IPO Market Timing

Aydoğan Altı
University of Texas at Austin

I develop a model of information spillovers in initial public offerings (IPOs). The outcomes of pioneers' IPOs reflect participating investors' private information on common valuation factors. This makes the pricing of subsequent issues relatively easier and attracts more firms to the IPO market. I show that IPO market timing by the followers emerges as an equilibrium clustering pattern. High offer price realizations for pioneers' IPOs better reflect investors' private information and trigger a larger number of subsequent IPOs than low offer price realizations do. This asymmetry in the spillover effect is more pronounced early on in a hot market. The model provides an explanation for recent empirical findings that illustrate the high sensitivity of going public decision to IPO market conditions.

Clustering of initial public offerings (IPOs) is a well-documented phenomenon. Starting with Ibbotson and Jaffe (1975), several studies have shown that IPOs tend to cluster both in time and in industries.[1] What causes these hot and cold market cycles is less clear, however. While the IPO clustering could potentially be due to clustering of real investment opportunities, empirical findings suggest that this link is weak. Most IPO firms do not have urgent funding needs [Pagano, Panetta, and Zingales (1998)]; instead, firms' equity-issue decisions seem to be driven mainly by market timing attempts [Baker and Wurgler (2002)]. Furthermore, hot versus cold market IPO firms do not appear to differ in their growth prospects or future operating performance [Helwege and Liang (2002)].

Recent empirical research has focused on information spillovers as the main driver of the hot market phenomenon. The idea is that information generated in valuing a set of pioneers makes the valuation of followers easier and hence triggers more IPOs. The evidence for the spillover effect is strong. Lowry and Schwert (2002) and Benveniste, Ljungqvist, Wilhelm, and Yu (2003) find that IPO volume is highly sensitive to the outcomes of recent and contemporaneous offerings. Specifically, if the

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[1] For example, see Ritter (1984) and Ibbotson, Sindelar, and Ritter (1988, 1994).

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offer prices of IPOs in a given month exceed initial expectations, the IPO volume in the subsequent months increases dramatically.[2] If, on the other hand, the offer prices turn out to be lower than expected, the IPO market dries out. In short, firms attempt to time the IPO market. The proper interpretation of these findings is difficult, however, as the theoretical dynamics of information spillovers remains largely unexplored. Our understanding of how information is incorporated into offer prices mainly comes from book-building models where the pricing of a single IPO is analyzed in isolation [Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990)]. Little is known about how the IPO price formation process is likely to take place when the outcome of this process is anticipated to have a spillover effect and trigger further IPOs.

This article develops a model of IPO clustering that highlights the endogeneity of information spillovers. I consider an environment where investors who participate in IPOs are asymmetrically informed about a valuation factor that applies to a number of firms. Since offer prices are set based on investors' indications of interest, the outcome of an IPO reflects information that was previously private. This reduces the valuation uncertainty for subsequent issuers and induces further IPOs. The main result of the analysis is that IPO market timing obtains as an equilibrium outcome. High offer price realizations facilitate a stronger spillover effect and trigger more subsequent IPOs than low price realizations do. The intuition for this result is quite simple but novel. A high offer price realization necessarily reveals some good news on fundamentals, as no rational investor would willingly overpay. But a low price realization may arise either when there is bad news or when informed investors with good news do not indicate interest in the offering. The model illustrates one reason for such lack of participation by the informed—an investor may shy away from bidding aggressively in the early IPOs in order to retain his informational advantage for subsequent offerings. More generally, informed investors may fail to participate in an IPO for other, exogenous reasons as well, such as the timely availability of cash resources. Due to the uncertainty about the presence of informed bidding, the degree of informational asymmetry remains relatively high following a low price realization. Thus fewer firms, those with more urgent capital needs, chose to go public upon observing low price outcomes. High prices reveal more private information, and thus reduce informational asymmetry to a greater extent, triggering a larger number of IPOs. The result that IPO market valuations, rather than their immediate financing needs, drive firms' decisions to go public is in line with the empirical evidence.

[2] Initial expectations are measured by the price range that is indicated in the IPO prospectus at the time of filing. Measures of subsequent months' IPO volume are the numbers of initial filings, completed offerings, and withdrawn offerings.

The model setup captures conditions at the beginning of a potential hot market. A set of private firms consider going public. These firms do not have investment opportunities that require immediate funding, but they expect to discover profitable projects with positive probability in the future. Firms lack funds to finance these potential projects, and the only source of external financing is issuing equity. New issues are sold to institutional investors, who are asymmetrically informed about a valuation factor that is common across firms. Therefore, informed investors earn information rents in the IPOs in which they participate, and this constitutes a cost to the issuers. Each firm weighs this cost of issuing equity against its need for external financing and chooses when to go public, if at all.

First, a set of pioneers go public. This set, determined endogenously in equilibrium, consists of those firms with the highest project discovery probabilities. Observing the outcome of pioneers' IPOs reduces the degree of informational asymmetry among investors, since the offer prices are functions of investors' bids, which, in turn, are functions of their information. Subsequent to the pioneers' IPOs, remaining private firms (followers) choose whether to go public immediately or wait until they discover projects. Waiting has an option-like value because a project may not necessarily be discovered in the future, in which case issuing equity, which is costly, can be avoided. The value of going public immediately stems from the temporarily reduced informational asymmetry. Since market conditions change over time, the asymmetry of information among investors is likely to be relatively high in the future, suggesting a high future issue cost. Facing this trade-off, those followers with relatively high project discovery probabilities decide to go public immediately in order to take advantage of reduced information rents. Even firms with small chances of discovering projects may decide to go public within this cluster if the outcome of the pioneers' IPOs sufficiently reduces the informational asymmetry.

If one assumes an exogenous spillover effect, that is, that the outcome of the pioneers' IPOs reveals all private information, then all followers go public subsequently regardless of whether the pioneers get a high or a low offer price. This is because of the fact that investors cannot earn any rents once information becomes symmetric; therefore, a follower's cost of going public becomes zero. However, the spillover effect is not, in fact, exogenous. It obtains endogenously, since informed investors anticipate the subsequent clustering of IPOs and act strategically in the pioneers' offerings. Specifically, an investor with good news has an incentive to conceal his information early on to keep it private and use it profitably once some of the followers decide to go public. The investor can accomplish this by bidding low and hence effectively staying out in the pioneers' IPOs. Clustering requires, however, that some of the private information of investors is incorporated into the pioneers' offer prices. If an informed investor were to always bid low regardless of his signal, the offer price would not reflect any private information. But in the absence of any information spillover, the followers would have no incentive to go public; thus, there would be no clustering, which is the very reason for the informed investors to conceal their information.

The tension between the tendency of informed investors to conceal information on the one hand and the necessity of information spillovers for a clustering to take place on the other determines the equilibrium outcome. In equilibrium, an investor with good news is indifferent between bidding aggressively in the pioneers' IPOs (bid high) and concealing his information (bid low) and does both with positive probability. This creates an asymmetry in the information content of the offer price realization. A high price reveals good news; a low price, however, may obtain either when informed investors have bad news or when they are concealing good news. The main result of the article follows from this asymmetry. The high offer price realization triggers more new IPOs than the low price realization does, as the high price is more informative and therefore reduces the informational asymmetry to a greater extent.

After illustrating the main idea in a two-period setup, I extend the model to incorporate multiple periods. The dynamic analysis shows that the sensitivity of IPO volume to market conditions is very high at the beginning of the hot market. As the hot market progresses, this sensitivity declines. The model also provides implications about issuers' investment and cash holding policies. Firm quality in terms of investment opportunities deteriorates in time. The late followers in a hot market are firms with little growth potential; thus these firms end up sitting on the cash they raise for extended periods of time. The decline in quality is more pronounced when firms have better investment opportunities on average. In this case, the pioneers are of very high and the late followers are of very low quality. The likelihood of holding onto IPO proceeds is especially high for those firms whose IPOs are triggered by high valuation outcomes.

While the main focus of this article is the IPO market, the analysis applies to other forms of corporate financing activity as well. For example, the model can easily be reinterpreted as a description of the mergers and acquisitions (M&A) market: issuers in the model are similar to merger targets, informed investors to bidding firms, and projects to merger synergies. The resulting predictions are in line with the empirical evidence on mergers. Similar to IPOs, mergers cluster in time and in industries [Mitchell and Mulherin (1996) and Andrade, Mitchell, and Stafford (2001)]; furthermore, merger waves coincide with high market valuations [Rhodes-Kropf, Robinson, and Viswanathan (2003)]. An implication of the model in this context is that late mergers in a wave should create less synergistic value. Hot markets for seasoned equity or bond issues constitute other potential applications of the model. Whether a hot market occurs owing to information spillovers as hypothesized in this article depends on the underlying informational structure in each application. The results are more likely to explain IPO hot markets or waves of mergers where targets are private firms, as in both cases the completion of a deal reveals a substantial amount of private information. The spillover effect may be weaker for acquisitions of publicly traded firms, seasoned equity issues, or bond issues, since the secondary market routinely generates information about the firms involved in these transactions.

To the best of my knowledge, this article presents the first model of clustering of IPOs in which the dynamics of information spillovers and IPO market timing arise endogenously. A few other articles have analyzed different aspects of IPO clustering taking as given an exogenous spillover effect. Maksimovic and Pichler (2001) examine how the decision to go public interacts with product market competition. In their model, the pioneers' IPOs reveal information that can induce further entry into the industry. Therefore, pioneers face a trade-off between obtaining public financing early and revealing their technology to potential new entrants. Unlike the current article, however, their model assumes exogenous revelation of information either by the pioneers' IPOs or by secondary market trading before the followers make their decisions. Similarly, Benveniste, Busaba, and Wilhelm (2002) present a model where the pioneer's IPO is assumed to reveal news about industry-wide growth opportunities. They focus on how the follower free-rides on such news and the potential coordination role of an investment bank in minimizing the adverse effects of this free-rider problem. Hoffmann-Burchardi (2001) develops a similar model of free-riding behavior but considers the case where the asymmetry of information is between entrepreneurs and investors. Her analysis relates the likelihood of clustering to the risk aversion of entrepreneurs. Finally, Subrahmanyam and Titman (1999) explore the link between the decision to go public and the informational efficiency of public equity markets. They point to the positive externality in information production when there is a larger number of publicly traded firms and suggest that this externality can lead to a clustering of IPOs in emerging economies.

