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IPOs and Product Quality*

Given recent public attention paid to high-flying Internet IPOs such as Yahoo and Amazon.com, we explore a product market motive for going public. We develop a model where consumers discern product quality from the stock price. The model predicts that only better-quality firms will go public. Effects of IPO announcements on rival firms' stock prices are related to inferences about market size and market share. The model also predicts that the likelihood of "hot issue" markets depends on the distribution of market size uncertainty and the degree of network externalities present in consumer preferences.

I. Introduction

Public interest in and attention to initial public offerings (IPOs) has accelerated in recent years with the boom in high-tech and Internet start-ups, many of whose stock prices have skyrocketed. As a result, being listed on a public exchange is often featured prominently in advertising and other marketing literature.

What really motivates firms to go public, and what trade-offs are involved? In surveys the most frequently mentioned motive for going public is to provide optimal access to capital markets in order to obtain new finance.[1] However, this explanation appears to have difficulty in explaining the precise nature of the timing

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1. See, e.g., the surveys discussed in Röell (1996).

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of public offerings, as firms often have substantial cash in their balance sheet prior to going public.[2] Moreover, the prospectus is often rather uninformative about this aspect as well, usually indicating that the proceeds of the issue are to be used for "general corporate purposes." In a similar vein, Pagano, Pinata, and Zingales (1998) find in an empirical study of Italian IPOs that the need to finance investment and growth has little power in explaining the likelihood of IPOs.

This article explores the second most frequently given explanation for a firm's decision to go public, namely, that it enhances the company's image and publicity.[3] It is easy to find anecdotal support for this motive. Edward McVaney, chief operating officer of J. D. Edwards, commented that his (September 1997) IPO has led more corporate customers to start thinking of his company as a valid ERP (enterprise resource planning) competitor. "Privately held companies get no respect," he stated (Brown 1997, p. 244).

In this article we formulate the intuition that being publicly traded can be desirable by allowing for a product market motive to go public. Our model depicts the interaction between information generated by informed speculators and research analysts of a publicly traded firm and consumers who infer product quality from the stock price. Going public provides a signal to consumers that the firm is willing to subject itself to the scrutiny of outside analysts who now have incentives to investigate the firm.[4] In our model the stock market is more than a certification mechanism.[5] It also implies that a large body of investors (security analysts) are actively engaging in the process of price discovery.

We believe that the considerations identified in this article are especially relevant for firms in high-tech industries where competitive dynamics are an important consideration for long-term success. In this respect, being the first firm to go public may convey strategic advantages relative to rival firms in the same market segment.[6] Empirical evidence of product market effects of going public has been the subject of several recent articles. Slovin, Sushka, and Ferraro (1995) document an average negative announcement effect on rival firms (in the same four-digit SIC code). They found that the rivals' stock price reaction for equity "carve-outs" and for conventional IPOs was about -1% and was statistically significant.[7] By contrast, Ward (1997) found that the average effect of IPO announcements on rival firms depends on the motive given in the prospectus. The product market explanation for going public also

2. For instance, one of the star performers of 1998, BroadCom, put the entire proceeds of their offering into T-bills.

3. In addition to the aforementioned survey, this motive is documented in Ferrari (1992) and Rydqvist and Högholm (1995) as well.

4. That is, outside analysts now substitute for inside monitoring by venture capitalists (Barry et al. 1990).

5. See Boot and Thakor (1997) for a discussion of the importance of this function.

6. See Reinganum (1989) for a discussion of such product market models.

7. Slovin, Sushka, and Benedeck (1991) found that rival firms' stock price reactions were positive to a firm going private.

extends to the international context. It may explain why some firms list their shares on several foreign markets, for example, as American Depository Receipts on U.S. markets. Confirming the importance of product markets, Pagano, Röell, and Zechner (2001) find that the propensity of firms to cross-list their shares on a foreign market increases with the percentage of export sales.[8]

The basic model we develop in the article features a stock market equilibrium model with a previously unexplored two-way effect. Consumers infer quality from the stock price, and the stock market rationally anticipates profits generated by the quality perceptions of consumers. The model also allows for demand path dependencies to capture network externalities. More precisely, the consumers' willingness to buy the good in the future periods may be positively related to the product quality as perceived when the stock begins trading.

