

A Theory of IPO Waves

Ping He

Department of Finance, University of Illinois at Chicago and Lehman Brothers

In the IPO market, investors coordinate on acceptable IPO price based on the performance of past IPOs, and this generates an incentive for investment banks to produce information about IPO firms. In hot periods, the information produced by investment banks improves the quality of IPO firms, and this allows *ex ante* low quality firms to go public and increases the secondary market price, thus synchronizing high IPO volumes and high first day returns. When investment banks behave asymmetrically in information production, the “reputations” of investment banks are interpreted as a form of market segmentation to economize on the social cost of information production. (*JEL G24, C73*)

In the United States, initial public equity offering (IPO) is a major channel through which private firms receive financing from public investors.¹ However, the number of IPOs and the total proceeds raised fluctuate over time. There are “hot markets” and “cold markets” (see, for example, Ibbotson and Jaffe (1975) and Ritter (1984)). Hot IPO markets have been characterized by an unusually high volume of offerings and severe underpricing, while cold IPO markets have much lower issuance and less underpricing. In this article, a theory of IPO waves is proposed based on the role of investment banks in certifying new firms for IPO. Fluctuations in IPO volume and first day return are an inherent part of the IPO market instead of a result of exogenous variations in economic and secondary equity market conditions.

The existence of IPO market dynamics is a puzzle because the aggregate capital demand of private firms cannot fully explain the fluctuation in IPO volume. Lowry (2003) finds that the variation in IPO volume is far in excess of the variation in capital expenditure. Related to the

This is a revised version of the third chapter of my PhD dissertation at the University of Pennsylvania. I am in debt to my dissertation advisor, Gary Gorton, for his enlightening supervision and tremendous encouragement. Invaluable advice is greatly appreciated from the other members of my dissertation committee, George Mailath, Richard Kihlstrom, Nicholas Souleles and Armando Gomes. I am grateful for insightful comments and constructive suggestions from Maureen O'Hara (the editor) and an anonymous referee. I also want to thank Michael Brennan, Richard Rosen and the seminar participants from University of Pennsylvania, Carnegie Mellon University, University of Illinois at Chicago, New York Fed and Chicago Fed for helpful discussions. Financial supports from the Department of Economics at the University of Pennsylvania and the Department of Finance at the University of Illinois at Chicago are gratefully acknowledged. Address correspondence to Ping He, 601 S Morgan, UH 2431, Chicago, IL 60607, or e-mail: heping@uic.edu.

¹ According to Ritter and Welch (2002), from 1980 to 2001, the number of companies going public in the United States exceeded one per business day, and these IPOs raised \$484 billion (in 2001 dollars) in gross proceeds.

capital demand explanation, some works argue that there is information externality driven by technological innovations causing IPOs to cluster in time (see Stoughton, Wong, and Zechner (2001), Benveniste, Busaba, and Wilhelm (2002), and Maksimovic and Pichler (2001)). But Helwege and Liang (2004) find that industry clustering is not unique to hot markets, and they conclude that technological innovations are not the primary determinant of hot markets because the IPO market cycles with a greater frequency than underlying innovations.

Another line of research on IPO waves links the IPO market to the secondary equity market. Pastor and Veronesi (2005) argue that entrepreneurs time the equity market conditions to exercise their “real option” of taking their firms public. Several other articles suggest that a high IPO volume is due to some form of irrationality or mispricing which “overvalues” IPO firms in a hot period (see Rajan and Servaes (1997, 2003), Lerner (1994), Pagano, Panetta, and Zingales (1998), and Lowry (2003)). Lucas and McDonald (1990) provide a theory of equity offering dynamics with endogenized time varying market “mispricing” due to information asymmetry between investors and entrepreneurs. These market-timing arguments explain well some of the stylized facts in the IPO market and the secondary market, however, the stylized facts in underpricing and its variation across time have been ignored by simply equalizing a high secondary market price to a high payoff to the entrepreneur.

As we have discussed above, there are a few explanations for the dynamics of IPO volume,² but little has been said on the dynamics of first day return. It is hard to explain why firms leave more money on the table when the market is hot (See, for example, Loughran and Ritter (2004)). Our theory generates dynamics in both volume and first day return. In a hot period, the information produced by investment banks makes it possible for investors to accept firms that would have been excluded without information production, and this explains the high volume. At the same time, the produced information improves the *ex post* quality of the IPO firm and drives up the secondary market price, and this leads to a high first day return.

We model the IPO market as a certification game among firms, investors and investment banks, as in Lizzeri (1999). The information asymmetry between IPO firms and outside investors provides two certifying roles for investment banks in IPOs. First, investment banks post underwriting

² Many articles discuss the firms’ decision to go public, and they also shed some light on IPO market dynamics. Subrahmanyam and Titman (1999) explore the linkage between stock price efficiency and the choice between private and public financing. Chemmanur and Fulghieri (1999) study the trade-off between selling to a private venture capitalist (who requires a higher risk premium but has private information about the firm) and selling to numerous small investors (who are less risk averse but can acquire information at a cost). Zingales (1995) argues that going public offers the advantage of a dispersed shareholder base which yields a higher acquisition price.

fee and offer price,³ which determine the number of shares retained by entrepreneurs and affect their incentives to take firms public. Thus, underwriting fee and offer price serve as screening devices that control the quality of the firms that choose to go public. Second, investment banks can acquire information about the quality of IPO candidates, thus improving the quality of IPO firms by selectively approving firms.

Dispersed small investors coordinate on acceptable offer price and underwriting fee, which we interpret as “investor sentiment,” and investment banks charge the fee and set the offer price based on the perceived investor sentiment. We construct an equilibrium in which the acceptable offer price fluctuates over time depending on the performance of past IPO firms. To avoid the “punishment” from investors, investment banks produce information in hot periods, when the acceptable offer price is high and more firms are willing to go public. Cold periods, when the acceptable offer price is low and fewer firms are willing to go public, are triggered after certain number of low quality IPO firms is observed. As in Green and Porter (1984), cold periods serve as a “punishment” to discipline the behavior of investment banks.

The decoupling of the IPO price from the secondary market price is an important feature of the model. The IPO price in our model does not reflect the true value of an IPO firm. Instead, it serves as a screening device. The secondary market price, however, does reflect the firm’s fundamentals. Underpricing (as first documented by Ibbotson (1975)) is a necessary condition for an IPO to succeed. As another important feature of our model, the underwriting fee also serves as a screening device, and it is a “reputation premium” paid to investment banks to induce information production. Therefore, a high underwriting fee (highlighted by Chen and Ritter (2000) and Hansen (2001) as the 7% puzzle) is an efficiency requirement for the IPO market.

When investment banks behave asymmetrically in information production, the reputation effect is generated from market segmentation instead of banks’ difference in information production technology. The reputation of an investment bank reflects what it does in equilibrium instead of what it is capable of doing. It is shown that market segmentation is necessary to economize on the social cost of information production. In equilibrium, investment bank reputation and market segmentation are enforced by the belief of investors.

The article proceeds as follows. We set up the basic model in Section 1. In Section 2, we study the stage game of the model. In Section 3, we study

³ During the commonly used practice of “bookbuilding,” the investment bank sets a preliminary offer price range and adjusts the IPO price based on demand side information. In this article, the communication between the investment bank and the investors is not modeled, and the IPO price is set directly by the investment bank. See Spatt and Srivastava (1991) for an example of preplay communication between buyers and sellers in IPOs.

the game in a repeated setting and construct an equilibrium with IPO waves. In Section 4, we extend the model to multiple investment banks and firms to check the robustness of IPO waves and discuss investment bank reputation. We conclude in Section 5. Technical notes and proofs are provided in Appendix 1 and Appendix 2, respectively.

1. Model Setup

In an economy with an infinite number of periods, there is an infinitely lived investment bank (I-Bank) and a continuum of infinitely lived small investors.

At the beginning of each period a new firm (or entrepreneur) arrives, which lives for one period.⁴ The firm needs resources (normalized to 1) at the beginning of the period to finance a project, which has a liquidation value v realized at the end of the period. The liquidation value v has two possible realizations, v_H and v_L . We assume $v_H > 1 > v_L$. The firm does not know v . Instead, the firm knows the probability of v being v_H , denoted as $\theta \in [0, 1]$, which is private information. We call θ the “type” of a firm. The type of a firm cannot be observed by outsiders, but the probability distribution function $g(\theta)$ is public knowledge. Denote $G(\theta)$ as the cumulative distribution function of $g(\theta)$.

If a firm goes public through an I-Bank, the I-Bank can spend a cost c to get a signal about the liquidation value v . We call this information acquisition “inspection.” The signal s has the following properties:

$$\begin{aligned} \text{If } v = v_H, s = & \begin{cases} s_H \text{ with probability } 1 \\ s_L \text{ with probability } 0 \end{cases} \\ \text{and if } v = v_L, s = & \begin{cases} s_L \text{ with probability } \lambda > 0 \\ s_H \text{ with probability } 1 - \lambda. \end{cases} \end{aligned}$$

This assumption tells us that the I-Bank always obtains good signals for truly good projects, but noisy signals for bad projects.⁵ We call this information production “inspection.” If the I-Bank does not inspect the firm, it always obtains a good signal (which is equivalent as no signal is obtained). Investors cannot observe the inspection.

⁴ This assumption eliminates the possibility of market timing.

⁵ This assumption substantially simplifies our analysis. If an I-Bank gets a bad signal about a firm, then with probability 1, the firm is of low value, while a good signal can be obtained from firms of both low value and high value. In this case, a firm that is rejected by an I-Bank due to a bad signal will never get financed no matter how high θ is. In a more general case, if a bad signal can come from firms of either low value or high value, then when there are more than one I-Bank, a firm rejected by one I-Bank can turn to another I-Bank as long as its θ is high enough. The key ingredients for our information production technology are: (i) The information produced by the I-Bank is complementary to the information that the firm has; (ii) The information produced by the I-Bank is imperfect.

The time line for the stage game is as follows:

1. The I-Bank posts the underwriting fee ϕ .
2. The firm, after observing ϕ , chooses to go public at a fixed cost $\kappa > 0$ or stay private.⁶
3. The I-Bank decides whether it should expend a cost c to get a signal. Then it decides whether to approve the firm for IPO or not. If the firm is approved, the I-Bank posts the IPO price, p_0 .⁷
4. The investors decide whether to buy the shares of the firm after observing ϕ and p_0 .
5. The shares are traded at p_1 (the entrepreneur is not allowed to trade).
6. The firm's true value is realized.

We assume that after a firm chooses to go public, it cannot withdraw no matter what p_0 has been posted by the I-Bank, and this is without loss of generality since κ is a sunk cost and the firm does not have incentive to withdraw as long as the continuation payoff is nonnegative.

We also assume that there is a lockup period after the IPO, during which the entrepreneur is not allowed to trade until the true value of the firm is realized. This assumption is necessary. The entrepreneur has private information about the firm, and the existence of an I-Bank does not completely eliminate the information asymmetry between the entrepreneur and the investors. If we allow the entrepreneur to trade before the true value of the firm is realized, no trade will occur due to the adverse selection problem. Therefore, p_1 is the investors' expectation about the firm value conditional on that it is approved by the I-Bank for IPO.

In order to pay ϕ to the I-Bank, the total IPO proceeds needed amount to $1 + \phi$. Therefore, the underwriting fee is "contingent;" that is, the I-Bank does not get paid unless the IPO succeeds.

If the I-Bank expends the cost c and only approves firms with a good signal, then a type θ firm gets approved with probability $q(\theta)$. So:

$$q(\theta) = \theta + (1 - \theta)(1 - \lambda). \quad (1)$$

⁶ For simplicity, we assume that firms must use an I-Bank to go public, because an I-Bank is the only avenue for signalling its type. We assume that κ , which includes such fixed costs as hiring legal council, preparing a business plan, having the financial statements audited, etc., is not large enough for this purpose. This assumption does not affect the main results. For example, if, in the model, we allow the firm to go public without an I-Bank, we can limit ourselves to studying equilibria in which investors only buy IPO shares from the firms with an underwriter, and the corresponding beliefs can be easily constructed.

⁷ In an earlier version of the paper, we assumed the I-Bank posts p_0 before the firm decides to go public. However, the order does not matter here as it does not affect the outcome of a Nash equilibrium.

From the point of view of a firm of type θ , the probability of being high value, conditional on being approved, is:

$$\theta^a = \frac{\theta}{q(\theta)} = \frac{\theta}{\theta + (1 - \theta)(1 - \lambda)}. \quad (2)$$

Setting $\lambda = 0$ gives the case in which the I-Bank approves the firm for IPO without inspection.

In this economy, the investors, the I-Bank, and the entrepreneur share the total social surplus, which is the gain from investing in firms with high project values net of the loss from investing in firms with low project values. The investors' profits come from underpricing; the I-Bank's profit comes from underwriting fee net of inspection cost; the entrepreneur's profit comes from share retention.

2. Stage Nash Equilibria

As a prelude to studying the repeated game, we first analyze the stage game, a one period version of the model. The formalization of the stage game can be found in Appendix 1.