This article also relates to the literature on IPO price formation process. Starting with Rock (1986) and Benveniste and Spindt (1989), this line of research has emphasized the costs of going public that arise when investors possess private information about issuers' value [Benveniste and Wilhelm (1990), Maksimovic and Pichler (2002), Sherman and Titman (2002), and Biais, Bossaerts, and Rochet (2002)]. These articles consider the pricing of a single IPO in isolation and typically analyze the design of optimal book-building mechanisms that minimize informed investors' information rents. In contrast, the objective of the current article is to develop a benchmark analysis of information spillovers that arise within a sequence of IPOs.

The trade-off an informed investor faces between being aggressive versus concealing information has been discussed in the market microstructure literature before, most notably by Foster and Viswanathan (1994, 1996). In these analyses, the informed agent trades in a single security through time and tends to reveal less information early on. The current article focuses on the equilibrium response of issuers to informed investors' strategies; hence the IPO cluster, i.e., the opportunity set of informed investors, evolves endogenously.

The remainder of the article is organized as follows. Section 1 presents the model. Section 2 examines the benchmark case with no information spillovers. Section 3 characterizes the equilibrium with information spillovers in the two-period setup. Section 4 extends the analysis to multiple periods. Section 5 discusses the empirical implications. Section 6 concludes.

1. The Model

1.1 The firms

I assume universal risk neutrality and a risk-free rate of zero throughout. I consider a continuum of firms with a total measure of one (the distribution of firms is explained in greater detail below). Firms live for two periods, year 1 and year 2. Each firm j has assets in place that generate a final net payoff of X_j at the end of year 2. This payoff is determined by the realizations of year-1 and year-2 factors, therefore $X_j = X_{1j} + X_{2j}$. For each year $i \in \{1,2\}$, either $X_{ij} = \alpha$ ("good news") or $X_{ij} = 0$ ("bad news"), where each outcome has equal probability. Suppressing the j subscript, I assume that X_1 is perfectly correlated across firms. Also, X_2 for any firm is independent of X_1.[3]

In addition to their existing assets, firms have future investment opportunities. Specifically, firm j expects to discover a project with probability ω_j in year 2. The project, if discovered, costs I at the beginning of year 2 and pays F at the end of year 2. Therefore, if a firm with a project invests its total final payoff will be $X + F$; otherwise the payoff will be X.[4] The firms are indexed by their project discovery probabilities. The measure of firms with discovery probability ω or less is denoted by $G(\omega)$, $\omega \in [0,1]$. I assume that the distribution G has no atoms; that is, G is continuous on [0,1].

1.2 Financing

Firms have no cash in hand in either year 1 or year 2. The only way for them to raise external funds is to go public and sell equity. Initially, each

[3] The second year factor X_2 may or may not be correlated across firms.

[4] The projects have positive NPV, i.e., $F > I$. Furthermore, it is assumed that the NPV is large enough so that a firm always prefers the costly IPO to letting the project expire. The costs of the IPO, due to asymmetric information among investors, are characterized below.

firm has one outstanding share owned by an entrepreneur. If a firm decides to go public, the entrepreneur sells her share (i.e., the whole firm) to outside investors through the equity issue game described below. Out of the proceeds V, the entrepreneur deposits I within the firm and consumes the rest of the proceeds $V - I$.[5]

1.3 Investors and information

Two classes of investors, informed and uninformed, participate as buyers in IPOs. There are $N > 1$ uninformed investors. In addition, there are $\widetilde{M}_i$ informed investors who observe the realization of X_i at the beginning of year i. The number of informed investors is random in each year. Specifically, $M_i = k$ with probability $p\,(1-p)^{k-1}$, where $k \in \{1,2,...\}$ and $p < 1$.[6] Notice that p parameterizes the degree of competition among informed investors. The expected number of informed investors equals $1/p$, which is decreasing in p. For technical reasons discussed below, I assume that $p > 1/8$.

An informed investor does not know whether he is the only informed investor or if there are other ones. The uninformed investors and the entrepreneurs have access only to public information.[7] At the end of year i, the realization of X_i becomes public information. Hence, private information is short-lived. To simplify the discussion, it is assumed that year-1 investors and year-2 investors are not the same. Within a year, however, the set of investors remain the same. Also, whether a specific investor is informed is not publicly known; otherwise the asymmetric information concerns trivially could be avoided by selling IPO shares only to the uninformed investors.

This structure of asymmetric information is similar to those in Benveniste and Wilhelm (1990) and Sherman and Titman (2002). The informed investors in the model correspond to large institutions. The informational advantage of these investors is likely to stem from the research they conduct on issuing firms, as well as their ability to better interpret and quantify the information they learn during road show presentations. The uninformed investors can be thought of as retail investors and small institutions who have access only to public information.

[5] In an earlier version of the article it was assumed that the entrepreneur sells only a fraction of the firm to raise I, and the results were identical to those reported here.

[6] Conditional on k, the informed investors are drawn from a continuum that represents the pool of potentially informed investors.

[7] As in several other studies that focus on the asymmetry of information among investors, I abstract from the potential asymmetry of information between the better informed issuers and the investors for simplicity. See Allen and Faulhaber (1989), Grinblatt and Hwang (1989), and Chemmanur (1993) for models where issuers are better informed than investors.

1.4 Equity issue game

The equity issue game is a second price auction. Each investor, whether informed or uninformed, bids a price for the issuing firm. The investor with the highest bid wins and pays the second highest bid. In case of ties, that is, when $J > 1$ investors bid the highest price V, each of these investors gets $1/J$ of the issue at the price V. After the auction, the selling price is announced, and the equity issue game ends.[8,9]

1.5 Timing of events

The timing of events within year 1 is as follows. First, informed investor(s) learn X_1. Afterwards, there are up to T periods in which firms can go public. Specifically, in the first period, those firms that decide to go public, if any, do so simultaneously by selling their shares in an aggregated second price auction. With probability β, the second period follows, in which the remaining private firms again have the chance to go public. With probability $1 - \beta$, year 1 ends and X_1 is revealed. Similarly, given that period $t < T$ is concluded, period $t + 1$ follows with probability β, or year 1 ends with probability $1 - \beta$. If period T is reached, following the potential IPOs in this period, year 1 ends and X_1 is revealed.

The timing of events in year 2 is similar, except that in year 2, only those firms that did not go public in year 1 and then have discovered projects go public.[10] First, informed investor(s) learn X_2. Then the issuing firms hold their IPOs. For simplicity, I assume that there is no sequencing of IPOs in year 2. Finally, X_2 is revealed and consumption takes place.

The hot market dynamics in year 1 are governed by the parameter pair (T, β). Year 1 is characterized by the uncertainty surrounding X_1. Once this uncertainty is resolved, a new period with new uncertainties, year 2, starts. In this context, T can be interpreted as the upper bound on the length of the time period in which the uncertainty about X_1 dominates firms' valuations. This time period can turn out to be shorter and is more likely to be so for smaller values of β. Thus, β captures the likelihood of an extended period of IPO clustering. In order to illustrate the main idea, I first focus on the simplest case with $T = 2$ and $\beta = 1$ in Sections 2 and 3. To gain further insights about hot-market dynamics, Section 4 then extends the analysis to allow for $T > 2$ and $\beta < 1$.

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[8] The results are robust to whether further information, such as the realized allocation, is announced.

[9] I do not model an active secondary market; investors hold shares for their final (i.e., end of year 2) payoff. Notice, however, that the model is consistent with the existence of a secondary market. Since all agents are risk neutral, the no-trade theorem applies and there will not be any trading activity when the secondary market opens.

[10] In this model, the only reason to go public is to raise funds for investment. In year 2, those firms that did not discover projects do not need financing, so they choose to remain private and avoid the costly equity issue.

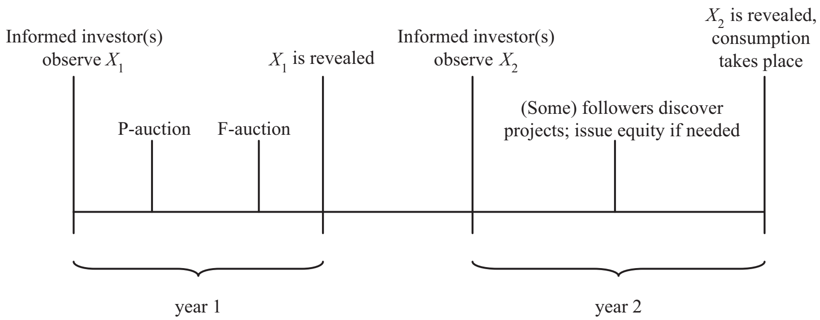

Figure 1
Timing of events

When $T = 2$, a firm may choose to be a *pioneer*, that is, it may go public in the first period of year 1. Alternatively, the firm may choose to be a *follower*, that is, it may wait until the pioneers' offering is concluded and then make its decision. Given the outcome of the pioneers' offering, a follower may then choose to go public in the second period of year 1, or remain private until year 2. I refer to the first and the second offerings of year 1 as the *P-auction* and the *F-auction*, respectively.

Figure 1 summarizes the timing of events. The beginning of year 1 corresponds to the end of a previous cold market. One can imagine year 1 as a period of increased commonality across firms' valuations, providing the conditions for information spillovers and a new hot market. Year 2 represents the distant future. While a firm has no projects to finance in year 1, such a project may be discovered with positive probability in the future. Therefore year 2 is not necessarily the same calendar period for all firms; rather, it should be interpreted as a firm-specific and possibly random point in time at which the firm learns about its investment opportunities.

