue and an underpricing strategy with the payoff stemming from the present issue sold in the separating equilibrium.

[17] One might argue that underpricing is also a solution for an experienced VC to resort to in situations where (8″) does not hold. It turns out, however, that this does not work. Either VCs with a type G project do not have an incentive to underprice or VCs with type B projects are unwilling to adhere to the reputational equilibrium and try to imitate type G projects. This is due to the fact that underpricing, while lowering the immediate gain from cheating, also reduces the implicit sanctions arising in later periods (the opportunity costs of cheating in later periods are reduced). In the aggregate, underpricing does not work as a solution for experienced VCs, if (8″) does not hold.

Underpricing is preferred if

$$1 + \varDelta - U \geqslant \beta \cdot (1 + \varDelta) \tag{16}$$

or

$$U \leqslant U_G \equiv (1 - \beta) \cdot (1 + \varDelta). \tag{16$'$}$$

With respect to the second requirement, we must make sure that VCs with type B projects do not want to deviate from the reputational equilibrium with underpricing. The discounted income stream with underpricing is

$$P_B^{\mathrm{tr}}(up) = 1 + \frac{\gamma_1}{1 - \gamma_2} \cdot \bigl[\alpha \cdot (1 + \varDelta) + (1 - \alpha) \cdot 1\bigr]. \tag{17}$$

In the case of cheating we obtain

$$P_B^{\mathrm{ch}}(up) = 1 + \varDelta - U + \frac{\gamma_1}{1 - \gamma_2} \cdot \bigl[\alpha \cdot \beta \cdot (1 + \varDelta) + (1 - \alpha) \cdot 1\bigr]. \tag{18}$$

Comparing the two equations leads us to the following second condition for a stable reputational equilibrium with underpricing:

$$U \geqslant U_B \equiv \varDelta - \frac{\gamma_1}{1 - \gamma_2} \cdot \bigl[\alpha \cdot (1 + \varDelta) \cdot (1 - \beta)\bigr]. \tag{19}$$

A necessary condition for a reputational equilibrium is therefore $U_B \leqslant U_G$. This requires that

$$\beta \leqslant \beta_{\mathrm{R,up}} \equiv 1 - \frac{1 - \gamma_2}{1 - \gamma_2 + \alpha \cdot \gamma_1} \cdot \frac{\varDelta}{1 + \varDelta}. \tag{20}$$

A reputational equilibrium with underpricing exists if the conditions expressed in Eqs. (8$'$), (8$''$) and (19) as well as $\beta \geqslant \beta_{\mathrm{P}}$ hold.

The results are delineated in Fig. 5. Given that a reputational equilibrium prevails, young VCs will choose underpricing $U = U_B$, since they have no reason to provide an even lower price of their type G projects. A lower price would only reduce the income of the VC without any additional gains.

Using our above analysis and Eq. (19) we can state:[18]

Proposition 5. (i) *There exists a reputational equilibrium in which young VCs are able to and have an interest to underprice their type G firms in the course of an IPO in order to build-up reputation.*
(ii) *The extent of underpricing increases with $\varDelta$ and β and decreases with α and the γ_i.*

Thus, although via a very different line of arguments, we arrive at the same conclusion as other papers on underpricing (see, e.g., Beatty and Ritter, 1986; Grinblatt and Hwang, 1989). Furthermore, just as our paper does, Welch (1989) hypothesizes that underpricing is negatively correlated with volatility in the secondary market. As underpricing in our

[18] The comparative static for $\varDelta$ holds for the relevant β-values which is seen by looking at Eq. (20).

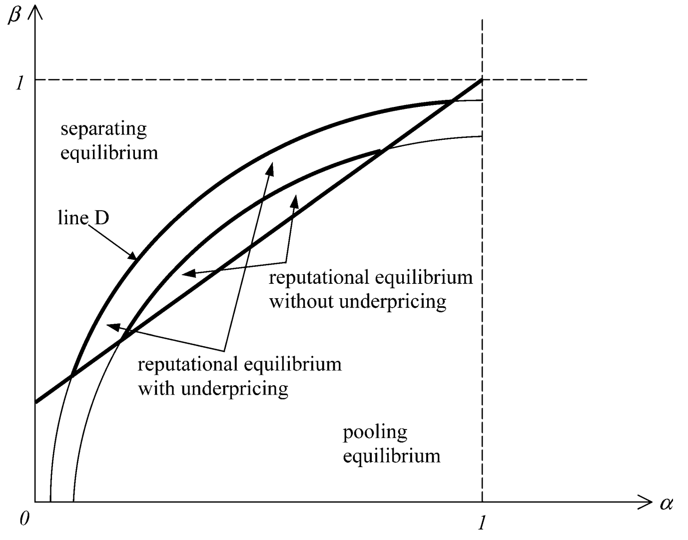

Fig. 5. Reputational equilibria with and without underpricing in an α–β space. *Note*: Line D is defined in Eq. (12).

model is part of a fully revealing signaling equilibrium, there is no need for further price adjustments and secondary market volatility will be low.

