Clustering of Initial Public Offerings, Information Revelation and Underpricing

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Clustering of Initial Public Offerings, Information Revelation and Underpricing

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Abstract

By providing an analysis of sequential going-public decisions the paper outlines conditions under which 'hot issue markets' arise, i.e. under which the likelihood of a second initial public offering increases after a first firm has gone public. Two effects can trigger the rise of hot issue markets in a setting with asymmetric and costly information about both firm quality and industry prospects. The risk-averse entrepreneur can be subject to risk-induced selling pressure because of uncertain industry prospects conveyed by a first IPO in the industry. Also, investors can free-ride on the industry news, and increase their valuation for a second firm by abstaining from further costly information production. Finally, the model offers an explanation for the empirical finding that hot issue markets exhibit a higher degree of underpricing than cold issue markets.

JEL Classification: G32

Keywords: Initial Public Offerings, Asymmetric Information, Clustering, Underpricing.

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Non-technical summary

The main objective of the paper is to determine the driving forces which cause the evident swings in the quantity of initial public offerings (IPOs) over time. By providing an analysis of sequential going-public decisions the paper outlines conditions under which hot issue markets arise, i.e. to define conditions under which the likelihood of a second IPO increases after a first firm has gone public. The feed-back mechanism from one IPO to the next consists of informational externalities about a common value factor (industry outlook) conveyed by the first IPO.

In the model there are two risk-averse utility maximising owner-entrepreneurs who successively decide whether to undertake an IPO or to remain private. There are potential gains to an IPO, since the entrepreneur can sell his firm to risk-neutral investors. At the same time entrepreneurs and investors have to overcome frictions due to bilateral asymmetry of information. The aggregate value of the firm depends -in a multiplicative way- on a firm-specific and an industry-wide factor. Whereas the entrepreneur knows the firm-specific factor, investors are neither aware of the firms' quality nor the industry prospects. They can, however, purchase a noisy signal about the overall firm value.

The signal realization in the wake of the first IPO allows investors to update their expectation about the industry-wide factor and thus the value of the second firm in the industry. There are two key factors in the model which increase the likelihood of a second IPO: risk-induced selling pressure and informational free-riding. First, if the uncertainty about the state of the industry rises after the first IPO, the risk of staying private increases so that the entrepreneur's private valuation decreases relative to the market valuation. Second, the superior knowledge about industry prospects after the first IPO reduces the marginal benefit of further information production. If investors free-ride on this additional information and abstain from further costly information production, the market valuation can increase to a larger extent than the entrepreneur's private valuation.

1 Introduction

While underpricing and long-term underperformance of initial public offerings (IPOs) have received considerable attention in the literature, the timing of the IPO decision has only recently been the subject of theoretical investigation. This is surprising since there exists ample empirical evidence that the market for IPOs is subject to dramatic swings. 'Hot' phases with an unusually high volume of offerings and severe underpricing alternate with 'cold' periods which are characterized by lower issuance activity and less pronounced underpricing. In addition, there seems to be some evidence on inter-industry variation in the timing of IPO decisions. This paper develops a model to examine the driving forces for these evident swings in issuance activity.

The modeling of clustering behaviour has become increasingly important in financial economics (see Devenow and Welch [1996] and Brunnermeier [1997] for an overview). This paper is related to herding models with information externalities by focusing on the revelation of a common-value component in the wake of price determination. A common value factor might represent the prospects for a specific industry or the overall state of the economy. The IPO price of one firm serves as a feed-back mechanism to other IPOs since it can reveal information about the common value factor and therefore change the value of other firms. In the presence of costly information acquisition and asymmetric information between a risk-averse owner-entrepreneur and risk-neutral investors, news about the common value factor can contribute to the clustering of IPOs in two ways. First, the risk of remaining private can increase in the wake of new information and induce the entrepreneur to sell-off his firm to risk-neutral investors. Second, investors might refrain from renewed information production and free-ride on the implicit information conveyed by the price of a previous IPO. Because investors do not incur information production costs their valuation might increase to a larger extent than the entrepreneur's private valuation and therefore lead to a higher probability of a second IPO.

1.1 Empirical evidence on IPO clustering

The IPO activity of biotechnology firms at the London Stock Exchange in the 1990s provides some anecdotal evidence on the bunching of issues according to industries. The IPO of British Bio-Technology in mid 1992 was followed by the flotation of Enviromed, Anagen and Celsis International in 1993. Another recent example is the wave of IPOs of fashion designers. After the successful IPO of Italian designer house Gucci, its national competitor Prada went public, as did US designers Donna Karan and Calvin Klein in June 1996 followed by Ralph Lauren which was floated in mid 1997.

In a recent paper Helwege and Liang [1996] document that in the US 575 firms went public in the hot issue year of 1983, whereas in the cold issue year of 1988 the number of firms shrunk to a quarter of the 1983 figure. Underpricing (the price run-up from the issue price to the secondary market price) averaged 14.6% in 1983 and only 6.6% in 1988. Ljungqvist [1997] also reports that a positive macroeconomic climate raises the average amount of underpricing. Furthermore, there exists evidence that hot issue markets typically arise from the bunching of IPO activity in a few industries (Ritter [1984], Helwege and Liang [1996]). The fact that four of the two-digit SIC categories[1] represent over a half of the volume of the 1983 sample, indicates that hot IPO markets are, at least to some extent, related to industry-specific shocks (Helwege and Liang [1996]).

Table A.I and A.II give further evidence that issuance activity is clustered in both a time series and cross-sectional dimension. The tables depict the number and percentage of IPOs in two-digit SIC categories in the US during 1975-1984 respectively. Both tables manifest a strong bunching of IPOs in 1983 and to a smaller extent in 1981 and 1984. Table A.I. shows that the sign test of an equal proportion of IPOs during the 10-year period can be rejected for almost all industries during 1983. Similarly the percentage of IPOs in 1983 is for most industries more than two standard deviations away from the cross-sectional sample average. Cross-sectional differences are more evident in Table A.II. Electrics and gas (SIC 49) as well as food and kindred products (SIC 20) exhibit substantial cross-sectional deviations from the sample means in 1980 and 1975, 1976 and 1978 respectively. Similarly, a large percentage of IPOs in fabricated metal products (SIC 34) took place during 1978-1980 counter to the overall inter-industry concentration in 1983. Other industries with industry-specific timing behaviour are transportation equipment (SIC 37) and oil and gas extraction (SIC 13) and to a smaller extent wholesale of non-durable products (SIC 51) as well as instruments and related products (SIC 38).

1.2 Overview

While these examples might suggest irrational herding behaviour, this paper explains the clustering of IPOs by the release of positive industry (or economy-wide) information in the wake of an IPO.[2] The paper develops a theoretical model which is used to analyse a sequence of going-public decisions[3]. It identifies conditions under which the likelihood of a second IPO increases after a firm first in the industry has gone public ('hot issue markets'). The model features two firms in an industry, which are owned by utility-maximising risk-averse entrepreneurs. The entrepreneur goes public if the utility he derives from the risky cash-flows of the firm are smaller than the (safe) proceeds he obtains by selling the firm to risk-neutral investors (who individually purchase only an arbitrarily small fraction of the firm's stock). Since it is assumed that the entrepreneur first sells his firm to an underwriter who can diversify risk over time, the entrepreneur does not bear any risk which might arise because of insufficient demand for the issue[4].

The overall firm value depends -in a multiplicative way- on a firm-specific and an industry-wide factor. The owner-entrepreneur only knows the realization of the firm-specific factor, but has no private information about industry prospects. Investors know

[1] Two-digit SIC categories represent the second level of the US industrial classification scheme comprising 81 industrial subsections, see Appendix A.I.

[2] An example for the practical significance of industry information for the clustering of IPOs provides a quotation from Neil Austin, new issue specialist with KPMG: "The Granada/Forte bid focused attention on the sector and this has helped the successful debuts of Macdonald Hotels and Millennium & Copthorne in April [1996]".

[3] While the basic model assumes that the ordering of the IPO decision is exogenous, the last part of the paper shows that the results can also hold if timing is endogenous.

[4] The last part of the paper relaxes this assumption and considers the case in which the entrepreneur is exposed to the volume-related risk as well.

neither the firm quality nor the industry prospects, but can purchase a noisy signal about the absolute firm value, the product of the industry- and firm-specific component. In this setting investors can be better informed about the state of the industry than the entrepreneur. This does not seem an unreasonable assumption, since investors such as managed funds or banks who consistently monitor the competitive dynamics of industries can be reasonably believed to have superior knowledge about future prospects of the industry. Also, investors are more likely to obtain information from other firms in the industry, from which the entrepreneur is shielded because of competitive considerations. The link from the first IPO to a second in the industry is established via information production of investors before the first IPO. The players use the secondary market price of the first issue to update their beliefs about the industry and, in particular, about the value of the second firm. There are two effects at place which determine the emergence of 'hot issue markets'.

First, the rise of hot issue markets depends on how the riskiness of the firm changes in response to news conveyed about the state of the industry ('variance effect'). If news about industry prospects are different from the prior belief of the entrepreneur, the variance of his firm value might increase and the entrepreneur becomes more inclined to go public. For example, if the a priori prospects of the industry are rather poor (there is an 80% probability of the industry being bad, and a 20% probability of the industry being good), but subsequent information reveals a 50% probability of the industry being good, the variance of the industry factor increases and risk-induced selling pressure mounts. In a similar vein, Stoughton, Wong and Zechner [1997] assume that the number of firms traded publicly affects the variance of investors' estimate of the total market size. Whereas in their set-up bunching can occur if the market variance shrinks, the present paper argues that a rise in the firm value's variance increases the risk of remaining private and induces the entrepreneur to sell off his firm to risk-neutral investors.

Second, it depends on whether the expected IPO proceeds rise to a larger extent than the expected private firm value ('expected value effect') after the first IPO. This can be the case if the level of information costs no longer justifies further information production and investors free-ride on the available signal realisation after the first IPO. The marginal benefit of further information collection is particularly small, if investors can rely on the informational outcome of the first IPO, i.e. if signal precision is relatively high. This 'informational free-riding behaviour' can increase the market valuation more than the entrepreneur's private valuation. The entrepreneur no longer has to compensate investors for information acquisition through a lower issue price. Also, the level of participation increases compared to informed bidding, since all investors, not only investors with positive signals, purchase a share in the IPO. In this respect the paper is related to Maksimovic and Pichler [1996] where an IPO is needed to raise the required finance in order to start full-scale production, but has the disadvantage of providing valuable information to potential entrants in the industry. Clumping of IPOs in their model occurs if other firms follow with an IPO to take advantage of bigger growth opportunities. In this model a second IPO also becomes more likely in the wake of favourable industry news, but rather through higher proceeds the entrepreneur can obtain by exploiting the superior informational state in which investors are detained from information production. Contrary to other models of IPOs with asymmetric information between firm insiders and investors along the lines of Myers and Majluf [1984] the reduction of adverse selection is not the central element in triggering hot issue markets (e.g. Korajczyck, Lucas and McDonald [1992]).

Finally, the model offers an explanation for why hot issue markets often coincide with more pronounced underpricing than cold issue markets. Because of the empirical evidence put forward by Jegadeesh et al [1993], which is not supportive of the signalling role of underpricing (e.g. Allen and Faulhaber [1989]), underpricing in this model is either directly or indirectly due to information collection costs. Underpricing arises if the secondary market price is (on average) higher than the price of the primary issue. This comes about if the private information accrued by investors during the IPO is better than prior expectations about the firm value. Equally risk-induced selling pressure is triggered by unexpectedly positive industry information. So, both the clustering and underpricing phenomena result from the same underlying fact, i.e. positive surprise about industry prospects.

The model highlights the importance of an underlying or common value component between firms (e.g. the overall state of the industry or the business cycle) in provoking clustering phenomena like hot issue markets. Combined with asymmetric information and costly information acquisition the price determination for one firm can - through news about the common value factor- change the value of other firms in the industry or economy. This feed-back mechanism can trigger hot issue markets because it changes the valuation of firm-owners and investors in different ways. The valuation differential of the two parties subsequent to news about a common value factor is the prime feature which differentiates this model from other analyses of the timing and pricing of IPOs.

