SIGNALING BY UNDERPRICING IN THE IPO MARKET*

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Empirical evidence suggests the existence of ‘hot-issue’ markets for initial public offerings; in certain periods and in certain industries, new issues are underpriced and rationing occurs. This paper develops a model consistent with this observation, which assumes the firm itself best knows its prospects. In certain circumstances, firms with the most favorable prospects find it optimal to signal their type by underpricing their initial issue of shares, and investors know that only the best can recoup the cost of this signal from subsequent issues.

1. Introduction

Ibbotson (1975) and others have presented evidence that initial public offerings (IPOs) of firms’ stocks are underpriced. In a recent summary Smith (1986) concludes that, on average, underpricing exceeds 15%. Ibbotson and Jaffe (1975) find that this phenomenon occurs only during particular periods, and Ritter (1984) presents evidence that it is focused in particular industries, such as new issues by oil and gas firms in 1980. Further, these ‘hot issues’ are often rationed by the investment banker distributing them, with demand exceeding supply by a factor of as much as 20 [see, for example, Beatty and Ritter (1986)].

Several explanations have been offered for this anomaly. Baron (1982) casts the new-issues market in a principal–agent context, in which investment bankers have superior information about demand in capital markets. The investment banker (i) advises the firm on price and (ii) sells the stock. Compensation in the optimal contract between the firm (principal) and the banker (agent) is a function of the IPO proceeds and the price. The contract may involve underpricing to induce the banker to put forth the correct level of

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effort. Muscarella and Vetsuyepens (1989), however, find underpricing in a sample of investment banks that go public and participate in the distribution of their own securities. Since there is no asymmetric information between the issuer and the investment banker in this case, this evidence suggests that Baron’s model cannot fully explain the underpricing phenomenon.

In Rock’s (1986) model, informed investors have better information about the new firm’s prospects than the issuer and its investment banker (which in this model is ‘an invisible intermediary’). Informed investors crowd out uninformed investors for the new issues that they alone know are most likely to be profitable. Uninformed investors’ purchases are therefore biased toward the less profitable new issues. Anticipating this bias, uninformed investors are willing to participate only if new-issue offer prices are low enough to compensate them for expected losses on less attractive issues. Ritter (1984) points out, however, that if hot-issue markets occur only in particular periods, then Rock’s model implies that the risk composition of IPOs is changing over time; Ritter’s results do not support this explanation.

We assume that the best information about the new firm’s prospects is held by the firm itself. The model is described fully in section 2. We find that in some circumstances, given in section 3, good firms wish to signal investors their superior prospects, and that a low IPO price and quantity can be used as such a signal. The model is in the spirit of Ibbotson’s (1975, p. 264) conjecture that IPOs are underpriced to ‘‘leave a good taste in investors’ mouths’ so that future underwritings from the same issuer could be sold at attractive prices’. Welch (1989) points out that about one-third of all IPO issuers between 1977 and 1982 had reissued equity by 1986, the typical amount being at least three times the initial offering. In contrast to Baron (1982) and Rock (1986),1 we argue that our theory is consistent with Ibbotson and Jaffe’s (1975) and Ritter’s (1984) findings that underpricing occurs at particular times and in particular industries.

Underpricing the firm’s initial offering (which is an immediate loss to the initial owners) is a credible signal that the firm is good to investors, because only good firms can be expected to recoup this loss after their performance is realized. Good firms find it worthwhile to underprice their IPOs, because by doing so they condition investors to more favorably interpret subsequent dividend results. The owners of bad firms know their expected performance and subsequent market valuation. They know they cannot recoup the initial loss from underpricing, and so cannot afford to signal. The model therefore provides an explanation for the underpricing of IPOs as an equilibrium signal of firm quality.

1Rock’s model has multiple equilibria; he makes a ‘very tentative connection’ between this multiplicity and the ‘hot/cold cycles’ of IPOs, but does not pursue it (see pp. 202–203).
In our model, the investment banker plays no active role, except as the rationing administrator.\textsuperscript{2} Without this role, or an information role as in Baron (1982), the methods by which investment banks distribute stock would appear to have little appeal to their client firms. It would seem that a Treasury-bill-type auction for the new firm's securities would result in a higher return. Such an auction would, of course, preclude the use of price as a signal. The type of price signaling portrayed in our model is facilitated by the Rules of Fair Practice of the National Association of Securities Dealers (NASD), which mandate that once a public offering price has been set, it cannot be raised [see Smith (1977)].

A number of contemporaneous papers concerned with underpricing also assume that the firm has the best information about its prospects.\textsuperscript{3} Nanda (1988) considers a model in which firms have a choice between debt and equity. If bad firms have a high probability of default, the interest rate, reflecting the pooled risk, will be high. Good firms may find it worthwhile to issue equity instead, even though to separate themselves they may have to underprice. In our model, firms only issue equity (but see note 5 below).

Perhaps closest in spirit to our model are those of Grinblatt and Hwang (1989) and Welch (1989). In both of those papers, underpricing is a signal that the firm is good. The sequence of events is similar to that in our model: a partial offering of stock is made initially, information is then revealed, and subsequently more stock is sold. Bad firms that signal run the risk that their true type may be revealed, in which case they don't benefit from the underpricing. Therefore, by bearing a sufficiently large initial cost, good firms can credibly signal their type. There are a number of differences between our paper and these two: in Grinblatt and Hwang underdiversification is combined with underpricing to signal both the mean and variance of returns, and in Welch there is a direct cost for bad firms to imitate good firms. The most important difference, however, is that in their models firm type is (randomly) fully revealed in some exogenous way. In our model, learning occurs as investors update their Bayesian priors on the basis of the firm's (noisy) performance.

An important question in any signaling model is whether the signal being examined would be used if the firm had a wider menu of signals available. In the context of IPOs, firms typically can signal their quality with several variables other than the offer price. Two such variables discussed in the literature are the firm's choice of underwriter [see, for example, Booth and Smith (1986)] and its choice of auditor [see, for example, Titman and Trueman

\textsuperscript{2}We do not distinguish between 'best efforts' and 'firm commitment' contracts. See Ritter (1987) for analysis and evidence regarding the use of these contracts.

\textsuperscript{3}In addition to the papers discussed below, see Giammarino and Lewis (1988) for a rather different approach. Ibbotson (1975; p. 264) also lists a number of other possible reasons for underpricing.
(1986)]. Other variables may also convey information about the firm’s quality; examples are operating results while private, the quality of the board of directors, the quality of bank loans, the provision of funds by venture capitalists, and the compensation structure for management. In fact, price is likely to be just one of several signals used to convey information.