2. The Benchmark Case: No Information Spillovers

As a benchmark, I first characterize the decision to go public and the outcome of the resulting IPO in the case where there is only one firm. Consider the bidding strategies of investors in an IPO. Let V_H be the bid submitted by an informed investor who has received good news $X_i = \alpha$, and let V_L be the bid submitted by an informed investor who has received bad news $X_i = 0$. The bid of an uninformed investor is denoted by V_U. For notational convenience, let $C(\omega) \equiv \omega F + (1 - \omega)I + \alpha/2$.[11]

[11] The number of periods within year 1 is irrelevant in this section, since there is only one firm in the IPO market and hence there are no information spillovers across periods.

Proposition 1. *In the single firm case:*

(i) *When a firm with project discovery probability ω goes public in year 1,*

$$V_H = C(\omega) + \alpha\,,\; V_L = V_U = C(\omega). \tag{1}$$

(ii) *When a firm (having discovered a project) goes public in year 2,*

$$V_H = F + X_1 + \alpha\,,\; V_L = V_U = F + X_1. \tag{2}$$

(iii) *In both cases above, the informational asymmetry among investors is resolved after the outcome of the IPO is announced.*

All proofs are in Appendix B unless they appear in the text. Parts (i) and (ii) of Proposition 1 describe the equilibrium bids of investors. When the informed investor(s) have bad news, the realized auction price is V_L, which is the full information value of the firm given bad news. Similarly, when there are at least two informed investors and the news is good, the auction price is V_H, which is the value of the firm given good news. It is when there is only one informed investor with good news that asymmetric information imposes a cost to the issuer. Specifically, the informed investor wins the whole issue at the price V_L, but the value of the firm conditional on good news is $V_L + \alpha$. Therefore, going public is costly; the *ex ante* expected rent earned by informed investors constitutes a cost to the issuing firm.

Notice that in the single firm case where there is no role for information spillovers, an informed investor plays a *revealing* strategy in equilibrium, in the sense that when he has good news, he bids high. Consequently, information becomes symmetric among investors once the outcome of the IPO is announced. The high price realization V_H reveals good news. Given the low price realization V_L, on the other hand, an uninformed investor can infer from his allocation what the news is. If he gets no shares, there must be one high bid, and hence the news is good; whereas if he gets a positive allocation, the informed bid(s) are low, and hence the news is bad. Therefore, in the case of a single IPO with no information spillovers, both the high and the low price realizations of an IPO resolve the informational asymmetry among investors. The implication is that if a follower were to exist, it would go public after a pioneer's IPO, regardless of whether the pioneer gets a high or low price, as symmetric information would imply a zero issue cost. Of course, the equilibrium described in Proposition 1 holds only for the case where there are no such followers. This result–that high versus low prices are equally informative if no clustering is anticipated–provides a benchmark. The next section will demonstrate that when clustering is anticipated by informed investors, the resulting offer price realizations differ in their information content.

Consider the IPO timing decision of the firm. Recall that as of year 1, the firm's year-2 project discovery probability is $\omega < 1$.

Proposition 2. *With no information spillovers, a firm never goes public in year 1. It goes public in year 2 only if it discovers a project.*

Going public is costly because privately informed investors extract rents in an IPO. A firm chooses the timing of its IPO to minimize this cost. Waiting until year 2 has an option value, since if no project is discovered, the firm will avoid the costly IPO in year 2. Therefore, the firm has a strict preference to wait and issue in year 2 only if a project is discovered. This result sets the benchmark for IPO timing: when there are no information spillovers, there is no room for IPO market timing; a firm goes public only if it needs immediate financing.[12]

3. Information Spillovers with a Common Valuation Factor

Now I turn to the case where firm values are driven by a common factor. Consider the benchmark equilibrium described in Proposition 1. Suppose, for now, that equations in (1) describe the equilibrium strategies of investors in the P-auction given a set of pioneers going public. Then, by part (iii) of Proposition 1, investors become symmetrically informed after the P-auction price is announced. Now consider the subsequent IPO decision of a follower. The cost of going public in year 1 is zero, as information has become symmetric among investors, and hence the entrepreneur will get the fair value for her firm. In contrast, the cost of waiting until year 2 is positive, because in year 2 informed investors will receive signals about X_2, and a new asymmetry of information will arise before a potential year-2 IPO. Comparing the costs of the two alternatives, then, the follower decides to go public in year 1 subsequent to the P-auction. This illustrates how the information spillover from the pioneers' IPOs can trigger the IPOs of other firms.

How does an informed investor bid in the P-auction in anticipation of this spillover effect? In particular, do the strategies described in Proposition 1 still constitute an equilibrium? Suppose that the measure of pioneers is z_p. Therefore the measure of followers is $1-z_p$. Consider the optimal bidding strategy of an informed investor with good news,

[12] The benchmark value of the results in this section should be emphasized. Clearly different patterns may emerge in another model with no information spillovers. For example, the IPO outcome may only reduce, but not completely eliminate, the informational asymmetry, or a firm with no immediate financing needs may nevertheless choose to go public if the degree of asymmetric information is temporarily low for exogenous reasons. The very simple benchmark the current model delivers is rather intended to make the illustration of the information spillover effects developed in the next section as transparent as possible.

say investor 1, given that other investors bid as in (1). By bidding V_H, investor 1 secures an expected profit of $p_s \alpha z_p$ from the P-auction, where

$$p_s = \frac{p}{\sum_{k=1}^{\infty} kp(1-p)^{k-1}} = p^2 \tag{3}$$

is the probability that investor 1 is the only informed investor.[13] However, by bidding V_H, investor 1 reveals his private information and cannot make any profits in the F-auction. Suppose investor 1 deviates to V_L. Now his P-auction profit is cut to $(p_s \alpha z_p)/(N + 1)$, because when he wins with a low bid he shares the issue with N uninformed investors. But by bidding V_L, investor 1 conceals his information and makes uninformed investors believe that he has bad news (provided that there is no other informed investor to reveal the good news). If a follower goes public subsequently, uninformed investors will bid the expected value of the firm given their belief that information has become symmetric, but investor 1 knows that the true value of the firm exceeds this bid by α, the amount he has concealed. Therefore, investor 1 can obtain a profit of α per follower in the F-auction by submitting an appropriate winning bid (recall that he will pay the second highest bid). Since the public also believes that information has become symmetric, all the followers go public in the F-auction. Hence, the expected F-auction profit of investor 1 when he conceals his information is $p_s \alpha(1 - z_p)$. The total payoff from deviating is

$$\frac{p_s \alpha z_p}{N+1} + p_s \alpha(1 - z_p), \tag{4}$$

which exceeds $p_s \alpha z_p$ when $z_p < (N+1)/(2N+1)$. It follows that with a relatively small group of firms choosing to be pioneers, investor 1 would profitably deviate to bidding V_L in the P-auction, and therefore the strategy profile (1) would not be an equilibrium of the P-auction.

The above discussion illustrates an important feature of the model: an informed investor with good news tends to conceal his information early on when he anticipates a wave of IPOs in the near future. In the analysis below, we will see that such strategic use of private information is the main factor shaping the equilibrium. The subgame perfect equilibrium is analyzed in three parts. First, the equilibrium of the P-auction is obtained, given conjectures about the F-auction. The second part characterizes the issue decisions of the followers given the

[13] Investor 1 calculates this probability conditional on the fact that he is informed.

outcome of the P-auction. Finally, the equilibrium sets of pioneers and followers are determined.

3.1 The P-auction

Suppose that the measure of pioneers is z_p. Also, suppose that the measure of followers that decide to go public in the F-auction after observing a low price realization in the P-auction is z_f.[14] Consider the following conjectures about the equilibrium strategies of investors in the P-auction. An informed investor with bad news bids V_L^P. An uninformed investor bids $V_U^P > V_L^P$. An informed investor with good news plays a mixed strategy by bidding V_L^P with probability q and bidding $V_H^P > V_U^P$ with probability $1 - q$. Notice that under this conjecture, a good-news informed investor tends to conceal his information by imitating a bad-news informed investor with positive probability. At one extreme, when $q = 0$, such imitation does not take place; at the other extreme, $q = 1$, a good-news informed investor always imitates. In this section, I characterize the equilibrium values of q, V_L^P, V_U^P, and V_H^P, given the investors' expectations about the subsequent F-auction.

Consider V_U^P first. Since uninformed investors do not observe any private signals about firm value, they compete away rents and make zero expected profits in equilibrium. Therefore V_U^P is the per share price at which an uninformed investor breaks even:

$$\frac{1}{2N}(C(\omega) - V_U^P) + \frac{1}{2N}\left(\sum_{k=1}^{\infty} p(1-p)^{k-1} q^k\right)(C(\omega) + \alpha - V_U^P) = 0 \quad (5)$$

If the news is bad, which happens with probability 1/2, informed investor(s) bid low. In this case, each uninformed investor gets $1/N$ of the issue; hence the first term in (5). Notice that when the news is good [the second term in (5)], the only time uninformed investors win shares is when the informed investor(s) bid low, which happens with probability q^k if there are k informed investors. Solving for the infinite sum in (5) and rearranging gives V_U^P as a function of q:

$$V_U^P(q) = \frac{\alpha p q + C(\omega)(1 - q + 2pq)}{1 - q + 2pq} \quad (6)$$

Let us conjecture that $V_H^P = C(\omega) + \alpha$. Consider the decision problem of an informed investor with good news, say, investor 1, given the strategies of other investors. By bidding V_H^P, investor 1 secures an expected payoff of

[14] The analysis below will show that in equilibrium, all of the followers, that is, a measure of $1 - z_p$, will go public in the F-auction if the P-auction price realization is high. The high and the low prices of the P-auction will also be characterized below.