We find that there exist separating equilibria in which firms above a critical quality level decide to go public, whereas firms with low quality levels stay private. High-quality firms are willing to pay for information acquisition in the stock market, since they benefit through better quality reputation in the product market. The propensity to go public depends on the growth in market size generated by network externality effects. We also show that such effects limit the degree to which entrepreneurs and venture capitalists can "sell off" their holdings. In this setting, IPOs imply stock price reactions of rival firms in the industry. Generally, announcing an IPO is bad news for competitors since this signals a higher product quality to consumers and, thus, lowers the price that competitors can charge for their products.

As an important alternative to going public, firms may signal their quality through the price they charge to consumers. This requires that marginal costs of production differ across firms with different product quality. We develop a related model to compare this alternative to signaling via going public. The analysis demonstrates that IPOs are preferred by high-quality types if network externalities are stronger and when the difference between production costs is small.

Initial public offerings have been the subject of a substantial amount of research in the finance literature. Yet, the interactions between the IPO decision and the product market have largely been ignored. Existing literature on IPOs can be classified in one of three categories. First, there is a class of work that analyzes IPOs but takes the firms' need to go public as given. In these models an investment project must be funded by going public and/or the entrepreneur is risk-averse and wants to diversify. This class of work derives the equilibrium pricing and equity issuance decisions given various kinds of informational asymmetries. Examples of work in this category are the signaling articles of Leland and Pyle (1977), Allen and Faulhaber (1989), Grinblatt and Hwang

8. Blass and Yafeh (2001) look at a sample of Israeli firms that are only listed in U.S. markets and characterize them as young, high-tech, and export-oriented.

(1989), Welch (1989), and Cao and Shi (2000), as well as articles by Brennan and Franks (1997), Stoughton and Zechner (1998), and Maksimovic and Pichler (2001).

The second category of work endogenizes the decision of whether to go public. Generally the alternative to the IPO considered in this literature is a private equity issue. For work in this category, the reason why firms may choose an IPO rather than a private equity issue is because of capital market frictions. An IPO may minimize transactions costs involved with financing a project but has no direct influence on firm fundamentals. For example, the cost of information acquisition by shareholders, which is high in the case of an IPO, must be traded off against the better risk-sharing opportunities that a publicly placed stock issue creates. Examples of this strand of literature are Zingales (1995) and Chemmanur and Fulghieri (1999).

The third category of literature endogenously explains IPOs by their potential direct effects on firm fundamentals. An IPO may result in optimal monitoring by shareholders or may allow improved incentive contracts between the firm and the manager, and so on. For example, work by Holmstrom and Tirole (1993), Maug (1997), Bolton and von Thadden (1998), Pagano and Röell (1998), and van Bommel (2000) falls into this literature category.

Our article also falls into the third category, but we focus on an effect on firm fundamentals that has thus far been ignored: the effect of an IPO on the firm's consumers.[9] In our model, firms do not necessarily need the stock market to raise new capital but, rather, wish to obtain independent certification about the quality of its products. This helps high-quality firms compete more effectively in the product market.

This article is also related to two strands of literature on industrial organization. First, it contributes to the literature on network externalities, standardization, and compatibility. As discussed in Farrell and Saloner (1985) and Katz and Shapiro (1986), positive network externalities arise when consumers derive additional benefits from the use of a good as the number of consumers purchasing the same good or compatible ones increases. Emerging industries such as Internet-based industries exhibit strong network externalities where eventually few products dominate a market. Our model incorporates the intertemporal nature of competition by featuring such network externalities. We thus link the informational advantages of an IPO to the firm's strategic position in future periods.