As in Milgrom and Roberts (1986), in our model the firm could apparently signal just as well by, say, contributing to a charity as by underpricing. This is a credible signal, however, only if investors can monitor the charitable contributions of IPO firms and detect any side-payments, which is likely to be costly. Underpricing as a signal requires no monitoring, since the investor is the direct recipient of the benefit. It is therefore likely to dominate any informationally equivalent signal that requires costly monitoring.

Underpricing has further advantages over other methods of signaling firm type; it reduces both the probability of, and damages in, lawsuits if subsequently the firm does not do well [see Tinic (1988)]. Moreover, underpricing may generate publicity for the firm that is more valuable if the firm succeeds than if it fails. For example, the Wall Street Journal regularly reports ‘IPO winners’, meaning firms whose stock had the largest percentage increase from offer price to current price. Underpricing increases the likelihood of receiving such publicity; this is more valuable for good firms, since they are more likely to succeed.4

Ultimately, theoretical arguments that signaling by underpricing dominates, or is dominated by, other types of signaling cannot be conclusive. The issue can be resolved only by resort to the data: either the data support the model or they do not. Both the Baron (1982) model and the Rock (1986) model have been shown by subsequent empirical work to be inconsistent with the data. There is currently no satisfactory model of hot-issue markets in the literature. In section 4, we argue that our model is consistent with the observation that underpricing apparently occurs only in particular periods and particular industries, as well as with other reported empirical observations. We also present a number of testable implications that have yet to be investigated.

2. The model

We consider a cohort of risk-neutral firms that come to the market for IPOs at time 0 and last until time 2. For simplicity, we normalize the total number of shares outstanding of each firm to one. The sequence of events is shown in fig. 1 (and a glossary of notation follows the appendix).

Firms are founded with an innovation; the firms’ founders then offer a fraction α of their equity to the public in an IPO, to acquire the capital C

3We are grateful to Cliff Smith for pointing this out.

4We assume that the firm finances its start-up costs in the first period (0, 1) with debt, but does not restructure its debt by the end of the first period. The second period (1, 2) is a data-driven model, and we leave the treatment of debt versus equity for future research.

5Should some earnings be retained, the payout be increased, or the debt by the end of the first period.

6The archetype here is Apple Computer, founded by Steve Jobs, then later managed by John Sculley, and then again by Steve Jobs, and then they sold the company.

7The archetype here is Apple Computer, founded by Steve Jobs, then later managed by John Sculley, and then again by Steve Jobs, and then they sold the company.
Firms are founded with an innovation. The original owners then offer a fraction $\alpha$ of the firm’s equity to acquire the capital $C$ needed to set up the firm and implement the innovation. Firms pay out their earnings as $H$ (high) or $L$ (low), $H > L \geq 0$, at the end of the first period and at the end of the second period. The founders of each firm, who are specialists in start-ups but not in running mature firms, sell the remaining $1 - \alpha$ of their equity at $t = 1$ after the first-period dividend has been paid.

$(> 0)$ needed to implement their innovation. Firms pay out all their earnings as dividends, which are either $H$ (high) or $L$ (low), $H > L \geq 0$, at the end of the first and second periods. The founders of each firm, specialists in start-ups but not in running mature firms, sell the remaining $1 - \alpha$ of their equity at time 1, after the first-period dividend has been declared.

There are two types of firms: good ($G$) and bad ($B$). Good firms have a higher expected dividend stream than bad firms. A firm’s type can change through time (see fig. 2). Initially, the innovation on which a firm is based can be either good or bad. Of the total number of firms entering the IPO market at any time, the proportion $\theta$, $0 < \theta < 1$, are good, and $1 - \theta$ are bad. Good

5We assume that the firm finances its start-up cost with equity capital only. Risk-free debt clearly dominates equity. If the full start-up costs cannot be financed with risk-free debt, the possibility of risky debt is introduced. But since we have assumed only two possible outcomes ($H$ or $L$), risky debt is no different from a suitable combination of risk-free debt and equity in this model. We leave the treatment of debt versus equity in a model with a richer structure to future research.

6Should some earnings be retained, the proceeds from selling shares of the firm at time 1 increase by an amount just equal to the decrease of the dividend; therefore, the total wealth of shareholders is independent of the payout ratio (assuming that retained earnings can be observed by investors).

7The archetype here is Apple Computer, founded by two computer hackers (Stephen Wozniak and Stephen Jobs), then later managed by a corporate marketing type (John Sculley). Our assumption that the decision makers sell out completely at time 1 is for expositional neatness; any significant seasoned issue of securities after the IPO will yield the same results.
innovations require skillful implementation for the firm to remain good. This occurs with probability \( \lambda, 0 < \lambda < 1 \). A good firm that fails to implement well in the first period becomes a bad firm. Firms with bad ideas remain bad firms. Hence the fraction of good firms after implementation is \( \theta \lambda \), and the fraction of bad firms is \( 1 - \theta \lambda \).

At time 0, the founders of each firm know whether their innovation is good or bad, but do not yet know whether their firm’s implementation will succeed. After implementation, good firms have a probability \( \pi_G \) of paying dividend \( H \) and their probability of paying dividend \( L \) is \( 1 - \pi_G \). Bad firms have a probability of paying dividend \( H \) of only \( \pi_B \), where \( \pi_G > \pi_B \).

Investors cannot directly observe either the quality of the firm’s innovation or the success or failure of its implementation; they can observe only (i) the price and proportion of the firm sold in the IPO and (ii) the dividends at the end of each period. Investors know there are two types of firms and also know \( \pi_i \) (\( i = G, B \)). They are risk-neutral.

The amount investors are willing to pay at time 0 depends on their prior beliefs about the probability that the firm will be good after implementation. The firm chooses the price and proportion of the firm sold in the IPO, and thereby informs investors’ prior beliefs about the firm’s type. For example, a particular choice of price and proportion may signal to investors that a firm is good. At the conclusion of period 1, dividends are revealed, and investors update their prior beliefs on the basis of this new information, which determines what they are willing to pay at time 1.

Investors’ prior probability that a particular firm is good after implementation is denoted \( r_0 \). At the end of the period they observe either \( H \) or \( L \), and update their prior probability \( r_0 \) that the firm is good, conditional on dividends.

\[
r_H(r_0) = \frac{\pi_G r_0}{\pi_G r_0 + \pi_B (1 - r_0)}
\]

\[
r_L(r_0) = \frac{(1 - \pi_G) r_0 + (1 - r_0)}{(1 - \pi_G) r_0 + (1 - r_0)}
\]

Suppose investors at time 0 initially hold the belief that at time 1 they observe dividend \( r \). They then change their beliefs about dividend \( r \) as follows:

\[ V_j(r_0) = \delta \left( H \pi_G + (1 - \pi_G) \right) \]

That is, second-period dividends can occur in two ways: a good firm or a bad firm (probability \( 1 - r \)) can pay dividends.