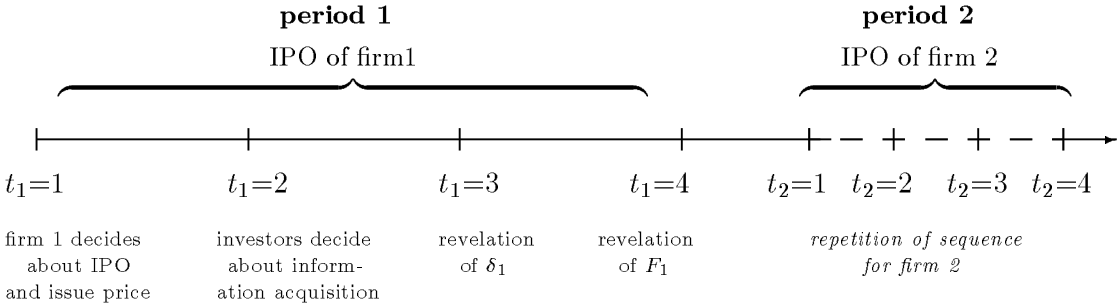
The paper proceeds as follows. The first part outlines the general set-up of the model. It describes the strategy space of investors and entrepreneurs for both a potential first and second IPO. The second part derives pooling equilibria for the first firm's IPO decision if the quality of the firm's projects. Both the firm and the industry may be of two types: $I = 1$ (good prospects) with probability α or $I = 0$ (bad prospects) with probability $1 - \alpha$. The firm characteristics can similarly be $F_i = 1$ (high quality) with probability ε and $F_i = 0$ (low quality) with probability $1 - \varepsilon$. The drawings for the value of the firm F_i are independently and identically distributed. Furthermore the distribution of industry prospects is independent of the distribution of firm characteristics. The overall firm value is given by the product of industry and firm specific characteristics, i.e. $V_i = I \cdot F_i$. The firm can therefore only be of high value $V_i = 1$ if both the firm-specific and industry-wide factor are favourable. In all other three cases the overall value of the firm is zero either because of bad firm characteristics, low industry prospects or both. Thus the firm is of high value $V_i = 1$ with probability $\alpha\varepsilon$ and of low quality $V_i = 0$ with probability $1 - \alpha\varepsilon$.

2.2 Timing

The timing structure consists of two periods in which the two firms decide sequentially about an IPO. Firm 1 is exogenously chosen to first decide about going public in period 1. The information set of the players is denoted by Θ_i where $i \in \{1, 2\}$ stands both for the respective firm and period. In the first round the information set of the players consists of the *a priori* expectations about firm and industry characteristics as outlined in 2.1, i.e. $\Theta_1 = \Omega$. The IPO of each firm is associated with four dates. If the entrepreneur decides to undertake an IPO at $t_1 = 1$ he sets a price p_1 for his firm, and investors decide whether to produce information about the value of the firm at $t_1 = 2$. At $t_1 = 3$, trading commences in the secondary market and the number of participants in the IPO, δ_1, is revealed. A new management takes over the firm at $t_1 = 4$[5], and the quality of firm 1 is made public.[6]

FIGURE I

TIMING



Both the number of participants in the IPO and the quality of the first firm allow the players to update their expectation about industry prospects and the value of the second

[5]IPOs are often associated with equity sales by controlling shareholders (see Pagano et al [1996]).

[6]It is not necessary to assume that the agents learn the true quality of the firm shortly after secondary trading starts. In effect, the revelation of firm type changes the factor by which the players update their information on the prospects of the second firm. Since the entrepreneur has an informational advantage about the quality of his firm he can advance his informational leap even further if information about the quality of the first firm is revealed. In this sense, this paper focuses on a special case with the maximum amount of asymmetric information between the entrepreneur and investors. The results of this paper hold even more so in the more general informational setting.

firm in the industry. They have a new information set, Θ_2, depending on the type of the first firm, F_1, and the number of participants in the IPO, δ_1. The information set Θ_2 therefore consists of a specific realization of the tuple $\{F_1, \delta_1\}$. The sequence of events from $t_2 = 1$ to $t_2 = 4$ is repeated for a potential second IPO. Figure 1 shows the time structure of the model for the first and second firm's IPO decision.

The equilibrium concept employed is a Perfect Bayesian Equilibrium which implies backward induction of the players' optimal strategies. Thus, investors' information production decision is derived before analysing the going-public decision of the entrepreneur. First, conditions for pooling equilibria are derived under which the first firm will go public. Second, equilibrium conditions are determined under which it is more likely for the second firm in the industry to go public after an IPO in the first period.

2.3 Investors

There are n risk-neutral, perfectly competitive investors who neither know the quality of the firms nor the prospects of the industry. Investors can, however, purchase a noisy signal S about the overall firm value, $V_i = F_i \cdot I$, at cost c. The signal can be either good $(S = G)$ or bad $(S = B)$ with the following degree of precision:

$$\begin{aligned} P(S_{ik} &= G \mid V_i = 1) = 1, \qquad & k \in \{1, \ldots, n\} \\ P(S_{ik} &= G \mid V_i = 0) = \gamma, \qquad & \gamma < 1 \end{aligned}$$

It is assumed that investors only purchase a share if they obtain a good signal. The informational set-up of this model is based on Chemmanur (1993) with the main difference being that firm value is a composite of industry and firm prospects. The information production decision is derived in its general form, which allows for different informational preconditions in the first and second period. We assume that the number of shares equals the number of investors, i.e. the value of the firm is divided into n shares[7]. Investors will only acquire information if the benefits of additional information at least outweigh its costs. If p_i is the issue price of the firm's shares then *uninformed* bidding will yield the following aggregate payoff for the n investors[8]

$$P(V_i = 1 \mid \Theta_i)(1 - p_i) + P(V_i = 0 \mid \Theta_i)(-p_i). \tag{1}$$

With probability $P(V_i = 1 \mid \Theta_i)$ the firm value is 1 and investors gain $(1 - p_i)$. Otherwise the value of the firm is 0 and investors incur a loss amounting to the price they paid for the firm. The benefit of informed compared to uninformed bidding is that informed investors only purchase a zero-value firm if they mistakenly receive a good signal, which happens with probability γ. The payoff from *informed bidding* is therefore

$$P(V_i = 1, S = G, \Theta_i)(1 - p_i) + P(V_i = 0, S = G, \Theta_i)(-p_i) - c$$

[7]It seems reasonable to assume that the number of shares to be sold is determined prior to the IPO and that it should take the number of potential investors into account.

[8]Note that the n investors are here considered in their aggregate; for an individual investor the condition (and also subsequent expressions) have to be divided by n.

where c denotes the aggregate information production costs of the n investors. Restating this expression in terms of known conditional probabilities, we obtain

$$P(V_i = 1 \mid \Theta_i)(1 - p_i) + \gamma P(V_i = 0 \mid \Theta_i)(-p_i) - c. \tag{2}$$

By setting the payoff from uninformed bidding [1] equal to the payoff from informed bidding [2] one obtains the minimum IPO share price which will induce informed bidding. This price $\underline{p}_i$ is given by

$$\underline{p}_i = \frac{c}{(1-\gamma)P(V_i = 0 \mid \Theta_i)}. \tag{3}$$

This is the price where the costs of information production exactly offset the benefit from not purchasing the stock if the investor receives a bad signal. The lower price bound for informed bidding is higher the greater the costs of information production. The lower the probability of the firm being of zero value and the lower the precision of the signal, the higher the lower bound for informed bidding. For p_i higher than $\underline{p}_i$, informed bidding is strictly preferred, as the loss from bidding for a bad firm increases. On the other hand, the maximum price the firm can charge for its stock is given at the point where the benefits from participating in the IPO with a good signal is equal to the payoff from not bidding which is 0. Therefore the maximum price which the firm might charge for its stock is

$$\bar{p}_i = \frac{P(V_i = 1 \mid \Theta_i) - c}{P(V_i = 1 \mid \Theta_i) + \gamma P(V_i = 0 \mid \Theta_i)}. \tag{4}$$

The upper price limit for informed bidding is higher the more likely the firm is of high value and the smaller the error probability of obtaining a bad firm despite a good signal. The smaller the information production costs the higher the maximum price that the firm can charge in the presence of informed bidding. In order for informed bidding to occur the following parametric restriction on the cost and precision of the signal has to hold:

$$c < (1-\gamma)P(V_i = 1 \mid \Theta_i)P(V_i = 0 \mid \Theta_i) \equiv c_i \tag{5}$$

This condition is more likely to hold if the costs of information production, c, are small, the precision of the signal is high (γ small) and $P(V_i = 1 \mid \Theta_i)$ is close to $1/2$ implying a high risk of uninformed bidding. The condition is equivalent to postulating that $\underline{p}_i < E(V_i \mid \Theta_i) < \bar{p}_i$. If condition (5) holds, then there are three possible regions of investor behaviour depending on the price of the IPO: for $\underline{p}_i \leqslant p_i \leqslant \bar{p}_i$ investors buy a signal and purchase a share in the IPO if they receive a good signal. If $p_i > \bar{p}_i$, they will refrain from participating in the IPO, since they expect to make a loss. For $p_i < \underline{p}_i$ the price is too low to warrant information production, hence investors engage in uninformed bidding.

If condition (5) does not hold, investor behaviour can only fall into the two categories of uninformed bidding or no bidding. The maximum issue price the entrepreneur can charge is the price where the payoff from uninformed bidding is equal to the payoff from no bidding, i.e. the firm's a priori expected value $E(V_i \mid \Theta_i)$.

2.4 Entrepreneurs

The two firms are fully owned by utility maximizing, risk averse entrepreneurs. The owner-entrepreneurs face the choice between remaining private and going public. The proceeds from going public depend on the firm's price setting strategy which is influenced by the size of information production costs.

2.4.1 Remain private

Entrepreneurs are assumed to exhibit an exponential utility function where ρ stands for the coefficient of constant absolute risk aversion. If the entrepreneur of a high-quality firm decides to remain private, he will obtain the following expected utilities $E(U_i^P)$ conditional on the quality of his firm

$$E(U_i^P \mid F_i = 1, \Theta_i) = P(I = 1 \mid \Theta_i) - \rho P(I = 1 \mid \Theta_i) \cdot P(I = 0 \mid \Theta_i). \quad (6)$$

$$E(U_i^P \mid F_i = 0, \Theta_i) = O. \quad (7)$$

Because of the normalisation of the firm value to $V_i \in \{0, 1\}$ and the composite nature of the overall firm value the expected utility for a high-quality firm reduces to the above probability terms. The entrepreneur knows the quality of the firm's projects F_i, but has no inside information about industry prospects. The owner of a high-quality firm faces some uncertainty about the realization of the industry-wide factor which manifests itself in the variance term of his utility function. The expected utility of an entrepreneur with a low-quality firm is zero independent of industry-wide prospects, since the firm value is a product of the industry and firm-specific factor.

2.4.2 Going public

Uninformed bidding. If the entrepreneur decides to float his firm, there are three possible optimal prices depending on the size of information production costs. If $c > c_i$, information production costs will impede investors from collecting information. The highest price the entrepreneur can charge will be the firm's *a priori* expected value. His expected utility from an IPO under *uninformed bidding* amounts to

$$E(U_i^{IPO} \mid c > c_i, \Theta_i) = P(V_i = 1 \mid \Theta_i). \quad (8)$$

independent of firm quality. Since investors do not produce information, all n investors will purchase the stock and there is no variance associated with the quantity of shares sold.

Informed bidding. If $c < c_i$, then the entrepreneur faces two choices: he can either set $\bar{p}_i$ in which case only investors with positive signals will purchase shares, or he can set $\underline{p}_i$ in which case investors will refrain from acquiring information and all n investors purchase shares. In order to derive the expected utility in the former case, we first have to determine the expected number of investors purchasing shares. Although the entrepreneur knows the quality of his firm, the number of participants in the IPO, δ_i, is a random variable for him. His action at $t_i = 0$ will therefore depend upon his expectation of the number of shares purchased, conditional on his firm type and industry prospects. The entrepreneur knows that n investors purchase information and that with probability γ zero-value firms can be mistaken for high-value firms. The expected number of investors X mistakenly purchasing a low-value firm is thus given by the mean of the binomial distribution $B(n, \gamma)$, $E(X) = n\gamma$. Even the owner of a low-quality firm can still expect proceeds of $\gamma \bar{p}_i$ from the flotation if his firm is mistaken for a high-value firm. The entrepreneur of a bad firm keeps a fraction of $(1 - \gamma)$ shares, but since the type of his firm is revealed these shares will be worthless and the variance is reduced to zero. Thus, if the entrepreneur sets $\bar{p}_i$ and investors engage in *informed bidding*, the expected utility for a firm with high and low quality projects respectively is given by

$$E(U_i^{IPO} \mid F_i = 1, p = \bar{p}_i, \Theta_i) = \bar{p}_i \cdot P(I = 1 \mid \Theta_i) + \gamma \bar{p}_i \cdot P(I = 0 \mid \Theta_i) \quad (9)$$
$$E(U_i^{IPO} \mid F_i = 0, p = \bar{p}_i, \Theta_i) = \gamma \bar{p}_i. \quad (10)$$

Induced uninformed bidding. If the entrepreneur, on the other hand, sets a price equal to $\underline{p}_i$, he will *induce uninformed bidding* in which case all n investors purchase a share. The expected utility from induced uninformed bidding is therefore

$$E(U_i^{IPO} \mid p = \underline{p}_i, \Theta_i) = \underline{p}_i \quad (11)$$

for both high- and low-quality firms. Equating equations (9) and (11) we find that firms will induce informed bidding iff

$$c < \frac{(1-\gamma)P(V_i = 1 \mid \Theta_i)P(V_i = 0 \mid \Theta_i)[P(I = 1 \mid \Theta_i) + \gamma P(I = 0 \mid \Theta_i)]}{P(V_i = 1 \mid \Theta_i) + P(V_i = 0 \mid \Theta_i)[\gamma + (1-\gamma)(P(I = 1 \mid \Theta_i) + \gamma P(I = 0 \mid \Theta_i))]} \equiv c_i^* \quad (12)$$

It can be easily seen that $c_i^* < c_i$, so that one can differentiate three different optimal prices depending on c. For small information production costs, the firm will set $\bar{p}_i$ in which case only investors who receive positive signals will purchase the stock. With rising costs of information production, the firm has to set a lower price in order to compensate investors for the higher information production costs. At $c = c_i^*$, it becomes no longer optimal for the firm to induce investors to produce information since the proceeds from the IPO will be greater in the presence of uninformed bidding. This is because without information production all investors will purchase a share in the IPO and not only investors who received positive signals. With $c > c_i$, the maximum price the firm will be able to set is $E(V_i \mid \Theta_i) = P(V_i = 1 \mid \Theta_i)$.