$$\pi_H(q) = p_s(q)[C(\omega) + \alpha - V_U^P(q)]z_p, \tag{7}$$

where

$$p_s(q) = \frac{\sum_{k=1}^{\infty} kp(1-p)^{k-1}q^{k-1}}{\sum_{k=1}^{\infty} kp(1-p)^{k-1}} = \left(\frac{p}{1-q+pq}\right)^2 \tag{8}$$

is the conditional probability that investor 1 wins the P-auction making a positive profit (which happens either when there is no other informed investor, or when there are other informed investors but they all bid low). The term in brackets in (7) is the per pioneer profit obtained in these cases.[15] Notice that investor 1's F-auction profit is zero when he bids V_H^P in the P-auction. This is because by bidding V_H^P, investor 1 reveals to the uninformed investors that he has good news, and therefore loses his informational advantage. For example, if the P-auction price turns out to be V_H^P, uninformed investors infer that there are at least two high bids. If, on the other hand, the price realization is $V_U^P(q)$, investor 1 wins the whole issue, and the uninformed investors, from their allocation of zero shares, infer that the winner has good news. In either case, the uninformed investors learn investor 1's signal, and therefore in the subsequent F-auction investor 1 has the same public information as the uninformed. Thus, regardless of the measure of follower firms going public, investor 1 cannot make any profits in the F-auction if he bids V_H^P in the P-auction. Using (6), (7) simplifies to

$$\pi_H(q) = \frac{p^2 \alpha z_p}{(1-q+pq)(1-q+2pq)} \tag{9}$$

Consider now the expected payoff of investor 1 when he bids V_L^P in the P-auction. His P-auction profit is now zero, since V_L^P is less than the uninformed bid $V_U^P(q)$. But by concealing his information, investor 1 can now hope to make profits in the subsequent F-auction. This expected profit is given by

$$\pi_L = p_s \alpha z_f \tag{10}$$

The details of the derivation of (10) are delegated to Lemma B.1 in Appendix B which characterizes the equilibrium of the F-auction, but the brief intuition is as follows. By bidding V_L^P, investor 1 conceals his private information from other investors. The effect of this information on firm value is α per follower; therefore, the aggregate effect, given that a measure z_f of followers

[15] If there are other informed investors who also bid high, the profit of investor 1 is zero, since V_H^P equals the firm value given good news.

will go public in the F-auction, is $z_f\alpha$. Investor 1 will realize this amount as his profit by bidding high in the F-auction, and only in those states of the world where the second highest bid is less than his bid. This is the case when investor 1 is the only informed investor, which has a probability of p_s as given by (3).

The payoff from bidding V_H^P weakly exceeds the payoff from V_L^P if and only if

$$Y(q) \equiv (1 - q + pq)(1 - q + 2pq) \leq \frac{z_p}{z_f} \tag{11}$$

Let

$$\overline{Y} = \max_{q\in[0,1]} Y(q) = \begin{cases} 1 & \text{if } p \leq \frac{2}{3} \\ \frac{p^2}{4(1-p)(2p-1)} & \text{if } p > \frac{2}{3} \end{cases}$$

$$\underline{Y} = \min_{q\in[0,1]} Y(q) = \begin{cases} 2p^2 & \text{if } p \leq \frac{\sqrt{2}}{2} \\ 1 & \text{if } p > \frac{\sqrt{2}}{2} \end{cases} \tag{12}$$

Also, let $q^*(z_p,z_f)$ denote the equilibrium value of q given z_p and z_f. Proposition 3 summarizes the analysis in this section.

Proposition 3 (The P-auction Equilibrium). *Suppose that the measure of pioneers is z_p and the measure of followers that decide to go public after observing V_U^P is z_f:*

(i) If $z_p/z_f \geq \overline{Y}$, informed investors with good news never conceal their information, that is, $q^*(z_p,z_f) = 0$.
(ii) If $\underline{Y} < z_p/z_f < \overline{Y}$, informed investors with good news conceal their information with probability $q^*(z_p,z_f)$, where $q^*(z_p,z_f)$ solves $Y(q) = z_p/z_f$.
(iii) If $z_p/z_f \leq \underline{Y}$, informed investors with good news always conceal their information, that is, $q^*(z_p,z_f) = 1$.
(iv) In all three cases above, uninformed investors bid $V_U^P(q^*(z_p,z_f))$. Informed investors with bad news bid some $V_L^P < V_U^P(q^*(z_p,z_f))$. Informed investors with good news bid V_L^P with probability $q^*(z_p,z_f)$ and bid $V_H^P = C(\omega) + \alpha$ with probability $1 - q^*(z_p,z_f)$.[16]

Note that in equilibrium, the realized price in the P-auction is never V_L^P. Either at least two informed investors bid V_H^P and the auction price is V_H^P,

[16] In part (ii) of Proposition 3, $q^*(z_p,z_f)$ is unique for $p \leq 2/3$. For $p > 2/3$, there are two solutions in the (0, 1) interval. Therefore, there may be two equilibria of the P-auction given z_p and z_f. However, this does not necessarily imply multiple equilibria for the overall game, since z_p and z_f are in fact endogenous quantities to be determined as part of the equilibrium.

or else the price $V_U^P(q)$ is dictated by the bids of the uninformed. The low bid V_L^P represents the strategy to stay out of the auction, that is, an investor who submits V_L^P never expects to win. Consequently, the bid V_L^P is indeterminate; all that matters is that $V_L^P < V_U^P(q)$ to ensure staying out of the auction. Given this, I refer to V_H^P as the *high price* and $V_U^P(q)$ as the *low price* of the P-auction in the rest of the discussion.

Proposition 3 illustrates a quite intuitive result. When the future IPO volume z_f is expected to be small relative to the current volume z_p, an informed investor does not tend to conceal his information; rather, he makes aggressive use of it in the pioneers' IPO. But if a big wave of IPOs is expected, an informed investor is better off saving his information for future use. By concealing the good news, an informed investor forgoes profits in the pioneers' IPO, but in return prevents the leakage of his information and hence secures his informationally advantaged position for the coming wave of IPOs. Notice the asymmetry in such strategic behavior. An informed investor with good news gains from saving his information for future use, but an informed investor with bad news does not. This is because of the natural asymmetry built into one-sided auctions. By overbidding, an informed investor with bad news would lose money in the P-auction. Moreover, such a move would only make the uninformed investors more aggressive in the F-auction, since they would mistakenly believe that the winning investor has good news. Therefore, overbidding in the early auction does not provide an informational advantage to the informed investor that can be exploited in the future offerings when he has received bad news. The next section will show that this asymmetry in the incentives of informed investors who receive good versus bad news has important implications for the information content of the outcome of the pioneers' IPO.

3.2 The IPO decisions of followers

This section characterizes the IPO decision of a follower, given the outcome of the P-auction. Suppose that in equilibrium, an informed investor with good news conceals his information with probability q in the P-auction. Consider a follower firm with a project discovery probability of ω. If the follower chooses to wait until year 2, with probability $1-\omega$ it will not discover a project and will not need to go public. With probability ω, it will discover a project and will go public in year 2 to raise financing. The cost of this potential year-2 IPO is the same as in the benchmark case, which is $p\alpha/2$ (see the proof of Proposition 2 in Appendix B). The probability of a year-2 IPO is ω; hence, the year-1 expected issue cost of the follower when it chooses to wait is

$$C^{Wait} = \frac{p}{2}\omega\alpha \tag{13}$$

The follower compares this cost to the expected issue cost of going public in the F-auction, that is, immediately after observing the outcome of the

P-auction. There are two possible outcomes: either the P-auction price is the high price V_H^P, or it is the low price $V_U^P(q)$. First consider the high price V_H^P. This price obtains only when at least two informed investors bid high. Thus the information asymmetry is resolved upon observing V_H^P. Then the year-1 issue cost of the follower is zero, since its shares will get their fair price from the now symmetrically informed investors. Consequently, upon observing V_H^P, the follower goes public regardless of ω.

Next, consider the low price $V_U^P(q)$. Observing this price realization, the follower infers that information may still be asymmetric among investors. For example, it may be the case that there is no high bid V_H^P, and therefore the uninformed investors cannot tell whether there is bad news or the informed investor(s) have strategically concealed good news.[17] Now the IPO decision of the follower is not trivial; the expected issue cost of going public in year 1 is positive. This cost is given by

$$\begin{aligned} C^{Issue}(q) &= \left[\frac{pq}{1+\sum_{k=1}^{\infty} p(1-p)^{k-1}(q^k + k(1-q)q^{k-1})}\right]\alpha \\ &= \left[\frac{pq(1-q+pq)^2}{(1-q+pq)^2 + p(1-(1-p)q^2)}\right]\alpha. \end{aligned} \tag{14}$$

Recall that only an informed investor who has concealed good news can extract rents in the F-auction and will do so only if there are no other informed investors. The term in brackets in (14) is the probability of this event conditional on having observed the low P-auction price $V_U^P(q)$. Lemma B.1 in Appendix B shows that in this state of the world, the investor who has concealed his information wins the F-auction and extracts a rent of α per follower going public. Therefore, we get the expected issue cost (14) for a follower conditional on having observed $V_U^P(q)$.