At time 0, investors have no information about the firm at

\[ V_0(r_0) = \delta \left( (H + V_H) r_0 \pi_G + (L + V_L) (1 - r_0) \right) \]

Since equity markets are assumed to be bid up to the value placed on knowledge regarding the quality of dividend payments, firms know their own type \( i = G \) or \( B \), and dividends. Since each is risk-neutral.
update their prior probability using Bayes' rule. The posterior probabilities that the firm is good, conditional on having observed \( H \) or \( L \), are

\[
\begin{align*}
    r_H(r_0) &= \frac{\pi_G r_0}{\pi_G r_0 + \pi_B (1 - r_0)}, \\
    r_L(r_0) &= \frac{(1 - \pi_G) r_0}{(1 - \pi_G) r_0 + (1 - \pi_B)(1 - r_0)}.
\end{align*}
\]

Suppose investors at time 0 initially believe the firm is good with probability \( r_0 \) and at time 1 they observe dividend \( H \) (or \( L \)). Then investors change their beliefs about the firm according to the above equations. If they observe a high dividend, they change the probability that the firm is good from \( r_0 \) to \( r_H(r_0) \). This is the ratio of the probability of a high dividend from a good firm to the probability of a high dividend from either firm. If they observe a low dividend, their revised probability that the firm is good is \( r_L(r_0) \). This is the ratio of the probability of a low dividend from a good firm to the probability of a low dividend from either firm.

At time 1, investors have observed \( j = H \) or \( L \), and using a one-period discount factor \( \delta \) [and writing \( r_j(r_0) \) as \( r_j \)], value the firm at

\[
V_j(r_0) = \delta \left[ H \left( r_j \pi_G + (1 - r_j) \pi_B \right) + L \left[ 1 - r_j \pi_G - (1 - r_j) \pi_B \right] \right].
\]

That is, second-period dividends \( H \) and \( L \) are weighted by the probabilities that they occur, taking into account first-period performance. A high dividend can occur in two ways: a good firm (probability \( r_j \)) can have a good draw (\( \pi_G \)), or a bad firm (probability \( 1 - r_j \)) can have a good draw (\( \pi_B \)). Otherwise, a low dividend occurs.

At time 0, investors have no experience (\( j = 0 \)), and therefore similarly value the firm at

\[
V_0(r_0) = \delta \left\{ \left( H + V_H \right) \left[ r_0 \pi_G + (1 - r_0) \pi_B \right] \right. \\
+ \left. \left( L + V_L \right) \left[ 1 - r_0 \pi_G - (1 - r_0) \pi_B \right] \right\}.
\]

Since equity markets are assumed to be competitive, the price of each firm will be bid up to the value placed on it by investors, given their (common) knowledge regarding the quality of the firm. Thus, eqs. (3) and (4) give the market prices of firms.

Firms know their own type (\( i = G, B \)), and therefore their distribution of dividends. Since each is risk-neutral, its expected return (that is, the present
value of its payoffs) after implementation, if investors hold prior beliefs \( r_0 \), is

\[
R_i(r_0) = \delta \left\{ \pi_i \left[ H + V_H(r_0) \right] + \left(1 - \pi_i\right) \left[ L + V_L(r_0) \right] \right\}, \quad i = G, B.
\]

The return is the sum, weighted by probabilities, of the dividend outcomes plus the value of the firm to investors after these outcomes.

Before implementation, the firm’s founders have private information about the quality of their innovation \((i = G, B)\), but they do not know whether their implementation will be successful. If a bad firm were to sell the fraction \( \alpha \) of its equity at time 0 at the price \( p_0 \), the return to the original owners, if investors held prior beliefs \( r_0 \), would be

\[
R^0_B(p_0, r_0) = \alpha p_0 + (1 - \alpha) R_B(r_0) - C. \tag{6}
\]

This reflects the proceeds from the IPO, the cost of implementation, and the expected dividends and proceeds from the sale of the original owners’ remaining equity at time 1.

Similarly, for a firm with a good innovation,

\[
R^0_G(p_0, r_0) = \alpha p_0 + (1 - \alpha) \left\{ \lambda R_G(r_0) + (1 - \lambda) R_B(r_0) \right\} - C. \tag{7}
\]

To review the notation regarding the value of the firm, note that \( V_i(r_0) \) is the value of the firm that reflects just the public information \( j \) \((j = 0, H, L)\). In contrast, \( R^0_i(p_0, r_0) \) is the expected return before implementation to the founders, given their private information about the quality of the firm’s innovation \( i \) \((i = G, B)\). Finally, \( R_i(r_0) \) is the expected return after implementation, given the private information about the outcome \( i = (G, B) \) of implementation. Most critically, \( V_0, R^0_G, \) and \( R_i \) all depend upon \( r_0 \), the prior beliefs of investors about the post-implementation quality of the firm. Note that

\[
R_G(r_0) > R_B(r_0): \text{ for given investor beliefs, a good firm has higher expected returns than a bad firm;}
\]

\[
dR_i / dr_0 > 0: \text{ for a given firm type, the more optimistic are investors’ beliefs about the firm, the greater its expected return; and}
\]

\[
R_B(0) = V_0(0): \text{ a bad firm’s expected return, given that investors believe it to be bad, is the same as investors’ valuation of a firm they believe to be bad.}
\]

Two constraints bind each type of firm: (i) each must initially raise at least \( C \) to implement its innovation, and (ii) investors will not pay more for the firm than its value to them:

\[
\alpha p_0 \geq C, \\
p_0 \leq V_0(r_0).
\]

The returns of either type of firm, and it might be expected to be maximum price possible. Either \( p_0 \) as a signal to condition in however, in which case (8b) is the IPO is underpriced, demand.

It can be seen from eqs. (1)–(2) is necessary to allow the model to be used, the fitness of the firm is good. For an exogenous deterministic (but initially unknown) \( \pi_B = 0 \). Then the firm’s type is deduced to be bad at time 0 play no role i.e., we have no incentive to send a unique equilibrium results, with inferences drawn from the entire population.

More subtle is the case in which both firms that are good initial implementation \((\lambda = 1)\). If a good firm found it worthwhile to do so, they might signal \( \pi_B = 1 \) eqs. (8b) posterior beliefs would be the same. The same alternating returns, bad firm signal, so separation would not occur, results, with \( r_0 = \theta \). This occurs is \( 0 < \lambda < 1 \).