2.5 Equilibrium conditions for first IPO with informed bidding

An IPO of a first firm in the industry only has implications for the going-public decision of a second firm in the industry when investors will engage in informed bidding. We will therefore only derive equilibrium conditions for an IPO with information acquisition. One of the two firms in the industry is exogenously chosen to first decide about an IPO. The firm undertakes an IPO if the expected utility the entrepreneur derives from an IPO is greater than the utility he derives as the owner of the firm. Since there are no costs of mimicing a high-quality firm (and no benefits from separation), there is no scope for separating equilibria. The following proposition states the conditions under which an entrepreneur decides to take his firm public in the first period.[9]

Proposition 1. *There exists a pooling equilibrium where good and bad firms choose to go public in the first period and investors produce information iff* $c < c_1^*$ *and*

$$\alpha(1-\alpha)\rho > \frac{\alpha\gamma(1-\epsilon) + c[\alpha + \gamma(1-\alpha)]}{\epsilon\alpha + \gamma(1-\epsilon\alpha)}. \quad (13)$$

[9]Proofs to this and other Propositions and Lemmas are relegated to the Appendix, except for straightforward applications of Bayes' Rule.

In the going-public equilibrium IPO proceeds are always smaller than the expected private value of a high-quality firm, α, which is reflected by the fact that the right hand side of the inequalities, the difference between expected firm value and IPO price is always positive. This difference, however, shrinks the higher the probability of the firm being good, since a high ε reduces the informational asymmetry between entrepreneurs and investors. The trigger of the IPO is the risk-aversion of the entrepreneur, ρ, and the variance of the firm value, $\alpha(1-\alpha)$. A firm is more likely to go public the higher ρ, and $\alpha(1-\alpha)$. The maximum variance is obtained when α is 0.5, i.e. when uncertainty about industry prospects is at its peak.

2.6 Secondary market trading

The informational role of the secondary market price tautologically depends on whether investors produced information during the IPO. The secondary market price can differ from the issue price for two reasons: first, information collected during the IPO is not in line with prior expectation and second, investors have to be compensated for information production costs. For purposes of this model it is useful to differentiate between observed and expected underpricing. In the former case issues are on average not (over-) underpriced, but (over-) underpricing occurs for issuers of (zero) high-value firms. This is the case if $c < c_1^\star$, where dependent on the number of bidders the secondary market price is higher or lower than the issue price. Expected underpricing, however, requires that $p_1 < E(V_1)$ on average. For $c_1^\star < c < c_1$, the entrepreneur induces uninformed bidding by setting $\underline{p}_1$, and issues will be on average underpriced, since $\underline{p}_1 < E(V_1)$. In case c is prohibitively high ($c > c_1$), investors will engage in uninformed bidding and bid no more than $E(V_1)$ in which case neither observed nor expected underpricing results.

Since we assume information production for the first IPO, we can only consider cases with observed underpricing. After the IPO the number of participants in the IPO (which are the ones that obtain $S = G$), δ_1, becomes public knowledge. The secondary market price of the firm will then equal V_i conditional on the aggregate of the information produced by all investors.

Lemma 1. *In a pooling equilibrium, where investors only participate in the IPO if they find $S = G$, and all investors receive good signals δ_1, then the secondary market price of the first firm will be*

$$\Pi_1 = E(V_1 \mid n = \delta_1) = \frac{\alpha\varepsilon}{\alpha\varepsilon + (1-\alpha\varepsilon)\gamma^n}.$$

If however, investors receive less than n good signals, the firm cannot be of high value and the secondary market price $E(V_1 \mid n > \delta_1) = 0$.

This Lemma derives directly from Bayes' Rule. The precision structure of the signal implies that high-value firms are always recognized as such, but zero-value firms can be mistaken for a high-value firm. Once one bad signal is obtained by an investor, the market infers that the respective firm can no longer be of a high-value. It can be shown that

Lemma 2. *If all investors obtain good signals the secondary market price is higher than the issue price so that underpricing $S_1 > \overline{p}_1$ results in an equilibrium in which $n = \delta_1$.*

The higher the information production costs and the lower the signal precision the larger the extent of underpricing. The impact of c is, however, by far stronger than the impact of γ. Information production costs unequivocally increase the extent of underpricing, whereas an increase in γ has dual implications: it not only decreases $\bar{p}_1$, but also the secondary market price, since the quality of private information is doubtful. Information production costs have less and γ more impact on the level of underpricing the higher the probability of the firm being of high value. With increasing prospects of the IPO firm being of high value, c loses in significance and the quality of the signal becomes more important. On average, of course, there is no underpricing, since in all other cases in which $n > \delta$ issues will be overpriced. So, in the case of informed bidding, observed underpricing only arises with positive information shocks.

3 Implications for the second firm's IPO decision

After investors learn the type of the first firm at $t_1 = 4$, they can use this information together with the number of participants in the IPO, δ_1, to update their beliefs about the probabilities of $V_2 = 1$ and $V_2 = 0$. Depending on the type of the first firm and the number of participants in the IPO we obtain four possible informational outcomes depending on the combination of F_1 and δ_1: 1. $\Theta_{21} \equiv \{n = \delta_1, F_1 = 1\}$, 2. $\Theta_{22} \equiv \{n > \delta_1, F_1 = 1\}$, 3. $\Theta_{23} \equiv \{n = \delta_1, F_1 = 0\}$, and 4. $\Theta_{24} \equiv \{n > \delta_1, F_1 = 0\}$. The four cases and the respective adjusted expectations of the investors and the entrepreneur about the value of the second firm are juxtaposed in Table I.

TABLE I

REVISED EXPECTATIONS OF SECOND FIRM VALUE AFTER FIRST IPO

Signal realization	Revealed type of first firm $F_1 = 1$		$F_1 = 0$	
	Investors	Entrepreneur $F_2 = 1$	Investors	Entrepreneur $F_2 = 1$
$n = \delta_1$	$\frac{\alpha\varepsilon}{\alpha+(1-\alpha)\gamma^n}$	$\frac{\alpha}{\alpha+(1-\alpha)\gamma^n}$	$\alpha\varepsilon$	α
$n > \delta_1$	0	0	$\alpha\varepsilon$	α

Since for Θ_{23} and Θ_{24} the expected value remains unchanged after the first IPO, these cases do not lead to a higher probability of a second firm going public. In Θ_{22} the entrepreneur will be indifferent between going public or remaining private, since in both cases his payoff will be zero. The case which deserves further consideration is the one where all investors obtain positive signals and the firm is revealed as a high-quality firm, $F_1 = 1$. In this case investors and the entrepreneur of a high-quality firm update their beliefs about the expected value of the second firm to $E(V_2 \mid \Theta_{21}) = P(V_2 = 1 \mid \Theta_{21}) = \alpha\varepsilon/(\alpha + (1-\alpha)\gamma^n)$ and $E(V_2 \mid F_2 = 1, \Theta_{21}) = P(I = 1 \mid \Theta_{21}) = \alpha/(\alpha + (1-\alpha)\gamma^n)$ respectively. It can be easily seen that the expected value of the second firm is greater after the first firm in the industry has undertaken an IPO.

It becomes obvious that both investors and the entrepreneur of a high-quality firm can extract the same relative amount of information from the secondary market price, namely $1/(\alpha + (1-\alpha)\gamma^n)$, but that the entrepreneur can exploit this information to a larger extent in absolute terms. This shows that the asymmetric information between investors and the entrepreneur actually increases after the first IPO, since the entrepreneur can better decode the information conveyed by the secondary market price of the first firm's IPO. Thus, asymmetric information increases after an information release. If bunching still occurs, then it must be triggered by other forces than a decrease of asymmetric information as put forward by Korajczyk, Lucas, and McDonald (1991).

3.1 Investor behaviour and information costs

Again, for the second IPO, investor behaviour depends on the information production costs and the price setting strategy of the entrepreneur. Table II describes investor behaviour in the second IPO depending on the level of information production costs. Because of information production in the first period, costs for information acquisition must be smaller than $c_1^\star$. In the second period, $c_2^\star$ and c_2 are the respective cut-off values for informed vs. induced uninformed and induced uninformed vs. uninformed bidding respectively. It can easily be seen that $c < c_1$ does not necessarily imply $c < c_2$.

Lemma 3. *The upper cost bound for informed bidding in the second IPO is smaller than the upper cost bound for informed bidding in the first IPO, i.e.* $c_2 < c_1$, *iff*

$$\alpha\varepsilon > \frac{\alpha + (1-\alpha)\gamma^n}{\alpha + (1-\alpha)\gamma^n + 1}.$$

The inequality in Lemma 3 holds the higher the precision of the signal, $1-\gamma$, and the higher the probability of the firm being good. If ε is high, then the second firm is likely to be of high value. The marginal benefit of further information collection is low and uninformed bidding more likely. Equally, the higher the precision of the signal, the more reliable the information conveyed in the first IPO and the higher the incentive to free-ride on this information.

Since similarly there is no predetermined ordering of $c_1^\star$ and $c_2^\star$, *informed bidding* in the second IPO only comes about if the costs of information production are smaller than $\min\{c_1^\star, c_2^\star\}$. This should be the case for firms and industries where the complexity of the product is minor and the competitive structure clear-cut, such as retailing, eating and drinking places and possibly manufacturing.

There are two ranges for possible values of c for which *induced uninformed bidding* arises after informed bidding in the first IPO. For induced uninformed bidding to arise in the second IPO, c has to be higher than $c_2^\star$, but smaller than c_2. One constellation of c values which provokes induced uninformed bidding in a second IPO after informed bidding in a first IPO is $c_2^\star < c < c_2 < c_1^\star$. In this situation the cost bound for induced uninformed bidding in the second IPO is more restrictive than the cost restriction for informed bidding in the first IPO. This is the case if the information conveyed in the first IPO is so reliable (γ low) that only low information production costs could provoke further information collection about the value of the second firm. Information production costs are, however, still high enough so that it is more profitable for the entrepreneur to induce uninformed bidding instead of compensating investors for their information production costs. This structure of information costs mostly applies to firms which operate in a complex technological environment (e.g. biotechnology), but where there are enough independent research laboratories able to assess the state of product development in the industry. On the one hand, information acquisition is not trivial, but the information obtained through independent sources is very reliable.

A second constellation of c values for induced uninformed bidding in the second IPO arises for $c_2^\star < c < c_1^\star < c_2$. In this case both $c_2^\star < c_1^\star$ and $c_1^\star < c_2$ impose restrictions on the parameter values. The latter restriction implies that for induced uninformed bidding in the second IPO information production costs are allowed to be higher than for informed bidding in the first. This situation can arise if investors expect the firm to be good (ε close to 1), industry prospects to be poor ($\alpha \leqslant 1/2$), and a good signal to be almost completely misleading (γ close to 1). Since the positive news conveyed after the first IPO are very unreliable the entrepreneur can obtain higher IPO proceeds in the absence of information production. This is true because in case investors obtain a positive signal they mistrust the signal and abstain from the IPO so that even a high-value firm will obtain minuscule IPO proceeds. In order for the second condition $c_2^\star < c_1^\star$ to hold, again the marginal benefit of further information collection has to be negligible. This can either be the case when information about industry prospects is very precise (γ close to 0) or, on the very contrary, if information is so bad (γ close to 1) that even further information collection during the second IPO does not add significantly to investors' knowledge. The latter is predominant in industries with a high pace of technological advancement, where it is costly to obtain information on the prospects of success for an individual company or the industry as a whole. An example might be electronic equipment as well as the telecommunications and software industries.