We will use the sequential equilibrium concept (see Kreps and Wilson (1982)) throughout this article, and we will focus on symmetric (among the investors) equilibria. The beliefs that the investors have about θ^a , which is the type of a firm that is approved by the I-Bank for IPO, can be written as a function of ϕ and p_0 , $\mu^a : \mathcal{R}_+^2 \rightarrow \mathcal{D}([0, 1])$, where $\mathcal{D}([0, 1])$ is the set of cumulative distribution functions on $[0, 1]$. The secondary market price p_1 is calculated based on these beliefs:

$$p_1 = \int_0^1 [\theta^a v_H + (1 - \theta^a) v_L] d\mu^a(\theta^a). \quad (3)$$

μ^a is determined by the equilibrium strategies of the firm and the investors. For convenience, we denote Θ as the set of types, with which a firm chooses to go public, and we call Θ the “feasible set” of types.

Definition 1. *In the stage game, an IPO-equilibrium is a pure strategy symmetric sequential equilibrium in which IPO occurs with a nonzero probability.*

In general, the equilibrium strategy for an investor can be “buy after observing $\{\phi, p_0\}$ in a subset of $\mathcal{R}_+^2$.” Based on its belief about other players' strategies, the I-Bank decides on what fee and IPO price to post and whether to inspect the firm. The firm decides whether to go public. The following (technical) lemma shows how the analysis can be simplified without loss of generality.

Lemma 1. *For any IPO-equilibrium with an equilibrium outcome $\{\phi^*, p_0^*\}$ if an IPO is approved, we can find an equilibrium with the same outcome using the following simple strategy for the investors: the investors buy only after observing $\{\phi^*, p_0^*\}$, but not after observing any other $\{\phi, p_0\}$ posted by the I-Bank.*

Proof. We only need to show that the above simple strategy is optimal for each individual investor. When a pair $\{\phi, p_0\}$ other than $\{\phi^*, p_0^*\}$ is posted, given that no other investors decide to buy, not buying is a best response for an individual investor. ■

We interpret $\{\phi^*, p_0^*\}$ as a focal point for the investors. Equivalently, for any equilibrium strategies that generate $\{\phi^*, p_0^*\}$ as the equilibrium outcome, we can always identify the focal point as if the investors would buy only after observing $\{\phi^*, p_0^*\}$. In expecting the investors' focal point, the I-Bank rationally posts ϕ^* and p_0^* , and the firm calculates the implied retained shares and makes its decision of going public based on its own type. The formation and evolution of focal points and beliefs will play an important role in the repeated setting. To highlight that, we call the investors' focal point $\{\phi^*, p_0^*\}$ "investor sentiment," and our definition of investor sentiment reflects the "fair" pair of IPO price and underwriting fee that is acceptable by investors.

We can write the payoff to the investors as:

$$\pi_I = \frac{1 + \phi}{p_0} (p_1 - p_0). \quad (4)$$

As we can see, given the belief about θ^a , there are many "fair" pairs of IPO price and underwriting fee that yield positive expected payoffs to the investors. Given $\{\phi, p_0\}$, the investors form their beliefs about θ^a and calculate p_1 as a function of ϕ and p_0 , and, as long as $p_0 \leq p_1(\phi, p_0)$, the investors always get nonnegative expected payoffs. A strategy in which the investors accept all "fair" pairs of $\{\phi, p_0\}$ would lead the I-Bank to post a high ϕ and p_0 (high p_0 is to attract more firms to go public) such that $p_0 = p_1(\phi, p_0)$, and that would drive the payoff to the investors to zero since there is no underpricing.

Dispersed investors is a key assumption to guarantee underpricing and profits for the investors. In an IPO-equilibrium, to discipline the behavior of the I-Bank in posting fee and IPO price, the investors' strategies involve truncating some "fair" pairs of $\{\phi, p_0\}$ from their list of acceptable ones. Labeling this "investor sentiment" seems natural in the sense that the investors would refuse to buy IPO shares at some *ex post* fair price/fee

pair posted by the I-Bank.⁸ More importantly, in the repeated setting, the fluctuations of focal points further discipline the behavior of the I-Bank in information production. Without loss of generality, we will focus on the equilibria with the simple investor strategy described in Lemma 1. Lowry (2003) and others find that investor sentiment is an important determinant of IPO volume. Lowry (2003) defines investor sentiment as investor “optimism,” which leads to mispricing in the market. In our model, the focal point of the investors’ coordination provides a rational interpretation of investor sentiment.

Two observations can be made before we characterize the equilibria of the stage game. First, in any stage IPO-equilibrium, since the investors cannot observe whether the I-Bank inspects or not, the I-Bank approves any applicant for IPO without inspection. Secondly, in any stage IPO-equilibrium, the feasible set of types can only be in the form of $\Theta = [\underline{\theta}, 1]$ with $\underline{\theta}$ being some cutoff value. To see this, we can write the expected payoff of a type θ firm that chooses to go public without inspection as follows:

$$\pi_F(\theta) = [\theta v_H + (1 - \theta)v_L] \left(1 - \frac{1 + \phi}{p_0} \right) - \kappa. \quad (5)$$

It is easy to show that $\pi_F(\theta)$ is increasing in θ .

For a given pair of $\{\phi, p_0\}$, define $\underline{\theta}$ as such that $\pi_F(\underline{\theta}) = 0$. The belief about the type of a firm after it is approved for IPO can now be written as:

$$d\mu^a(\theta^a) = \begin{cases} \frac{g(\theta^a)}{1 - G(\underline{\theta})} d\theta^a & \text{when } \theta^a \geq \underline{\theta} \\ 0 & \text{when } \theta^a < \underline{\theta} \end{cases}. \quad (6)$$

The following proposition gives a necessary and sufficient condition for the existence of an IPO-equilibrium in the stage game.

Proposition 1. *In the stage game, there exists an IPO-equilibrium in which the I-Bank approves a firm for IPO without costly inspection if and only if*

⁸ Notice that since we have a continuum of investors, we do not need to change the investors’ beliefs μ^a to make them optimally choose not to buy: when all other investors decide not to buy, not buying is the optimal choice of an individual investor. It would make a difference if we had a single investor: we need to assume a crazy belief off the equilibrium path, for example, $\hat{\mu}^a(0) = 1$, that is, only the lowest type firm is approved for IPO if the I-Bank posts a different fee charge or IPO price. $\hat{\mu}^a(0) = 1$ can be supported if the investors believe that the I-Bank inspects the firm and approves the firm only when a bad signal is observed, and this is consistent with the firm’s decision, which is to go public with $\theta \in \Theta = [\underline{\theta}, 1]$. However, the investment bank’s strategy of inspecting the firm and approving it with a low signal is strictly dominated by the strategy of not inspecting the firm and approving the firm. Therefore, for the case with one investor, if we exclude these types of strictly dominated strategies when we construct off-equilibrium beliefs, then only IPO-equilibrium with no underpricing exists since the I-Bank will always set a high p_0 to attract firms.

$\{\phi, p_0\}$ and the associated $\underline{\theta}$ satisfy:

$$1 + \phi \leq p_0 \leq \int_{\underline{\theta}}^1 [\theta v_H + (1 - \theta)v_L] \frac{g(\theta)}{1 - G(\underline{\theta})} d\theta. \quad (7)$$

Proof. In equilibrium, the number of shares sold to public in an IPO cannot exceed 1, and that implies $\frac{1+\phi}{p_0} \leq 1$. The second half of the inequality comes from $p_0 \leq p_1$, since otherwise, no investors will buy IPO shares. In order to make $\{\phi, p_0\}$ optimal for the I-Bank to post, investors' strategies are "refuse to buy for any $\{\phi', p_0'\} \neq \{\phi, p_0\}$." ■

Next, we briefly discuss the efficiency of stage IPO-equilibria.

In a stage IPO-equilibrium, we can calculate the social surplus as follows:

$$W_0 = \int_{\underline{\theta}}^1 [\theta v_H + (1 - \theta)v_L - 1 - \kappa] g(\theta) d\theta. \quad (8)$$

For comparison, let us also calculate the social surplus when the I-Bank inspects the firm and approves it for IPO only when a good signal is observed. Similarly, the feasible set of types can only be in the form of $\Theta = [\underline{\theta}, 1]$ with $\underline{\theta}$ being some cutoff value. To see this, we can write the expected payoff of a type θ firm that goes public after being inspected as follows:

$$\pi_F^i(\theta) = [\theta v_H + (1 - \theta)(1 - \lambda)v_L] \left(1 - \frac{1 + \phi}{p_0}\right) - \kappa, \quad (9)$$

which is increasing in θ .

With inspection, the social surplus can be written as:

$$W_1 = \int_{\underline{\theta}}^1 [\theta(v_H - 1) + (1 - \theta)(1 - \lambda)(v_L - 1) - c - \kappa] g(\theta) d\theta, \quad (10)$$

which is increasing in λ and decreasing in c .

- Assumption: $v_H > 1 + \kappa + c$.

With the above assumption, W_1 is maximized at $\underline{\theta} = \theta_1^* = \frac{c + \kappa + (1 - \lambda)(1 - v_L)}{(v_H - 1) + (1 - \lambda)(1 - v_L)}$, and W_0 is maximized by setting $\underline{\theta} = \theta_0^* = \frac{1 + \kappa - v_L}{v_H - v_L}$. It is easy to check that θ_1^* is increasing with c and κ and decreasing with λ , while θ_0^* is increasing with κ .

When the inspection cost c is small enough, the socially optimal W_1^* is greater than the socially optimal W_0^* . For the rest of the article, we assume $W_1^* > W_0^*$. In the stage game, the I-Bank has no incentive to inspect a firm, thus the highest social surplus cannot be reached in the stage game.

In the next section, we will discuss how the information production behavior of the I-Bank interacts with the screening devices, p_0 and ϕ , in generating IPO waves.

3. Repeated Game

In a repeated setting, the investors, the firms, and the I-Bank make decisions based on history. In this economy, the public history is $h^{t-1} = \{h^{t-2}, h_{t-1}\} \in H^t$, with $h^{-1} = \emptyset$ and

$$h_t = \{\phi_t, \chi_t^s, p_{0t}, p_{1t}, v_t\} \in H_t \quad (11)$$

$$\text{where } \chi_t^s = \begin{cases} 0 & \text{if no IPO succeeds} \\ 1 & \text{if an IPO succeeds} \end{cases}.$$

The investors' strategy at time t is $\sigma_{I_t} : H^t \rightarrow S_I$; a firm's strategy at time t is $\sigma_{F_t} : H^t \rightarrow S_F$; the I-Bank's strategy at time t is $\sigma_{B_t} : H^t \rightarrow S_B$. S_I , S_F and S_B are the stage strategy spaces as defined in Appendix 1.

Given the realizations of firm type, θ_t , and firm value, v_t , a strategy profile $\sigma = (\sigma_I, \sigma_F, \sigma_B)$, determines a stochastic process of fee charges, $\{\phi_t\}_{t=0}^\infty$, IPO prices, $\{p_{0t}\}_{t=0}^\infty$, secondary market prices, $\{p_{1t}\}_{t=0}^\infty$, feasible sets of types, $\{\Theta_t\}_{t=0}^\infty$, probabilities of a type θ firm being approved by the I-Bank, $\{q_t(\theta)\}_{t=0}^\infty$, and the investors' beliefs about firm type after it is approved by the I-Bank, $\{\mu_t^a\}_{t=0}^\infty$.

The expected payoff for the investors can be written as:

$$V_I(\sigma_I, \sigma_F, \sigma_B) = E \left[\sum_{t=0}^{\infty} \delta^t \chi_t (p_{1t} - p_{0t}) \right], \quad (12)$$

The expected payoff for the I-Bank can be written as:

$$V_B(\sigma_I, \sigma_F, \sigma_B) = E \left[\sum_{t=0}^{\infty} \delta^t \chi_t (\phi_t - \mathbf{1}_t c) \right], \quad (13)$$

where $\mathbf{1}_t$ is the indicator function of the I-Bank's decision on inspection. The expected stage payoff for a type θ firm if it chooses to go public can be written as:

$$\pi_{F_t}(\theta)(\sigma_I, \sigma_F, \sigma_B) = q_t(\theta)[\theta_t^a(\theta)v_H + (1 - \theta_t^a(\theta))v_L] \left(1 - \frac{1 + \phi_t}{p_{0t}} \right) - \kappa. \quad (14)$$

A symmetric (among investors) sequential equilibrium with public information is called Perfect Public Equilibrium (PPE) (see Fudenberg, Levine, and Maskin (1994)). This is the equilibrium concept that will be used; it is a triplet $(\sigma_I, \sigma_F, \sigma_B)$ that satisfies the following conditions:

1. When $\chi_t^s = 1$, $p_{1t} \geq p_{0t}$.
2. $V_B(\sigma_I, \sigma_F, \sigma_B) \geq V_B(\sigma_I, \sigma_F, \hat{\sigma}_B)$ for any $\hat{\sigma}_B \neq \sigma_B$.
3. For any $\theta \in \Theta_t$, $\pi_{F_t}(\theta)(\sigma_I, \sigma_F, \sigma_B) \geq 0$, and for any $\theta \notin \Theta_t$, $\pi_{F_t}(\theta)(\sigma_I, \sigma_F, \sigma_B) < 0$.