3. Separating and pooling equilibria

In a separating equilibrium, a particular price-and-proportion strategy that uses this strategy to signal all bad firms \((r_0 = 0)\), provided that is bad, than not signaling, and signaling

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\( ^{8} \) For a fuller exposition, see Allen and...
than its value to them:

\[ \alpha p_0 \geq C, \quad (8a) \]
\[ p_0 \leq V_0(r_0). \quad (8b) \]

The returns of either type of firm appear to be increasing in the initial price \( p_0 \), and it might be expected that any firm would wish to sell shares at the maximum price possible. Either type of firm may wish to use the initial price \( p_0 \) as a signal to condition investors’ prior beliefs \( r_0 \) about its prospects, however, in which case \( (8b) \) is not binding. When this occurs in equilibrium, the IPO is underpriced, demand outstrips supply, and the shares are rationed.

It can be seen from eqs. (1)–(4) that the uncertainty structure of the model (fig. 2) is necessary to allow the IPO price and proportion to act as a signal that the firm is good. For example, suppose that dividends are completely deterministic (but initially unknown), so that the probabilities are \( \pi_g = 1 \) and \( \pi_b = 0 \). Then the firm’s type is revealed completely at time 1, investors’ prior beliefs at time 0 play no role in determining firm value at time 1, and firms have no incentive to send a costly signal at time 0. A simple pooling equilibrium results, with investors’ prior beliefs being that all firms are a random draw from the entire population, so that \( r_0 = \theta \lambda \).

More subtle is the case in which dividend outcomes are noisy \( (1 > \pi_g > \pi_b > 0) \) but firms that are good initially are certain that they will be good after implementation \( (\lambda = 1) \). If a good firm could somehow signal its type (and found it worthwhile to do so), then (assuming that investors’ expectations are rational, so that \( r_0 = \lambda = 1 \)) eqs. (1) and (2) tell us that investors’ prior and posterior beliefs would be the same, no matter what the subsequent dividend outcome \( (r_0 = r_H = r_L = \lambda = 1) \). Since the benefit of the signal does not depend on dividend outcomes, bad firms would find it worthwhile to send the same signal, so separation would not be possible. Again, a simple pooling equilibrium results, with \( r_0 = \theta \lambda \). Therefore, a necessary condition for separation to occur is \( 0 < \lambda < 1 \).\(^8\)

3. Separating and pooling equilibria

In a separating equilibrium, good firms signal their type to investors with a particular price-and-proportion strategy \((p_0, \alpha)\). Investors believe that all firms that use this strategy to signal are good \((r_0 = \lambda)\) and all those that don’t signal are bad \((r_0 = 0)\), provided that signaling by bad firms is no more profitable than not signaling, and signaling by good firms is no less profitable than not signaling.

\(^8\)For a fuller exposition, see Allen and Faulhaber (1988).
signaling. These conditions are

\begin{align}
R^0_{p_0}(p_0, \lambda) & \leq R^0_{\theta}(V_0(0), 0), \\
R^0_{C}(p_0, \lambda) & \geq R^0_{C}(V_0(0), 0).
\end{align}

(9a)  (9b)

If signaling is to be both credible and profitable for good firms, the initial price \( p_0 \) must satisfy (8) and (9). It can be shown that:

**Proposition 1.** A separating equilibrium exists iff

\[ R_C(\lambda)/R_{\theta}(\lambda) \geq R_C(0)/R_{\theta}(0) \]

(10)

and

\[ C < V_0(0). \]

(11)

Rationing always occurs in a separating equilibrium.

**Proof.** See appendix.

The intuition of (10) is straightforward. Any firm would prefer investors to think it is good, since the amount obtained from the sale of stock is greater for firms believed to be good than for those believed to be bad \([V_0(\lambda) > V_0(0)]\). If good firms wish to signal their type, however, they must forego some of their returns by charging a price \( p_0 \) lower than they could otherwise obtain (and hence sell off more of their firm). This cost of foregone returns must be great enough to dissuade bad firms from using the same strategy. The ratio \( R_C(r_0)/R_{\theta}(r_0) \) is the value of a good firm in relation to the value of a bad firm, given prior beliefs \( r_0 \). If this is greater at the more optimistic prior \((r_0 = \lambda)\) than at the pessimistic prior \((r_0 = 0)\), so that (10) is satisfied, good firms benefit more from underpricing and signaling is worthwhile.

There is rationing in a separating equilibrium, since the asking price \( p_0 \) is less than the market-clearing price for a known good firm \( V_0(\lambda) \). This occurs because signal credibility requires the asking price to be no greater than the value of a known bad firm \([p_0 \leq V_0(0) < V_0(\lambda)]\).

Good firms establish a (low) price, which the NASD’s Rules of Fair Practice ensure is maintained in the face of excess demand. In this instance, price does not play its usual market-clearing role, since it is playing a signaling role. Investors become informed by the low price itself: the firm must be good, because bad firms do not find it worthwhile to take such losses from underpricing. The Rules of Fair Practice ensure that the market doesn’t work, in the usual meaning of the phrase.

Not all equilibria are separating; pooling equilibria can exist as well. In a pooling equilibrium, investors cannot distinguish between good firms and bad firms at the time of their IPOs. Their firms is that \( r_0 = \theta \lambda \).

For pooling to be an equilibrium less profitable for them than pooling proportion signal is credible only if the firm than pooling. This condition is

\[ R^0_{p_0}(p_0, \lambda) \leq R^0_{\theta}(V_0(\theta \lambda), \theta) \]

But for pooling to be an equilibrium choose a credible signaling strategy proportion strategies \((p_0, \alpha)\) satisfy

\[ R^0_{C}(p_0, \lambda) \leq R^0_{C}(V_0(\theta \lambda), \theta) \]

(12)

In addition, it is clear that neither good nor bad are bad.

**Proposition 2.** A pooling equilibrium

\[ R_C(\lambda)/R_{\theta}(\lambda) \leq R_C(\theta \lambda)/R_{\theta}(\lambda) \]

(13)

and

\[ C \leq V_0(\theta \lambda). \]

(14)

Markets clear in a pooling equilibrium.

**Proof.** See appendix.

The intuition of (14) is similar to that of market valuation would be greater \( [V_0(\lambda) > V_0(0)] \), however, because returns are sufficient to dissuade bad firms from also prefer to be known as good. C cannot be relatively more valuable at the \( r_0 \), good firms do not find it worthwhile.

In a pooling equilibrium, no unqual investors’ valuation of the firm no different from other securities with good and bad firms exist, but investors can.