In (14), $C^{Issue}(0) = 0$ and $C^{Issue}(1) = p\alpha/2$. Intuitively, if informed investors never conceal their information ($q = 0$), the outcome of the P-auction always resolves the asymmetry of information, and the follower can go public subsequently at zero cost. Therefore, if $q = 0$, all followers will go public after the P-auction. At the other extreme, if informed

[17] It is important to emphasize that the asymmetry in the information content of high versus low price realizations is not an artifact of employing second price auctions in the analysis. For example, in the benchmark case where a single IPO is considered, both the high and the low price realizations resolve the informational asymmetry between the informed and the uninformed investors. The low price becomes less informative than the high price only when the informed investors strategically conceal their information in anticipation of clustering. One can also show, at a cost of complicating the algebra, that the same results hold with first price auctions; that is, that the low price realization becomes less informative when a subsequent clustering of IPOs is anticipated.

investors always conceal their information ($q = 1$), the outcome of the P-auction does not reveal any information at all. But with no information spillovers from the P-auction, the issue decision of a follower is identical to the decision in the benchmark case. From Proposition 2, a follower strictly prefers to wait until year 2 rather than paying the high issue cost of $p\alpha/2$ in year 1. Hence, if $q = 1$, no follower goes public subsequent to the P-auction. In the intermediate cases $q \in (0,1)$, a follower compares (13) to (14) to make its decision. Let

$$\omega^*(q) = \frac{2q(1-q+pq)^2}{(1-q+pq)^2 + p(1-(1-p)q^2)} \tag{15}$$

denote the cutoff project discovery probability ω at which (13) equals (14).[18] Firms with $\omega > \omega^*(q)$ decide to go public in year 1, as waiting is more costly than issuing immediately for these firms. Firms with $\omega < \omega^*(q)$, on the other hand, choose to wait, as they are less likely to discover projects in the future and consequently their waiting options are more valuable.

3.3 Equilibrium

Let q^e, ω^e, z_p^e, and z_f^e denote the equilibrium quantities. First, notice that $q^e = 0$ is not an equilibrium outcome. At $q^e = 0$, the issue cost in the P-auction is the same as in the benchmark case. Recall from Proposition 2 that in this case, firms prefer waiting to going public. Therefore $z_p^e = 0$, that is, all firms choose to be followers. Now, suppose that one firm deviates and decides to be a pioneer. Since $q^e = 0$, the public believes that the outcome of the P-auction will resolve the asymmetry of information. Hence all followers will subsequently go public in the F-auction, that is, $z_f^e = 1$. But then, case (iii) of Proposition 3 applies: $z_p^e/z_f^e = 0$, which implies $q^*(z_p^e, z_f^e) = 1$, contradicting the firms' belief that $q^e = 0$. In other words, when informed investors are anticipated to reveal their information completely in the P-auction, firms are better off waiting. But this creates incentives for investors to conceal their information should some firms go public in the P-auction, breaking the sustainability of the belief $q^e = 0$.

Similarly, $q^e = 1$ is not an equilibrium outcome. At $q^e = 1$, the issue cost in the P-auction is zero. Intuitively, if informed investors never reveal any information, the uninformed do not face a winner's curse problem, and thus they are willing to pay the *ex ante* expected value of the firm. At zero cost, all firms decide to go public in the P-auction, that is, $z_p^e = 1$ and $z_f^e = 0$. But then, part (i) of Proposition 3 applies: $z_p^e/z_f^e = \infty$, which implies $q^*(z_p^e, z_f^e) = 0$, contradicting the firms' belief that $q^e = 1$. In other words, when informed investors are anticipated to conceal their information completely, the information rents become zero, inducing all

[18] For $p > 1/8$, (15) is guaranteed to be a probability, that is, $\omega^*(q) \in [0, 1]$ for any $q \in [0,1]$.

firms to go public early. But with no firms remaining private, investors' incentives to conceal their information is eliminated, breaking the sustainability of the belief $q^e = 1$.

The intermediate case $q^e \in (0,1)$ corresponds to part (ii) of Proposition 3, which requires $\overline{Y} > \frac{z_p}{z_f} > \underline{Y} > 0$. It follows that with $q^e \in (0,1)$, both z_p and z_f are positive. Let C_p and C_f denote the expected issue costs in the P-auction and the F-auction, respectively, where the expectations are taken before either auction takes place. For z_p to be positive, it must be the case that $C_p \leq C_f$; otherwise no firm would prefer to be a pioneer. For z_f to be positive, it must be the case that $C_f \leq C_p$; otherwise those firms that make up z_f would be better off joining the pioneers. Therefore,

$$C_p \equiv \left(\frac{1}{2}\sum_{k=1}^{\infty} kp(1-p)^{k-1}q^{k-1}(1-q)\right)[C(\omega) + \alpha - V_U^P(q)] = \frac{1}{2}pq\alpha \equiv C_f. \quad (16)$$

Above, the left-hand side is the expected issue cost in the P-auction. The term in parentheses is the probability that one informed bidder with good news bids high and others, if there are any, bid low in the P-auction. In these states of the world, the winner of the P-auction extracts the rent in the bracketed term. The right-hand side is the expected issue cost of the F-auction. Only an investor who has concealed good news can make a profit in the F-auction and only in those cases when there are no other informed investors. The probability of this event is $pq/2$, and the investor's profit is α. Substituting from (6), solving for the infinite sum, and rearranging, (16) can be written as

$$1 - q - q(1 - q + pq)(1 - q + 2pq) = 0. \quad (17)$$

Some algebraic manipulation shows that there exists a unique $q^e \in (0,1)$ that solves (17).[19] Given this value of q^e, the other equilibrium quantities are determined easily as follows:

$$\omega^e = \frac{2q^e(1 - q^e + pq^e)^2}{(1 - q^e + pq^e)^2 + p(1 - (1-p)(q^e)^2)},$$

$$z_p^e + z_f^e = 1 - G(\omega^e), \quad (18)$$

$$\frac{z_p^e}{z_f^e} = (1 - q^e + pq^e)(1 - q^e + 2pq^e)$$

[19] Specifically, let $f(q)$ be the function on the left hand side of (17). The existence of a solution $q^e \in (0,1)$ to $f(q) = 0$ is guaranteed by the facts that $f(0) > 0$, $f(1) < 0$, and that f is continuous. Also, $f'(q) < 0$ for any $q \in (0,1)$ such that $f(q) = 0$. Therefore there can be at most one solution to $f(q) = 0$ in the (0,1) interval, that is, q^e is unique.

The first line of (18) restates (15); it gives the equilibrium cutoff project discovery probability ω^e such that firms with $\omega < \omega^e$ choose to remain private after observing the low price realization in the P-auction. Therefore all of these firms are followers. The remaining firms with $\omega > \omega^e$, which have a measure of $1 - G(\omega^e)$, go public either in the P-auction or the F-auction, hence the second line of (18). Whether an individual firm in this set chooses to be a pioneer or a follower is indeterminate, since by (17), the firm is indifferent between the two auctions. However, the equilibrium ratio of pioneers to followers within the set of firms $\{\omega > \omega^e\}$ is determinate, given by the third line of (18). This simply restates $Y(q) = z_p/z_f$ (from part (ii) of Proposition 3), which must be satisfied for informed investors to be indifferent between the high and the low bids in the P-auction. In equilibrium, the total measure of followers is $z_f^e + G(\omega^e)$. All of these followers go public in the F-auction if the P-auction price realization is high, since then the asymmetry of information is resolved. However, only those with $\omega > \omega^e$, that is, a measure of z_f^e, choose to go public if the P-auction price realization is low. Thus, we obtain the main result of the article:

Proposition 4. *In equilibrium, the IPO volume following the high price realization of the P-auction is higher than the IPO volume following the low price realization.*

In deciding when to go public, each firm attempts to minimize the information rents investors are expected to extract. In contrast, investors desire to trade on their information when such rents are maximal. The tension between these two timing objectives shapes the equilibrium. If the set of pioneers is very small relative to the followers, investors are better off concealing their information early on. This makes the pricing of a pioneer's IPO less sensitive to private information, alleviating the winner's curse problem for the uninformed and hence reducing the cost of going public. At the same time, it becomes less attractive for a firm to wait and free-ride on the information spillover, as the pioneers' IPOs are expected to reveal scant information. For both reasons, the pioneer set attracts more firms, and the follower set shrinks. At the other extreme with a very large set of pioneers, investors have no reason to conceal their information, as few followers remain to be exploited in the future. With pioneers' IPO outcomes expected to reflect plenty of information, firms' free-riding incentives become stronger. As a result, the set of followers expand at the expense of pioneers. Equilibrium obtains when the spillover effect is just strong enough to make an issuer indifferent between the two IPO dates. While both dates attract issuers in equilibrium, the preference for waiting is strict for some of the followers, namely those with relatively low project discovery probabilities. These firms go public subsequently only if the pioneers' offer prices turn out to be high. The result is the asymmetric response of the IPO volume to offer prices described in Proposition 4.

Recall that the expected number of informed investors is $1/p$. Therefore lower values of p correspond to a more competitive informational environment.

Proposition 5 (Comparative Statics for *p*). *As p decreases,*

(i) q^e *increases.*
(ii) z_p^e/z_f^e *decreases.*

An investor conceals his information early on so that he can profit from it in the next round of IPOs. His ability to do so crucially depends on whether there are other informed investors in the market. All else equal, a decrease in p makes it more likely that other informed investors exist, and hence reduces the per-follower profit the investor expects to make in the F-auction. This has two equilibrium implications. First, the reduced information rent of the F-auction tilts firms toward being followers. Since some firms have to be pioneers in equilibrium, q^e must change in such a way as to restore the relative attractiveness of being a pioneer. This happens via an increase in q^e, which reduces the information content of the outcome of the P-auction and thus increases the relative cost of going public for a follower. Second, the profitability of the F-auction relative to the P-auction must be restored in order to keep the informed investors indifferent between bidding high and low. The decrease in pioneer-to-follower ratio facilitates this by shifting some of the information rents from the P-auction to the F-auction.

4. Dynamic Analysis

The analysis so far has illustrated the endogenous formation of information spillovers in a simple two-period setup. To examine the dynamic patterns in the spillover effect, I now turn to the general case with $T > 2$ and $\beta < 1$.

In the model, hot markets occur during periods when firm values are relatively highly correlated. Various macroeconomic and technological shocks outside the model contribute to the emergence as well as the eventual demise of such periods. For example, a hot market may come to an unexpected end when the economy is hit by a downturn that adversely affects the firms' current cash flows and makes their valuation more sensitive to idiosyncratic future prospects. The parameter β captures this uncertainty in the length of the hot period. When $\beta = 1$, a firm knows that it has exactly T chances to go public during the clustering period. In the more realistic case $\beta < 1$, each period $t < T$ is followed by either another period $t + 1$, or a shock that ends the hot market, where the two events have probabilities β and $1 - \beta$, respectively.