Notice that in condition 1, we do not write out $V_I(\sigma_I, \sigma_F, \sigma_B) \geq V_I(\hat{\sigma}_I, \sigma_F, \sigma_B)$ for any $\hat{\sigma}_I \neq \sigma_I$. The reason is that no individual investor's decision affects the equilibrium outcome, and the only case when an individual investor can be better off by deviating from the aggregate investor strategy is when all other investors decide to buy at p_{0t} and $p_{1t} < p_{0t}$.

We provide some results on the characterization of a PPE in Appendix 1.

Again, we will focus on the equilibria with the simple strategy that we introduced in the stage game, that is, in period t , investors will coordinate to buy only when they observe some $\{\phi_t^*, p_{0t}^*\}$. It is without loss of generality; each sequential equilibrium can be supported by such a simple strategy. This is similar to the idea of a "sustainable plan," as in Chari and Kehoe (1990).

As discussed in Section 2, when the inspection cost is low enough, it will be more efficient to have the I-Bank inspect the candidate IPO firms. In the stage game, as we have already shown, the moral hazard problem cannot be solved because inspection cannot be observed. In the repeated game, we will show (by construction) that there exist equilibria in which the I-Bank engages in costly inspection and truthfully reports the signal.

The realized values of IPO firms are used by the investors to monitor, though imperfectly, the inspection behavior of the I-Bank, and (we can formally prove that) the continuation value of the I-Bank has to depend on the realized values of IPO firms to induce the I-Bank to produce information in equilibrium. However, as we will show, because the signals that the I-Bank obtains are imperfect, there does not exist an equilibrium in which the I-Bank inspects firms every period.

Lemma 2. *There does not exist a PPE in which the I-Bank inspects the firms that apply for IPO every period on each equilibrium path.*

Proof. See Appendix 2. ■

Intuitively, in order to provide an incentive for the I-Bank to produce information, the I-Bank has to be punished when a low value is realized for an IPO firm (or when there is some history of low value IPO firms). It is possible that a low value keeps occurring on the equilibrium path, which drives the payoff of the I-Bank to the lower bound. However, when the payoff to the I-Bank is low, the present payoff has to be very low so that the future payoff can be high to allow for enough payoff variations to generate incentives for the I-Bank to produce information. This is simply impossible.

Therefore, we will focus on equilibria in which the I-Bank produces information in some periods, but not in other periods. In Section 3.1 below, we will construct such an equilibrium with Green and Porter (1984) type trigger strategy.

3.1 An equilibrium with “Hot” and “Cold” IPO markets

There are many ways to construct a public perfect equilibrium, and efficient outcomes in general involve public randomization. The equilibrium that we construct has the following features:

1. There are normal (*hot*) and punishment (*cold*) periods in the economy.
2. In a *hot* period, the I-Bank inspects the firm at a cost and truthfully reveals the signal, and the efficient stage outcome with inspection is reached, that is, the optimal cutoff value θ_1^* is implemented. In a *cold* period, the I-Bank does not incur the cost of inspection, and the efficient stage outcome without inspection is reached, that is, the optimal cutoff value θ_0^* is implemented.
3. We look at an equilibrium in which ϕ does not change over time, that is, $\phi^h = \phi^c = \phi$ in both *hot* and *cold* periods.⁹
4. *Cold* periods, as a punishment to the I-Bank, are triggered after a low value is observed for an IPO firm in a *hot* period. After several periods of punishment, the economy goes back to a *hot* period.

Formally, the equilibrium is constructed as follows.

Each period can be either *hot* or *cold*. Define period t to be *hot* if (a) $t = 0$, or if (b) $t - 1$ was *hot*, and $h_{t-1} = \{\phi, 1, p_0^h, p_1^h, v_H\}$ or $\{\phi_{t-1}^h, 0, p_{0t-1}^h, p_{1t-1}^h, v_{t-1}\}$, or if (c) $t - T - 1$ was *hot*, $t - T$ was *cold* (as we will define in a moment) and $t - 1$ was *cold*. Define period t to be *cold* if (a) $t - 1$ was *hot*, and $h_{t-1} \neq \{\phi, 1, p_0^h, p_1^h, v_H\}$ or $\{\phi_{t-1}^h, 0, p_{0t-1}^h, p_{1t-1}^h, v_{t-1}\}$, or if (b) $t - 1$ was *cold*, and either $t - \tau$ is *hot* for some $\tau < T$ or $t < T$.

The above description says: (i) the punishment lasts for T periods before the economy goes back to a hot period; (ii) the punishment is triggered after an observation of either a low value IPO firm or some deviation of the I-Bank.

In a hot period, the investors buy only after certain $\{\phi, p_0^h\}$ is observed; in a cold period, the investors buy only after certain $\{\phi, p_0^c\}$ is observed. $\{\phi, p_0^h\}$ and $\{\phi, p_0^c\}$ satisfy the following conditions:

$$[\theta_0^* v_H + (1 - \theta_0^*) v_L] \left(1 - \frac{1 + \phi}{p_0^c} \right) - \kappa = 0 \quad (15)$$

$$[\theta_1^* v_H + (1 - \theta_1^*)(1 - \lambda) v_L] \left(1 - \frac{1 + \phi}{p_0^h} \right) - \kappa = 0, \quad (16)$$

⁹ In general, fluctuations in both underwriting fee and IPO price drive the market dynamics in our model. In practice, the underwriting fees in terms of gross spread do change across firms and over time, however, the variability of fees (which are typically 7%) is a lot smaller than the variability of IPO price and underpricing. By looking at equilibria with constant underwriting fees, we can focus our attention on how time varying IPO prices affect volume and underpricing.

where θ_0^* and θ_1^* are the socially optimal cutoff values with or without inspection as defined earlier.

Again, let Θ_t be the feasible set of types at time t . Θ_t changes over time as follows:

$$\Theta_t = \begin{cases} \Theta^h = [\theta_1^*, 1] & \text{if } t \text{ is hot} \\ \Theta^c = [\theta_0^*, 1] & \text{if } t \text{ is cold} \end{cases} \quad (17)$$

For the beliefs after a firm is approved, we have:

$$\mu_t^a = \begin{cases} \mu_1^{a*} & \text{if } t \text{ is hot} \\ \mu_0^{a*} & \text{if } t \text{ is cold} \end{cases}, \quad (18)$$

and μ_1^{a*} & μ_0^{a*} can be expressed as:

$$d\mu_1^{a*}(\theta^a) = \begin{cases} 0 & \text{if } \theta^a \leq \frac{\theta_1^*}{\theta_1^* + (1 - \theta_1^*)(1 - \lambda)} \\ \frac{[\theta + (1 - \theta)(1 - \lambda)]g(\theta)}{\int_{\theta_1^*}^1 [\hat{\theta} + (1 - \hat{\theta})(1 - \lambda)]g(\hat{\theta})d\hat{\theta}} d\theta & \text{with } \theta = \frac{(1 - \lambda)\theta^a}{1 - \lambda\theta^a} \\ 0 & \text{if } \theta^a > \frac{\theta_1^*}{\theta_1^* + (1 - \theta_1^*)(1 - \lambda)} \end{cases}, \quad (19)$$

and

$$d\mu_0^{a*}(\theta^a) = \begin{cases} 0 & \text{if } \theta^a \leq \theta_0^* \\ \frac{g(\theta^a)}{1 - G(\theta_0^*)} d\theta^a & \text{otherwise} \end{cases}. \quad (20)$$

The expressions of μ_0^{a*} and μ_1^{a*} tell us that, in cold periods, all the firms with a type higher than θ_0^* choose to go public and get approved, and in hot periods, all the firms with a type higher than θ_1^* choose to go public and get approved only when the I-Bank gets a good signal after inspection.

Investors coordinate with each other to discipline the behavior of the I-Bank, and the fluctuations of investor sentiment (focal point $\{\phi, p_0\}$) govern the fluctuations of the IPO market. The firms' incentives to go public vary with IPO price, and so does the I-Bank's incentive to produce information.

In cold periods, the probability of a firm being approved for IPO is:

$$Q_0 = \int_{\theta_0^*}^1 g(\theta)d\theta. \quad (21)$$

In a hot period, the probability of having a firm approved for IPO is:

$$Q_1 = \int_{\theta_1^*}^1 [\theta + (1 - \theta)(1 - \lambda)]g(\theta)d\theta. \quad (22)$$

Define:

$$Q_2 = \int_{\theta_1^*}^1 g(\theta)d\theta, \quad (23)$$

and we can see Q_2 is the probability that a firm chooses to go public (might be rejected though) in a hot period.

Define:

$$\rho = \int_{\theta_1^*}^1 (1 - \theta)(1 - \lambda)g(\theta)d\theta \quad (24)$$

$$\text{and } \hat{\rho} = \int_{\theta_1^*}^1 (1 - \theta)g(\theta)d\theta.$$

We can see that ρ is the probability of an IPO firm being low value in a hot period, while $\hat{\rho}$ is the probability of an IPO firm being low value if the I-Bank deviates by not producing information and approving every firm. It is easy to check $\hat{\rho} > \rho$.

The following proposition gives some necessary conditions for the existence of the equilibrium with hot and cold periods described above.

Proposition 2. *For a given T and δ , the equilibrium described above is sustained only if*

$$(Q_1 - Q_0 - \rho) \sum_{t=1}^T \delta^t - 1 > 0, \quad (25)$$

and

$$\phi \geq \frac{cQ_2 \left(1 + \hat{\rho} \sum_{t=1}^T \delta^t\right)}{(\hat{\rho} - \rho) \left[(Q_1 - Q_0 - \rho) \sum_{t=1}^T \delta^t - 1\right]} = \phi^*. \quad (26)$$

Proof. See Appendix 2. ■

Intuitively, the above proposition implies that there are more firms going public in hot periods, and this gives the I-Bank a larger expected profit (net of the cost of inspection) in a hot period than in a cold period. In order to stay in hot periods, the I-Bank inspects firm in a hot period since cold periods are triggered after a low value IPO firm is observed, which is more likely to happen if the I-Bank does not inspect the firm.

Thus the volume fluctuations induce the I-Bank to produce information. At the same time, the information produced by the I-Bank in hot periods makes it possible for investors to accept those firms which would have been excluded from the IPO market without information production. IPO volume and investment bank information production are connected to each other; a high volume can not be supported without the information production by the I-Bank in hot periods, and the I-Bank will not produce information if the volume is not high enough in hot periods. Therefore, *a key feature of IPO waves in our model is the co-movements of the IPO volume and the information production by the I-Bank.*

In our model, the high underwriting fee is to induce the high quality service provided by the I-Bank. This is similar to the idea of a reputation premium for a high quality good as in Shapiro (1983). It is easy to check that the minimum underwriting fee, ϕ^* , is decreasing with δ and T . Intuitively, the more patient the I-Bank is, the lower underwriting fee is required to generate an incentive for information production. At the same time, a longer punishment phase also lowers the minimum underwriting fee for the equilibrium to sustain. Efficiency requires a shorter length of cold periods, however that leads to a higher underwriting fee. Therefore, in our model, it is an efficient outcome to have a high underwriting fee. Chen and Ritter (2000) suggest that the high charge comes from implicit collusion by independent I-Banks. However, in this certification game with asymmetric information, the collusion between I-Banks is hard to justify. As we will argue in the extension of the model to multiple I-Banks, depending on the investors' beliefs and equilibrium strategies of the investors, an I-Bank charging a lower fee does not necessarily attract more firms or make IPOs more likely to succeed. Hansen (2001) provides evidence against the collusion hypothesis and argues that the "7%" charge is an "efficient contract." Our theory favors the "efficient contract" interpretation. A "7%" contract survives because it is necessary to give the I-Bank incentive to produce information.

In the subsections below, we will discuss the equilibrium properties in share retention, IPO pricing and underpricing, and post-IPO performance, respectively.

3.2 Properties of hot and cold markets

- **IPO pricing and share retention**

Given the underwriting fee, a lower IPO price is associated with a smaller fraction of retained equity. This positive correlation between IPO price and share retention is also consistent with a signalling story, as in Leland and Pyle (1977), Allen and Faulhaber (1989) or Welch (1989). Our theory shares a similar feature of information asymmetry between

investors and firms.¹⁰ The difference lies in who takes the initiative in setting the IPO price. In our model, the IPO price is not chosen by the firm, but set by the I-Bank based on the investor focal point. At the same time, firm type is completely revealed after the lockup period, and a firm with underpricing cannot recoup its loss in the future. Therefore, empirically, the key difference between our screening story and the signalling story is whether a firm with underpricing will recoup its loss from seasoned offerings in the future.¹¹

We can compare the IPO price and the fraction of retained equity in hot periods with those in cold periods:

$$\alpha^h = 1 - \frac{1 + \phi}{p_0^h} = \frac{\kappa}{\theta_1^* v_H + (1 - \theta_1^*)(1 - \lambda)v_L} \quad (27)$$

$$\alpha^c = 1 - \frac{1 + \phi}{p_0^c} = \frac{\kappa}{\theta_0^* v_H + (1 - \theta_0^*)v_L}. \quad (28)$$

Since $\theta_1^* < \theta_0^*$, it is easy to see that $\alpha^h > \alpha^c$ and $p_0^h > p_0^c$. In a hot period, a high IPO price attracts more firms to go public; the investors are willing to accept this high IPO price because the I-Bank is producing information. In a cold period, only a low IPO price is acceptable for the investors given that the I-Bank is not producing information, and that discourages low type firms from going public. This generates fluctuations in share retention as well as IPO price. Consistent with this prediction, Loughran and Ritter (2004), using data from 1980 to 2003, find that share overhang (the ratio of retained shares to the public float) is very high during hot markets in 1990s and internet bubble years. Therefore, our model offers a rational explanation of the fluctuations in IPO pricing and share retention, and the key driving force is the fluctuation in information production, which allows a high IPO price and a high fraction of retained equity in hot periods.