There are parameter values for which exist. In such cases, the following re
firms at the time of their IPOs. Therefore, investors’ prior belief about all new firms is that \( r_0 = \theta \lambda \).

For pooling to be an equilibrium, credible signaling by good firms must be less profitable for them than pooling. In a pooling equilibrium, a price-and-proportion signal is credible only if this strategy is less profitable for a bad firm than pooling. This condition is

\[
R^0_B(p_0, \lambda) \leq R^0_C(V_0(\theta \lambda), \theta \lambda).
\]  
\tag{12}

But for pooling to be an equilibrium, good firms must find it less profitable to choose a credible signaling strategy than to pool. That is, for all price-and-proportion strategies \((p_0, \alpha)\) satisfying (8a), (8b), and (12),

\[
R^0_C(p_0, \lambda) \leq R^0_C(V_0(\theta \lambda), \theta \lambda).
\]  
\tag{13}

In addition, it is clear that neither good nor bad firms want to signal that they are bad.

**Proposition 2.** A pooling equilibrium exists iff

\[
\frac{R_C(\lambda)}{R_B(\lambda)} \leq \frac{R_C(\theta \lambda)}{R_B(\theta \lambda)}
\]  
\tag{14}

and

\[
C \leq V_0(\theta \lambda).
\]  
\tag{15}

Markets clear in a pooling equilibrium.

**Proof.** See appendix.

The intuition of (14) is similar to that of (10); any firm would prefer investors to think it is good rather than a random draw, since their stock market valuation would be greater \([V_1(\lambda) > V_1(\theta \lambda)]\). Signaling this to investors is costly, however, because returns must be foregone. This cost must be great enough to dissuade bad firms from mimicking the strategy, since they would also prefer to be known as good. Condition (14) is true only if good firms are not relatively more valuable at the more optimistic prior \((r_0 = \lambda)\). In this case, good firms do not find it worthwhile to signal their type.

In a pooling equilibrium, no underpricing occurs, prices of all securities equal investors’ valuation of the firm, and therefore clear the market. IPOs are no different from other securities with similar risk characteristics. Both good and bad firms exist, but investors cannot tell them apart.

There are parameter values for which both pooling and separating equilibria exist. In such cases, the following result is useful.
Fig. 3. Uncertainty and type of equilibrium.

The relationship between the type of equilibrium, the probability good firms successfully implement, λ, and the proportion of good firms before implementation, θ, when C < V₀(θ) where C is the cost of setting up a firm and V₀(θ) is the value of a firm at θ = 0 that investors believe to be a bad firm. The case illustrated involves a high dividend, H, of 10, a low dividend, L, of 1, a probability of a high dividend for the good firm, π₀, of 0.9 and for the bad firm, πₜ, of 0.1, and a discount factor, δ, of 1.

Proposition 3. When both pooling and separating equilibria exist, both good and bad firms are better off in the pooling equilibrium.

Proof. See appendix.

Fig. 3 shows for a particular example the regions in (θ, λ)-space in which each type of equilibrium exists, presuming that the start-up cost is less than investors’ initial valuation of a known bad firm [C < V₀(0) < V₀(θλ)]. It can be seen that when there is a small probability that the firm will remain good (low λ) a separating equilibrium exists; when this probability is large (high λ) a pooling equilibrium exists. For intermediate values both a pooling and a separating equilibrium exist; however, Proposition 3 suggests it is the pooling equilibrium that is of interest in these circumstances.

That a small probability of successful implementation leads to a separating equilibrium and a large probability leads to a pooling equilibrium is perhaps counterintuitive. It might be thought that signaling would be more profitable for good firms if they are more likely to remain good firms, and pooling more profitable when they are less likely to do so.

In fact the reverse is true. The

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The relationship between investors' posterior a firm is good, $r_j$ ($j = H, L$), having observed a high, $H$, or low, $L$, dividend and their prior, $r_0$. The case illustrated involves a probability of a high dividend for the good firm, $\pi_H$, of 0.9 and for the bad firm, $\pi_L$, of 0.1. For a low prior, such as $\nu'$, the change $r_H - r_0'$, when a low dividend $L$ is observed. For a high prior such as $\nu''$, the reverse is true.

In fact the reverse is true. The root of the seemingly paradoxical form of fig. 3 lies in the nature of investors' Bayesian learning. Suppose that (i) good firms are much more likely to earn a high dividend than are bad firms ($\pi_G \gg \pi_B$), and (ii) the likelihood of remaining good is small ($\lambda$ and $\theta \lambda$ close to 0). Then investors will be surprised to see a high dividend $H$ rather than a low dividend $L$ at the end of the first period. In other words, the absolute value of the change from their prior probability to their posterior probability is larger if they observe dividend $H$ rather than dividend $L$. In fig. 4, we plot $r_H$ and $r_L$ against $r_0$ for the parameters of the example in fig. 3. For a prior probability $r_0$ near zero, such as $r_0''$, the increase in probability due to a high-dividend observation ($r_H - r_0''$) is substantially larger than the decrease in probability due to a low-dividend observation ($r_0' - r_L$). Since good firms are more likely than bad ones to have high dividends $H$, they have an advantage at the prior $\lambda = r_0'$ over their bad counterparts, and therefore wish to signal. For a prior probability $r_0$ close to unity, such as $r_0''$, investors are more surprised by bad news, so that the decrease in probability due to a low-dividend observation ($r_0'' - r_L$) is larger than the increase in probability due to a high-dividend observation ($r_H - r_0''$). Hence, comparing $\theta r_0''$ and $r_0''$, good firms are at a relative disadvantage at the prior $r_0''$, and therefore wish to pool.
If, however, the probabilities of high dividends for good and bad firms \( (\pi_g, \pi_b) \) are relatively close, there is little difference between the two distributions. In this circumstance, the relative advantage of good firms at low values of \( r_i \) disappears, and they therefore wish to pool at all values of \( \lambda \).

The presumption of fig. 3 is that the start-up cost of a new venture is less than investors' initial valuation of a firm they believe to be bad; that is, \( C < V_0(0) \). Other equilibria can obtain if the start-up cost is greater than this valuation. There are three cases of interest: (i) \( V_0(0) \leq C \leq V_0(\theta \lambda) \); (ii) \( V_0(\theta \lambda) < C \leq V_0(\lambda) \); and (iii) \( V_0(\lambda) < C \).