If $c_2^\star < c_2 < c < c_1^\star$, then investors will abstain from information production and engage in *uninformed bidding*. With information production costs higher than c_2, investors voluntarily abstain from further information collection and prefer to bet blindly the firm's expected value $P(V_2 = 1 \mid \Theta_{21})$. Here, information acquisition costs are substantially higher, but again the validity of information spares investors renewed information collection. Firms in industries like electrical engineering, fabricated metal and transportation equipment are likely to fall into this category.

TABLE II

INFORMATION ACQUISITION COSTS AND INVESTOR BEHAVIOUR

Case	Information costs	Parameter restrictions	Investor behaviour in second IPO
1	$c < \min\{c_1^\star, c_2^\star\}$	–	informed
2a	$c_2^\star < c < c_2 < c_1^\star$	$\varepsilon \nearrow 1 \wedge \gamma \searrow 0$	induced uninformed
2b	$c_2^\star < c < c_1^\star < c_2$	$\varepsilon \nearrow 1 \wedge \gamma \nearrow 1 \wedge \alpha \nearrow 1/2$	induced uninformed
3	$c_2^\star < c_2 < c < c_1^\star$	$\varepsilon \nearrow 1 \wedge \gamma \searrow 0$	uninformed

3.2 Equilibrium conditions for hot issue markets

In the following, we will analyse how the going-public decision of the second entrepreneur is affected by the positive news about industry prospects conveyed by the first IPO. Again, the conditions are only derived for $F_2 = 1$, since there are no costs of mimicing a high-quality firm and no benefits from separation.

Definition 1. *Hot issue markets arise if the first IPO in the industry makes it more likely for a second firm to go public, i.e. if the expected utility derived from an IPO rises to a larger extent than the expected utility from remaining private after a first IPO occurred, i.e.*

$$E(U_2^{IPO} \mid F_2 = 1, \Theta_{21}) - E(U_1^{IPO} \mid F_2 = 1) > E(U_2^{P} \mid F1 = 1, \Theta_{21}) - E(U_1^{P} \mid F_1 = 1). \tag{14}$$

This equation can be broken down into two components.

Definition 2. *The change in the difference between the expected firm value to the entrepreneur and expected IPO proceeds R_i^{IPO} from the first to the second IPO*

$$\Delta E = E(V_1 \mid F_1 = 1) - E(R_1^{IPO} \mid F_1 = 1) - [E(V_2 \mid F_2 = 1, \Theta_{21}) - E(R_2^{IPO} \mid F_2 = 1, \Theta_{21})]$$

is termed 'expected value effect'.

The effect is positive if $\Delta E > 0$ and negative for $\Delta E < 0$. If the 'expected value effect' is positive, expected IPO proceeds rise to a larger extent than the expected firm value to the entrepreneur. A positive 'expected value effect' does not imply that expected IPO proceeds surmount the expected firm value to the entrepreneur [10], but that a second entrepreneur might be more inclined to undertake an IPO after a first firm in the industry has prepared the ground. The economic interpretation of the 'expected value effect' is the *free-riding* of investors on information about the industry factor conveyed in the first IPO. The market valuation of the firm can increase to larger extent than the entrepreneur's private valuation because investors abstain from renewed information acquisition.

Definition 3.

3.2.1 Hot issue markets due to risk-induced selling pressure

With *informed bidding* in the second IPO, i.e. $c < \min\{c_1^*, c_2^*\}$, the expected private firm value rises to a larger extent than expected IPO proceeds so that the 'expected value effect' is negative or at most neutral. Hot issue markets can therefore only be triggered by an increase in the firm's variance:

Proposition 2. ***Case 1***: *Hot issue markets with informed bidding* $[c < min\{c_1^*, c_2^*\}]$*: The second firm is more likely to undertake an IPO after the first firm in the industry is floated if the firm is likely to be of high quality (*ε *is close to 1), and* $\frac{\alpha^2}{(1-\alpha)^2} < \gamma^n$.

The conditions ensure that a positive 'variance effect' dominates the negative 'expected value effect'. A high probability that the firm is of high quality reduces the negative impact of the 'expected value effect'. The latter condition yields a positive 'variance effect' by imposing parameter conditions which increase the entrepreneur's risk of remaining private.

Although both the price and the expected percentage of investors participating in the IPO rise, the growth in IPO proceeds is weaker than the gain in the entrepreneur's private valuation. If ε is close to 1, the information asymmetry between the entrepreneur and investors is negligible and the 'expected value effect' is almost neutral. If ε equals one and there are no information production costs, expected private firm value and IPO proceeds coincide. While there is no informational advantage for the entrepreneur, investors are able to obtain superior information about the firm value by way of their private signal. But this is exactly offset by the fact that only investors with positive signal realizations purchase a share in the IPO. The more the parameters deviate from these values the greater the wedge between expected IPO proceeds and private firm value. Similarly the valuation differential widens from the first to the second IPO with increasing c and decreasing ε.

With an only moderately negative 'expected value effect' hot issue markets can be triggered by risk-induced selling pressure. The risk of remaining private increases for two parameter constellations: First, if α is close to zero, there is an almost unequivocal understanding of gloomy industry prospects. Any signal realization after the first IPO which reverses the picture by conveying a prosperous industry outlook, will increase the uncertainty about the industry factor. Second, if α is smaller but close to $1/2$, there is still potential for an increase in the variance of the private firm value. With an equal probability of a good and bad industry uncertainty about the future state of the industry reaches its climax. In order for the firm's variance to increase an imprecise signal quality ($\gamma \nearrow 1$) has to ensure that the expectation about the industry factor does not rise above $1/2$.

Even if the informational asymmetry between investors and entrepreneur is resolved (ε close to 1) the likelihood of a second IPO can diminish if the firm's variance decreases after the first IPO. This points to the fact that a decrease in asymmetric information per se is not sufficient to generate bunching of IPOs. Since the variance of the industry factor $\alpha(1-\alpha)$ reaches its maximum at $\alpha = 1/2$, a sufficient condition for the variance to decrease after positive industry news is $\alpha \geq 1/2$. Thus, when the *a priori* probability of bright industry prospects is greater than 50%, further positive news will reduce the risk of remaining private.

3.2.2 Hot issue markets due to informational free-riding

A common feature of hot issue market equilibrium conditions in the presence of induced or "voluntary" uninformed bidding is that investors "free-ride" on the industry news conveyed by the first IPO. While it was profitable for investors to engage in information production in the first period, the level of information production costs no longer justifies information acquisition given the incremental knowledge about the industry factor after the first IPO. The entrepreneur does not have to compensate investors for their information production activity, and the unrestricted participation in the IPO increases proceeds from a second IPO. Contrary to the case of informed bidding in the second IPO, the 'expected value effect' can become positive in the presence of (induced) uninformed bidding. Hot issue markets can thus arise due to the dual trigger of informational free-riding ('expected value effect') and risk-induced selling pressure ('variance effect').

Proposition 3. *Hot issue markets with induced uninformed bidding: The second firm is more likely to undertake an IPO after the first firm in the industry is floated if*

> *Case 2a:* $c_2^* < c < c_2 < c_1^*$*: the firm is likely to be of high value (*ε *close to 1), the signal is sufficiently precise (*γ *close to 0) and industry prospects are very bad (*α *close to 0);*
>
> *Case 2b:* $c_2^* < c < c_1^* < c_2$*: the firm is likely to be of high value (*ε *close to 1), the signal is sufficiently imprecise (*γ *close to 1), industry prospects are very uncertain (*α *smaller but close to 1/2) and information production costs are sufficiently large (*c *smaller but close to* c_1^**).*

Compared to the previous case of informed bidding IPO volume is always greater under (induced) uninformed bidding. The maximum price the entrepreneur can charge, however, is lower if investors are induced to abstain from information production. Note that for $c < c_2$, the maximum price under informed bidding is $\bar{p}_2 > \underline{p}_2$. Since in the presence of informed bidding the 'expected value effect' is at most neutral, the parameter constellations which trigger a positive 'expected value effect' with induced uninformed bidding will have to make the 'volume effect' more than outweigh the disadvantageous price differential.

In case 2a, with ε approaching 1 and γ close to zero, $\bar{p}_2$ and $\underline{p}_2$ move closer together[11], reducing the price differential between informed and induced uninformed bidding. The precise signal and high expected firm quality makes additional information acquisition after the first IPO less attractive and the difference between informed and uninformed bidding shrink. Also, the comparison between the first period IPO price $\bar{p}_1$ and $\underline{p}_2$ shows that the higher value of c depresses $\bar{p}_1$, but has a counter-current effect on $\underline{p}_2$. In case 2a, a positive 'expected value effect' additionally requires α or γ to be close to 0. If α approaches zero, the entrepreneur expects low proceeds with informed bidding since only investors with wrong signals participate in the IPO. Furthermore, given that the signal is very precise (low γ), there would be very few misguided investors. The percentile participation in the first period IPO, $\alpha + \gamma(1-\alpha) < 1$, is thus decreasing for small α and

[11] Both $\bar{p}_2$ and $\underline{p}_2$ increase with rising ϵ, but the first derivative of $\underline{p}_2$ with respect to ϵ at $\gamma = 0$ is greater than the first derivative of $\underline{p}_2$ with respect to ϵ for $\epsilon > 1/2$.

γ. With induced uninformed bidding, however, the entrepreneur lures all n investors into the IPO and thus more than compensates for the lower IPO price. Hot issue markets are further fostered by a positive 'variance effect' which is released by a combination of an a priori miserable industry outlook (α close to 0) and a subsequent startlingly positive outcome of the first IPO. This contradictory informational evidence increases uncertainty about industry prospects and the risk associated with remaining private.

In case 2b, hot issue markets arise if information asymmetry between investors and entrepreneur is trifling (ε close to 1), the precision of the signal is inferior, the prospects of the industry almost at the peak of uncertainty (α only insignificantly smaller than 1/2) and c close to its upper limit c_1^*. It is clear that the higher information production cost, the smaller the price the first entrepreneur could charge in the presence of information production and therefore the larger the price increase from $\bar{p}_1$ to $\underline{p}_2$. A similar effect is obtained by a low signal precision which increases $\underline{p}_2$ and lowers $\bar{p}_1$. An unreliable signal ($\gamma \nearrow 1$) also makes $\underline{p}_2$ rise to a larger extent than $\bar{p}_2$ if ε increases. [12] A poor signal does not drastically increase the benefit of information acquisition over uninformed participation, so that an increase in expected firm quality has a more pronounced effect on $\underline{p}_2$. Since the price difference between $\underline{p}_2$ and $\bar{p}_2$ is minor and there is still a slight increase in IPO volume, higher IPO proceeds are obtained by charging $\underline{p}_2$ and leaving investors in a state of 'ignorant benevolence' after the first IPO. The positive 'variance effect' disengages because of increasing uncertainty about industry prospects, this time induced by general uncertain investor sentiment (α close to, but still smaller than 1/2) and poor signal quality (γ close to 1). The poor signal precision makes the industry outlook only slightly less opaque after the positive outcome of the first IPO. Industry prospects are revised upwards, but the increase is marginal (α still $\leqslant 1/2$).

Proposition 4. ***Case 3:*** *Hot issue markets with uninformed bidding [$c_2^* < c_2 < c < c_1^*$]: The second firm is more likely to undertake an IPO after the first firm in the industry is floated if the firm is likely to be of high value (ε close to 1), the signal is sufficiently precise (γ close to 0) and industry prospects are very bad (α close to 0).*

In case 3 the highest possible price the entrepreneur can charge is $E(V_i \mid \Theta_{21}, F_2 = 1)$ which for $c > c_2$ exceeds $\bar{p}_2$. Here it is clear that both IPO price and volume are higher compared to informed bidding. Since information production costs are substantial, investors rely on the current reliable industry information (γ close to 0) and abstain from further information collection. In order for the 'expected value effect' to be positive, it suffices if the information asymmetry between investors and entrepreneur is low, i.e. ε close to 1. In this case proceeds in the second IPO and expected firm value to the entrepreneur are almost the same; in the first IPO expected proceeds were, however, significantly lower than expected firm value to the entrepreneur (which was close to α) so that the rise in expected IPO revenue exceeds the increase in expected firm value from remaining private. The parameter restrictions imposed by the sequence of cost bounds again trigger a positive variance effect as in case 2.

[12] Both $\bar{p}_2$ and $\underline{p}_2$ increase with rising ε, but $\bar{p}_2$ is concave in ε, whereas $\underline{p}_2$ in convex. The first derivative of $\underline{p}_2$ with respect to ε for $\gamma \nearrow 1$ is greater than the first derivative of $\underline{p}_2$ at $\varepsilon = 0$.