The next lemma gives us how the fraction of retained equity depends on the exogenous variables, λ , c and κ .

Lemma 3. α^h is increasing with λ and κ , and decreasing with c , while α^c is increasing in κ and does not depend on λ or c .

¹⁰ There are other IPO theories based on different types of information asymmetry. Rock (1986) suggests there is information asymmetry among investors, and due to the winner's curse, the underpricing in an IPO gives uninformed investors enough incentive to submit purchase orders. Benveniste and Spindt (1989) model the IPO process as an auction constructed to induce asymmetrically informed investors to reveal their information to the underwriter. Baron (1982) assumes that issuers know less than underwriters, so that underpricing induces the marketing efforts from underwriters.

¹¹ Empirical findings for signalling stories are mixed; see, for example, Michaely and Shaw (1994).

Proof. With $\theta_1^* = \frac{c + \kappa + (1 - \lambda)(1 - v_L)}{(v_H - 1) + (1 - \lambda)(1 - v_L)}$, we can write $\alpha^h = \frac{\frac{c + \kappa + (v_H - v_L - c - \kappa)(1 - \lambda)}{v_H - 1 + (1 - \lambda)(1 - v_L)} + c + \kappa}{\frac{\kappa}{1 + \kappa}}$. At the same time, with $\theta_0^* = \frac{1 + \kappa - v_L}{v_H - v_L}$, we can write $\alpha^c = \frac{\kappa}{1 + \kappa}$. The results are immediate. ■

Intuitively, in hot periods, a higher information production accuracy allows more firms to go public, which requires more shares retained by the entrepreneur. The effect of information production cost is the opposite. At the same time, entrepreneurs with higher fixed cost of going public need to retain more shares to have incentives to take their firms public. Therefore, as the information production technology improves, λ goes up and c goes down, we will observe a larger fraction of retained equity in hot periods. At the same time, cross-sectionally, for a more transparent industry (higher λ), entrepreneurs retain more shares.

• IPO Underpricing

Our equilibrium also generates fluctuation in underpricing. Denote p_1^h as the secondary market price in a hot period, and denote p_1^c as the secondary market price in a cold period. We have:

$$p_1^h = \int_{\theta_1^*}^1 \frac{[\theta v_H + (1 - \theta)(1 - \lambda)v_L]g(\theta)}{\int_{\theta_1^*}^1 [\hat{\theta} + (1 - \hat{\theta})(1 - \lambda)]g(\hat{\theta})d\hat{\theta}} d\theta \quad (29)$$

$$p_1^c = \int_{\theta_0^*}^1 [\theta v_H + (1 - \theta)v_L] \frac{g(\theta)}{1 - G(\theta_0^*)} d\theta. \quad (30)$$

A complete comparison of underpricing in hot periods and cold periods is tedious, but we observe that $\lim_{\kappa \rightarrow 0} p_0^h = \lim_{\kappa \rightarrow 0} p_0^c = 1 + \phi$ and $\lim_{\lambda \rightarrow 1} p_1^h = v_H$, that is, the secondary market price in hot periods is higher if λ is close to 1, while the IPO prices are close in hot and cold periods if κ is small. If v_H is high, when λ is close to 1, p_1^h can be much greater than p_1^c . Therefore, there can be greater underpricing in hot periods even though IPO prices are higher in hot periods.

We summarize the above results in the following lemma.

Lemma 4. *If κ is small, λ is close to 1, and v_H is large, then we will observe greater underpricing in hot periods with higher IPO price.*

It has been a long standing puzzle that firms are more willing to go public when there are more money left on the table (see, for example, Ibbotson and Jaffe (1975) and Ritter (1984)). Ljungqvist, Nanda, and Singh (2003) show that underpricing in hot periods can be firms' optimal response to the presence of sentiment investors and short sale constraints. The equity offering is underpriced to make the rational institutional investors, who will resale shares to sentiment investors, break even with a risk of the ending of

hot periods prematurely. Our model provides a fully rational explanation for the synchronism of IPO volume and underpricing. The information produced by the I-Bank in hot periods leads to higher secondary market prices and greater underpricing.

• Post-IPO Performance

We can also compare the post-IPO performance after hot and cold periods. In the equilibrium we constructed, the expected return of an IPO firm is zero, while the volatility of the secondary market return could be different depending on whether it is in a hot period or in a cold period.

The volatility of secondary market return can be defined as:

$$vol = \Pr(v_H) \left(\frac{v_H - p_1}{p_1} \right)^2 + [1 - \Pr(v_H)] \left(\frac{v_L - p_1}{p_1} \right)^2, \quad (31)$$

where $p_1 = \Pr(v_H)v_H + [1 - \Pr(v_H)]v_L$ and $\Pr(v_H)$ is the probability of v_H conditional on that the firm is approved to go public.

Lemma 5. *The volatility of second market return is increasing (decreasing) with $\Pr(v_H)$ if $\Pr(v_H) < (>) \frac{v_L}{v_H + v_L}$.*

Proof. We can show:

$$\frac{\partial vol}{\partial \Pr(v_H)} = \frac{v_L - \Pr(v_H)(v_H + v_L)}{p_1^3}. \quad (32)$$

The result is immediate. ■

Lemma 5 gives us a sufficient condition to compare the volatility of secondary market return across time as well as across industries. As we have discussed, as long as λ is high enough, the secondary market price p_1 , or, equivalently, the conditional probability of high value $\Pr(v_H)$, is higher in hot periods. Therefore, a high λ implies a lower volatility in a hot period. Cross-sectionally, λ links to the transparency of an industry, and higher transparency leads to higher λ . Therefore, if λ is high enough such that $\Pr(v_H) > \frac{v_L}{v_H + v_L}$, then a more transparent industry have a smaller volatility for second market returns. Intuitively, with a more reliable information production by the I-Bank, second market returns are less volatile because more of the low value firms are excluded from the IPO market.

The equilibrium we constructed does not generate any post-IPO underperformance, as reported in, for example, Loughran and Ritter (1995) and Brav and Gompers (1997). Miller (1977) credits the long-run underperformance to the convergence of the investors' opinions. Bradley, et al. (2001) argue that post-IPO underperformance is due to the exit of venture capitalists. Schultz (2003) offers an explanation for post-IPO underperformance that is quite related to our model. He argues that more IPOs follow successful IPOs. Thus, the last large group of IPOs

would underperform. If underperformance is measured by weighting each IPO equally, the high-volume periods carry a large weight, resulting in underperformance, on average. Based on his argument, our model is potentially able to generate post-IPO underperformance statistically. For that purpose, we can construct an equilibrium in which the number of IPOs following successful IPOs is higher. Alternatively, it is a straightforward extension to have the firm arrival rate depend on the history of IPO performance.¹²

3.3 Numerical examples

In this subsection, we give some numerical examples in demonstrating how the exogenous variables ($\lambda, c, \kappa, v_H, v_L$) affect equilibrium outcomes in underwriting fee, IPO volume, IPO pricing, first day return, post-IPO performance and share retention in hot and cold periods.

Assume we have uniform distribution in firm type θ , that is, $g(\theta) = 1$ for any $\theta \in [0, 1]$. We will study how equilibrium outcomes change with λ , the accuracy of I-Bank information production. For other exogenous variables we assume $v_H = 1.25, v_L = 0, c = 0.005, \kappa = 0.005, T = 10$, and $\delta = 0.98$ as a benchmark case. We report the results in underwriting fee, share retention, first day return and post-IPO return volatility in Figure 1.

As we can see from Figure 1, the chosen parameters generate reasonable statistics. (i) The underwriting fee is decreasing in λ , ranging from 4% to 11%. When λ increases, it becomes easier to detect a deviation from the I-Bank in hot periods, and this reduces the level of underwriting fee required to generate incentives for the I-Bank to produce information. (ii) Firms retain more shares in hot periods, and the difference is greater when λ is higher. Intuitively, when λ is higher, the I-Bank is more selective in hot periods, thus firms need to retain more shares to go public. (iii) The first day return in hot periods ranges from 4% to 15%, which is higher than those in cold periods ranging from 1% to 7%. There is a drop in first day returns of hot periods as λ is close to 1. To explain this, we identify two effects on first day returns when λ increases: (1) the IPO price goes up to allow low type firms to go public; and (2) the secondary market price goes up due to more accurate information production. The net effect on first day return is hump-shaped. (iv) In terms of the post-IPO return volatility, as we have discussed in Section 3.2, when λ and $\Pr(v_H)$ are high, the volatility is decreasing with $\Pr(v_H)$. With our parameter values, the secondary market price p_1 is higher in hot periods (which implies a higher $\Pr(v_H)$), and that leads to a lower post-IPO return volatility.

Next, we change some of the parameter values to check the robustness of the results. Figure 2 contains the results with $v_H = 1.35$ (corresponding

¹² Consistent with this assumption, Lowry and Schwert (2002) report that more companies tend to go public following periods of high initial returns.

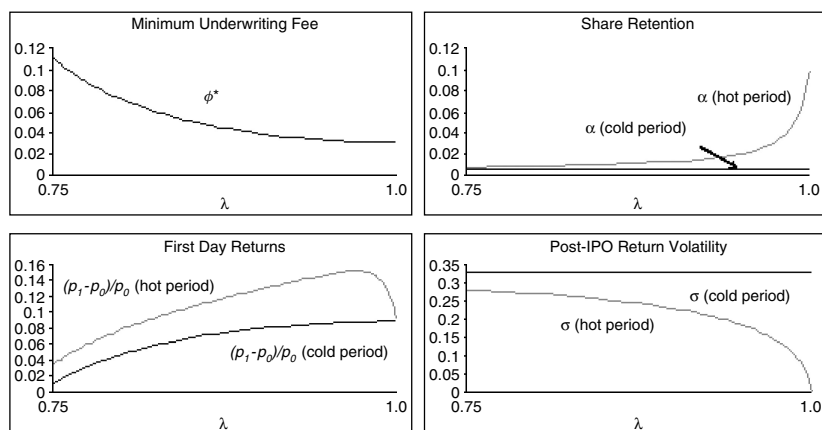


Figure 1
This graph gives the numerical results with one investment bank when $v_H = 1.25$, $v_L = 0$, $c = 0.005$, $\kappa = 0.005$, $T = 10$ and $\delta = 0.98$. We report how minimum underwriting fee, first day return, share retention and post-IPO return volatility change with the information production technology, λ .