In cases (i) and (ii) partial pooling (mixed strategy) equilibria exist. In these equilibria, firms that enter the market sell out entirely at time 0 (\( \alpha = 1 \)), thereby just covering their start-up cost and earning zero profits. They are thus indifferent between entering and not entering, and so choose randomly whether to enter the market. In case (i), all bad firms enter and a fraction \( \gamma \), \( 0 \leq \gamma \leq 1 \), of good firms enters. In case (ii), all good firms enter, and a fraction \( \beta \), \( 1 > \beta > 0 \), of bad firms enters. If both pooling and partial pooling equilibria exist [as when \( C < V_0(0) \) this occurs when \( \lambda \) is large], both types of firms prefer pooling to partial pooling (since they earn positive profits if they pool), and pooling is the equilibrium of interest. In case (iii), no entry occurs. We illustrate the range of equilibria in fig. 5.9

4. Empirical evidence and testable implications

Ibbotson (1975), Ibbotson and Jaffe (1975), and Ritter (1984), among others, have presented evidence of underpricing of IPOs [see Smith (1986) for a full discussion]. Ibbotson (1975) finds that the average of initial returns on unseasoned new issues calculated for the entire period of the 1960s and across all industries is large. Ibbotson and Jaffe (1975) show that the degree of underpricing is cyclical and concentrated in particular periods. At the beginning and end of the 1960s new issue markets are hot in the sense that there is significant underpricing. In the interim, however, there is no evidence of underpricing. They also find that the volume of new issues is cyclical. Using a similar method, Ritter (1984) identifies a hot-issue market in 1980. He shows that this hot-issue market is almost exclusively associated with natural resource issues. In addition he finds that it occurs at a time when the value of all publicly traded natural resource firms is high. Previous theories are not consistent with this evidence.

We argue that the results of Propositions 1–3 are consistent with the observed time and industry effects. In the formal model above, we assume that the potential dividends \( H \) and \( L \) are exogenous; of course, they are actually determined by the market conditions in which positive net present values \( C < V_0(0) \) could persist for a period. A new issue market may involve several or all firms to be common, however, entry of a few IPOs, then, will be concentrated.

In the long run, free entry by all firms in an industry will be such that the average stock price is approximately equal to the cost of capital. In our model, we would expect the cost of partial pooling (non-pooling) equilibrium in the absence of externalities. Profitability, however, we would expect to be

Consider, for example, an industr

\[\text{Fig. 5. Start-up costs vs. returns at } r.\]

The relationship between the type of equity and the valuation at \( r = 0 \), \( V_0(0) \), is shown. The proportion of firms that have gone public is shown, and the proportion of firms that have gone public is shown to be higher in the case of a positive valuation. The proportion of firms that have gone public is shown to be higher in the case of a positive valuation.

For a formal analysis of these partial pooling equilibria and a proof of these results, see Allen and Faulhaber (1987).
Fig. 5. Start-up costs and type of equilibrium.

The relationship between the type of equilibrium and the cost of setting up a firm, $C$, relative to investors’ valuation at $t = 0$, $V_0(\delta)$, where $\delta$ is their prior the firm is a proportion of firms that have good innovations and $\lambda$ is the proportion that successfully implements these and remains good. The third is $\delta = \lambda$. When two types of equilibria exist, the pooling equilibrium Pareto dominates either the separating equilibrium or the partial pooling equilibrium.

determined by the market conditions the firm faces over its life. In an industry in which positive net present value projects are common, the condition that $C < V_0(0)$ could persist for a prolonged period. In that case equilibrium in the new issue market may involve separation and underpricing. For such projects to be common, however, entry opportunities must be limited, and IPOs will be few. IPOs, then, will be concentrated in reasonably competitive industries.

In the long run, free entry ensures that prices in a fairly competitive industry will be such that the expected value of the earnings stream is approximately equal to the cost of establishing the business. This suggests that in our model, we would expect $V_0(x) = C$, for $0 \leq x \leq \lambda$, so that a pooling (or partial pooling) equilibrium in the IPO market would occur. Underpricing is not a feature of such equilibria. When exogenous shocks increase expected profitability, however, we would expect an expansion of the industry through entry.

Consider, for example, an industry in which condition (10) of Proposition 1 holds and market prices support a pooling equilibrium at, say, $V_0(0) = C$. Now suppose demand and cost conditions in the industry change, so that economic rents can be expected for at least some time in the future where none existed
in the recent past. Prices in the industry would support increased values of \( H \) and \( L \), which would lead to increases in \( V_0(0) \). Since \( C < V_0(0) \), the market for IPOs would move to a separating equilibrium, in which underpricing would occur.

Thus, in industries in which condition (10) holds, we would expect that a perceived change in market conditions would lead to (i) a flow of firms into the IPO market and (ii) underpricing of these firms' initial issues. After the number of firms in this industry approached its new equilibrium level, the flow of firms into the industry would stop, marking the end of the hot-issue market. In short, we would expect hot-issue markets to be temporary, industry-specific, and associated with improvements in the perceived profitability of entry.

Ritter (1984) presents evidence that the value of natural-resource firms increased substantially around the period of the 1980 hot-issue market. It is plausible that this increase in value was associated with the exogenous shock of the 1979 oil crisis, which resulted in substantially increased prices for petroleum products worldwide. The new prospect of highly profitable energy may well have been the impetus for the 1980 hot-issue market in natural-resource firms, characterized by both underpricing and the flood of new issues noted by Ritter. In fact, he found that ‘almost all of these [natural-resource-related] stocks had large initial price jumps...’ (p. 224). In the context of our model, this would correspond to \( \theta \) near unity, which is the case when almost all founders believe their firms are good. This does not mean, however, that all firms are good after implementation; indeed, \( \lambda \) may be quite small. For example, successful implementation for a drilling firm means actually finding oil or gas, an uncertain outcome even if seismographic reports are favorable. With this interpretation (\( \theta \) near unity), our model is consistent with Ritter's findings.

In other empirical work, Barry, Muscarella, Peavy, and Vetsuyrens (1988) present evidence that IPOs of firms initially backed by venture capitalists are just as underpriced as those without such backing. Venture capitalists share at least some of the private information about the prospects of the firms they back, and they come to the IPO market repeatedly. Therefore, the authors speculate, venture capitalists may have an even greater incentive to build a reputation, as the type that back good firms.

In summary, the implications of our model are that (i) hot-issue markets may occur in specific industries whenever an exogenous shock substantially improves expected profitability; (ii) such a market continues until the number of firms in that industry adjusts to the new conditions (or those conditions again change); (iii) firms for which there is no information asymmetry, and hence no need to signal, do not underprice; and (iv) when others are involved in an IPO, such as venture capitalists, underpricing is more severe.

The consistency of our model with the observations of Ritter (1984) and Barry et al. (1988) is clearly only suggestive. There are, however, other testable implications that have not yet been explored.