4 Underpricing and hot issue markets

Again, the level of information production costs decides about the type of potential underpricing. In case $c < \min\{c_1^\star, c_2^\star\}$ investors collect information about the value of the second firm. Again, it can be shown that the issue price is smaller than the secondary market price if all investors obtain positive signals during the second IPO ('observed underpricing'). The amount of observed underpricing can even increase from the first to the second IPO:

Proposition 5. *The amount of underpricing increases after the first IPO, i.e.* $(\Pi_2 - \overline{p}_2) > (\Pi_1 - \overline{p}_1)$*, if the firm is likely to be of high value (*ε *close to 1), the costs of information production* c *are close to zero and*

$$\gamma^{2n+1} > \frac{\alpha^2}{(1-\alpha)^2}. \tag{16}$$

It can be shown that the lower the costs of information production, the stronger the increase in underpricing from the first to the second IPO. The higher c, the higher the resulting underpricing in both IPOs. High information production costs, however, have a higher impact on underpricing in the first IPO than in the second. Therefore, an increase in underpricing is more likely the smaller the influence of information production costs.

The conditions which ensure an increase in underpricing coincide with the ones yielding hot issue markets. The parameter combination ε close to 1 and c close to zero simultaneously ensure that the 'expected value effect' becomes close to neutral. The 'variance effect' comes about if investors are surprised by the positive outcome of the first IPO. Observed underpricing results from the same effect, namely unexpectedly positive information about the overall firm value. Both underpricing and hot issue markets are therefore phenomena which arise from realizations which increase the firm's a priori expected value. Although this does not explain why issues are *on average* underpriced, it highlights why underpricing is *higher than average* when issues are clustered. Condition [16] is almost identical to the condition for a positive 'variance effect', $\gamma^n > \alpha^2/(1-\alpha)^2$. The higher power of γ in [16], however, imposes a more exacting condition on the signal precision and the industry factor. This is due to the fact that secondary market prices incorporate the signal realizations of both rounds of information production. Therefore both an increase in underpricing and hot issue markets arise if uncertainty reaches its peak either due to a very unpromising prior industry outlook and stunningly good news in the first IPO (small α), or by way of general uncertainty about industry prospects and very poor signal quality (α smaller but close to 1/2 and $\gamma \nearrow 1$).

For information production costs of $c_2^\star < c < c_2$ the entrepreneur optimally charges $\underline{p}_2 < E(V_2 \mid \Theta_{21})$ which provokes induced uninformed bidding The issue is thus, on average, priced below its expected value. The measure for underpricing in this case is no longer the difference between the issue price and the secondary market price (which in the case of induced uninformed bidding is zero, i.e. no observed underpricing, as no private information is transmitted into the secondary market price), but the difference between the average issue price and the firm's expected value. In case of expected or average underpricing there is no requisite coincidence with hot IPO markets. Given the specific cost bounds for information acquisition, issues will always be priced below their expected value. Since no new information gets into prices, induced uninformed bidding will cut off the path to further hot issue markets. Thus hot issue markets die away either because uncertainty can no longer rise, or because investors abstain from information production. Table 2 provides an overview of how a positive 'expected value' and 'variance effect' concur with underpricing.

TABLE III

HOT ISSUE MARKETS AND UNDERPRICING

Case	Hot issue markets due to				Underpricing	
	ΔE	Parameter values	ΔVar	Parameter values	Type	Parameter values
1	-	$\varepsilon \nearrow 1$	+	$\gamma \nearrow 1 \wedge \alpha \nearrow 1/2$	observed	$\varepsilon \nearrow 1 \wedge \gamma \nearrow 1 \wedge$ $\alpha \nearrow 1/2 \wedge c \searrow 0$
2a	+	$\varepsilon \nearrow 1 \wedge \gamma \searrow 0$	+	$\alpha \searrow 0$	average	no restriction
2b	+	$\varepsilon \nearrow 1 \wedge c \nearrow c_1^*$	+	$\gamma \nearrow 1 \wedge \alpha \nearrow 1/2$	average	no restriction
3	+	$\varepsilon \nearrow 1 \wedge \gamma \searrow 0$	+	$\alpha \searrow 0$	no	-

5 Extensions

5.1 Endogenous timing of IPO decision

An interesting path of further investigation is to analyse whether the equilibrium conditions for hot issue markets still hold if the ordering of the IPO decision is endogenous. In a case where industry prospects are rather moderate, an IPO of one firm in the industry can raise IPO proceeds of competitor firms (relative to private firm value) by disclosing unexpectedly positive industry prospects. Waiting for another firm to pave the way to the stock market with favourable industry news may therefore be profitable. In particular, entrepreneurs with low-quality firms might be tempted to wait for a second period in which investors abstain from information production. On the other hand, the waiting strategy involves the risk for both high- and low-quality firms that another high-quality firm precedes with an IPO and reveals poor industry prospects. In this case the expected utility for entrepreneurs of both high- and low-quality firms shrinks to zero. The respective risk aversion coefficients of the two entrepreneurs should therefore be a determinant for the timing of the IPO. We therefore assume that entrepreneurs exhibit different coefficients of risk-aversion, ρ_1 and ρ_2 respectively. Sufficiently risk-averse entrepreneurs will independently of firm type always choose to go public in the first period so as to avoid the risk of a total loss. In fact it can be shown that

Proposition 6. *There exists a pooling equilibrium, in which independent of firm type an entrepreneur with risk aversion coefficient ρ_1 goes public in the first period, and a second entrepreneur with a risk aversion coefficient of ρ_2 is more likely to follow with an IPO after the flotation of the first firm, iff*

$$\rho_1 > \rho^*, \quad \rho_2 < \min\{\rho^*, \rho^{**}\} \ \textit{and} \ \rho_2 > \rho^{***}.$$

For the parameter values of the hot issue market equilibria in cases 2b and 3 (see propositions [3] and [4]) there exists a solution to the system of inequalities. If we further assume that $c^2 = k\alpha$ where $k < 1$, then this also holds for the parameter constellations of hot issue markets under informed bidding, i.e. $\varepsilon \nearrow 1$ and $\alpha \searrow 0$ (proposition [2]).

A necessary condition for a pooling equilibrium of hot issue markets is therefore $\rho_1 > \rho_2$. This condition ensures that the first entrepreneur undertakes an IPO because of the risk-reduction benefit, but the less risk-averse second entrepreneur waits for a second round with higher expected proceeds. The risk-tolerance of the second entrepreneur is, however, limited by $\rho_2 < \min\{\rho^*, \rho^{**}\}$ in order to still leave an incentive for an IPO in the second period.

5.2 Variance of IPO proceeds

In section [2.4.2] we assumed that the entrepreneur could sell his firm to a risk-neutral underwriter who could diversify the risk of varying IPO proceeds over time. This assumption is obviously only necessary if investors engage in information production. Only then is it possible that fewer than n investors participate because they can possibly obtain a negative signal. If the entrepreneur is exposed to the risk of insufficient demand for the IPO issue, the variance of IPO proceeds has to be taken into account in order to determine the benefits of an IPO. Even if the variance term is included in the entrepreneur's expected utility from an IPO, hot issue markets can arise:

Proposition 7. *Hot issue markets with informed bidding $c < \min\{c_1^{**}, c_2^{**}\}$: The second firm is more likely to undertake an IPO after the first firm in the industry is floated if there is a sufficient number of investors $n > n^*$, the firm is likely to be of high value ($\varepsilon \nearrow 1$), the signal is sufficiently imprecise ($\gamma \nearrow 1$) and industry prospects are very bad ($\alpha \searrow 0$);*

First, a relatively large number of investors is required in order for the variance of private firm value to outweigh the variance of IPO proceeds in the first period IPO. Poor industry prospects (small α) in combination with a positive signal realization after the first IPO ensure that the variance of private firm value increases after the first IPO. The variance of IPO proceeds depends crucially on the degree of signal precision. If the signal is very unreliable ($\gamma \nearrow 1$), almost all investors will participate in the IPO so that the variance of expected IPO proceeds is negligible and rises to a smaller extent than the variance of private firm value.

One could also easily include the variance of IPO proceeds for the case of (induced) uninformed bidding in the second period. Under the equilibrium conditions for hot issue markets the variance of the private firm value increases after the first IPO. The volume-related risk factor associated with an IPO, however, would disappear and the likelihood of a second IPO would rise to an even larger extent.

5.3 Robustness of 'variance effect'

Since the 'variance effect' is crucial for the emergence of hot issue markets, it is worthwhile investigating whether the effect is robust to the introduction of other distributions than the binomial distribution $B(1, p)$ used in this paper. The trigger for a hot issue market is a simultaneous increase in both the firm's expected value and its variance due to positive news about one of the valuation factors. If we use other distributional assumptions to characterise the firm value, this feature of the first and second moments has to be fulfilled. In fact, it can be easily shown that

Proposition 8. *The variance of an underlying asset can increase in line with its expected value if the distribution of the asset is subject to a $B(n, p)$ binomial or a normal distribution.*

This result holds since the expected value and variance of the $B(n, p)$ binomial distribution only change for a constant factor in comparison with $B(1, p)$. For large n, the normal distribution approximates the binomial distribution and can therefore also exhibit the required characteristic.

6 Conclusion

This paper has argued that there are two effects at place which can trigger hot issue markets in a setting where both entrepreneurs and investors do not have complete information about industry prospects. First, it depends upon whether the expected IPO proceeds rise to a larger extent than the expected private firm value after one firm in the industry has gone public. This in turn depends on whether investors free-ride on the industry information revealed in the first IPO. If the marginal benefit of further information production does not outweigh its costs, investors' 'uninformed valuation' of the firm can increase to a larger extent than the expected private firm value. This is because more investors participate in the IPO (not only the ones with positive signal realizations) and investors do not have to be compensated for information acquisition through a smaller issue price. Second, the rise of hot issue markets depends on the change in the riskiness of the firm in response to news conveyed about the state of the industry ('variance effect'). If the uncertainty about the state of the industry rises after the first IPO, the risk-reduction benefits of an IPO render a flotation relatively more attractive.

The model also offers an explanation for why hot issue markets often coincide with more pronounced underpricing than cold issue markets. Both underpricing and hot issue markets arise from the same underlying phenomenon, namely that the value of the IPO firm is higher than initially expected. The model could be generalized to a setting in which there are n privately owned firms in the industry, each with a decreasing degree of risk-aversion. Less risk-averse owners can only be induced to go public if the riskiness of their firm has increased in the wake of an IPO. Waves of IPO activity thus fade away if the increase in the firm's variance is so small that the remaining private entrepreneurs with their comparatively small degree of risk- aversion will no longer tap the stock market.

7 Bibliograph

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A Appendix

A.1 Tables

TABLE A.I

NUMBER OF IPOS IN TWO-DIGIT SIC CATEGORIES IN THE US DURING 1975-1984

The table lists the IPOs in each two-digit SIC category in which at least 10 IPOs took place during 1975-84. In order to test for the clustering of IPOs across time a decile-based variant of the sign-test is used. Under the null hypothesis of $H_0^{ij} := P(X_{ij}) = 0.1$ where X_{ij} denotes the number of IPOs in a specific industry $i = 1, ..., 26$ in a specific year $j = 1975, ..., 1984$ the random variable $\widetilde{X}_{ij}$ is distributed binomially $B(n_i, 0.1)$. The null hypothesis is rejected if $X_{ij} \leqslant k_{\alpha/2}$ or $X_{ij} \geq k_{1-\alpha/2}$ where $k_{\alpha/2}$ and $k_{1-\alpha/2}$ are the greatest respectively the smallest integers which satisfy

$$\Sigma_{m=0}^{k_{\alpha/2}} \binom{n_i}{m} 0.1^{n_i} \leqslant \alpha/2 \quad \text{and} \quad \Sigma_{m=k_{1-\alpha/2}}^{k_{\alpha/2}} \binom{n_i}{m} 0.1^{n_i} \leqslant \alpha/2$$

respectively. Numbers market with * indicate years in which the null hypothesis can be rejected at the 5% significance level.