The intuition of part (ii) of our proposition is the following. A larger demand for liquidity (larger β) and a smaller expected proportion of high-quality firms (smaller α) increases the incentive to deviate from the reputational equilibrium. In order to overcome this, a larger extent of underpricing has to be chosen. The same is true if project heterogeneity Δ is rather pronounced. In the latter case, VCs with a type B firm have a strong incentive to falsely report selling a good firm. Pronounced underpricing prevents this effect. If the market share of the VC in the IPO becomes larger (large γ_1 and γ_2), cheating becomes relatively unattractive, which implies that the extent of underpricing required to enforce the reputational equilibrium is small.

The young VCs' incentive to underprice may have obvious repercussions for the investment process of this particular class of VCs. Good-type firms could anticipate the incentive of the VC and hence would require additional compensation, since underpricing reduces its expected revenue from the IPO. Given that potential portfolio firms anticipate this correctly and can observe the characteristics of VCs, such behavior would impose an additional cost on young VCs without affecting, however, our line of argument.

Table 2 illustrates the impact of different parameter settings on the likelihood of a reputational equilibrium with underpricing. The first three cases show that a reputational equilibrium with underpricing may exist. The larger the difference between the discount factors of young and experienced VCs, the larger the parameter range for which an underpricing regime prevails (see cases 1 and 2). Generally, the likelihood of such an equilibrium increases with an increasing Δ (cases 2 and 3). With low absolute discount factors, the reputational equilibrium does not prevail anymore, even for experienced VCs (case 4). If, finally, the proportion of good projects α is very small, VCs with a type G project prefer the pooling equilibrium (case 5).

Table 2
Examples for the existence and non-existence of a reputational equilibrium with underpricing

Cases	Parameters					Critical values	
	α_1	α_2	γ_1	γ_2	Δ	$\beta_{\min} = \max\{\beta_P; \beta_{R,y}\}$	$\beta_{\max} = \beta_{R,e}$ [a]
1	0.5	0.5	0.7	0.85	0.5	0.8571	0.8824
2	0.5	0.5	0.75	0.85	0.5	0.8667	0.8824
3	0.5	0.5	0.75	0.85	0.25	0.9200	0.9294
4	0.5	0.5	0.6	0.75	0.5	0.8333	0.7778
5	0.2	0.2	0.7	0.85	0.5	0.7333	0.7059
6	0.3	0.7	0.85	0.85	0.5	0.9081	0.9160
7	0.3	0.7	0.9	0.9	0.5	0.9439	0.9471

[a] As Eq. (8″) dominates (20) in the relevant parameter range, the latter condition can be neglected.

To show that our underpricing explanation is quite robust against variations in our setting, we investigate the idea that inexperienced and experienced VC differ in the proportion of expected G firms in future IPO rounds. Whereas experienced VCs expect a proportion of α_2 for all future periods, inexperienced VCs expect only the proportion α_1 of type G firms for the next period and α_2 ($\alpha_2 > \alpha_1$) for all future periods. Cases 6 and 7 delineate examples for this alternative interpretation. A look at these examples reveals that they are in a reasonable parameter range.[19]

5. Testable implications

The purpose of the present analysis was to investigate the disinvestment decision of VCs during an IPO. Due to informational asymmetries, product quality is only revealed after the IPO period. Using a repeated game framework we asked whether (and if so, how) expected sanctions in future periods can force VCs, who might otherwise falsely report the quality of their venture, to report the venture quality correctly and allow for early disinvestments of high-quality firms at the true value. This avoids the welfare costs associated with disinvestment decisions during an IPO.

In addition, we investigated the circumstances under which VCs may have an incentive to engage themselves in their ventures even after the IPO period. We went on to provide a previously unexplored reason for underpricing during a venture capital-backed IPO. In our setting, underpricing serves as a device for young VCs to credibly invest in the building up of reputation, which especially for first time funds is so often urgently needed.