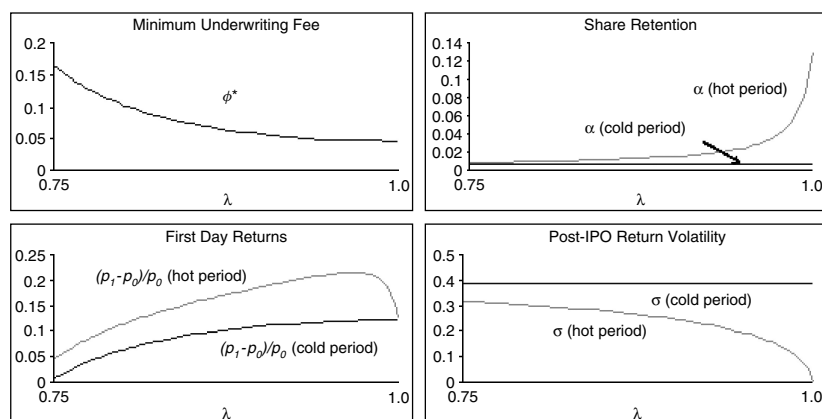
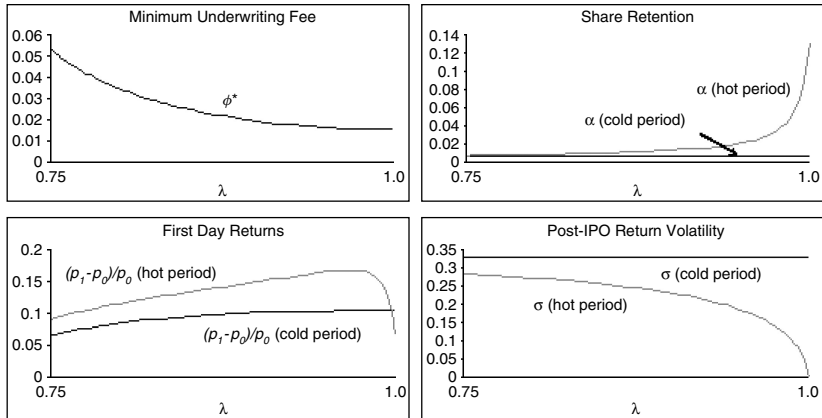


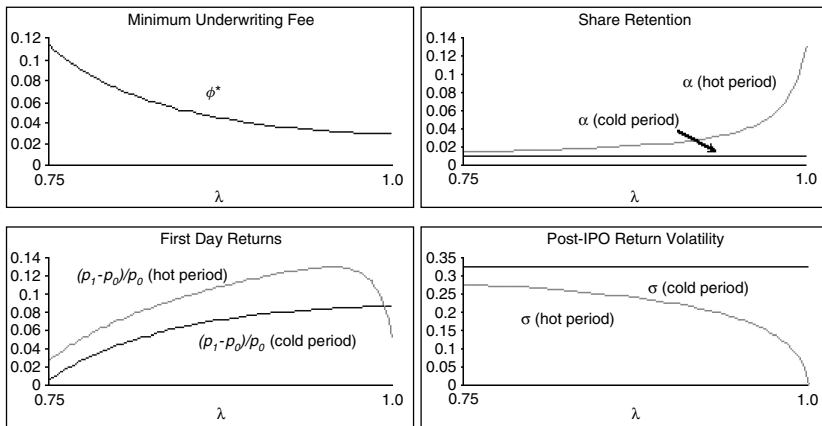
Figure 2
This graph gives the numerical results with one investment bank when $v_H = 1.35$, $v_L = 0$, $c = 0.005$, $\kappa = 0.005$, $T = 10$ and $\delta = 0.98$. We report how minimum underwriting fee, first day return, share retention and post-IPO return volatility change with the information production technology, λ .

to an internet bubble period, when investors desire a superstar like Microsoft), Figure 3 contains the results with $c = 0.0025$ (corresponding to a technology advancement in cutting the cost of information production), and Figure 4 contains the results with $\kappa = 0.01$ (corresponding to increased regulation on the IPO market which makes it more costly for an entrepreneur to take his firm public).

In Figure 2, a higher v_H leads to a higher underwriting fee, a higher first day return and a higher post-IPO volatility in hot periods. A higher


Figure 3

This graph gives the numerical results with one investment bank when $v_H = 1.25$, $v_L = 0$, $c = 0.0025$, $\kappa = 0.005$, $T = 10$ and $\delta = 0.98$. We report how minimum underwriting fee, first day return, share retention and post-IPO return volatility change with the information production technology, λ .


Figure 4

This graph gives the numerical results with one investment bank when $v_H = 1.25$, $v_L = 0$, $c = 0.005$, $\kappa = 0.01$, $T = 10$ and $\delta = 0.98$. We report how minimum underwriting fee, first day return, share retention and post-IPO return volatility change with the information production technology, λ .

v_H expands the set of firm type that is feasible for an IPO, and a greater number of applicants in hot periods aggravates the moral hazard problem, which leads to a higher minimum fee to induce information production. At the same time, a higher v_H leads to a higher secondary market price, which drives up the first day return. The result on volatility is easy to understand with Lemma 5.

In Figure 3, a lower c leads to a lower underwriting fee and a higher first day return (when λ is not close to 1). The result on underwriting fee is

easy to interpret, and we omit the discussion. With a lower underwriting fee, the IPO price will be lower given the same fraction of retained equity ($\alpha = 1 - \frac{1+\phi}{p_0}$), and this leads to a higher first day return. A lower c also expands the set of firm type that are feasible for IPO, and this leads to a larger fraction of retained equity and a higher IPO price, but the effect on first day returns is dominated by the effect of a lower underwriting fee when λ is not close to 1.

In Figure 4, a higher κ leads to a lower underwriting fee and a larger fraction of retained equity in both hot and cold periods. With a higher κ , firms need to retain more shares to break even when they go public. At the same time, a higher κ drives down the IPO volume in both hot and cold periods, especially in cold periods when λ is large (we can formally compared the change in Q_0 and Q_1 due to change of κ), and this makes the punishment phase more effective, which implies a lower minimum underwriting fee.

In summary, our model generates dynamics in IPO volume, share retention, first day return and post-IPO return volatility, and we demonstrate how equilibrium outcomes are affected by changes in v_H , λ , c and κ . Many of these predictions are consistent with the empirical findings in the literature, while others are new testable implications, which we will summarize in Section 5.

4. Extensions to Multiple I-Banks and Multiple Firms

Now let us formally consider the case with multiple I-Banks and multiple firms. In this economy, the history is $h^{t-1} = \{h^{t-2}, h_{t-1}\} \in H^t$, with $h^{-1} = \emptyset$ and $h_t = \{\phi_t, \chi_t, p_{0t}, p_{1t}, v_t\}$, and ϕ_t , χ_t , p_{0t} , p_{1t} , and v_t are vectors instead of scalars. The characterization of the PPE for the repeated game is similar to the case with one I-Bank, so we omit it for the sake of brevity. The existence of multiple I-Banks does not necessarily result in competition. Depending on the investors' strategy (represented by the focal point), higher p_0 (less underpricing) and/or lower ϕ do not necessarily attract more firms.

We will first consider the case in which I-banks behave symmetrically to check the robustness of the model in generating IPO waves, and then we discuss the reputation effect when I-banks behave asymmetrically in information production.

4.1 Symmetric I-banks

Assume that there are M I-Banks living forever, and there are N potential IPO firms each period. All the other assumptions are the same as in the case with one I-Bank. For simplicity, assume that no I-Bank can handle two IPOs in the same period and $N \leq M$.

We will construct an equilibrium similar to the one in the case with one I-Bank, that is, the economy starts with a hot period, hot periods continue

unless certain number of low value IPO firms are observed, which lead to cold periods, and cold periods last for T periods until a hot period returns.

In a hot period, the investors observe the number of IPOs, denoted as n , and decide whether to trigger the punishment given the number of low value IPO firms, denoted as j .

With Q_1 defined in (22) as the probability of a firm being approved for IPO in a hot period, we can write out the probability of n IPOs:

$$\Pr(n) = \binom{n}{N} Q_1^n (1 - Q_1)^{N-n}, \quad (33)$$

where $\binom{n}{N} = \frac{N!}{n!(N-n)!}$.

With Q_2 defined in (23) as the probability of a firm applying to go public in a hot period, we can write out the probability of n IPOs if one I-Bank approves a firm for IPO without inspection:

$$\begin{aligned} \tilde{\Pr}(n) = & \frac{N}{M} [Q_2 \binom{n-1}{N-1} Q_1^{n-1} (1 - Q_1)^{N-n} \\ & + (1 - Q_2) \binom{n}{N-1} Q_1^n (1 - Q_1)^{N-1-n}] + \left(1 - \frac{N}{M}\right) \Pr(n). \end{aligned} \quad (34)$$

To save future notation, define:

$$\hat{\Pr}(n) = \frac{N}{M} [Q_2 \binom{n-1}{N-1} Q_1^{n-1} (1 - Q_1)^{N-n}]. \quad (35)$$

In a hot period, denote D as the probability of an IPO firm being low value when the I-Bank inspects the firm, and $\hat{D}$ as the probability of an IPO firm being low value when the I-Bank does not inspect the firm. We have:

$$\begin{aligned} D &= \frac{\int_{\theta_1^*}^1 (1 - \theta)(1 - \lambda)g(\theta)d\theta}{Q_1} = \frac{\rho}{Q_1} \\ \hat{D} &= \frac{\int_{\theta_1^*}^1 (1 - \theta)g(\theta)d\theta}{Q_2} = \frac{\hat{\rho}}{Q_2}. \end{aligned} \quad (36)$$

It is easy to check $\hat{D} > D$. We can write out the probability of j low value IPO firms given that the total number of IPOs is n :

$$\Pr(j|n) = \binom{j}{n} D^j (1 - D)^{n-j}, \quad (37)$$

where $\binom{j}{n} = \frac{n!}{j!(n-j)!}$.

Define:

$$J(n) = \{j | j \leq n \text{ and cold periods will be triggered with } j \text{ lowvalue firms.}\} \quad (38)$$

Thus, $J(n)$ is the “trigger set” such that, given n IPOs, after observing $j \in J(n)$ low value IPO firms, the investors will start the cold periods. The next lemma gives out the optimal trigger rule.

Lemma 6. *In a hot period, if there are $n \geq 1$ IPOs, then the $J(n)$ that is most sensitive to deviation of an I-Bank is given by:*

$$J^*(n) = \{j | j \geq \bar{j}(n)\}, \quad (39)$$

where

$$\bar{j}(n) = \min\{j | j \leq n \text{ and } \frac{j}{n} > D\}. \quad (40)$$

Proof. When there are $n \geq 2$ IPOs, then the probability that among them there are $j < n$ low value firms is given by (37):

$$\Pr(j|n) = D \Pr(j-1|n-1) + (1-D) \Pr(j|n-1). \quad (41)$$

If one I-Bank deviates by not inspecting the firm, the probability becomes:

$$\hat{\Pr}(j|n) = \hat{D} \Pr(j-1|n-1) + (1-\hat{D}) \Pr(j|n-1). \quad (42)$$

It is easy to check:

$$\hat{\Pr}(j|n) > \Pr(j|n) \text{ iff } \frac{j}{n} > D. \quad (43)$$

It is also easy to check that the above condition is satisfied when $j = n$ and $n = 1$. ■

Intuitively, the more low value firms, the more likely some I-Bank deviated by not inspecting the firm. When there are n IPOs, on average there will be nD firms to be of low value; if there are more than nD low value IPO firms, it is likely some I-Bank deviated.

Define:

$$\Pr(J^*(n)) = \sum_{j \in J^*(n)} \Pr(j|n) \quad (44)$$

$$\text{and } \hat{\Pr}(J^*(n)) = \sum_{j \in J^*(n)} \hat{\Pr}(j|n).$$

It is easy to check:

$$\widehat{\Pr}(J^*(n)) - \Pr(J^*(n)) = (\hat{D} - D) \Pr(\bar{j}(n) - 1 | n - 1), \quad (45)$$

that is, an I-Bank's deviation will lead to cold periods only if its IPO firm will be the "trigger." The externality effect here makes it hard to detect the deviation of an I-Bank: if there is fewer than $\bar{j}(n) - 1$ or more than $\bar{j}(n) - 1$ low value IPO firms from other I-Banks, its behavior will not affect the phase of hot or cold periods, and it will choose to deviate. Therefore, only $\Pr(\bar{j}(n) - 1 | n - 1)$ matters.

For a hot period, the probability of being triggered into a cold period can be written as:

$$\rho_{(M,N)} = \sum_{n=0}^N \Pr(n) \Pr(J^*(n)) \quad (46)$$

If one I-Bank deviates by not producing information, the probability of being triggered into a cold period can be written as:

$$\hat{\rho}_{(M,N)} = \sum_{n=0}^N [\widehat{\Pr}(n) \widehat{\Pr}(J^*(n)) + (\tilde{\Pr}(n) - \widehat{\Pr}(n)) \Pr(J^*(n))]. \quad (47)$$

The next corollary gives necessary conditions for the existence of the equilibrium with hot and cold periods as defined in Section 3.1.

Corollary 1. *For a given T and δ , the equilibrium described above is sustained only if*

$$Q_1 - Q_2 + \frac{(\hat{\rho}_{(M,N)} - \rho_{(M,N)})(Q_1 - Q_0) \sum_{t=1}^T \delta^t}{1 + \rho_{(M,N)} \sum_{t=1}^T \delta^t} > 0, \quad (48)$$

and

$$\begin{aligned} \phi \geq & \frac{c Q_2 \left(1 + \hat{\rho}_{(M,N)} \sum_{t=1}^T \delta^t\right)}{(Q_1 - Q_2) \left(1 + \rho_{(M,N)} \sum_{t=1}^T \delta^t\right)} = \phi_{(M,N)}^*. \quad (49) \\ & + (\hat{\rho}_{(M,N)} - \rho_{(M,N)})(Q_1 - Q_0) \sum_{t=1}^T \delta^t \end{aligned}$$

Proof. The proof is similar to the proof for Proposition 2, thus omitted. ■

When there is one I-Bank and one firm for each period, we have $Q_2 - Q_1 = \hat{\rho}_{(M,N)} - \rho_{(M,N)} = \hat{\rho} - \rho$, and the conditions in the above corollary are reduced to those in Proposition 2.

Next, we give a numerical example in demonstrating how the number of I-Banks and firms affect the equilibrium outcomes in underwriting fee, first day return, post-IPO performance and share retention in hot and cold periods.