The β shock makes a firm's timing problem more involved and interesting. Recall that when $\beta = 1$, each firm j with $\omega_j > \omega^e$ is indifferent between being a pioneer and a follower in equilibrium. In contrast, the timing preferences are strict for all firms except a measure-zero set when $\beta < 1$. To understand why this is so, consider a firm l that is indifferent between going public in the current period t and waiting for another period. Firm l's cost of waiting is a probability-weighted average of the issue costs in various future paths. In some of these paths, the β shock is realized and the hot market ends, leaving the firm with the expected issue cost of going public in year 2, which is increasing in ω_l. Now consider another firm j with $\omega_j > \omega_l$. For both firms, the issue cost of period t is the same as it does not depend on ω. However, the cost of waiting for firm j is higher, since in those future paths where the hot market ends, firm j will experience a larger year-2 expected issue cost. It follows that all firms j with $\omega_j > \omega_l$ strictly prefer going public in the current period t to waiting. Since the equilibrium exhibits the same property for all periods, the model with $\beta < 1$ puts more structure on the IPO timing problem of a firm.

Formally, the equilibrium is characterized by vectors $q^e = (q_1,..., q_T)$, $\omega^e = (\omega_1,..., \omega_T)$ such that

(i) An informed investor with good news plays a revealing strategy in period T: $q_T = 0$;
(ii) After $t - 1$ periods with low price realizations, an informed investor with good news bids low with probability q_t and high with probability $1 - q_t$ in period t;
(iii) Firms with project discovery probabilities $\omega \in [\omega_1, 1]$ go public in the first period;
(iv) Firms with $\omega \in [\omega_t, \omega_{t-1})$ go public in period t if period $t - 1$ price is low;
(v) Firms with $\omega \in [0, \omega_{t-1})$ go public in period t if period $t - 1$ price is high.

The structure of the dynamic equilibrium is similar to the two-period equilibrium of Section 3. Investors play a revealing strategy in period T, as it is their last chance to use their information. In previous periods, however, they are likely to conceal their information. After observing the outcome of period $t - 1$, and provided that the market proceeds to period t, remaining private firms decide whether to go public immediately or wait. If period $t - 1$ price realization is high, the asymmetry of information is resolved and all remaining firms go public in period t. If the price realization is low, only some firms, those with project discovery probabilities above the threshold ω_t go public.

The system of equations characterizing the equilibrium are formally stated in Appendix A. While similar to the equilibrium conditions in Section 3, these equations constitute a more complicated system due to the larger number of periods involved. As a result, I analyze the dynamic equilibrium numerically. For the base case analysis, I assume that the project discovery probabilities of firms are distributed uniformly in [0,1], that is, $G(\omega) = \omega$. I pick $T = 10$, $\beta = 0.95$, and $p = .4$ for the remaining base case parameters.

Table 1 summarizes the results. Notice that q_t decreases in t and does so at an increasing rate. Investors tend to reveal very little information in the early periods, as the pool of private firms is large and the incentive to conceal information is strong. As more firms proceed with their offerings, fewer potential IPO firms remain. Accordingly, investors start bidding more aggressively in later periods.

The IPO volume is very low in the first period; only those firms with very good investment opportunities ($\omega > 0.966$) go public. The last column in Table 1 reports the probability that good news still remains private information at the end of period t, conditional on the market lasting at least t periods. Not surprisingly, the degree of informational asymmetry is quite high early on. As a result, low price realizations are followed by little IPO activity in the early periods. Recall that after a high price realization, all remaining firms go public. Therefore, IPO volume is highly sensitive to market conditions at the beginning of a hot market. This is illustrated in the fourth column of Table 1, which reports the ratio of the IPO volume following a high price outcome to the volume following a low price. For instance, a high price in the first period triggers about 23 times as many subsequent IPOs as a low price does. In time, information

Table 1
Base case equilibrium

t	q_t	ω_t	Vol^H/Vol^L	Pr(H concealed)
1	0.893	0.966	—	0.770
2	0.878	0.923	22.69	0.593
3	0.863	0.871	17.91	0.456
4	0.846	0.810	14.19	0.349
5	0.823	0.738	11.21	0.263
6	0.793	0.654	8.78	0.193
7	0.748	0.557	6.75	0.134
8	0.670	0.446	5.03	0.084
9	0.509	0.320	3.53	0.040
10	0.000	0.176	2.23	0.000

Base case parameter values are $T = 10$, $\beta = .95$, and $p = .4$. Firms' project discovery probabilities are uniformly distributed in [0,1]. The second and third columns above report q_t and ω_t for each round t. The fourth column displays the ratio of the IPO volume following a high price realization to the volume following a low price realization. The last column is the *ex ante* probability that good news remain private information at the end of round t conditional on round t being reached.

gets relatively less asymmetric, as it becomes less likely that investors are holding back good news. Therefore in the late part of a clustering period, IPO volume responds less sharply to the outcomes of recent offerings.

To examine the effects of increased competition among informed investors, I now replicate the above analysis for $p = .2$, keeping other parameter values as in the base case. The resulting equilibrium is summarized in Table 2. A comparison of Table 2 to Table 1 shows that Proposition 5 generalizes to the multi-period setting. For all t, q_t is higher when p is lower. In words, an investor is more likely to hold back information when he faces more competition. Of course, this by itself would not necessarily imply less information revelation, as the expected number of informed investors is not constant across the two tables. However, the last column of Table 2 shows that the degree of informational asymmetry indeed remains higher when there is more competition among informed investors. This results in a thinner IPO market that attracts only those firms with relatively good investment opportunities (column three). It follows that with more competition, IPO volume is more sensitive to recent outcomes at every period (column four).

At first look, these are counter-intuitive results. Why would more competition hamper information spillovers and reduce the IPO volume? After all, competition should lead to lower information rents, and if anything, encourage going public. Issue costs are indeed lower with more competition, yet this is true for hot and cold markets alike (i.e., not only for year 1, but also for year 2). Hence, a more competitive market structure does not necessarily favor more clustering. We have seen in the previous section that all else being equal, firms' free-riding incentives become stronger under increased competition. Restoring equilibrium then requires a weakening of the spillover effect so that not all firms choose to wait and free-ride. The by-product of this adjustment is a hot market where less information is revealed and fewer firms go public.

Table 2
Increased competition among informed investors: p = .2

t	q_t	ω_t	Vol^H/Vol^L	Pr(H concealed)
1	0.959	0.989	—	0.824
2	0.951	0.975	69.49	0.674
3	0.941	0.956	52.38	0.547
4	0.928	0.932	39.13	0.438
5	0.909	0.900	28.84	0.344
6	0.882	0.856	20.85	0.260
7	0.837	0.798	14.65	0.187
8	0.758	0.717	9.86	0.120
9	0.584	0.601	6.19	0.058
10	0.000	0.426	3.43	0.000

Table 3 summarizes the impact of reducing β. Concealing good news is a less attractive strategy in this case, since the hot market is more likely to end without giving the investor another chance to trade. As a result, investors make relatively more aggressive use of their information. This has an asymmetric effect on the IPO volume in the early versus late parts of clustering. The early periods attract fewer firms relative to the base case, as the increased presence of informed investors amplifies issue costs. At the same time, each period ends up revealing more information due to more aggressive informed bidding. Eventually, enough information is revealed to dominate the effect of increased informed participation, so late periods attract more issuers relative to the base case. Similarly, the sensitivity of IPO volume to past outcomes is higher at the start of the hot market, but lower at the end.

The growth potential of a firm is captured by its project discovery probability ω in the model. The numerical analysis so far presented cases where the distribution of firms with respect to ω is uniform. Table 4 illustrates the equilibrium when firms have relatively poorer growth prospects. Specifically, $G(\omega) = 1 - (1 - \omega)^3$ in Table 4; therefore the density function $g(\omega) = 3(1 - \omega)^2$ puts more weight on small project discovery probabilities relative to the uniform distribution. Since the typical firm is less likely to need financing in this case, it requires more information to be revealed before going public. Therefore fewer firms go public in every period relative to the base case. Investors are more likely to save information for future use, as the pool of potential issuers remains larger at any given time. The sensitivity of IPO volume to recent price outcomes is higher throughout the hot market. In terms of project discovery probabilities, the pioneers that start the hot market are of lower quality relative to the base case. This is true for early followers as well. However, the very late followers are in fact of higher quality (compare period 10 in Tables 1 and 4). In other words, the quality of issuers deteriorates more slowly as the hot market progresses.

Table 3
Reduced likelihood of an extended hot market: β = .90

t	q_t	ω_t	Vol^H/Vol^L	Pr(H concealed)
1	0.845	0.972	—	0.686
2	0.812	0.934	25.33	0.467
3	0.784	0.883	18.38	0.318
4	0.751	0.818	13.57	0.213
5	0.715	0.737	10.11	0.140
6	0.674	0.639	7.53	0.088
7	0.626	0.523	5.51	0.053
8	0.561	0.389	3.88	0.029
9	0.439	0.234	2.52	0.012
10	0.000	0.058	1.33	0.000

Table 4
Fewer firms with high growth potential: $G(\omega) = 1 - (1 - \omega)^3$

t	q_t	ω_t	$G(\omega_t)$	Vol^H/Vol^L	Pr(H concealed)
1	0.912	0.730	0.980	—	0.806
2	0.902	0.649	0.957	41.54	0.651
3	0.891	0.585	0.929	34.07	0.524
4	0.875	0.529	0.896	28.01	0.417
5	0.854	0.477	0.857	23.01	0.327
6	0.823	0.426	0.811	18.84	0.247
7	0.775	0.377	0.758	15.30	0.177
8	0.693	0.328	0.696	12.28	0.113
9	0.523	0.279	0.624	9.67	0.055
10	0.000	0.228	0.540	7.42	0.000

5. Empirical Implications

As discussed in the introduction, Lowry and Schwert (2002) and Benveniste, Ljungqvist, Wilhelm, and Yu (2003) find that firms attempt to time IPO market conditions. Unexpectedly high offer prices are followed by dramatic increases in the numbers of initial filings and completed offerings, whereas low prices lead to an increase in withdrawal rates. These findings are consistent with a number of explanations. For example, if macroeconomic or sector-wide expectations about the profitability of investment are time-varying, increasing expectations would cause positive price revisions for pioneers' IPOs, and at the same time, would trigger IPOs of other firms whose financing needs have just risen. As indicated above, however, the link between the clustering of financing activities and real investment is weak in the data. Alternatively, as Baker and Wurgler (2002) suggest, issuers may be timing investor sentiment. Positive price revisions of pioneers may simply signal high investor sentiment and attract more firms to the IPO market.