The model predicts that, ceteris paribus, a reasonable period after their initial public offerings, future returns are less, but the predictability of those returns is even less.\(^{10}\) It is straightforward to show that the expected returns of the firm sold initially, with respect to signals that firms will go public (either because they are better informed or because they have more complete information context), is greater than the expected returns of the firm sold later.

5. Concluding remarks

Empirical evidence suggests that underpricing is a common phenomenon. We have assumed that the firm is better off when it sells its shares early. This assumption may be incorrect in some cases. It is possible that the firm would be better off waiting for a later offering.

Appendix

Proof of Proposition 1

We start by describing a separating equilibrium. \( p_0 < V_0(0) = R_H(0) \).

The firm would not wish to underprice its shares, even if it held with equality. Since the firm will be underpriced at time \( 1 \), this means that \( \alpha \) must be

\[ 1 - \alpha = \frac{(V_0(0) - C)}{R_H(0) \cdot C} \]

Differentiating \( C \cdot (C + R_H(0) \cdot V_0(0)) < 1 \). When only \( (C/\alpha) (d\alpha/dC) = 1 \).

However, note that some incentive for shareholders to anticipate the subsequent sale of the firm's plans for subsequent issues. We have

\( \lambda \) is a separating equilibrium, both \( \delta \) and \( (1 - \delta) \) are underpriced with equality. Since the firm will be underpriced at time \( 1 \), this means that \( \alpha \) must be

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Differentiating \( C \cdot (C + R_H(0) \cdot V_0(0)) < 1 \). When only \( (C/\alpha) (d\alpha/dC) = 1 \).
implications that have not yet been investigated in the empirical literature. (i) The model predicts that, *ceteris paribus*, firms that do not issue equity within a reasonable period after their IPO will be less underpriced than those that return to the market more quickly. If a firm does not expect to sell new equity for some time after the IPO, then not only are the discounted benefits of the future returns less, but the predictive power of the underpricing signal is less as well.10 (ii) It is straightforward to show that the elasticity of α, the fraction of the firm sold initially, with respect to C, the amount raised, is less than one for firms that signal they are good by underpricing.11 For firms that do not signal (either because they are bad, or are in a pooling equilibrium, or are in a complete information context), this elasticity is unity. On average, then, our model predicts that the measured elasticity of the share offered with respect to the amount raised is less than unity in a hot-issue market.

5. Concluding remarks

Empirical evidence suggests that underpricing of new issues occurs at certain times in particular industries. We have developed a model consistent with this phenomenon. We depart from previous theories of underpricing by assuming that the firm is better informed about its prospects than anybody else. We show that underpricing can signal favorable prospects for the firm. In instances that appear to correspond to the empirical evidence of Ritter (1984), underpricing occurs in a separating equilibrium.

Appendix

*Proof of Proposition 1*

We start by describing a separating equilibrium. It is straightforward to show that (9a) implies

\[ p_0 < V_0(0) = R_B(0). \]  \hspace{1cm} (A.1)

The firm would not wish to underprice more than is necessary, so that (9a) holds with equality. Since the founders wish to retain as many shares as possible for sale at time 1, α is minimized and (8a) also holds with equality.

10 However, note that some incentive for underpricing would be present if any of the original shareholders anticipate the subsequent sale of part of their remaining holdings, independent of the firm’s plans for subsequent new issues. We thank the referee for pointing this out.

11 In a separating equilibrium, both (8a) and (9a) are satisfied with equality, and imply \[ 1 - \alpha = \frac{[V_0(0) - C]}{R_B(\lambda)}. \] Differentiating α with respect to C, we obtain (C/α)(dα/dC) = \( C/[C + R_B(\lambda) - V_0(0)] < 1 \). When only (8a) is satisfied (no signaling by underpricing), (C/α)(dα/dC) = 1.
Therefore, the good firm’s optimal signaling price-and-proportion strategy \((p'_0, \alpha')\) is
\[
\alpha' = 1 - \frac{R_B(0) - C}{R_B(\lambda)}, \quad p'_0 = \frac{C}{\alpha'}.
\]
(A.2)

We now demonstrate that the existence of a separating equilibrium implies the conditions in the proposition. We first show that (11) is implied. In a separating equilibrium, (A.1) is satisfied and (8a) is satisfied with equality; these two conditions, and the fact that \(\alpha' \leq 1\), imply (11).

To show that (10) is satisfied in a separating equilibrium, we note that since (8a) holds with equality,
\[
R^0_G(p'_0, \lambda) = \left[\frac{R_B(0) - C}{R_B(\lambda)}\right] \left[\lambda R_G(\lambda) + (1 - \lambda) R_B(\lambda)\right],
\]
(A.3)

If a good firm does not signal, its expected first-period dividends are greater than implied by its initial valuation, so it wishes to sell as little of the firm as necessary, and \(\alpha V_0(0) = C\). Its expected returns, \(R^0_G(V_0(0), 0)\), are the same as in (A.3), but with \(R_G(\lambda)\) replaced by \(R_B(0)\).

In any separating equilibrium, (9b) must hold. Using the expressions for \(R^0_G\), it can be seen that (9b) implies (10).

To show that (10) and (11) imply the existence of a separating equilibrium, we note that a good firm prefers to signal its type rather than be identified as bad since (10) and (11) imply (9b). Also, a good firm that maximizes its returns by signaling with strategy \((p'_0, \alpha')\) finds that signaling is feasible since (A.2) and (11) imply (9a). Hence, if (10) and (11) hold, a separating equilibrium exists.

It follows from (A.1) and \(dV_0(r_0)/dr_0 > 0\) that \(p_0 < V_0(\lambda)\). Therefore, in any separating equilibrium, condition (8b) is satisfied with a strict inequality, underpricing occurs, and the IPO of good firms is rationed. This proves the last part of the proposition.

**Proof of Proposition 2**

We start by describing the equilibrium. Since in a pooling equilibrium good firms’ first-period dividends will on average be better than expected by investors, they would prefer to sell as little of their firm as possible at time 0, so that constraint (8a) is binding. If a good firm does not signal, it can charge a market-clearing price \(f\) and \(p_0 = V_0(\theta\lambda)\). A good firm and has expected returns
\[
R^0_G(V_0(\theta\lambda), \theta\lambda) = \left[\frac{V_0(\theta\lambda) - C}{V_0(\theta\lambda)}\right].
\]

Although a bad firm would signal that it is bad and (8b) are also binding for both firms, \(R^0_G(V(\theta\lambda), \theta\lambda), \theta\lambda\), are
\[
R_B(\theta\lambda).
\]

We now prove that the equilibrium (15) and, second, (14) hold. The maximum amount that can be sold is \(V_0(\theta\lambda)\), so that (15) must hold.