A second strand of the economics literature deals with equilibrium price-quality schedules for markets where product quality is unobservable (see Klein and Leffler 1981; Shapiro 1983; Allen 1984; Bagwell and Riordan 1991; and Judd and Riordan 1994). In their models of competitive firms, a quality premium (i.e., price above marginal cost) is called for to keep the firms from cutting product quality, thereby milking their reputation. We include an al-

9. An interesting interpretation of our results is provided by the analogous extension to employees and input suppliers.

ternative analysis of product price signaling versus signaling through the IPO process and demonstrate an advantage to the latter for competitive industries with low marginal costs of production.

The article is structured as follows. Section II introduces the model and derives the results for the case of a single firm. In Section III we allow for competition in the product market. Section IV compares signaling through the product price with signaling by going public. Section V gives a summary of results and highlights empirical predictions with particular attention to cross-sectional industrial and competitive implications.

II. The Single-Firm Model

We develop the model first for a setting in which there is a single firm. The model features several types of agents. A firm is in the process of deciding whether to go public. If it goes public, the original owners retain a fraction α of the equity and issue the fraction $1 - \alpha$. The alternative to going public is obtaining private financing in order to implement the same investment and production strategy.

If the firm decides to go public, it offers equity at a fixed price to a set of uninformed investors who have rational expectations about future price movements. Specifically, we assume that these uninformed investors later trade with informed speculators once secondary trading opens.[10] The value or profits of the firm are related to consumers' perceptions of the product quality sold by the firm. Consumers make purchase decisions in two periods. In the first period, assumed to be simultaneous with the introduction of secondary trading, consumers use information about whether the firm made a public offering in conjunction with the security price, if it exists, to infer the quality of the product. The higher the quality, the greater is consumers' willingness to pay, which translates into higher profits for the firm. In the second period, consumers know quality perfectly, presumably because of their purchase experiences in the previous period. The total value of the firm at the time of the IPO is determined by the sum of both first- and second-period profit. The sequence of events is depicted in figure 1.

In deciding whether to go public, the firm has to consider the associated cost along with the potential benefit. The cost in our model is related to underpricing of the issue. The potential benefit is the fact that if the firm's stock is publicly held, consumers will be able to use the stock price as a means to estimate the product quality. All agents in the model, the firm, consumers, uninformed investors, speculators, and market makers, always have rational expectations given their information sets and utilize the form of the equilibrium in making decisions.

10. Chemmanur (1993) contains a more elaborate model with endogenous information production by traders.

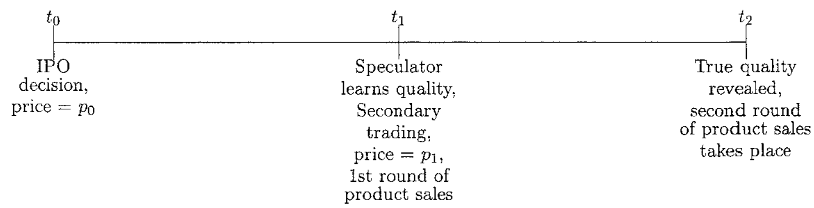

FIG. 1.—Events in the model

A. *The Basic Elements*

The essential elements of the market microstructure model are the same as in Kyle (1985). However, there is an additional ingredient in that a part of the intrinsic value derives from inferences about product quality obtained from the stock price.

At some initial time, t_0, the firm learns its expected product quality, $\bar{q}_i$, and decides whether to go public. The expected product quality is commonly known to be distributed over the two-point support $\{\bar{q}_L, \bar{q}_H\}$. For simplicity, we assume that the prior probability distribution establishes equal probability for each of the two points, that is, the probability of $\bar{q}_L = \bar{q}_H = 1/2$. There is a set of uninformed investors (i.e., who do not observe quality directly) who purchase all of the IPO at the price p_0.

The firm knows whether it has high expected quality, $\bar{q}_H$, or low expected quality, $\bar{q}_L$, at the time of the IPO. We denote a firm that has high expected quality as a "high type" and that of a low expected quality as a "low type." The final quality realization conditional on the firm's inside information is denoted by q and is random and distributed normally with mean $\bar{q}_i \in \{\bar{q}_L, \bar{q}_H\}$ and variance σ_q^2. The firm does not know the true quality level at the time of the IPO.