SIC	Industry	75	76	77	78	79	80	81	82	83	84	n_i
89	Services, NEC	0	0	1	0	0	0	2	0	4*	3*	10
49	Electric/Gas/Sanitary	1	0	0	0	0	3	2	1	3	2	12
20	Food/Kindred Prod.	2	1	0	1	0	1	2	0	1	5*	13
39	Misc. Manufacturing	0	1	0	0	0	3	5*	0	4*	1	14
62	Security/Comm. Brokers	0	0	0	0	0	1	0	0	13*	0	14
63	Insurance Carriers	0	0	2	1	0	1	2	1	7*	1	15
27	Printing and Publishing	0	0	0	0	0	1	3	0	10*	2	16
56	Apparel/Accessory Stores	1	0	0	0	0	0	3	0	11*	2	17
34	Fabricated Metal Prod.	0	1	0	1	1	3	4	2	5*	1	18
37	Transportation Equip.	0	1	1	0	1	2	3	0	7*	4	19
51	Wholesale: Non-durables	0	0	0	0	0	2	3	1	11*	7*	24
59	Miscellaneous Retail	0	1	0	0	1	1	3	1	11*	6*	24
45	Transportation by Air	0	0	0	1	0	5	8*	2	7*	2	28
48	Communications	0	0	0	0	0	5	5	4	10*	6	30
60	Depository Institutions	0	0	0	0	0	0	0	0	17*	18*	35
50	Wholesale: Durables	0*	1	0*	0*	0*	4	8*	2	15*	9*	39
67	Holding/Investment Co.	1	0*	0*	0*	1	5	1	2	13*	16*	39
58	Eating/Drinking Places	0*	0*	1*	1*	1*	1*	9	9	23*	9	54
80	Health Services	0*	1*	1*	0*	3	1*	8	1*	29*	14*	58
28	Chemical/Allied Prod.	2	0*	0*	2	1*	5	14*	3	32*	4	63
61	Non-Depository Instit.	0*	0*	0*	0*	0*	0*	0*	1*	49*	16*	66
13	Oil and Gas Extraction	0*	1*	1*	2*	15	30*	63*	1*	2*	0*	115
38	Instruments/Related Prod.	0*	0*	3*	4*	8	5*	29*	10	49*	13	121
36	Electronic Equipment	0*	3*	1*	4*	6*	15	43*	11	53*	31*	167
73	Business Services	1*	3*	1*	3*	3*	4*	33*	20	70*	29*	167
35	Industrial Machinery	2*	8*	3*	6*	8*	17	27*	12	63*	22	168
	n_t	10	22	15	26	49	115	280	84	519	226	1346

TABLE A.II

PERCENTAGE NUMBER OF IPOS IN TWO-DIGIT SIC CATEGORIES IN THE US DURING 1975-1984

The table presents the percentage of IPOs in two-digit SIC categories in the US during 1975-1984. The last two columns show the time series averages and standard deviations for each industry, whereas the last two rows denote the cross- sectional averages and standard deviations for each year. Numbers marked with $^*_*$ and * are two respectively one standard deviations away from the cross-sectional average, numbers marked with ^{2} and ^{1} are two respectively one standard deviations away from the time series average.

SIC	75	76	77	78	79	80	81	82	83	84	$\overline{X_i}$	SD_i
89	0.0	0.0	10.0^*_*	0.0	0.0	0.0^*	20.0	0.0^*	40.0^2	30.0^1	10	14.9
49	8.3^*	0.0	0.0	0.0	0.0	25.0^{*1}_*	16.7	8.3	25.0	16.7	10	10.2
20	15.4^*_*	7.7^*_*	0.0	7.7^*_*	0.0	7.7	15.4	0.0^*	7.7^*	38.5^2	10	11.5
39	0.0	0.0	0.0	0.0	0.0	7.1	0.0^*	0.0^*	92.9^{*2}_*	0.0^*	10	29.2
62	0.0	7.1^*_*	0.0	0.0	0.0	21.4	35.7^1	0.0	28.6^1	7.1	10	13.6
63	0.0	0.0	13.3^*_*	6.7^*_*	0.0	6.7	13.3	6.7	46.7^2	6.7	10	13.8
27	0.0	0.0	0.0	0.0	0.0	6.3	18.8	0.0	62.5^2	12.5	10	19.6
56	5.9^*	0.0	0.0	0.0	0.0	0.0^*	17.7	0.0^*	64.7^{*2}	11.8	10	20.2
34	0.0^1	5.6^*	0.0^1	5.6^*	5.6^*	16.7^*	22.2^1	11.1^*	27.8^1	5.6^*	10	9.4
37	0.0	5.3^*	5.3^*	0.0	5.3	10.5	15.8	0.0^*	36.8^{*2}	21.1	10	11.8
51	0.0	4.2^*	0.0	0.0	4.2	4.2	12.5	4.2	45.8^2	25.0^1	10	14.7
59	0.0	0.0	0.0	0.0	0.0	8.3	12.5	4.2	45.8^2	29.2^1	10	15.6
45	0.0	0.0	0.0	3.6	0.0	17.9^*	28.6^1	7.1	25.0^1	17.9	10	11.3
48	0.0	0.0	0.0	0.0	0.0	16.7^*	16.7	13.3^*	33.3^1	20.0	10	11.8
60	0.0	0.0	0.0	0.0	0.0	0.0^*	0.0^*	0.0^*	48.6^1	51.4^*_*	10	21.1
50	2.6	0.0	0.0	0.0	2.6	12.8	2.6^*	5.1	33.3^1	41.0^{*2}	10	14.9
67	0.0	2.6	0.0	0.0	0.0	10.3	20.5	5.1	38.5^2	23.1	10	13.2
58	0.0	0.0	1.9	1.9	1.9	1.9	16.7	16.7^*_*	42.6^2	16.7	10	13.6
80	0.0	1.7	1.7	0.0	5.2	1.7	13.8	1.7	50.0^2	24.1	10	16.0
28	3.2	0.0	0.0	3.2	1.6	7.9	22.2	4.7	50.8^2	6.4^*	10	15.7
61	0.0	0.0	0.0	0.0	0.0	0.0^*	0.0^*	1.5	74.2^2	24.2	10	23.8
13	0.0	0.9	0.9	1.7	13.0^*_*	26.1^*_*	54.8^*_*	0.9	1.7^*	0.0^*	10	17.8
38	0.0	0.0	2.5	3.3	6.6^*	4.1	24.0^1	8.3	40.5^2	10.7	10	12.8
36	0.6	1.8	0.6	1.8	1.8	2.4	19.8	12.0^*	41.9^2	17.4	10	13.4
73	0.0	1.8	0.6	2.4	3.6	9.0	25.8^1	6.6	31.7^1	18.6	10	11.4
35	1.2	4.8	1.8	3.6	4.8	10.1	16.1	7.1	37.5^2	13.1	10	10.8
$\overline{X_t}$	1.4	1.7	1.5	1.6	2.2	9.0	17.8	4.8	41.3	18.8		
SD_t	3.5	2.5	3.3	2.3	3.2	7.6	11.4	4.8	18.8	12.4		

A.2 Proofs to Propositions and Lemmas

A.2.1 Proof to Proposition 1:

For $c < c_1^\star$ the entrepreneur will set the maximum price for his firm that he can obtain in the presence of informed bidding $\bar{p}_1$. If the entrepreneur decides to keep his firm in private hands, he obtains $\alpha[1-\rho(1-\alpha)]$ if he owns a good firm and 0 if he owns a bad firm. If he decides to go public, the entrepreneur of a good firm obtains $\bar{p}_1[\alpha+\gamma(1-\alpha)]$ and the entrepreneur of a bad firm obtains $\gamma\bar{p}_1$. Since $\gamma\bar{p}_1 > 0$ the bad firm always has an incentive to go public. The good firm, however, only goes public if the proceeds from the IPO outweigh the utility from owning the firm which is the case if condition (13) holds.

In the cases where it is more profitable for a good firm to stay private it will be impossible for an entrepreneur of a bad firm to increase his utility by way of an IPO since investors foresee that it will only be profitable for a bad firm to undertake an IPO. Investors will not pay more than $p_1 = 0$ for the shares of the firm so that also a bad firm will remain private when an IPO incurs infinitesimally small transaction costs. ■

A.2.2 Proof to Lemma 1:

The difference between the secondary market price and the issue price

$$\Pi_1 - \bar{p}_1 = \frac{\alpha\varepsilon}{\alpha\varepsilon + (1-\alpha\varepsilon)\gamma^n} - \frac{\alpha\varepsilon - c}{\alpha\varepsilon + (1-\alpha\varepsilon)\gamma}$$

can be simplified to

$$\frac{\alpha\varepsilon(1-\alpha\varepsilon)\gamma(1-\gamma^{n-1}) + c(\alpha\varepsilon + \gamma^n(1-\alpha\varepsilon)}{[\alpha\varepsilon + (1-\alpha\varepsilon)\gamma^n][\varepsilon\alpha + \gamma(1-\alpha\varepsilon)]}.$$

Since numerator and denominator are both greater than zero the secondary market price is greater than the issue price if $c > 0$ or $\gamma < 1$. ■

A.2.3 Proof to Lemma 3:

- Substituting for $P(V_i = 1 \mid \Theta_i)$ and $P(V_i = 0 \mid \Theta_i)$ in [5] for $i = 1, 2$ yields $c_1 = (1-\gamma)\varepsilon\alpha(1-\varepsilon\alpha)$ and

$$c_2 = \frac{\varepsilon\alpha(1-\gamma)[(1-\alpha)\gamma^n + \alpha(1-\varepsilon)]}{[\alpha + (1-\alpha)\gamma^n]^2}.$$

- $c_1 > c_2$ implies $(k-\alpha\varepsilon)/k^2 < 1-\alpha\varepsilon$, where $k \equiv \alpha + (1-\alpha)\gamma^n$. Solving $k^2 - k/(1-\alpha\varepsilon) + \alpha\varepsilon/1-\alpha \equiv f(k) > 0$ as a quadratic equality yields

$$k_{1,2} = \frac{1}{2-2\alpha\varepsilon} \pm \sqrt{\frac{1-(4-4\alpha\varepsilon)\alpha\varepsilon}{(2-2\alpha\varepsilon)^2}}$$

which gives $k_1 = \frac{\alpha\varepsilon}{1-\alpha\varepsilon}$ and $k_2 = 1$. The roots have the following characteristics:

  - For $\alpha\varepsilon = 1/2$ the roots coincide.

– For $\alpha\varepsilon > 1/2$, $k_1 > 1$ so that $f(k) > 0$ for all k, since $0 < k < 1$.
– For $\alpha\varepsilon < 1/2$, k_1 lies in the interval $[0, 1[$ so that $f(k) > 0$ for $k < k_1$.

- Summarizing the conditions for which $c_2 < c_1$ yields

$$\alpha\varepsilon > \frac{\alpha + (1-\alpha)\gamma^n}{\alpha + (1-\alpha)\gamma^n + 1}. \blacksquare$$

A.2.4 Proof to Proposition 2:

Since $c < \min\{c_1^\star, c_2^\star\}$ does not impose any restriction on the parameter values, we only need to consider the sign of the "expected value" and "variance effect":

- "Expected value effect":
Substituting for $P(V_i = 1 \mid \Theta_i)$ and $P(V_i = 0 \mid \Theta_i)$ in [9] for $i = 1, 2$ we obtain the issue prices for the first and second IPO:

$$E(U_1^{IPO} \mid F_i = 1) = \frac{\varepsilon\alpha - c}{\varepsilon\alpha + \gamma(1-\varepsilon\alpha)}[\alpha + \gamma(1-\alpha)]$$
$$E(U_2^{IPO} \mid F_2 = 1, \Theta_{21}) = \frac{\varepsilon\alpha - c[\alpha + (1-\alpha)\gamma^n]}{\varepsilon\alpha + \gamma[(1-\alpha)\gamma^n + \alpha(1-\varepsilon)]}\left(\frac{\alpha + \gamma(1-\alpha)\gamma^n}{\alpha + (1-\alpha)\gamma^n}\right).$$

The difference between the expected private firm value $E(V_1 \mid F_1 = 1)$ and expected IPO proceeds of a high-quality firm $E(U_1^{IPO} \mid F_1 = 1)$ in the first period is

$$D_1 = \frac{\alpha\gamma(1-\varepsilon) + c[\alpha + \gamma(1-\alpha)]}{\varepsilon\alpha + \gamma(1-\varepsilon\alpha)}.$$

The difference between the expected value of a high-quality firm $E(V_2 \mid F_2 = 1, \Theta_{21})$ and IPO proceeds $E(U_2^{IPO} \mid F_2 = 1, \Theta_{21})$ in the second period is

$$D_2 = \frac{\alpha\gamma(1-\varepsilon) + c[\alpha + \gamma^{n+1}(1-\alpha)]}{\varepsilon\alpha + \gamma[\gamma^n(1-\alpha) + \alpha(1-\varepsilon)]}.$$

The difference is increasing for the second IPO, since can be rearranged to

$$\Delta Var = \frac{\rho\alpha(1-\alpha)(1-\gamma^n)[(1-\alpha)^2\gamma^n]-\alpha^2]}{[\alpha+(1-\alpha)\gamma^n]^2}$$

so that an increase in the variance ($\Delta Var > 0$) comes about if $\gamma^n > \frac{\alpha^2}{(1-\alpha)^2}$ which is the case either for $\alpha \searrow 0$ or $[\alpha \nearrow 1/2 \wedge \gamma \nearrow 1]$.