The assumptions on model parameters are: $g(\theta) = 1$ for any $\theta \in [0, 1]$, $\lambda = 0.98$ or 0.99 , $v_H = 1.25$, $v_L = 0$, $c = 0.005$, $\kappa = 0.005$, $T = 10$, and $\delta = 0.98$. To study the externality effect as the number of firms/I-Banks increase, we first set $M = N$, and we report the minimum underwriting fee, the first day returns in hot and cold periods, and the probability of being triggered into cold periods in a hot period in Figure 5.

As we can see from Figure 5, due to the externality effect, it becomes harder to detect an individual I-Bank's deviation in information production when N , the number of firms/I-Banks, increases. When there are more firms/I-Banks, it requires a higher underwriting fee to keep the I-Banks producing information in the constructed equilibrium with trigger

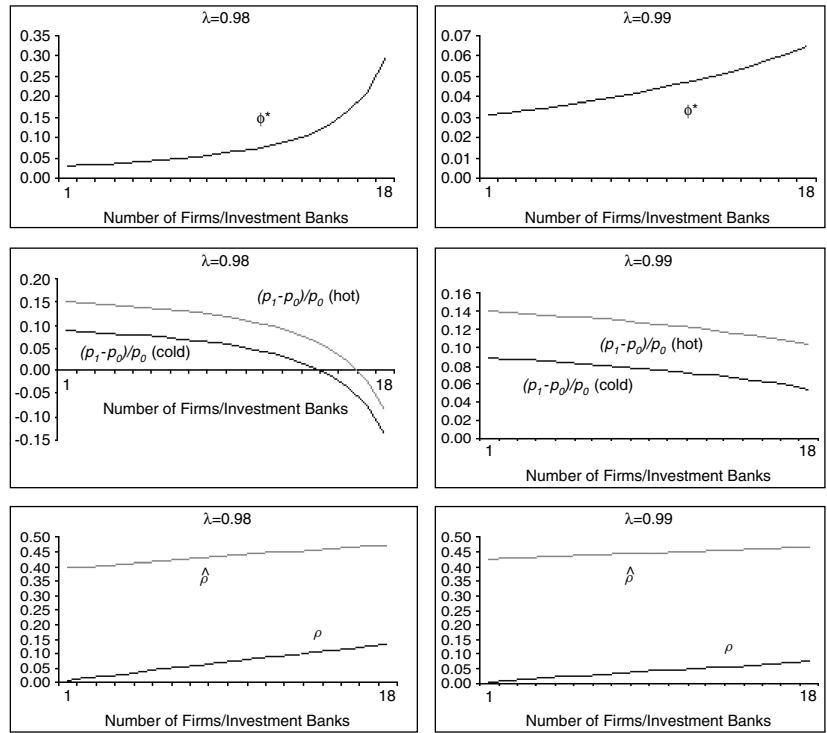


Figure 5
This graph gives the numerical results with multiple investment banks when $v_H = 1.25$, $v_L = 0$, $c = 0.005$, $\kappa = 0.005$, $T = 10$, $\delta = 0.98$ and $\lambda = 0.98$ or 0.99 . We report how minimum underwriting fee, first day return and the probability of being triggered into cold periods change with the number of investment banks or firms.

strategy. In equilibrium, the I-Banks and the investors share the total surplus (net of the payoff to the entrepreneur), therefore, as underwriting fee increases, the payoff to the investors decreases, which is reflected by a decrease in underpricing. When N is large enough, underpricing goes to negative, which means the constructed equilibrium can not sustain given a large N . At the same time, in a hot period, the probability of being triggered into cold periods increases as the number of firms/I-Banks increases since it is more likely that a low value IPO firm gets approved by mistake; it is more likely the economy stays in inefficient cold periods. When inspection technology improves, or λ increases, the externality effect is mitigated, which is reflected by a lower ϕ^* , a higher $\frac{p_1 - p_0}{p_0}$ and a lower ρ as N increases.

Next, we fix $M = 10$, and study the effect of N on the equilibrium outcomes. The results are reported in Figure 6.

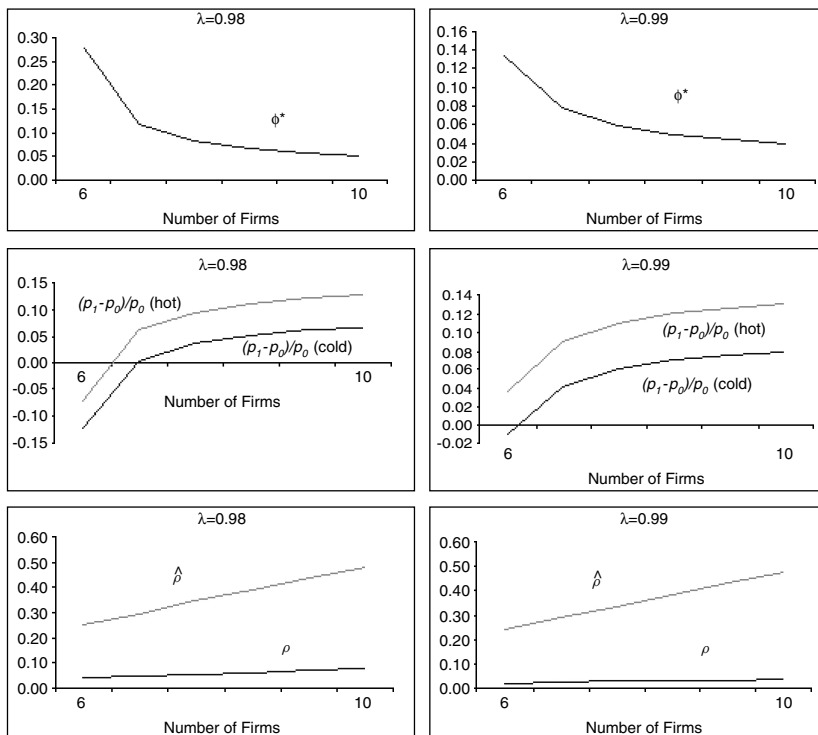


Figure 6

This graph gives the numerical results with multiple investment banks when $v_H = 1.25$, $v_L = 0$, $c = 0.005$, $\kappa = 0.005$, $T = 10$, $\delta = 0.98$ and $\lambda = 0.98$ or 0.99 . We report how minimum underwriting fee, first day return and the probability of being triggered into cold periods change with the number of firms given the number of investment banks fixed.

As we can see from Figure 6, given the number of I-Banks, if the number of potential IPO candidate is small, the constructed equilibrium with information production in hot periods can not sustain--either because there does not exist a positive minimum ϕ^* or ϕ^* is too high to support a positive first day return. Therefore, when there are not many new firms in a recession, the IPO market can only stay in cold market without information production. However, when there are many new firms (for example, due to technology innovation in certain industry), equilibrium with information production can sustain, and it has an externality effect on the whole economy because more firms (in other industries) can go public due to the information production. Also, notice that, as the number of firms increases, the probability of being triggered into cold periods increases. This generates a natural boom-bust pattern of the IPO market. Therefore, our model provides a framework to interpret the interaction between the IPO market and the real economy.

4.2 Asymmetric I-banks

To simplify our analysis, we assume that there are two I-Banks and one firm. We First show that the efficient outcome involves market segmentation.

Denote α_1 as the retained shares of the firm if it goes to I-Bank 1 for IPO and is approved. α_2 is similarly defined. So:

$$\alpha_1 = 1 - \frac{1 + \phi_1}{p_{01}} \quad (50)$$

$$\alpha_2 = 1 - \frac{1 + \phi_2}{p_{02}}. \quad (51)$$

Again, define an IPO-equilibrium as an equilibrium in which there is a nonzero probability that a firm goes public through either of the two I-Banks. Similarly, as in the case of one I-Bank, we can show that, in the stage game, there does not exist an IPO-equilibrium in which either of the two I-Banks inspects the candidate firm.

Without inspection, a firm of type θ has an expected payoff of $\pi_{Fi}(\theta)$ if it goes to I-Bank i for IPO. So:

$$\pi_{Fi}(\theta) = [\theta v_H + (1 - \theta)v_L]\alpha_i - \kappa. \quad (52)$$

When we have only one I-Bank in the economy, if the cost of inspection is low enough, it is socially optimal to have a firm with type $\theta \geq \theta_1^*$ inspected, as we argued earlier. However, when two I-Banks share the market, it might not be optimal to have both of them inspect the firms. The marginal social gain from inspecting a type θ firm is $\lambda(1 - \theta)(1 - v_L)$, which is a decreasing function of θ . The net gain is negative when θ is close to 1. This means that for a firm of high type, there is no need to inspect it

given the cost of inspection. Let $\theta_2^* = 1 - \frac{c}{\lambda(1-v_L)}$ be the cutoff value; firms with a type above θ_2^* should not be inspected. An efficient outcome must involve market segmentation: When $\theta \geq \theta_2^*$, a firm should go public with an I-Bank that does not inspect the firm; when $\theta_1^* \leq \theta < \theta_2^*$, a firm should go public with an I-Bank that does inspect the firm. The question is: can the efficient market segmentation be implemented in an equilibrium? We answer this question in the lemma below.

Lemma 7. *When a firm incurs the same fixed cost to go public regardless of its choice of I-Bank, the efficient market segmentation cannot be reached in equilibrium.*

Proof. Without loss of generality, assume that at some stage of the game I-Bank 1 inspects the firm, while I-Bank 2 does not. The payoff to a firm with type θ when it chooses to go public with I-Bank i is given by:

$$\pi_{F1}(\theta) = [\theta v_H + (1 - \theta)(1 - \lambda)v_L]\alpha_1 - \kappa \quad (53)$$

$$\pi_{F2}(\theta) = [\theta v_H + (1 - \theta)v_L]\alpha_2 - \kappa. \quad (54)$$

Efficient segmentation by type can only occur as shown in Figure 7.

As we can see from Figure 7, in order for efficient segmentation to occur, we need:

$$\text{Slope restriction : } [v_H - (1 - \lambda)v_L]\alpha_1 < (v_H - v_L)\alpha_2, \quad (55)$$

and

$$\text{Intercept restriction : } (1 - \lambda)v_L\alpha_1 - \kappa > v_L\alpha_2 - \kappa. \quad (56)$$

However, the slope restriction implies $\alpha_1 < \alpha_2$, and the intercept restriction implies $\alpha_1 > \alpha_2$. Thus we have a contradiction. ■

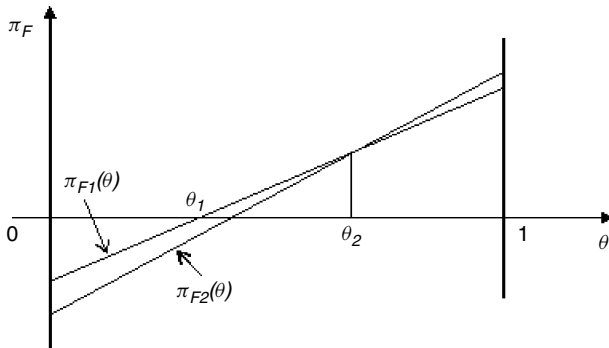


Figure 7
This graph describes the efficient market segmentation.

Intuitively, the I-Bank that inspects firms will be preferred by a low-type firm only when it offers more retained shares. However, offering more retained shares favors high-type firms. Thus the I-Bank that does not inspect firms will be driven out of the market.

In the proof of Lemma 7, the “slope restriction” requires $\alpha_1 < \alpha_2$, and we can check that a necessary condition to satisfy the “intercept restriction” is $\kappa_1 < \kappa_2$. For the rest of this subsection, we assume that firms incur different κ when they go public with different I-Banks. We should interpret the difference in κ as that the I-Bank with lower κ offers some free services in terms of hiring legal council, preparing a business plan, having the financial statements audited, and etc. In the efficient market segmentation, the I-Bank with lower κ is the one with good reputation and the one that produces more information. This feature matches with the general impression of a reputable I-Bank, which is more aggressive in getting IPO customers and has a large research department (Logue (1973) documents that prestigious underwriters are more selective, which is also consistent with our definition of reputation).

With $\kappa_1 < \kappa_2$, and we can check that the efficient market segmentation can be reached with the efficient α_1^* and α_2^* defined in the following equations:

$$[\theta_1^* v_H + (1 - \theta_1^*)(1 - \lambda)v_L]\alpha_1^* - \kappa_1 = 0 \quad (57)$$

$$[\theta_2^* v_H + (1 - \theta_2^*)(1 - \lambda)v_L]\alpha_2^* - \kappa_1 = [\theta_2^* v_H + (1 - \theta_2^*)v_L]\alpha_2^* - \kappa_2, \quad (58)$$

where θ_1^* and θ_2^* are as defined earlier. Therefore, I-Bank 1 approves the firms with types in $[\theta_1^*, \theta_2^*)$ for IPO after inspection, and I-Bank 2 approves the firms with types in $[\theta_2^*, 1]$ for IPO without inspection.