At time t_1, secondary trading begins, and a single informed speculator learns the firm's true quality, q. The speculator utilizes this information in deciding on his trading demand, x. At this time, uninformed investors make portfolio adjustments. While they expect to sell all of their holdings purchased in the IPO, $1 - \alpha \equiv v$, the actual amount of their sales is random, because of factors outside their control (e.g., endowment shocks).[11] Whatever remains unsold after time t_1 is sold later in the second period. Specifically, uninformed traders sell $v - u$, where u is assumed to be normally distributed with mean zero and variance σ_u^2. Trades at time t_1 are cleared through a market maker (arbitrageur) who observes the total order flow and realizes expected profit of zero. We

11. It can be shown that the results remain the same if uninformed investors expect to sell only a fraction of the shares immediately and the rest later. For a model of endogenous informed trading, see Khanna, Slezak, and Bradley (1994).

assume that all agents are risk-neutral. The rational expectations equilibrium price is denoted by p_1.

Given observation of the secondary market price, consumers are willing to pay a price for the good sold by the firm equal to $\hat{q} = E(q \mid p_1)$ in the first period. That is, consumers are risk-neutral and are willing to pay a price equal to their perceived quality given the observed stock price, p_1. Each consumer demands one unit of the good.

After the first round of product sales, quality is revealed. We assume that the consumer's willingness to pay in the second period increases with the revealed quality. In addition, we consider a time-dependence effect whereby the perceived quality from the first period increases the willingness to pay in the second period. This represents the fact that consumers' tastes in the second period may exhibit path dependencies. Alternatively this can be interpreted as a network externality effect. While the network externality is usually modeled directly as a function of the number of consumers who purchase the product (Katz and Shapiro 1986), we shall see in Section III, when competition in the product market is considered, that a high perceived product quality in the first period is generally associated with a larger market share. Specifically, we assume that consumers pay an amount $q + \gamma\hat{q}$ in the second period, where $\gamma \geq 0$ is a coefficient representing intertemporal demand dependencies. The specification considered can be motivated by experience and resource-specific investments. For instance, suppose that the initial period perceived quality is high for a particular software application. The consumer may then make specific investments in that application so that, even if another application appears better in the subsequent period, it is still better to stay with the original software application.

It is worth pointing out that in this model product price cannot serve as a signal of quality by itself. This is because the respective firm types have identical production costs, and therefore any attempt by the high-quality firm to signal through a higher price would be mimicked by the low-quality firm.[12] However, we consider a related model in Section IV in which price signaling is feasible.

The expected number of consumers in the first period and the second period, respectively, is denoted by $\bar{M}_1$ and M_2. Before the IPO the financial market regards the market size in the first period to be uniformly distributed with mean $\bar{M}_1$ and support $[\bar{M}_1 - s, \bar{M}_1 + s]$.[13] Market size is assumed to be independent of the distribution of product quality. We assume that the IPO communicates the true size of the market in period 1, M_1. For simplicity we assume that the IPO process does not reveal new information about the long-term size of the product market, M_2.

12. That is, the well-known Mirrlees-Spence-Riley single-crossing condition is not satisfied in our model.

13. Random market size is not important until the product market is introduced (in Sec. III).

The secondary market price, p_1, is established by the market maker to break even:

$$p_1 = M_1 E(q|p_1) + M_2[E(q|y) + \gamma E(q|p_1)],$$

where $y \equiv x - v + u$ is the total order flow observed by the market maker. Thus, at time t_1, the value of the firm is equal to the number of consumers in the first period, M_1, times the price they are willing to pay for the good, given the stock price, $E(q|p_1)$, plus the expected second-period value conditional on observing the order flow.