If a good firm deviates from the price-and-proportion strategy used in equilibrium, (12) would be satisfied if \(\alpha'' p''_0 < V_0(\theta\lambda)\) and \(\alpha'' p''_0^0\) would be.
\[
R^0_G(p''_0, \lambda) = \left[\left[\frac{R_B(\theta\lambda)}{R_B(\lambda)}\right]\right]^{-1}
\]

In any pooling equilibrium, it can be seen that (13) implies (14).

To show that (14) and (15) imply that (13) is satisfied, we need to show that (14) is satisfied. We note that the strategy of not signaling to signaling, so that (13) is satisfied. Further, the strategy of not signaling being feasible (\(\alpha \leq 1\)).

Finally, as argued above, we conclude that the strategy of initial shares \(p_0 = 1\) of initial shares takes place.
a market-clearing price for the initial sale, so constraint (8b) is also binding, and \( p_0 = V_0(\theta \lambda) \). A good firm sells off \( \hat{\alpha} = C/V_0(\theta \lambda) \) of its shares at time 0 and has expected returns of

\[
R^0_G(V_0(\theta \lambda), \theta \lambda) = \left[ \frac{V_0(\theta \lambda) - C}{V_0(\theta \lambda)} \right] \left[ \lambda R_G(\theta \lambda) + (1 - \lambda) R_B(\theta \lambda) \right]. \tag{A.4}
\]

Although a bad firm would prefer to sell more equity at time 0, if it did so it would signal that it is bad. To pool, it must sell no more than \( \hat{\alpha} \), so that (8a) and (8b) are also binding in this case. Expected returns from pooling for bad firms, \( R^0_B(V(\theta \lambda), \theta \lambda) \), are as in (A.4) except that the last factor is simply \( R_B(\theta \lambda) \).

We now prove that the existence of a pooling equilibrium implies that, first, (15) and, second, (14) hold. Since (8a) and (8b) are binding for all firms, the maximum amount that can be raised by a firm in any pooling equilibrium is \( V_0(\theta \lambda) \), so that (15) must be satisfied in such an equilibrium.

If a good firm deviates from a pooling equilibrium by using a signaling price-and-proportion strategy \( (p_0^*, \alpha^*) \), that strategy must satisfy (12) to be credible. Since (8a) and (8b) are binding for both types of firm in the pooling equilibrium, (12) would be binding as well. Also, as in the proof of Proposition 1, \( p_0^* < V_0(\theta \lambda) \) and \( \alpha^* p_0^* = C \). It can be shown that

\[
R^0_G(p_0^*, \lambda) = \left[ \frac{R_B(\theta \lambda)}{R_B(\lambda)} \right] \left[ \frac{V_0(\theta \lambda) - C}{V_0(\theta \lambda)} \right] \left[ \lambda R_G(\lambda) + (1 - \lambda) R_B(\lambda) \right]. \tag{A.5}
\]

In any pooling equilibrium, (13) must hold. Using (A.4) and (A.5), it can be seen that (13) implies (14).

To show that (14) and (15) imply the existence of a pooling equilibrium, we need to show that (13) is satisfied for all credible strategies and the initial offering is feasible. We note that a good firm finds that if (14) obtains it prefers not signaling to signaling, for any credible price-and-proportion strategy, so that (13) is satisfied. Further, if (15) obtains, the initial share offering is clearly feasible \( (\alpha \leq 1) \).

Finally, as argued above, constraint (8b) is binding so that the initial price equals market value \( [p_0 = V_0(\theta \lambda)] \), no underpricing occurs, and no rationing of initial shares takes place. This proves the last part of the proposition.
**Proof of Proposition 3**

Clearly, bad firms are better off in a pooling equilibrium than if they are identified as bad. Returns for good firms in separating and pooling equilibria can be written, using (A.3) and (A.4) respectively, as

\[
R_G^0(p_0, \lambda) = \left[ V_0(0) - C \right] \left[ \frac{\lambda R_G(\lambda) + (1 - \lambda) R_\beta(\lambda)}{R_\beta(\lambda)} \right]. \tag{6.6}
\]

\[
R_G^0(\theta_\lambda, \theta_\lambda) = \left[ V_0(\theta_\lambda) - C \right] \left[ \frac{R_\beta(\theta_\lambda)}{V_0(\theta_\lambda)} \right] \left[ \frac{\lambda R_G(\theta_\lambda) + (1 - \lambda) R_\beta(\theta_\lambda)}{R_\beta(\theta_\lambda)} \right]. \tag{6.7}
\]

A necessary condition for a pooling equilibrium to exist is (14). It can be seen from this that the last term in (6.6) is less than or equal to the last term in (A.7). In addition, it is straightforward to show that the difference between the leading terms of these return formulae is positive, since \( V_0(\theta_\lambda) > R_\beta(\theta_\lambda) > V_0(0) \). It follows that \( R_G^0(\theta_\lambda, \theta_\lambda) > R_G^0(p_0, \lambda) \), so that good firms are better off in a pooling equilibrium than in a separating equilibrium.

**Glossary of notation**

**Subscripts**

- \( H, L \) = High or low dividend outcome;
- \( G, B \) = Good or bad firm;
- \( 0 \) = No observed outcome (i.e., at time 0).

**Variables**

- \( \alpha \) = Fraction of the firm offered in the IPO market at time 0;
- \( C \) = Cost of establishing a firm;
- \( \theta \) = Fraction of firms with good innovations;
- \( \lambda \) = Probability that a firm with a good innovation will implement successfully and remain good;
- \( \pi_i \) = Probability of dividend \( H \) from a firm of type \( i = G, B \);
- \( r_j \) = Investors' probability that a firm is good after implementation; for \( j = 0 \), this is investors' prior; for \( j = H, L \), it is the posterior, given a single observation \( j \) of the dividend outcome at the end of period 1;
- \( V_j \) = Value of the firm, either at time 0 with no dividend observations \( (j = 0) \) or at time 1 with a single dividend observation \( (j = H, L) \), to investors with no private information.
\( \delta \) = Single-period discount factor;

\( p_0 \) = Price of the firm at the initial offering (i.e., at time 0);

\( R_i \) = Return after implementation to the firm's founders, with private information about the outcome of implementation \( i (= G, B) \);

\( R_i^0 \) = Return before implementation to the firm's founders, with private information about the quality of the firm's innovation \( i (= G, B) \);

\( \gamma, \beta \) = Mixing probabilities in the partial pooling equilibria.

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