There are many ways to construct a PPE in which the efficient stage outcome occurs on the equilibrium path. For example, we can construct an equilibrium as follows. There are two kinds of I-Banks, “prestigious” and “notorious.” I-Bank 1 (with the lower κ) is “prestigious,” and I-Bank 2 (with higher κ) is “notorious.” In period t , assume that the “prestigious” I-Bank charges the same as the “notorious” I-Bank does, that is, $\phi_1 = \phi_2$, but we assume that the “prestigious” I-Bank has a higher payoff than the “notorious” I-Bank does (which implies there are more firms going public with the “prestigious” I-Bank). The “prestigious” I-Bank inspects firms and attracts firms with type in $[\theta_1^*, \theta_2^*]$. The “notorious” I-Bank does not inspect firms and attracts firms with type in $[\theta_2^*, 1]$. When a low value IPO firm approved by the “prestigious” I-Bank is observed, the two I-Banks switch their categories, the “notorious” one is promoted to “prestigious,” and the “prestigious” one is demoted to be “notorious.” In order to switch the reputations of the two I-Banks, they must switch κ . To interpret this in a more natural way, we can imagine that, in order to make investors believe that the reputation switch is in place, an I-Bank becomes more

aggressive by offering some subsidy to IPO candidates when it gains a good reputation.

Another way to construct an equilibrium with “reputations” is to punish the “prestigious” I-Bank through the market fluctuation between “hot” and “cold” periods. The “prestigious” I-Bank keeps its reputation over time, but it is punished after a low value IPO firm is observed. Therefore, in this type of equilibrium, the efficient market segmentation cannot be sustained during punishment periods. This type of equilibrium has an implication in terms of the dynamics of the quality difference in information production between reputable I-Banks and less reputable I-Banks.

In either case, with market segmentation, the unnecessary cost of inspection for good type firms is saved, and the total social welfare is improved. Different from the existing literature on I-Bank reputation, we argue that I-Banks underwrite different types of firms to economize on the social cost of inspection instead of arguing that I-Banks differ in inspection technologies (see, for example, Chemmanur and Fulghieri (1994) and Titman and Trueman (1986)). In our model, I-Banks with different reputations are not intrinsically different in their quality of information production, and instead the reputation of an I-Bank reflect what it does in equilibrium instead of what it can do. The market segmentation is enforced by the market belief from investors, who coordinate their behavior to discipline the behavior of I-Banks. Carter and Manaster (1990) assume that underwriters with different reputation differ in the risk dispersion of the IPOs brought to the market. Consistent with that, our theory demonstrates how the risk composition of IPO firms differs when they go public through I-Banks with different reputations.

Some properties of the efficient market segmentation can be summarized in the Lemma below.

Lemma 8. *In the efficient market segmentation, a firm going public through a more reputable I-Bank sells shares at a lower price and retains fewer shares. When λ is high, the underpricing is more severe in an IPO associated with a more reputable I-Bank.*

Proof. It is a direct result of the “slope restriction” in the proof of Lemma 7 that firms retain fewer shares (lower IPO price) when they go public through a more reputable I-Bank. As for the underpricing, notice that when λ goes to one, the secondary market price of the IPO firm associated with a more reputable I-Bank goes to v_H due to information production. At the same time, the IPO price is lower for an IPO firm associated with a more reputable bank. The underpricing result is immediate. ■

The above lemma implies that for a very transparent industry (λ is high), the underpricing is more severe with a more reputable I-Bank.

There are many related works in examining the effects of underwriter reputation on the initial performance of IPOs (See Logue (1973), Beatty and Welch (1996), and Carter and Manaster (1990)). However, the empirical evidence with respect to the reputation effect on underpricing is mixed. For example, Carter and Manaster (1990) show that prestigious underwriters are associated with IPOs that have lower initial returns due to lower risk, while Logue (1973) and Beatty and Welch (1996) report the opposite results. According to our theory, if we differentiate firms by the transparency of the industry that they belong to, we can get unambiguous prediction.

A *key* implication of the above lemma is that firms retain a smaller fraction of equity (and lower IPO price) when they go public through a more reputable I-Bank, but they are compensated with a better service (low κ) and possibly a higher secondary market price. The difference in share retention is a necessary condition for efficient market segmentation. There are many works studying the link between investment bank reputation and IPO firm performance (as we discussed in the paragraph above) as well as the link between share retention and IPO firm performance (as in those signalling stories of equity sales such as Leland and Pyle (1977)), however, little has been said about the relation between share retention and investment bank reputation. Based on the efficient market segmentation theory of reputation, a more reputable underwriter is more selective in approving IPOs and it leads to a smaller fraction of equity retained by entrepreneurs.

5. Conclusion

In this article, we provide a theory of IPO market dynamics. We model the IPO market as a repeated certification game, and we discuss many stylized facts in the IPO market. We argue that the IPO price is not so much a reflection of the true value of a firm as it is a screening device affecting the firm's decisions to go public. IPO price and underwriting fee jointly determine the number of shares an entrepreneur retains. In equilibrium, in order to induce the information production by investment banks, the IPO market fluctuates over time. In hot periods, investment banks produce information and get a high payoff. Hot periods are characterized by more information produced by investment banks, and IPO prices are high in hot periods to attract more firms to go public. The results are robust when there are multiple investment banks. At the same time, we show that the efficient outcome is reached only when there is market segmentation. Less reputable investment banks attract firms of high types and approve them without producing information; more reputable investment banks attract firms of low types, and approve them only when good signals are observed.

We summarize the major contributions of the article as follows.

First, the model generates market dynamics in both volume and underpricing, and studies the interactions between the IPO market and the secondary equity market. The interpretation of investor sentiment is rationalized in our framework.

Second, with the efficient market segmentation argument, the article offers a new interpretation of investment bank reputation in the IPO market, which can be applied to many other social and economic environment with reputation effects involved.

Third, besides explaining many stylized facts in the existing literature, the model produces several new testable empirical implications that can be summarized as follows.

- (i) *For an industry with a high(low) probability of successful IPOs, a higher secondary market price implies a lower(higher) volatility of second market returns.*
- (ii) *Firms going public through a more reputable investment bank retain fewer shares.*
- (iii) *For firms in a transparent industry, underpricing is more severe in IPOs with a more reputable I-Bank.*

Doubtless, the above implications are related to other characteristics of IPO firms, such as firm size, value of assets in place, industry, and etc. Testing these empirical implications are subjects for future research.

Appendix A: Technical Notes

(Formalization of Stage Game)

The extensive form of the stage game (without secondary market trading) is given in Figure 8.

The stage strategy for the I-Bank is: $s_B \in S_B = \mathcal{R}_+ \times M \times \Psi$. $\mathcal{R}_+$ is the set for feasible underwriting fees. $M = \{\text{inspection}, \text{ni}\}$ is the set of inspection decisions, where “ni” represents “no inspection.” For $\psi \in \Psi$, $\psi : \mathcal{R}_+ \times \{\text{is}_H, \text{is}_L, \text{nis}_H\} \rightarrow \mathcal{R}_+ \cup \{\text{na}\}$ is about the decisions to approve or reject the firm for IPO and to set the IPO price for approved firms: “is_H” represents “getting a good signal after inspection,” “is_L” represents “getting a bad signal after inspection,” “nis_H” represents “getting a good signal without inspection,” the first $\mathcal{R}_+$ is the set of underwriting fee ϕ , the second $\mathcal{R}_+$ is the set of p_0 posted by the I-Bank, and “na” represents “a firm is not approved for IPO.”

The stage strategy for the firm is a function $s_F : \mathcal{R}_+ \times [0, 1] \rightarrow \{\text{public}, \text{private}\}$, where $\mathcal{R}_+$ is the underwriting fee posted by the I-Bank, $[0, 1]$ is the set of types, “public” means “going public,” and “private” means “staying private.”

The stage strategy for the investors is: $s_I : \mathcal{R}_+^2 \rightarrow \{b, \text{nb}\}$, where $\mathcal{R}_+^2$ is the set of $\{\phi, p_0\}$, “b” represents “buy,” “nb” represents “not buy.”

(Characterization of a PPE)

Let $V \equiv \{V_I(\sigma), V_B(\sigma) | \sigma \text{ is a PPE}\}$ be the set of PPE payoffs for the investors and the I-Bank. Note that by the existence of the stage game Nash equilibrium, Γ is not empty. Abreu, Pearce, and Stacchetti (1986, 1990) (APS) define the notion of “self-generation” to

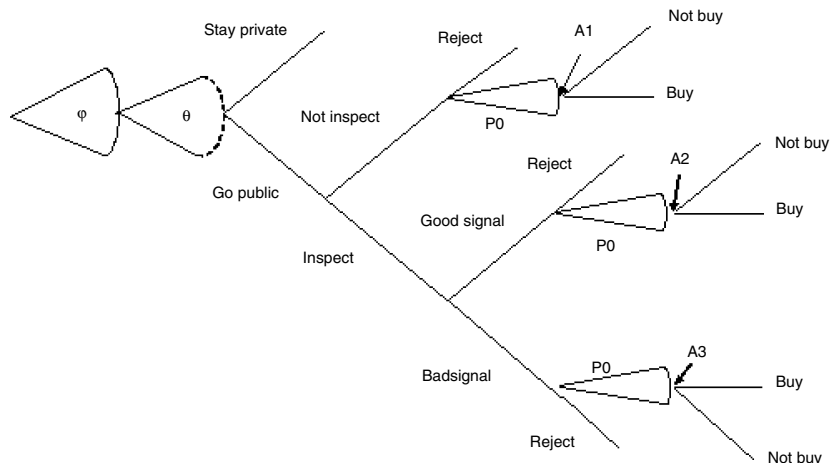


Figure 8

This graph gives the extensive form of the stage game. A1, A2 and A3 are in the same information set.

“factor” the PPE into the first period payoff and the continuation payoff, depending on the first period outcome. Phelan and Stacchetti (2001) extend the idea of APS to a game with a continuum of individuals.

To characterize V , define a “self-generation” operator Γ as follows:

$$\Gamma(V) = \{(V_I, V_B) : \exists (s_I, s_B, s_F) \in S_I \times S_B \times S_F \text{ and } (V'_I, V'_B) : H_t \rightarrow V\} \quad (A1)$$

$$s.t. V_I = E[\pi_{I_t}(s_I, s_B, s_F) + \delta V'_I(h_t)]$$

$$V_B = E[\pi_{B_t}(s_I, s_B, s_F) + \delta V'_B(h_t)],$$

$$V_B \geq E[\pi_B(s_I, \hat{s}_B, s_F) + \delta V'_B(\hat{h}_t)],$$

$$\chi_t^s = 1 \text{ implies } p_{1t} \geq p_{0t} \text{ for any } h_t \in H_t,$$

and

$$\pi_{F_t}(\theta)(s_I, s_F, s_B) \geq 0, \text{ for any } \theta \in \Theta_t,$$

$$\pi_{F_t}(\theta)(s_I, s_F, s_B) < 0, \text{ and for any } \theta \notin \Theta_t,$$

where Θ_t is the feasible set of types at time t . The key property of Γ required to adopt the methodology of APS is shown in Lemma 1.

Lemma 1. *The operator Γ maps compact sets to compact sets.*

Proof. This follows because the constraints entail weak inequalities, the feasible set is compact, and utility and constraint functions are real valued, continuous, and bounded. ■

With this property of Γ , let V_0 be compact and contain all feasible, individually rational payoffs, for example, $V_0 = [0, \frac{W^*}{\delta}] \times [0, \frac{W^*}{\delta}]$, with W^* being the largest social surplus that can be reached in one period, and define $V_{n+1} = \Gamma(V_n)$, $n \geq 0$. Then the definition of Γ

implies that $\Gamma(V_n) \subseteq V_{n+1}$. Following APS, $V^* = \lim_{n \rightarrow \infty} V_n$ is the largest invariant set of Γ , and thus is equal to the set of symmetric PPE values of this game.

Appendix B: Proofs

Proof. (Lemma 2) We prove it by contradiction. Assume that there exists a PPE in which the I-Bank inspects the candidate firm every period on the equilibrium path. Each equilibrium outcome generates a sequence of payoffs to the I-Bank at time t , $\{V_{Bt}\}_{t=0}^{\infty}$. For the continuation value of the I-Bank at period t , we write:

$$V'_{Bt}(\phi, 1, p_0, p_1, v_H) = V'_{Bt}(H) \quad (B1)$$

$$V'_{Bt}(\phi, 1, p_0, p_1, v_L) = V'_{Bt}(L) \quad (B2)$$

$$V'_{Bt}(\phi, 0, p_0, p_1, v) = V'_{Bt}(0). \quad (B3)$$

When a firm applies for IPO, the payoff for the I-Bank on the equilibrium path is:

$$V_{Bt}^i = -c + [P_{Ht} + (1 - \lambda)P_{Lt}]\phi_t + P_{Ht}\delta V'_{Bt}(H) + (1 - \lambda)P_{Lt}\delta V'_{Bt}(L) + \lambda P_{Lt}\delta V'_{Bt}(0), \quad (B4)$$

where P_{Ht} is the probability of an IPO firm being high value, P_{Lt} is the probability of a firm being low value, and $P_{Ht} + P_{Lt} = 1$.