Our analysis provides a number of explanations for stylized facts and hypotheses which can be directly tested by using available data for venture and non-venture backed IPOs.

First, we provide an explanation for a number of characteristics associated with a "hot-issue" market in Proposition 1. With a "hot-issue" market, a pooling equilibrium with

[19] A further extension of the basic argument is to allow the difference between the experienced and the inexperienced VCs to persist for more than one period. Analyzing this possibility strengthens our argument, at the cost of a significant extension of the calculations: we find for a larger parameter range that a reputational equilibrium with underpricing exists.

early disinvestments associated with a high degree of price uncertainty is obtained. This is reminiscent of the grandstanding hypothesis for early disinvestments put forward by Gompers (1996). But in contrast to Gompers, we focus not on the timing of the IPO but on the disinvestment decision of the VC. In addition, and in contrast to Gompers' argument, in our analysis early selling does not have any information content (i.e., does not send a signal to potential investors) but rather results from a high degree of uncertainty.

Second, we find in Proposition 2 that a high market share on the part of an individual VC facilitates the building up of reputation, together with a high degree of credibility and low price uncertainty. We should therefore expect that experienced VCs with a high market share establish reputation, disinvest early, and are able to sell even their high-quality ventures at close to their true value. This is in line with Lin and Smith (1998), who find based on US data that only VCs that sell during the IPO have a well-established reputation. It can also be interpreted as explaining the empirical observation that markets react favorably to the presence of seasoned venture capital financing at the time of an IPO (see Barry et al., 1990; Megginson and Weiss, 1991).

Third, we show with our Propositions 3 and 4 that a careful selection of ventures on the one hand, and late-stage investment in the value of the portfolio firms via intense management support on the other hand, constitute clear substitutes. In our model, VCs with an expected preponderance of high-quality firms have little incentive to undertake investments in the improvement of firm value via intense management support in late stages. This suggests the formation of clientele groups. Typical VCs, who are highly specialized in active investment, will disinvest late and provide very little price uncertainty. They will sell "mature" firms. More conventional financiers, who have little competitive edge in the area of "active" investment, will disinvest early and provide for a higher degree of price uncertainty.

Fourth, VCs engaged in high-risk ventures have a higher incentive to establish a reputation for selling high-quality ventures at their true value and not reporting falsely on the quality of their ventures (see Proposition 2). Hence, for them the credible building up of reputation should be facilitated, leading to early disinvestments and little price uncertainty.

A *fifth* hypothesis emerging from our Proposition 5 is that especially unseasoned VCs have an incentive to engage in underpricing, whereas seasoned VCs do not need to underprice. This hypothesis is in line with empirical findings on the US market.[20]

Acknowledgments

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[20] See Muscarella and Vetsuypens, 1989; Gompers, 1996 for VCs; Johnson and Miller, 1988; Carter and Manaster, 1990 for investment bankers in general.

on an earlier version of the paper. Walz gratefully acknowledges financial support for his research from the German Science Foundation (Wa 825/6-1) and the European Commission (Grant HPSE-CT-2002-00140). All remaining errors are our own.

Appendix A. An alternative to the basic model

We now allow for an infinite number of types of firms to be sold, which are continuously distributed over the interval $[1; (1+\Delta)]$. In this case, the VC may signal the true quality of the venture by its choice of the part θ, which is sold to the public at time $t = 1$. This kind of signaling may succeed, because waiting is generally costly ($\beta < 1$). Furthermore, better types have to bear lower costs of waiting because at time $t = 2$ the relatively high true value is revealed for sure. This avoids a pooling with the less good types. Therefore, the analytical prerequisites for a signaling equilibrium are fulfilled.

In what follows, we assume that the investors estimate the value of the venture by means of looking at the part θ: $V(\theta) = \varphi(\theta)$. This estimation is taken into account by the VC to ensure that the issue can actually be sold. Presumably, and still to be proven, the proportion sold at time $t = 1$ is negatively correlated with the value of the venture.