This article offers an alternative explanation for IPO market timing that emphasizes the role of information spillovers. Anecdotal as well as empirical evidence suggests that IPO offer prices are highly sensitive to institutional demand; underwriters gather the input of key investors in pricing new issues and award these investors with favorable allocations and prices in return.[20] In going through this process a potential issuer benefits from observing the outcomes of recent IPOs, as these outcomes reflect investors' demand. The strength of this spillover effect is likely to

[20] Aggarwal, Prabhala, and Puri (2002) find that institutional investors are awarded with more shares when they indicate demand for issues priced at the upper end of the filing range, which are also expected to appreciate more in the secondary market. More direct evidence comes from Cornelli and Goldreich (2001, 2003), who use detailed data on investors' indications of interest. They show that although the number of bids is usually large, only a small fraction of these bids provide information in setting the offer price. Moreover, the investors who submit these larger and more informative bids are awarded with more shares.

be a major determinant in a firm's decision to go public. The central prediction of this article is that higher offer price outcomes better facilitate the spillover effect, that is, they are more informative about investors' demand for new issues. In other words, it is the *information content*, not the *level*, of high IPO offer prices that triggers subsequent issue activity.

In this regard, the distinguishing empirical implications of the model relate to measures of uncertainty and informational asymmetry among market participants. If high price outcomes indeed result in less uncertainty and more symmetric information, subsequent valuation of both the newly public firms and the new offerings should become relatively easier. In particular, the secondary market trading of the pioneers should be more liquid (lower bid-ask spreads, smaller price impact of trades), and the book-building process for the followers should involve less uncertainty (tighter filing ranges, smaller price revisions in absolute value). These patterns should be more pronounced early on in a hot market, when the pool of potential issuers is large and the degree of valuation uncertainty high (see Section 4).[21]

The model also provides predictions about the investment policies of hot market issuers. The hot market is triggered by the IPOs of pioneers, which are firms with good investment opportunities. Followers, on the other hand, have weaker growth prospects. As a result, followers are more likely to hold onto IPO proceeds for extended periods of time. These predictions have not been formally tested before; however, some supporting evidence exists. For example, Van Bommel and Vermaelen (2003) show that firms whose IPOs are more underpriced invest at higher rates subsequent to becoming public. Since underpricing constitutes a cost to the issuing firm, these firms resemble the pioneers in the model, which face relatively high issue costs and possess better investment projects. More direct evidence comes from Altı (2005), who finds that hot market issuers add more of the IPO proceeds to their cash balances relative to their cold market counterparts. This finding is consistent with the prediction that followers tend to sit on the cash they raise, as most of the hot market issuers are by definition followers.

The results in Section 4 yield further testable implications with regard to issuers' investment and cash holding policies:

- Issuer quality increases with the degree of competition among informed investors. Deeper markets with greater institutional investor participation result in IPO clusters where both the pioneers and the followers are less likely to sit on the cash they raise.

[21] Consistent with these predictions, Benveniste, Ljungqvist, Wilhelm, and Yu (2003) find that followers experience smaller price revisions than pioneers and that this pattern is stronger in the early part of the hot market.

- The likelihood of a change in market conditions is captured by β in the model. Low β values correspond to highly volatile markets where information gets stale relatively quickly. Comparing Table 3 to Table 1, pioneers and early followers are predicted to be high quality firms in high volatility environments. Conditional on a long clustering period, however, late followers are of lower quality in the high volatility case.
- Issuer quality deteriorates faster through time in the case of the high growth industries. The pioneers are highly likely to invest, whereas the late followers are highly likely to sit on the cash. Mature industries that lack growth opportunities exhibit a less pronounced time-series pattern in this regard.

6. Conclusion

This article presents a model of information spillovers in IPOs. The IPO timing decision of a firm is driven by its concern to minimize the offer mispricing, which obtains because of asymmetric distribution of information among investors. A hot market starts when common factors become relatively more important determinants of firms' values. Information spillovers from pioneers' IPOs help reduce uncertainty on common valuation factors and make going public less costly for the followers. IPO market timing emerges as an equilibrium outcome in this setup. High offer price realizations for pioneers better reflect investors' information, facilitate a stronger spillover effect, and hence trigger a larger number of subsequent IPOs. The model emphasizes one reason for this to happen, namely, the strategic use of information by long-term investors in the IPO market. More generally, any factor that creates uncertainty about the presence of informed investors in pioneers' offerings can give rise to the same outcome: a high price reveals good news, but a low price only reveals lack of high bids, and not necessarily bad news.

The dynamic analysis shows that the jump in the IPO volume in response to high offer prices is more pronounced early on in a hot market. Issuer quality declines as the hot market progresses. Pioneers are more likely to use the IPO proceeds for investment in the near future, whereas followers tend to hold onto these proceeds for extended periods of time. Further testable implications of the analysis relate hot market dynamics to the depth of the institutional investor presence in the IPO market and the industry characteristics of the issuers.

Appendix A: Characterization of the Dynamic Equilibrium

(i) Indifference conditions of firms $\{\omega_1,..., \omega_{T-1}\}$: After observing $t-1$ low price realizations, firm ω_t is indifferent between going public in period t and waiting if and only if

$$\begin{aligned} C_t^{wait} &\equiv (1-\beta)\tfrac{p}{2}\omega_t\alpha + \beta\left(\sum_{k=1}^{\infty} P_k^H(q_1,...,q_{t-1})q_t^k k(1-q_{t+1})q_{t+1}^{k-1}\right)\pi(q_1,...q_{t+1}) \\ &= \left(\sum_{k=1}^{\infty} P_k^H(q_1,...,q_{t-1})k(1-q_t)q_t^{k-1}\right)\pi(q_1,...,q_t) \equiv C_t^{issue},\ t\in\{1,...,T-1\} \end{aligned} \tag{A1}$$

Above, $P_k^H(q_1,...,q_{t-1})$ is the public's posterior that there are k informed investors with good news given $t-1$ low price realizations. The term $\pi(q_1,..., q_t)$ is an investor's profit when he wins with a high bid and pays the uninformed bid:

$$\pi(q_1,...,q_t) = C(\omega_t) + \alpha - V_U\left(\prod_{s=1}^{t} q_s\right), \tag{A2}$$

where the uninformed bid $V_U(q)$ is calculated as in (6).

(ii) Indifference condition of firm ω_T: Since T is the last period, a firm that waits in this period defers its potential IPO until year 2. Accordingly, the indifference condition of firm ω_T is obtained by setting $\beta = 0$ in (A1).

(iii) Indifference condition of an informed investor with good news in period $t \in \{1,..., T-1\}$:

(a) If $q_t \in (0,1)$, then

$$\begin{aligned} &\beta\left[\sum_{k=1}^{\infty} P_k^I(q_1,...,q_{t-1})(q_t q_{t+1})^{k-1}\right]\pi(q_1,...,q_{t+1})[G(\omega_t)-G(\omega_{t+1})] \\ &= \left[\sum_{k=1}^{\infty} P_k^I(q_1,...q_{t-1})q_t^{k-1}\right]\pi(q_1,...,q_t)[G(\omega_{t-1}) - G(\omega_t)],\ t\in\{1,...,T-1\} \end{aligned} \tag{A3}$$

Above, $P_k^I(q_1,...,q_{t-1})$ is the investor's posterior that there are $k-1$ other informed investors given $t-1$ low price realizations. The first line of (A3) is the expected profit when the investor bids low in period t and plans to bid high in period $t+1$ in case the hot market continues. The second line is the expected profit from bidding high in period t.

(b) If $q_t = 0$, then

$$\begin{aligned} &\beta P_1^I(q_1,...,q_{t-1})\pi(q_1,...q_{t+1})[G(\omega_t) - G(\omega_{t+1})] \\ &\le P_1^I(q_1,...,q_{t-1})\pi(q_1,...q_t)[G(\omega_{t-1}) - G(\omega_t)]. \end{aligned} \tag{A4}$$

This condition states that when $q_t = 0$, the expected profit from bidding high in period t should be at least as large as the expected profit from deviating to a low bid.

(iv) Equilibrium: The dynamic equilibrium is characterized by $q^e = \{q_1,..., q_T\}$ and $\omega^e = \{\omega_1,..., \omega_T\}$, which solve the recursive system of equations (A1) and (A3), with the boundary conditions (A4) and $q_T = 0$.