B. Stock Market Equilibrium

In our model a rational expectations equilibrium is defined to be a set of trades, market prices, and consumer conjectures at time t_1 such that the speculator uses her inside information about the true quality and takes into account the impact her trades have on market prices. Market makers use the information implicit in order flow to establish market prices. Consumers use the information implicit in market prices to estimate expected quality. We now derive the functional form of the rational expectations equilibrium under the assumption that only one type of firm goes public. As is commonly assumed, we consider only the set of linear rational expectations equilibria, that is, where demand of the speculator is linearly related to product quality, market prices are linear in order flow, and consumer conjectures are linear in prices. Let the expected quality of the type that goes public be $\bar{q}$. Then we can solve for the equilibrium demands of the speculator, x, the secondary market price, p_1, and consumer's conjectures.

PROPOSITION 1. Suppose that type $\bar{q}$ goes public. Then, there exists a rational expectations equilibrium in which (i) the speculator's demand schedule is

$$x = \frac{\sigma_u}{\sigma_q}(q - \bar{q}); \tag{1}$$

(ii) the equilibrium stock price is

$$p_1 = [M_1 + M_2(1 + \gamma)]\left[\bar{q} + \frac{\sigma_q}{2\sigma_u}(y + v)\right], \tag{2}$$

(iii) the perceived first-period product quality is

$$\hat{q} = \frac{1}{M_1 + M_2(1 + \gamma)} p_1, \tag{3}$$

and (iv) the speculator's expected revenue is

$$R = \frac{M_2}{2}\sigma_q\sigma_u. \tag{4}$$

Proof. See Section I of the appendix.

With one exception, the derivation of this equilibrium follows standard procedures and, therefore, is deferred to the appendix. The exception is that consumers' perceptions are an integral component of the price and are, in turn, determined by the price.

Proposition 1 shows that the speculator's demand is determined by whether her observation of the true quality is above its expected value given that the firm has gone public. The higher is the ratio of the standard deviation of uninformed demand to the standard deviation of quality, the more significance is placed on the observation by the speculator. The stock price is a linear combination of expected quality conditional on going public plus the order flow. In equilibrium, prices are partially informative about quality so that the higher the stock price, the more consumers are willing to pay to purchase the product.[14] Finally, the speculator's expected revenue is positively related to the size of the product market in the second period and to the ex ante uncertainty about product quality and uninformed trades. We note that the speculator's profits do not depend on first-period product market sales. This occurs because the speculator's information is only valuable at the time true quality is revealed in the second round of sales.

Since the uninformed traders purchase all of the IPO and then expect to sell to the informed trader, the IPO price is reduced in anticipation of such trades. This leads to IPO underpricing in our model.[15] We now solve for the amount of underpricing.

The uninformed investors sell $v - u$ to the informed speculator at time t_1 and then sell their remaining holdings, u, at the end. Given competition between uninformed investors for the IPO, the cost of purchasing the shares at the IPO price, $(1 - \alpha)p_0$, must be set to equal the expected revenue from future trades. That is,

$$(1 - \alpha)p_0 = E[(1 - \alpha - u)p_1 | \bar{q}] + E\{u[M_1\hat{q} + M_2(q + \gamma\hat{q})] | \bar{q}\}.$$

Using proposition 1, the above expression becomes

$$\begin{aligned}(1 - \alpha)p_0 &= (1 - \alpha)[M_1 + M_2(1 + \gamma)]\bar{q} \\ &\quad - \frac{M_1 + M_2(1 + \gamma)}{2}\sigma_q\sigma_u + \frac{(M_1 + M_2\gamma)}{2}\sigma_q\sigma_u \\ &= (1 - \alpha)[M_1 + M_2(1 + \gamma)]\bar{q} - \frac{M_2}{2}\sigma_q\sigma_u \\ &= (1 - \alpha)[M_1 + M_2(1 + \gamma)]\bar{q} - R.\end{aligned}$$

14. By contrast, in the model of Sec. IV, we assume that prices are perfectly informative about quality.

15. As in Rock (1986), underpricing is required here to compensate uninformed investors for participating in the IPO. However, as in Holmstrom and Tirole (1993), the uninformed traders' losses result from liquidity trading. Beatty and Ritter (1986) document a positive relation between IPO underpricing and ex ante uncertainty, as in our model.