- Combining the two effects in one inequality yields

$$\underbrace{\frac{\rho[\gamma^n(1-\alpha)^2-\alpha^2]}{[\alpha+(1-\alpha)\gamma^n]^2}}_{\text{"variance effect"}} > \underbrace{\frac{(1-\varepsilon)\gamma[\gamma+(1-\gamma)c]}{[\varepsilon\alpha+\gamma(1-\varepsilon\alpha)][\varepsilon\alpha+\gamma[\gamma^n(1-\alpha)+\alpha(1-\varepsilon)]]}}_{\text{"expected value effect"}}$$

If ε and γ are both close to 1, $\alpha < 1/2$ and for n not too big, this inequality is satisfied. Since the difference between the expected firm value to the entrepreneur and the IPO proceeds is increasing from the first to the second IPO, hot issue markets can only be triggered if the increase in firm variance outweighs this effect. Since all terms are continuous at the chosen parameter values, the inequalities also hold in an environment of these values. Summarizing the above conditions for the parameter values we find that a combination of $\varepsilon \nearrow 1$, and $\alpha \searrow 0 \vee [\alpha \nearrow 1/2 \wedge \gamma \nearrow 1]$ yields hot issue markets. Cold issue markets arise if the variance of a second firm in the industry is decreasing in the wake of the first IPO. Since expected IPO proceeds are growing less than the expected value, it is obvious that if the variance decreases after the first IPO, the entrepreneur will derive greater utility from remaining private. ■

A.2.5 Proof to Proposition 3:

The proof proceeds in the following steps. First, it will be shown for which parameter values information production costs are such that induced uninformed bidding arises in the second IPO. The two cases for which this situation arises are (2a) $c_2^\star < c < c_2 < c_1^\star$ and (2b) $c_2^\star < c < c_1^\star < c_2$ which will be considered separately. After identifying the parameter values for which these specific constellations of c values arise, we will investigate for which parameter values the going-public decision of the second entrepreneur will become more likely after the first IPO. Finally, the combinations of parameter values are compared to find existence of a solution.

1. Derivation of $c_i^\star$: Using [12] for $i = 1, 2$ we find

$$\begin{aligned} c_2^\star &= \frac{\alpha\varepsilon(1-\gamma)[k-\alpha\varepsilon)][\alpha+\gamma(1-\alpha)\gamma^n]}{k\{k[\varepsilon\alpha+\gamma(k-\alpha\varepsilon)]+[\alpha+\gamma(1-\alpha)\gamma^n](1-\gamma)(k-\alpha\varepsilon)\}} \\ c_1^\star &= \frac{\varepsilon\alpha(1-\gamma)(1-\varepsilon\alpha)[\alpha+(1-\alpha)\gamma]}{\varepsilon\alpha+(1-\varepsilon\alpha)\{\gamma+(1-\gamma)[\alpha+(1-\alpha)\gamma]\}} \end{aligned}$$

where $k \equiv \alpha + (1-\alpha)\gamma^n$.

2. Case 2a: $c_2^\star < c < c_2 < c_1^\star$

(a) Since $c_2^\star < c_2$, it remains to be found for which values of ε, α and γ, the inequality $c_2 < c_1^\star$ holds. With $\varepsilon \nearrow 1$, the inequality simplifies to

$$\frac{\gamma^n}{[\gamma^n(1-\alpha)+\alpha]^2} < \frac{\alpha+\gamma(1-\alpha)}{\alpha+(1-\alpha)[\gamma+(1-\gamma)(\alpha+\gamma(1-\alpha))]}.$$

Cross-multiplying and collecting terms we obtain

$$g(\gamma) \equiv \alpha^3 + \gamma\alpha^2(1-\alpha) + 3\alpha^2\gamma^n - 2\alpha(1+\alpha^2)\gamma^n - 2\gamma^{n+1}(1-\alpha)^3 + \gamma^{n+2}(1-\alpha)^2 + \alpha\gamma^{2n}(1-\alpha)^2 + \gamma^{2n+1}(1-\alpha)^3 > 0$$

This inequality holds if $\gamma \searrow 0$.

(b) In a next step we have to ensure that for the given parameter values above, $\Delta E + \rho\Delta Var > 0$, so that a second IPO becomes more likely. For means of clearer exposition we separate the change in the variance of the firm's value and the change in the difference between the expected firm value and expected IPO proceeds.

- "Expected value effect":
  - For $c_2^\star < c < c_2$, the entrepreneur will set $\underline{p}_2$ in order to induce all investors to engage in uninformed bidding so that IPO proceeds in the second round equal:

$$E(U_2^{IPO} \mid F_2 = 1, \Theta_{21}) = \underline{p}_2 = \frac{c[\alpha+(1-\alpha)\gamma^n]}{(1-\gamma)[(1-\alpha)\gamma^n + \alpha(1-\varepsilon)]}$$

  - The change in the difference between the expected firm value and expected IPO proceeds from the first to the second IPO equals

$$\Delta E = \frac{\alpha\gamma(1-\varepsilon) + c[\alpha+\gamma(1-\alpha)]}{\varepsilon\alpha+\gamma(1-\varepsilon\alpha)} + \frac{ck}{(1-\gamma)(k-\alpha\varepsilon)]} - \frac{\alpha}{k} \qquad (17)$$

    where again $k \equiv \alpha + (1-\alpha)\gamma^n$. Setting $\varepsilon \nearrow 1$ we find that $\Delta E > 0$ iff

$$\frac{c[\alpha+(2-\gamma)\gamma^n(1-\alpha)]}{(1-\gamma)\gamma^n(1-\alpha)} > \frac{\alpha}{\alpha+(1-\alpha)\gamma^n}$$

    This inequality holds for $\gamma \searrow 0$.

- "Variance effect"
  See Proof to Proposition 2.

Since all terms are continuous at the chosen parameter values, the inequalities also hold in an environment of these values. Summarizing the above conditions for the parameter values we find that for any arbitrarily small α there exists an $\varepsilon \nearrow 1$ and $\gamma \searrow 0$ to satisfy the inequalities, i.e. a combination of $\varepsilon \nearrow 1$, $\gamma \searrow 0$, and $\alpha \searrow 0$ triggers hot issues markets with induced uninformed bidding.

3. Case 2b: $c_2^\star < c < c_1^\star < c_2$

(a)

- First we need to find parameter values for which $c_1^\star < c_2$. With $\varepsilon \nearrow 1$ we obtain $g(\gamma) < 0$. Further we let $\gamma \nearrow 1$. Since $g(1) = 0$ we need to differentiate $g(\gamma)$ with respect to γ and evaluate the derivative at $\gamma = 1$ which yields

$$\left.\frac{\partial g(\gamma)}{\partial \gamma}\right|_{\gamma=1} = n + 1 + \alpha(-2n - 1)$$

  In order for $g(\gamma) < 0$ for $\gamma \nearrow 1$ the function must be monotonically increasing at $\gamma = 1$. $\left.\frac{\partial g(\gamma)}{\partial \gamma}\right|_{\gamma=1} > 0$ for $\alpha < \frac{n+1}{2n+1}$ which is true for $\alpha \leqslant 1/2$.

- Furthermore the relationship $c_2^\star < c_1^\star$ has to hold. For $\varepsilon \nearrow 1$ and $\alpha = 1/2$ this inequality translates into

$$i(\gamma) \equiv \gamma^{2n+1} - 2\gamma^{2n} - \gamma^{n+1} + 3\gamma^n - 1 < O \qquad (18)$$

  Since $i(1) = 0$ and $\left.\frac{\partial j(\gamma)}{\partial \gamma}\right|_{\gamma=1} = 0$ we have to calculate the second derivative and evaluate at $\gamma = 1$ which yields

$$\left.\frac{\partial^2 i(\gamma)}{\partial^2 \gamma}\right|_{\gamma=1} = 2n(1 - n)$$

  Since $\left.\frac{\partial^2 i(\gamma)}{\partial^2 \gamma}\right|_{\gamma=1} < 0$ for $n > 1$, $i(\gamma)$ reaches its maximum at $(1; 0)$. Because $i(\gamma)$ is monotonically increasing for $\gamma \nearrow 1$, inequality [18] is satisfied.

- "Expected value effect":
  The expected utility from an IPO in this case will be $E[U_2^{IPO} \mid c > c_2, \Theta_{21}] = \frac{\varepsilon\alpha}{\alpha+(1-\alpha)\gamma^n}$. Consequently,

$$\Delta E = \frac{\alpha\gamma(1-\varepsilon) + c[\alpha + \gamma(1-\alpha)]}{\varepsilon\alpha + \gamma(1-\varepsilon\alpha)} - \frac{\alpha(1-\varepsilon)}{\alpha + (1-\alpha)\gamma^n}$$

  For $\varepsilon \nearrow 1$, the expected value effect is positive, since $\Delta E > 0$ for all $c > 0$.

- "Variance effect":
  See Proof to Proposition 2.

Since all terms are continuous at the chosen parameter values, the inequalities also hold in an environment of these values. Summarizing the above conditions for the parameter values we find that for any arbitrarily small α there exists an $\varepsilon \nearrow 1$ and $\gamma \searrow 0$ to satisfy the inequalities, i.e. a combination of $\varepsilon \nearrow 1$, $\gamma \searrow 0$, and $\alpha \searrow 0$ triggers hot issues markets with induced uninformed bidding. ■

A.2.7 Proof to Proposition 5:

In a pooling equilibrium, where investors only participate in the IPO if they find $S = G$, and all investors receive good signals δ_2, the secondary market price of the second firm will be

$$\Pi_2 = E(V_2 \mid n = \delta_2, \Theta_{21}) = \frac{\alpha\varepsilon}{\alpha[\varepsilon + (1-\varepsilon)\gamma^n] + (1-\alpha)\gamma^{2n}}$$

The second IPO in the industry is thus associated with underpricing of the following amount:

$$\Pi_2 - \bar{p}_2 = \frac{\alpha\varepsilon\gamma(1-\gamma^{n-1})[\gamma^n(1-\alpha) + \alpha(1-\varepsilon)] + c\{\alpha[\varepsilon + \gamma^n(1-\varepsilon)] + (1-\alpha)\gamma^{2n}\}[\alpha(1-\alpha)\gamma^n]}{\{\varepsilon\alpha + \gamma[\gamma^n(1-\alpha) + \alpha(1-\varepsilon)]\}\{\alpha[\varepsilon + (1-\varepsilon)\gamma^n] + (1-\alpha)\gamma^{2n}\}}$$

Comparing the amount of underpricing in the first IPO (see Lemma 1) with underpricing in the second, and setting $\varepsilon \nearrow 1$ and $c = 0$ we find that

$$\Pi_2 - \bar{p}_2 \;>\; \Pi_1 - \bar{p}_1$$

$$\Longleftrightarrow \frac{\gamma^n}{[\alpha + (1-\alpha)\gamma^{2n}][\alpha + (1-\alpha)\gamma^{n+1}]} > \frac{1}{[\alpha + (1-\alpha)\gamma^n][\alpha + (1-\alpha)\gamma]}$$

Cross-multiplying and rearranging terms we find that this inequality holds for

$$\gamma^{2n+1} > \tfrac{\alpha^2}{(1-\alpha)^2}.$$

A special solution to this inequality is $\alpha \searrow 0$ or $[\alpha \nearrow 1/2 \wedge \gamma \nearrow 1]$. ■

A.2.8 Proof to Proposition 6:

In order for the equilibrium conditions derived in propositions [2]-[4] to hold true also in a setting with an endogenous ordering of the IPO decision, we have to find restrictions on ρ_i which will trigger an IPO in the first and second period independent of firm type. Therefore for all four possible combinations of firm types, the first entrepreneur with ρ_1 will always have to be the first one to go public, while the second one with ρ_2 should follow in the second period. The discount rate between the first and second period is normalized to 1. We assume that entrepreneurs maximize their period 2 expected utility. The subscripts of ρ and F stand for the two entrepreneurs with different coefficients of risk-aversion, while the subscripts in relation to U denote the first and second period utility. An equilibrium is defined as a set of strategies where the strategy of F_1 is optimal given the strategy of F_2 and vice versa.