Appendix B: Proofs of Results

Proof of Proposition 1. (i) If the discovery occurs, the payoff will be F; otherwise shareholders will get I. Hence, the project related payoff is $\omega F + (1-\omega)I$. Also, the assets in place will generate X_2 in year 2, whose year-1 expected value is $\alpha/2$. The sum of these two components is $C(\omega)$. Notice that there is no asymmetric information about $C(\omega)$ in year 1. The asymmetric information is about X_1. First, consider the bid by a good-news informed investor, say investor 1, given the equilibrium strategies of other investors. If investor 1 bids V_H, then either there are other informed investors who also bid V_H, or there is no other informed investor. In the first case, the expected profit from winning a share is $C(\omega) + \alpha - V_H = 0$. In the second case, all other investors bid V_L; hence, the profit is $C(\omega) + \alpha - V_L = \alpha$. Now, by bidding $V < V_L$, investor 1 can never win. Bidding any $V \in (V_L, V_H)$ results in the same expected profit as with bidding V_H, since the auction price is the second highest bid. Finally, bidding $V > V_H$ makes investor 1 win more shares when there are other informed investors, but the profit per share in this state of the world is zero. Comparing all three cases, bidding V_H is a best response for investor 1. Now consider a bad-news informed investor, say, investor 2. His equilibrium payoff is zero, since the price he pays V_L equals the value of the shares C. By bidding $V > V_L$, investor 2 gets more shares but obtains the same payoff of zero since per share profit is zero. Therefore, bidding V_L is a best response for investor 2. Finally, an uninformed investor makes zero profits by bidding V_L, since he wins shares only when the informed investor(s) bid low. By bidding $V > V_L$, he would obtain the same per share payoff zero, and only win more shares. Hence, V_L is a best response for an uninformed investor.

(ii) The proof in this case is identical to case (i), except that $C = F + X_1$, since $\omega = 1$ for a firm going public in year 2, and X_1, the payoff from year 1 performance, has already become public information.

(iii) After the auction, the realized price is announced. If the price is V_H, all investors learn that the news is good. If the price is V_L, but investors who bid V_L do not get any shares, they conclude that there is a high bid, and hence the news is good. Finally, if the price is V_L and all investors get a positive allocation, they conclude that the informed investor(s) have bad news. Thus, information becomes symmetric after the auction is completed.

Proof of Proposition 2. Since the net present value (NPV) of the project is assumed to be large enough to always induce investment, the IPO is a zero-sum game between the issuer and the investors. Therefore, from the viewpoint of the issuer, the objective of maximizing the expected proceeds coincides with the objective of minimizing the expected rents that accrue to the investors. Consider a firm with project discovery probability ω. If the firm waits until year 2, then with probability $1 - \omega$ there will not be any discovery, and the firm will not need to go public. In this case the expected profits of investors is zero. With probability ω, the discovery takes place and the firm goes public in year 2. From Proposition 1, investors capture rents only when there is one informed investor and the news is good. The probability of this event is $p/2$, and the informed investor earns a profit of α in this case. Then, the year-1 expected cost of going public in year 2 is $p\omega\alpha/2$. If the firm goes public in year 1, the expected cost is again $p\alpha/2$. Since $\omega < 1$, the firm strictly prefers waiting until year 2 to going public in year 1.

Lemma B.1 (The F-auction Equilibrium): *Suppose that the measure of followers that decide to go public after the P-auction is z_f. Let $R(X_1) \equiv \alpha$ if the outcome of the P-auction has revealed good news to the uninformed investors and $R(X_1) \equiv 0$ otherwise.*

(i) The following bids constitute an equilibrium of the F-auction for a follower with project discovery probability ω:

$$V_U^F(\omega) = C(\omega) + R(X_1),\ V_L^F(\omega) = C(\omega),\ V_H^F(\omega) = C(\omega) + \alpha \tag{B1}$$

(ii) The aggregate F-auction profit of an informed investor with good news who has concealed his information in the P-auction is αz_f if there is no other informed investor and zero otherwise.

Proof of Lemma B.1. (i) First, consider the uninformed bid in the first line of (B1). An uninformed investor wins only when there is no good-news investor who has concealed his information. In this case the bid in the first line of (B1) breaks even. Bidding $V > V_U^F(\omega)$ gives the same per share profit of zero; therefore, winning more shares by bidding higher does not increase the payoff. Hence, $V_U^F(\omega)$ is optimal for an uninformed investor. Next, consider a bad-news informed investor. With the bid in the second line of (B1) he breaks even. Since all other investors will bid at least $V_L^F(\omega)$, the bad-news investor cannot hope to bid higher and make a positive profit. Thus, $V_L^F(\omega)$ is optimal for a bad-news informed investor. Finally, consider a good-news informed investor who has concealed his information. Since the selling mechanism is a second price auction, this investor will choose a bid that maximizes the number of states in which he wins and pays less than or equal to the true value of the firm. Since, given the strategy profiles in (B1), the good-news investor can never overpay, he is willing to bid as high as possible. Then, any bid $V > V_U^F(\omega)$ is optimal.

(ii) When there is only one informed investor with good news and he has concealed his information, the F-auction price is $V_U^F(\omega)$, whereas the true value of the firm is $V_U^F(\omega) + \alpha$. Therefore, the increment α is the profit of the good-news winner. Since the measure of followers that go public in the F-auction is z_f, the aggregate F-auction profit of the good-news winner is z_f α. If there are multiple informed investors with good news, they all bid $V_H^F(\omega)$, which equals the true value of the firm given the good news. Hence they all make zero profits in this case.

Proof of Proposition 3. First consider a bad-news investor, say, investor 2. In all three cases, his total expected profit is zero. If investor 2 bids $V \geq V_U^P$, his expected profit is negative, because, unlike the uninformed, he knows that he has bad news. Also, such aggressive bidding can only induce the uninformed to believe that the news is good, which will make them aggressive in the F-auction (see Lemma B.1). Hence, $V \geq V_U^P$ loses money in the P-auction and cannot increase the payoff in the F-auction. Then bidding $V < V_U^P$ is optimal for a bad-news investor. Next, consider an uninformed investor, say, investor 3. Bidding V_U^P has an expected P-auction payoff of zero by construction. From Lemma B.1, F-auction profit of investor 3 is also zero. Bidding $V < V_U^P$ never wins the P-auction. Also, such a bid does not alter the information revealed by the outcome of the P-auction, since only bids $V > V_U^P$ reveal information. Thus, $V < V_U^P$ is not a profitable deviation. A bid $V \in (V_U^P, V_H^P)$ delivers zero P-auction profit (with more shares won, but the same zero payoff per share) and makes other uninformed investors think that investor 3 has good news. Then, other investors bid more aggressively in the F-auction (see Lemma B.1), and this cannot increase investor 3's F-auction profits. Therefore, $V \in (V_U^P, V_H^P)$ has a total payoff of zero as well. Finally, $V \geq V_H^P$ also has a zero payoff, since either there is no high bid and the payoff to investor 3 is as in the previous case with $V \in (V_U^P, V_H^P)$, or there is at least one high bid, in which case investor 3 pays the full information price V_H^P for the shares he wins and therefore makes zero profits. Hence, V_U^P is optimal for investor 3.

Finally, consider a good-news informed investor, say, investor 1. In case (i), any bid $V > V_U^P$ has the same payoff; hence, V_H^P is optimal. In case (ii), a bid $V \in (V_U^P, V_H^P)$ has the same payoff as in equilibrium, since losing to such a bid makes uninformed investors infer that investor 1 has good news. It remains to be shown that bidding V_U^P is not a profitable deviation. Suppose investor 1 bids V_U^P. Relative to bidding V_H^P, his P-auction profit is reduced by a factor of $N + 1$, since when he wins at a profitable state he shares the issue with the uninformed investors. Also, investor 1's F-auction profit upon bidding V_U^P in the P-auction is zero: either there are other informed investors, in which case the informed investors will compete away the rents in the F-auction, or there is no other informed investor, in which case being allocated $1/(N+1)$. of the issue in the P-auction will reveal to the uninformed investors that the deviating informed investor has good news (note that a bad-news informed investor would never deviate to V_U^P, as this deviation would ensure a strictly negative expected profit). Hence, investor 1 strictly prefers bidding V_H^P to bidding V_U^P. In case (iii), any bid $V < V_U^P$ results in a payoff of zero from the P-auction and $p^2 \alpha z_f$ from the F-auction, whereas bidding any $V > V_U^P$ results in a payoff of $\alpha z_p/2$ from the

P-auction and zero from the F-auction. From

$$\frac{z_p}{z_f} \le \underline{Y} \le Y(1) = 2p^2, \tag{B2}$$

it follows that $p^2 \alpha z_f \ge \alpha z_p/2$. therefore bidding $V < V_U^P$ weakly dominates bidding $V > V_U^P$. Bidding $V > V_U^P$ in turn strictly dominates bidding V_U^P, since the bid V_U^P leads to sharing the issue with the uninformed and hence reduces the P-auction profits and also earns zero F-auction profits as it reveals the good news when investor 1 is the only informed investor. Therefore bidding some $V < V_U^P$ is optimal for investor 1.

Proof of Proposition 5. (i) Let $q^e = q(p)$. Taking the derivative of both sides of (17) with respect to p and rearranging gives

$$q'(p) = \frac{(1-q+2pq)q^3 + 2(1-q+pq)q^3}{(2-3p)q^2 - 2(1-p)(1-2p)q^3 - 1} \tag{B3}$$

The numerator of (B3) is positive. Therefore we need to show that the denominator is negative:

$$(2-3p) - 2(1-p)(1-2p)q < \frac{1}{q^2} \tag{B4}$$

If $p \ge 1/2$ (B4) is satisfied, since the two terms on the left-hand side are less than 1/2 and 1/4, respectively. For $p < 1/2$, suppose that (B4) is not satisfied. Then

$$q > q^2 \ge \frac{1}{2-3p} \tag{B5}$$

It follows that

$$\begin{aligned} \frac{1}{q^2} &\le (2-3p) - 2(1-p)(1-2p)q \\ &< (2-3p) - \frac{2(1-p)(1-2p)}{2-3p} = \frac{(1-p)^2 + (1-2p)^2}{(1-p)+(1-2p)} < 1, \end{aligned} \tag{B6}$$

which is a contradiction since $q \in (0,1)$. Therefore (B4) is satisfied and $q'(p) < 0$, which proves part (i).

(ii) From (17) and the third line of (18), $z_p^e/z_f^e = (1-q^e)/q^e$. By part (i), q^e is decreasing in p, hence z_p^e/z_f^e is increasing in p.

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