This gives the following relation for the determination of the IPO price:

$$p_0 = [M_1 + M_2(1 + \gamma)]\bar{q} - \frac{R}{1 - \alpha}. \tag{5}$$

The second term of equation (5) represents the underpricing of the IPO. It is easy to see that underpricing is positively related to the fraction of equity retained by the firm.[16]

C. Going Public Decision

We now consider the question of whether the firm should go public or remain private. As before, suppose the market conjectures that the type of firm that goes public is equal to $\bar{q}$. Let the firm's true type be $\bar{q}_i$, where $i = H, L$. If the firm goes public, the firm's entrepreneur of type $\bar{q}_i$ receives a payoff equal to

$$w = (1 - \alpha)p_0 + \alpha[M_1\hat{q} + M_2(q + \gamma\hat{q})]. \tag{6}$$

That is, the entrepreneur receives the proceeds from the IPO at a price of p_0 plus the value of the retained equity, depending on the consumer's perception, $\hat{q}$, of firm quality.

The entrepreneur is assumed to be risk-averse with a negative exponential utility function of wealth, $u(w) = -\exp(-\rho w)$, where ρ is the constant coefficient of absolute risk aversion. Given that both $\hat{q}$ and q are normally distributed, it is well known that expected utility maximization is equivalent to maximizing the following function:

$$U(\text{public}) = (1 - \alpha)p_0 + \alpha E[M_1\hat{q} + M_2(q + \gamma\hat{q})|\bar{q}_i] - \frac{\rho\alpha^2}{2}\text{Var}[M_1\hat{q} + M_2(q + \gamma\hat{q})|\bar{q}_i]. \tag{7}$$

From proposition 1, we have

$$\hat{q} = \frac{1}{2}(q + \bar{q}) + \frac{\sigma_q}{2\sigma_u}u,$$

in which case the value of the firm can be written as

$$M_1\hat{q} + M_2(q + \gamma\hat{q}) = [M_1 + M_2(2 + \gamma)]\frac{q}{2} + (M_1 + M_2\gamma)\frac{\bar{q}}{2} + (M_1 + M_2\gamma)\frac{\sigma_q}{2\sigma_u}u.$$

Evaluating the expectation and variance in equation (7) then gives

16. James and Wier (1990) have examined the relation between underpricing and the proportion of insider shares sold.

$$U(\text{public}) = (1-\alpha)[M_1 + M_2(1+\gamma)]\bar{q} - R + \frac{\alpha}{2}\{[M_1 + M_2(2+\gamma)]\bar{q}_i + (M_1 + M_2\gamma)\bar{q}\} - \frac{\rho\alpha^2}{4}K\sigma_q^2, \tag{8}$$

where $K = [M_1 + M_2(2+\gamma)](M_1 + M_2\gamma) + 2M_2^2$. Expected utility is interpreted as consisting of the value of the equity that is sold through the IPO less the cost of underpricing plus the value of retained equity, which is reduced by the cost of nondiversification.

Alternatively, if the firm remains private, consumers will learn that the firm chose not to go public. Suppose that type $\underline{q}$ chose not to go public. Then, since the entrepreneur retains all the equity in the firm, the entrepreneur's wealth is

$$w = M_1\underline{q} + M_2(q + \gamma\underline{q}).$$

The entrepreneur's expected utility can therefore be derived as

$$U(\text{private}) = (M_1 + M_2\gamma)\underline{q} + M_2\bar{q}_i - \frac{\rho}{2}M_2^2\sigma_q^2. \tag{9}$$

We are now ready to state the entrepreneur's problem. The entrepreneur of type $\bar{q}_i$ chooses to go public if and only if $U(\text{public}) \geq U(\text{private})$. In doing so, a comparison is made between any potential pricing benefits or losses, the cost of underpricing, and a comparison of the risks incurred. Going public carries risk only to the extent that some degree of equity is retained and the value of that equity is affected by randomness in the market price. Remaining private also carries risk, however, since more equity is retained and the quality is still uncertain.