If the I-Bank deviates by approving firms without inspection, the payoff for the I-Bank is:

$$V_{Bt}^{ni} = \phi_t + P_{Ht}\delta V'_{Bt}(H) + P_{Lt}\delta V'_{Bt}(L). \quad (B5)$$

If the I-Bank deviates by rejecting firms without inspection, the payoff for the I-Bank is:

$$V_{Bt}^r = \delta V'_{Bt}(0). \quad (B6)$$

The incentive constraint $V_{Bt}^i \geq \max\{V_{Bt}^{ni}, V_{Bt}^r\}$ implies:

$$V'_{Bt}(0) \geq V'_{Bt}(L) + \frac{\phi_t}{\delta} + \frac{c}{\delta \lambda P_{Lt}} \quad (B7)$$

$$\text{and } V'_{Bt}(H) \geq V'_{Bt}(L) + \frac{c}{\delta \lambda P_{Ht} P_{Lt}}. \quad (B8)$$

In any PPE, V_B is bounded below and above. For each PPE, there exists an upper bound $\overline{V}_B$ and a lower bound $\underline{V}_B$ on all the possible equilibrium payoffs. Let $\{V_{Bt}\}$ be a sequence of equilibrium payoffs such that there exists a subsequence, which, without loss of generality, we assume to be the sequence itself, and $\lim_{t \rightarrow \infty} V_{Bt} = \underline{V}_B$. For any $\varepsilon > 0$, there exists T large enough such that $V_{BT} < \underline{V}_B + \varepsilon$. Let Q_T be the probability of a firm choosing to go public at time T on the equilibrium path we have:

$$\begin{aligned} V_{BT} &= \pi_{BT} + Q_T[P_{HT}\delta V'_{BT}(H) + (1 - \lambda)P_{LT}\delta V'_{BT}(L) + \lambda P_{LT}\delta V'_{BT}(0)] + (1 - Q_T)\delta V'_{BT}(0) \\ &\geq \pi_{BT} + \delta \underline{V}_B + Q_T \left(\frac{c}{\lambda P_{LT}} + c \right) + (1 - Q_T) \left(\phi_T + \frac{c}{\lambda P_{LT}} \right), \end{aligned} \quad (B9)$$

which implies

$$\pi_{BT} < -Q_T \left(\frac{c}{\lambda P_{LT}} + c \right) - (1 - Q_T) \left(\phi_T + \frac{c}{\lambda P_{LT}} \right) + (1 - \delta)\underline{V}_B + \varepsilon \leq \frac{-c}{\lambda P_{LT}} + (1 - \delta)\underline{V}_B + \varepsilon.$$

However, we know:

$$\pi_{BT} = Q_T[-c + \phi_T(P_{HT} + (1 - \lambda)P_{LT})] > -c, \quad (\text{B10})$$

Let ε be close enough to zero, and we have a contradiction since $\underline{V}_B = 0$ (this can be reached by playing a stage game with zero payoff to the I-Bank repeatedly). ■

Proof. (Proposition 2) The expected stage profit of the I-Bank in a hot period is:

$$\pi_B^h = \phi Q_1 - c Q_2, \quad (\text{B11})$$

The expected stage profit of the I-Bank in a cold period is

$$\pi_B^c = \phi Q_0. \quad (\text{B12})$$

The incentive constraint for the I-Bank not to inspect the firm in a cold period is obviously satisfied. Let us now check the incentive constraints for the I-Bank to inspect the firm and truthfully reveal the signal in a hot period. Denote $\hat{\pi}_B^h$ as the deviation profit of the I-Bank when it does not inspect the firm in a hot period, and we have:

$$\hat{\pi}_B^h = \phi Q_2. \quad (\text{B13})$$

We can see that $\hat{\pi}_B^h > \pi_B^h$ since $Q_2 > Q_1$. Denote V_B^h as the expected lifetime payoff for the I-Bank at the beginning of a hot period if it follows the equilibrium strategy, and denote $\hat{V}_B^h$ as the expected lifetime payoff for the I-Bank with a one-shot deviation for this period. We have:

$$V_B^h = \pi_B^h + \rho \left(\sum_{t=1}^T \delta^t \pi_B^c + \delta^{T+1} V_B^h \right) + (1 - \rho) \delta V_B^h, \quad (\text{B14})$$

and

$$\hat{V}_B^h = \hat{\pi}_B^h + \hat{\rho} \left(\sum_{t=1}^T \delta^t \pi_B^c + \delta^{T+1} V_B^h \right) + (1 - \hat{\rho}) \delta V_B^h. \quad (\text{B15})$$

Taking the difference of V_B^h and $\hat{V}_B^h$, we have:

$$V_B^h - \hat{V}_B^h = \pi_B^h - \hat{\pi}_B^h + (\hat{\rho} - \rho)[(\delta - \delta^{T+1})V_B^h - \sum_{t=1}^T \delta^t \pi_B^c]. \quad (\text{B16})$$

The lower bound on ϕ to induce the inspection from the I-Bank can be calculated by imposing $V_B^h - \hat{V}_B^h \geq 0$. There are two other interim incentive constraints: (i) the I-Bank will inspect a firm that applies for going public, and (ii) The I-Bank will reject a firm when it observes a low signal. These constraints are also satisfied when $V_B^h - \hat{V}_B^h \geq 0$. ■

References

- Abreu, D., D. Pearce, and E. Stacchetti, 1986, "Optimal Cartel Equilibria with Imperfect Monitoring," *Journal of Economic Theory*, 39, 251–269.
- Abreu, D., D. Pearce, and E. Stacchetti, 1990, "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring," *Econometrica*, 58, 1041–1063.
- Allen, F., and G. R. Faulhaber, 1989, "Signaling by Underpricing in the IPO Market," *Journal of Financial Economics*, 23, 303–324.

- Baron, D. P., 1982, "A Model of the Demand of Investment Banking Advising and Distribution Services for New Issues," *Journal of Finance*, 37, 955–976.
- Beatty, R., and I. Welch, 1996, "Legal Liability and Issuer Expenses in Initial Public Offerings," *The Journal of Law and Economics*, 39, 545–603.
- Benveniste, L. M., W. Y. Busaba, and W. J. Wilhelm, Jr., 2002, "Information Externalities and the Role of Underwriters in Primary Equity Markets," *Journal of Financial Intermediation*, 11, 61–86.
- Benveniste, L. M., and P. A. Spindt, 1989, "How Investment Bankers Determine the Offer Price and Allocation of New Issues," *Journal of Financial Economics*, 24, 343–361.
- Bradley, D. J., B. D. Jordan, H. Yi, and I. C. Rothen, 2001, "Venture Capital and IPO Lockup Expiration: An Empirical Analysis," *Journal of Financial Research*, 24, 465–492.
- Brav, A., and P. A. Gompers, 1997, "Myth or Reality? The Long-Run Underperformance of Initial Public Offerings: Evidence from Venture and Nonventure Capital-Backed Companies," *Journal of Finance*, 52, 1791–1821.
- Carter, R., and S. Manaster, 1990, "Initial Public Offerings and Underwriter Reputation," *Journal of Finance*, 45, 1045–1067.
- Chari, V. V., and P. J. Kehoe, 1990, "Sustainable Plans," *Journal of Political Economy*, 98, 783–802.
- Chemmanur, T. J., and P. Fulghieri, 1994, "Investment Bank Reputation, Information Production, and Financial Intermediation," *Journal of Finance*, 49, 57–79.
- Chemmanur, T. J., and P. Fulghieri, 1999, "A Theory of the Going Public Decision," *Review of Financial Studies*, 12, 249–279.
- Chen, H., and J. R. Ritter, 2000, "The Seven Percent Solution," *Journal of Finance*, 55, 1105–1131.
- Fudenberg, D., D. K. Levine, and E. Maskin, 1994, "The Folk Theorem with Imperfect Public Information," *Econometrica*, 62, 997–1039.
- Green, E. J., and R. H. Porter, 1984, "Noncooperative Collusion under Imperfect Price Information," *Econometrica*, 52, 87–100.
- Hansen, R. S., 2001, "Do Investment Banks Compete in IPOs?: The Advent of the '7% Plus Contract'," *Journal of Financial Economics*, 59, 313–346.
- Helwege, J., and N. Liang, 2004, "Initial Public Offerings in Hot and Cold Markets," *Journal of Financial and Quantitative Analysis*, 39, 541–569.
- Ibbotson, R. G., 1975, "Price Performance of Common Stock New Issues," *Journal of Financial Economics*, 2, 235–272.
- Ibbotson, R. G., and J. F. Jaffe, 1975, "'Hot Issue' Markets," *Journal of Finance*, 30, 1027–1042.
- Kreps, D. M., and R. Wilson, 1982, "Sequential Equilibria," *Econometrica*, 50, 863–94.
- Leland, H. E., and D. H. Pyle, 1977, "Information Asymmetries, Financial Structure, and Financial Intermediation," *Journal of Finance*, 32, 371–387.
- Lerner, J., 1994, "Venture Capitalists and the Decision to Go Public," *Journal of Financial Economics*, 35, 293–316.
- Lizzeri, A., 1999, "Information Revelation and Certification Intermediaries," *RAND Journal of Economics*, 30, 214–231.
- Ljungqvist, A., V. K. Nanda, and R. Singh, 2003, "Hot Markets, Investor Sentiment, and IPO Pricing," Working Paper, New York University.
- Logue, D., 1973, "On the Pricing of Unseasoned Equity Issues: 1965–1969," *Journal of Financial and Quantitative Analysis*, 8, 91–103.
- Loughran, T., and J. R. Ritter, 1995, "The New Issues Puzzle," *Journal of Finance*, 50, 23–51.

- Loughran, T., and J. R. Ritter, 2004, "Why Has IPO Underpricing Changed Over Time?" *Financial Management*, 33, 5–37.
- Lowry, M., 2003, "Why Does IPO Volume Fluctuate So Much?" *Journal of Financial Economics*, 67, 3–40.
- Lowry, M., and G. W. Schwert, 2002, "IPO Market Cycles: Bubbles or Sequential Learning?" *Journal of Finance*, 57, 1171–1200.
- Lucas, D. J., and R. L. McDonald, 1990, "Equity Issues and Stock Price Dynamics," *Journal of Finance*, 45, 1019–1043.
- Maksimovic, V., and P. Pichler, 2001, "Technological Innovation and Initial Public Offerings," *Review of Financial Studies*, 14, 459–494.
- Michaely, R., and W. H. Shaw, 1994, "The Pricing of Initial Public Offerings: Testing of Adverse-Selection and Signalling Theories," *Review of Financial Studies*, 12, 653–686.
- Miller, E. M., 1977, "Risk, Uncertainty, and Divergence of Opinion," *Journal of Finance*, 32, 1151–1168.
- Pagano, M., F. Panetta, and L. Zingales, 1998, "Why Do Companies Go Public? An Empirical Analysis," *Journal of Finance*, 53, 27–64.
- Pastor, L., and P. Veronesi, 2005, "Rational IPO Waves," *Journal of Finance*, 60, 1713–1757.
- Phelan, C., and E. Stacchetti, 2001, "Sequential Equilibria in a Ramsey Tax Model," *Econometrica*, 69, 1491–1518.
- Rajan, R.G., and H. Servaes, 1997, "Analyst Following of Initial Public Offerings," *Journal of Finance*, 52, 507–529.
- Rajan, R. G., and H. Servaes, 2003, "The Effect of Market Conditions on Initial Public Offerings," in J. McCahery, and L. Rennebog (eds), *Venture Capital Contracting and the Valuation of High-Tech Firms*, Oxford University Press, Oxford.
- Ritter, J., 1984, "The 'Hot Issue' Market of 1980," *Journal of Business*, 57, 215–240.
- Ritter, J., and I. Welch, 2002, "A Review of IPO Activity, Pricing, and Allocations," *Journal of Finance*, 57, 1795–1828.
- Rock, K., 1986, "Why New Issues are Underpriced," *Journal of Financial Economics*, 15, 187–212.
- Schultz, P. H., 2003, "Pseudo Market Timing and the Long-Run Underperformance of IPOs," *Journal of Finance*, 58, 483–518.
- Shapiro, C., 1983, "Premiums for High Quality Products as Returns to Reputations," *Quarterly Journal of Economics*, 98, 659–680.
- Spatt, C., and S. Srivastava, 1991, "Preplay Communication, Participation Restrictions, and Efficiency in Initial Public Offerings," *Review of Financial Studies*, 4, 709–726.
- Stoughton, N. M., K. P. Wong, and J. Zechner, 2001, "IPOs and Product Quality," *Journal of Business*, 74, 375–408.
- Subrahmanyam, A., and S. Titman, 1999, "The Going Public Decision and the Development of Financial Markets," *Journal of Finance*, 54, 1045–1082.
- Titman, S., and B. Trueman, 1986, "Information Quality and the Valuation of New Issues," *Journal of Accounting and Economics*, 8, 159–172.
- Welch, I., 1989, "Seasoned Offerings, Imitation Costs, and the Underpricing of Initial Public Offerings," *Journal of Finance*, 44, 421–449.
- Zingales, L., 1995, "Insider Ownership and the Decision to Go Public," *Review of Economic Studies*, 62, 425–448.

Copyright of Review of Financial Studies is the property of Society for Financial Studies and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.