- Conjecture: Investors believe that an entrepreneur's going public decision is not influenced by his private signal about firm quality, but only by his coefficient of risk-aversion, ρ_i.
- The following generic conditions for all categories of investor behaviour lead to a pooling equilibrium in pure strategies, where F_1 goes public in the first period and F_2 follows in the second period.

$$\begin{aligned} F_1 = 1: &\quad E(U_1^{IPO} \mid F_1 = 1) > E(U_1^P \mid F_1 = 1) &(19)\\ F_2 = 1: &\quad (U_2^{\max\{IPO,P\}} \mid F_1 = 1, F_2 = 1) > E(U_1^{IPO} \mid F_2 = 1) &(20)\end{aligned}$$

$$\begin{aligned} F_1 = 0: &\quad \text{identical expected utility for all strategies}\\ F_2 = 0: &\quad \text{identical expected utility for all strategies}\end{aligned}$$

$$\begin{aligned} F_1 = 0: &\quad \text{identical expected utility for all strategies}\\ F_2 = 1: &\quad E(U_1^{IPO} \mid F_2 = 1) < E(U_1^P \mid F_2 = 1) &(21)\end{aligned}$$

$$\begin{aligned} F_1 = 1: &\quad \text{same as condition [19]}\\ F_2 = 0: &\quad E(U_2^{\max\{IPO,P\}} \mid F_1 = 1, F_2 = 0) > E(U_1^{IPO} \mid F_2 = 0) &(22)\end{aligned}$$

The conditions translate into the following specific restrictions on ρ_1 and ρ_2 for the different categories of bidding behaviour in the second period:

1. $c < \min\{c_1^\star, c_2^\star\}$: informed bidding

   (a) For entrepreneur of F_1 :

$$\alpha - \rho_1\alpha(1-\alpha) < \overline{p}_1[\alpha + \gamma(1-\alpha)]$$

(b) For entrepreneur of F_2 :

$$\alpha - \rho_2\alpha(1-\alpha) > \overline{p}_1[\alpha + \gamma(1-\alpha)] \tag{23}$$

$$\text{If } \overline{p}_2\tfrac{\alpha+\gamma(1-\alpha)\gamma^n}{\alpha+(1-\alpha)\gamma^n} > \tfrac{\alpha}{\alpha+(1-\alpha)\gamma^n} - \rho_2\tfrac{\alpha(1-\alpha)\gamma^n}{[\alpha+(1-\alpha)\gamma^n]^2} \quad \text{then} \tag{24}$$

entrepreneur 2 will choose to undertake an IPO in the second period. However, waiting until the second period involves the risk of negative industry news in the first IPO. The risky second period IPO proceeds therefore have to outweigh the safe proceeds of an IPO in the first period:

$$\overline{p}_2[\alpha + \gamma(1-\alpha)\gamma^n] - \rho_2\overline{p}_2^2\tfrac{[\alpha+\gamma(1-\alpha)\gamma^n]^2}{\alpha+(1-\alpha)\gamma^n}(1-\alpha)(1-\gamma^n) > \overline{p}_1[\alpha+\gamma(1-\alpha)] \tag{25}$$

$$\gamma\overline{p}_2[\alpha + (1-\alpha)\gamma^n] - \rho_2\gamma^2\overline{p}_2^2[\alpha+(1-\alpha)\gamma^n](1-\alpha)(1-\gamma^n) > \gamma\overline{p}_1 \tag{26}$$

Solving inequalities [23]-[26] for ρ_2, we obtain $\rho_2 < \rho^{1*}$, $\rho_2 > \rho^{2*}$, $\rho_2 < \rho^{3*}$, and $\rho_2 < \rho^{4*}$. In order for a solution to exist for the system of inequalities, $\rho^{2*} < \rho^{1*}, \rho^{2*} < \rho^{3*}$ and $\rho^{2*} < \rho^{4*}$, which is equivalent to postulating that $\rho^{2*}/\rho^{1*} < 1$, $\rho^{2*}/\rho^{3*} < 1$, and $\rho^{2*}/\rho^{4*} < 1$. Using the parameter values which trigger hot issue markets in Proposition (2), $\alpha \searrow 0$ and $\varepsilon \nearrow 1$ we find

$$\begin{aligned} \rho^{2*}/\rho^{1*} &= \gamma^n < 1 \\ \lim_{\alpha\to\infty} \rho^{2*}/\rho^{3*} &= \lim_{\alpha\to\infty} \rho^{2*}/\rho^{4*} = \lim_{\alpha\to\infty} \tfrac{c^2\gamma^{2n}}{\alpha} < 1 \text{ if } c^2 = k\alpha \text{ where } k < 1 \end{aligned}$$

Thus, if $\rho_1 > \rho^{1*}$, $\rho_2 < \min\{\rho^{1*}, \rho^{3*}, \rho^{4*}\}$, and $c^2 = k\alpha$ where $k < 1$, Proposition (2) still holds if we allow for an endogenous timing of the IPO decision.

2. $c_2^\star < c < c_1^\star < c_2$: induced uninformed bidding. Since $E(U_2^{\max\{IPO,P\}} \mid F_1 = 1, F_2 = 1) = E(U_2^{\max\{IPO,P\}} \mid F_1 = 1, F_2 = 0)$ and $E(U_1^{IPO} \mid F_2 = 1) > E(U_1^{IPO} \mid F_2 = 0)$, condition [20] implies [22]. Thus the conditions for F_2 reduce to

$$\begin{gathered} \alpha - \rho_2\alpha(1-\alpha) > \overline{p}_1[\alpha+\gamma(1-\alpha)] \\ \underline{p}_2 > \tfrac{\alpha}{\alpha+(1-\alpha)\gamma^n} - \rho_2\tfrac{\alpha(1-\alpha)\gamma^n}{[\alpha+(1-\alpha)\gamma^n]^2} \\ \underline{p}_2[\alpha+(1-\alpha)\gamma^n] - \rho_2\underline{p}_2^2[\alpha+(1-\alpha)\gamma^n](1-\alpha)(1-\gamma^n) > \overline{p}_1[\alpha+\gamma(1-\alpha)] \end{gathered}$$

Using the parameter values which trigger hot issue markets in Proposition (3), $\varepsilon \nearrow 1$, $\gamma \nearrow 1$ and $\alpha \nearrow 1/2$ we find that $\rho_2 < 4c$, $\rho_2 > -\infty$, $\rho_2 < \frac{1}{nc}$. Thus, if $\rho_1 > 4c$ and $\rho_2 < \min\{4c, \frac{1}{nc}\}$, Proposition (3) still holds if we allow for an endogenous timing of the IPO decision.

3. $c_2^\star < c_2 < c < c_1^\star$: uninformed bidding. As under 2 ρ_2 only has to satisfy the following three inequalities:

$$\begin{gathered} \alpha - \rho_2\alpha(1-\alpha) > \overline{p}_1[\alpha+\gamma(1-\alpha)] \\ \tfrac{\varepsilon\alpha}{\alpha+(1-\alpha)\gamma^n} > \tfrac{\alpha}{\alpha+(1-\alpha)\gamma^n} - \rho_2\tfrac{\alpha(1-\alpha)\gamma^n}{[\alpha+(1-\alpha)\gamma^n]^2} \\ \tfrac{\varepsilon\alpha}{\alpha+(1-\alpha)\gamma^n}[\alpha+(1-\alpha)\gamma^n] - \rho_2\left(\tfrac{\varepsilon\alpha}{\alpha+(1-\alpha)\gamma^n}\right)^2[\alpha+(1-\alpha)\gamma^n](1-\alpha)(1-\gamma^n) \\ > \overline{p}_1[\alpha+\gamma(1-\alpha)] \end{gathered}$$

Using the parameter values which trigger hot issue markets in Proposition (4), $\varepsilon \nearrow 1$, $\gamma \nearrow 0$ and $\alpha \nearrow 0$ we find that the above conditions are satisfied. Thus, if $\rho_1 > \rho^{1*}$ Proposition (4) also holds if we allow for an endogenous timing of the IPO decision.

- In all three cases the investors' initial beliefs that the going public decision is not influenced by the entrepreneur's private signal, but only by his coefficient of risk-aversion, ρ_i, are consistent with the equilibrium strategies given the above parameter values. ■

A.2.9 Proof to Proposition 7:

The variance associated with IPO proceeds under informed bidding is given by

$$Var(R_i \mid F_i = 1, p = \bar{p}_i, \Theta_i) = E(R_i^2 \mid F_i = 1, p = \bar{p}_i, \Theta_i) - [E(R_i \mid F_i = 1, p = \bar{p}_i, \Theta_i)]^2$$

where

$$E(R_i^2 \mid F_i = 1, p = \bar{p}_i, \Theta_i) =$$
$$\bar{p}_i^2 \left\{ P(I = 1 \mid \Theta_i) + P(I = 0 \mid \Theta_i) \tfrac{1}{n^2} \left[1^2 \tbinom{n}{1} \gamma (1-\gamma)^{n-1} + ... + n^2 \tbinom{n}{n} \gamma^n \right] \right\}.$$

The last term in square brackets corresponds to the second moment M_2 of a random variable X (number of investors mistakenly receiving a good signal) which is binomially distributed $B(n, \gamma)$. M_2 can be determined by way of the generating function $G(z) = [\gamma z + (1-\gamma)]^n$ of the binomial distribution $B(n, \gamma)$ where

$$M_2 = G''(1) + G'(1) = n[(n-1)\gamma^2 + \gamma].$$

Thus we obtain

$$Var(R_i \mid F_i = 1, p = \bar{p}_i, \Theta_i) = \bar{p}_i^2 \{ [P(I = 1 \mid \Theta_i) + P(I = 0 \mid \Theta_i) \tfrac{1}{n} [(n-1)\gamma^2 + \gamma] - [P(I = 1 \mid \Theta_i) + P(I = 0 \mid \Theta_i)\gamma]^2 \}$$

In order for an IPO to take place under informed bidding in the first period we have to redefine the cost bounds between informed and induced uninformed bidding. Solving $E(R_1^{IPO} \mid F_1 = 1,\ p_1 = \bar{p}_1) - Var(R_1^{IPO} \mid F_1 = 1, p_1 = \bar{p}_1) > E(R_1^{IPO} \mid F_1 = 1,\ p_1 = \underline{p}_1)$, we find that there exists a c_1^{**} such that for $c < c_1^{**}$ the inequality is satisfied. The above expression corresponds to a quadratic inequality of the form $a_1 c^2 + a_2 c + a_3 > 0$ with $a_1 < 0$ and $a_3 > 0$. We obtain c_1^{**} as the positive root of the corresponding quadratic equality. Similarly, $c < c_2^{**}$ ensures that an IPO with information acquisition dominates uninduced informed bidding in the second period. Furthermore, we have to ensure that $Var(V_1 \mid F_1 = 1) > Var(R_1^{IPO} \mid F_1 = 1)$ which is the case if $n > \frac{\bar{p}_1^2(1-\gamma)\gamma}{\alpha[1-\bar{p}_1^2(1-\gamma)]} = n^*$. A positive 'variance effect' giving rise to hot issue markets finally requires that

$$\Delta Var = Var(V_1 \mid F_1 = 1) - Var(R_1^{IPO} \mid F_1 = 1) - [Var(V_2 \mid F_2 = 1, \Theta_{21}) - Var(R_2^{IPO} \mid F_2 = 1, \Theta_{21})] < 0.$$

Substituting for the variance terms in the first and second period and simplifying, we obtain

$$\overline{p}_2^2(1-\alpha)(1-\gamma)\frac{\gamma^n}{[\alpha+(1-\alpha)\gamma^n]^2}[\gamma^{n+1}(1-\alpha)+\alpha\gamma+n\alpha(1-\gamma)]-\overline{p}_1^2(1-\alpha)(1-\gamma)[\gamma+n\alpha(1-\gamma)]$$
$$< \frac{n\alpha(1-\alpha)\gamma^n}{[\alpha+(1-\alpha)\gamma^n]^2} - n\alpha(1-\alpha)$$

Rearranging this inequality we obtain

$$\alpha c\gamma^{3n+2}[nc(1-\gamma)(1-\gamma^n) - 2(1-\gamma^n)(c+\gamma) - c\gamma^{n+1}] + \alpha^2 P(\alpha) < 0$$

where $P(\alpha)$ is a polynomial in α. The inequality holds for $\alpha \searrow 0 \wedge \gamma \nearrow 1$. Combining this with the condition for an almost neutral 'expected value effect' we obtain that hot issue markets arise for $n > n^*$, $\varepsilon \nearrow 1$, $\gamma \nearrow 1$ and $\alpha \searrow 0$ if $c < \min\{c_1^{**}, c_2^{**}\}$. ■

A.2.10 Proof to Proposition 8:

- *Robustness to $B(n,p)$ binomial distribution:* Assume a random variable for the firm value $X \equiv \frac{1}{n}Y$ with Y being binomially distributed $B(n,p)$. The expected value of the random firm value, $E(X)$, is equal to p which is identical to the expected value of a random variable Z with a binomial distribution $B(1,p)$. The variance $Var(X) = \frac{1}{n}p(1-p)$ corresponds to the variance of Z, $Var(Z) = p(1-p)$ except for a constant factor. Thus, even if the firm value is binomially distributed $B(n,p)$, the variance of the firm value increases if p increases from 0 to 1/2.

- *Robustness to normal distribution:* Since the binomial distribution $B(n,p)$ can be approximated by a normal distribution for n big enough, i.e. $Y \sim B(n,p) \underset{n\to\infty}{\approx} N(np, np(1-p))$, the distribution of $X = \frac{1}{n}Y$ can equally be approximated by $N(p, \frac{1}{n}p(1-p))$. So, even if the firm value is normally distributed, there can still be a 'variance effect' if the expected value of the firm increases. ■