Given this setting, the wealth W of a VC with a venture of a true value V, selling a share θ of the venture at the price of $\varphi(\theta)$ immediately and the remaining part $(1-\theta)$ in $t = 2$ at the true value V, which has become common knowledge by that time, amounts to

$$W(V,\theta) = \theta \cdot \varphi(\theta) + \beta \cdot (1-\theta) \cdot V.$$

The following conditions are necessary for a signaling equilibrium: First, the investors have to build rational expectations:

$$\varphi(\theta) = V. \tag{A.1}$$

Second, the VC has to maximize its wealth by choosing the correct signal (incentive compatibility):

$$\frac{\partial W(V,\theta)}{\partial \theta} = \theta \cdot \varphi'(\theta) + \varphi(\theta) - \beta \cdot V = 0, \tag{A.2}$$

$$\frac{\partial^2 W(V,\theta)}{\partial \theta^2} = 2 \cdot \varphi'(\theta) + \theta \cdot \varphi''(\theta) < 0. \tag{A.3}$$

Inserting Eq. (A.1) into Eq. (A.2) and solving the resulting differential equation leads to

$$\varphi(\theta) = C \cdot \theta^{-(1-\beta)}, \tag{A.4}$$

where the integration constant C still has to be evaluated. As conjectured, $\varphi(\cdot)$ is indeed a decreasing function because of $\beta < 1$. It can easily been shown that the solution (A.4) meets condition (A.3), as well.

By determining the integration constant, the signaling equilibrium becomes unambiguous. A useful criterion for equilibrium selection is to minimize total signaling costs. This is achieved by imposing no costs on the lowest type ($V = 1$). I.e., the lowest type immediately sells off the complete venture $[\theta^*(V = 1) = 1]$. Therefore,

$$\varphi(1) = C \cdot 1^{-(1-\beta)} = 1 \tag{A.5}$$

has to hold, which implies

$$\varphi(\theta) = \theta^{-(1-\beta)}, \tag{A.6}$$

and allows the following conclusions:

(1) Only the worst type, $V = 1$, sells off the complete venture immediately (see Eq. (A.5)).
(2) The better the venture, the lower is the proportion sold at time $t = 1$. This follows from inverting (A.6) to

$$\theta^* = V^{-1/(1-\beta)} \tag{A.7}$$

with θ^* being a decreasing function of V because of $\beta < 1$.
(3) The lowest share sold, $\theta_{\min}$, corresponds to the highest possible value of the venture, $(1 + \Delta)$. $\theta_{\min}$ is strictly bounded away from zero, because

$$0 < \theta_{\min} = (1 + \Delta)^{-1/(1-\beta)} < 1.$$

As a result, there will not be any VC choosing not to divest at all at time $t = 1$.

Appendix B. A modification of the two-type model

In Appendix A we showed that even VCs with the best type will not choose to postpone complete disinvestment. Alas, this is just the assumption we used in the main part of our paper. Therefore, we now check the robustness of our model by relaxing this assumption. We show that all qualitative results continue to hold and the quantitative results are even strengthened.

Allowing for a positive share θ of the venture to be sold in $t = 1$ even with the good type gives an additional variable. By keeping the share $(1 - \theta)$ until $t = 2$ a VC with a good venture can potentially signal quality and sell θ at the true price $1 + \Delta$ in $t = 1$. This is preferred to selling at the pooling price if

$$\theta \cdot (1 + \Delta) + \beta \cdot (1 - \theta) \cdot (1 + \Delta) \geqslant 1 + \alpha \cdot \Delta.$$

For this to be an equilibrium, a VC with a type B venture need not have an incentive to imitate a VC with a good type, i.e.,

$$\theta \cdot (1 + \Delta) + \beta \cdot (1 - \theta) \cdot 1 < 1$$

has to hold. Therefore, in the single-issue case a partially separating equilibrium may exist if

$$\theta_{\min} = \frac{1 + \alpha \cdot \Delta}{(1 - \beta) \cdot (1 + \Delta)} - \frac{\beta}{1 - \beta} < \theta_{\max} = \frac{1 - \beta}{1 - \beta + \Delta}.$$

In order to separate at minimum costs, type G will definitely choose $\theta = \theta_{\max}$. Separation is hence preferred by type G if

$$\beta \geqslant \beta_P^* \equiv \frac{\alpha \cdot (1 + \Delta)}{\alpha + \Delta}. \tag{B.1}$$

A comparison of Eqs. (B.1) and (3) immediately shows that $\beta_{\mathrm{P}}^{*} < \beta_{\mathrm{P}}$, i.e., with a positive share sold at the IPO, a separating equilibrium becomes more probable. As the separating equilibrium in the single-issue case is a prerequisite for any reputational equilibrium, this result implies that reputational effects become feasible for a wider range of parameters.

In order to shorten our argument, it is useful to observe that throughout the paper the necessary and sufficient conditions can be restated by replacing β with

$$\tilde{\beta} = \theta_{\max} + \beta \cdot (1 - \theta_{\max}) = \frac{1 - \beta + \beta \cdot \Delta}{1 - \beta + \Delta} > \beta \tag{B.2}$$

without changing the respective RHS (cf. Eqs. (8), (15), (8′), (8″) and (20)). Thus, upper bounds for β become generally harder while lower bounds are weakened because of $\tilde{\beta} > \beta$. Rearranging terms leads to the conditions which have to hold for reputational equilibria with and without value enhancing investment as well as reputational equilibria with underpricing.

As a result, a necessary condition for a reputational equilibrium is

$$\beta \leqslant \beta_{\mathrm{R}}^{*} \equiv 1 - \frac{(1-\gamma) \cdot \Delta}{\alpha \cdot \gamma \cdot (1+\Delta) - (1-\gamma)} \; (< \beta_{\mathrm{R}}), \tag{B.3}$$

which is sufficient if (B.1) also holds. While (B.3) puts a more restraining condition on a reputational equilibrium, (B.1) has considerably weakened the restriction on β. Therefore, the reputational equilibrium becomes feasible for a wider range of parameters, even though for somewhat lower values of the discount factor β (cf. Table B.1).

Likewise one obtains

$$\beta \leqslant \beta_{\mathrm{R},I}^{*} \equiv 1 - \frac{(1-\gamma) \cdot \Delta \cdot (\Delta - NPV)}{\alpha \cdot \gamma \cdot \Delta \cdot (1+\Delta) - (1-\gamma) \cdot (\Delta - NPV)} \tag{B.4}$$

as a necessary condition for a reputational equilibrium with profitable investment. Furthermore,

$$\beta \leqslant \beta_{\mathrm{R,up}}^{*} \equiv 1 - \frac{(1-\gamma_2) \cdot \Delta}{(\alpha \cdot \gamma_1 + 1 - \gamma_2) \cdot (1+\Delta) - (1-\gamma_2)} \tag{B.5}$$

is necessary for an equilibrium with underpricing. Comparing these conditions with the respective ones in the main part of the paper reveals that all qualitative results carry over to the model presented in this appendix.

The only thing left to be shown is that for any numerical example presented in Tables 1 and 2, the reputational equilibria (with and without underpricing) hold for a wider range of parameters. Table B.1 shows that this is indeed the case.

A final remark is in order about the two basic equilibria. Different from the main part of the paper, in this appendix we have a two-parameter signaling model where both parameters may be chosen separately. In this case, the existence of a pooling equilibrium might be questioned. Indeed, if we had chosen a self-selection model instead of a signaling model, the pooling equilibrium would have failed to exist. Within a signaling model, however, the existence of certain equilibria is mainly driven by the expectations of the uninformed side. We assume, that badly informed investors do not “like” excessively sophisticated VCs. Therefore, any deviation from straightforward equilibria will be answered by paying the lowest price, $P = 1$, which supports the equilibria presented above.

Table B.1
Proof of the robustness of the simple model (β^*_{min} and β^*_{max} being defined as in the headlines of Tables 1 and 2, respectively)

	Parameters					Critical values	
	α_1	α_2	γ_1	γ_2	Δ	β^*_{min}	β^*_{max}
Example 1	0.2	0.2	0.9	0.9	0.9	0.7333	0.8980
2	0.5	0.5	0.9	0.9	0.9	0.9167	0.9747
3	0.8	0.8	0.9	0.9	0.9	0.9231	0.9490
4	0.5	0.5	0.9	0.9	0.9	0.8571	0.9545
5	0.9	0.9	0.95	0.95	0.95	0.9818	0.9892
Case 1	0.5	0.5	0.7	0.85	0.5	0.8000	0.8462
2	0.5	0.5	0.75	0.85	0.5	0.8182	0.8462
3	0.5	0.5	0.75	0.85	0.25	0.8824	0.9016
4	0.5	0.5	0.6	0.75	0.5	0.7500	0.6000
5	0.2	0.2	0.7	0.85	0.5	0.4286	0.2857
6	0.3	0.7	0.85	0.85	0.5	0.8874	0.8990
7	0.3	0.7	0.9	0.9	0.5	0.9368	0.9408

Note. A reputational equilibrium occurs for βs being in the interval between β_{min} and β_{max}. This requires this interval to be non-empty.

But even if other assumptions on the investors' expectations would prevent the pooling equilibrium from existing in the one-shot model, our main conclusions would remain unaltered. As we have seen, it is just the separating equilibrium in the one-shot model that allows interesting results to emerge, which include reputation acquisition, value-enhancing investment or underpricing.

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