D. Separating Equilibria

We now solve for the existence of a family of signaling equilibria in which the high-type firm, $\bar{q}_H$, goes public and the low-type firm remains private. The existence of such equilibria is possible because the high-type firm is willing to pay the cost of IPO underpricing if it means that its high expected quality is communicated to consumers who then pay higher prices for the product. By contrast, the low-expected-quality firm is unwilling to go public, because, although this communicates positive information to the market, the speculator knows the true quality and causes prices to reflect partly his inside information.

A standard signaling game is considered in which the informed entrepreneur moves first by choosing whether to go public and, if so, what level of equity to retain. Based on this action, the financial market establishes beliefs and therefore prices the equity that is offered.

PROPOSITION 2. Suppose that

$$(M_1 + M_2\gamma)\Delta q - R - \frac{\rho}{4}\Big(K\hat{\alpha}^2 - 2M_2^2\Big)\sigma_q^2 \geq 0 \tag{10}$$

and

$$\frac{1}{2}(M_1 + M_2\gamma)\Delta q - R - \frac{\rho}{4}\Big(K - 2M_2^2\Big)\sigma_q^2 < 0, \tag{11}$$

where $\Delta q = \bar{q}_H - \bar{q}_L$ and $\hat{\alpha} = 2M_2/[M_1 + M_2(2 + \gamma)] \in (0, 1)$. Then there exists a family of separating signaling equilibria in which the high-type firm goes public with equity retention, $\alpha^* \leq \alpha \leq \min(\alpha_H, 1)$, while the low-type firm remains private, where α^* and α_H are, respectively, defined by

$$(M_1 + M_2\gamma)\Big(1 - \frac{\alpha^*}{2}\Big)\Delta q + (1 - \alpha^*)M_2\Delta q - R - \frac{\rho}{4}\Big(K\alpha^{*2} - 2M_2^2\Big)\sigma_q^2 = 0 \tag{12}$$

and

$$(M_1 + M_2\gamma)\Delta q - R - \frac{\rho}{4}\Big(K\alpha_H^2 - 2M_2^2\Big)\sigma_q^2 = 0. \tag{13}$$

Proof. See Section II of the appendix.

Proposition 2 presents sufficient conditions for existence of a separating equilibrium in which the high type goes public with equity retention at least equal to α^*, while the low type remains private.[17] To have existence of this equilibrium, the cost to the high type from going public, incurring the risk of retained equity and paying the cost of underpricing must be sufficiently small. Simultaneously, the low type's benefits from being mispriced and laying off risk by selling equity must be less than the loss resulting from underpricing. The essential reason why both conditions can hold is that the informed speculator prevents the gains from mispricing to the low type from being as large as the gains to the high type from revealing itself through the IPO process. If the high type offers too much equity, the gains from mispricing to the low-type firm would be too great.

It is worth noting the critical importance that consumers react to the information contained in the stock price. Suppose instead that consumers based their purchase decisions only on whether the firm went public. Then, the benefit to going public would be the same for both the high- and low-quality firms. Since the cost of going public (underpricing) is also identical, a separating equilibrium would fail to exist.

The most significant empirical prediction arising from this proposition is

17. Using Pareto dominance, or one of the other equilibrium refinements, it is easy to see that the efficient equilibrium has the high type's equity retention identically equal to α^*.

the fact that a firm that has undergone an IPO provides an important signal of quality to consumers. This signal is informative even before the stock price becomes available. As mentioned in the introduction, we would expect quality-driven IPOs for industries where new products are being introduced simultaneously with the IPO. Obviously this is most applicable to the high technology area in which new products are constantly being introduced and where quality is difficult to ascertain directly.

There are a number of other empirical predictions that are also embodied in this proposition. First, a sufficient amount of equity retention is a necessary condition. Although equity retention seems to be counter to the aspect of going public, it still is critical. Thus, we would not expect to observe quality-driven IPOs in which the entrepreneurs are selling out entirely. Second, going public requires a sufficiently large market size in the first period. Essentially, the critical condition is that the degree of information asymmetry about quality known to the firm must be greater than the amount of information learned by the speculator for the second period. Hence, this prediction of the model implies that for the listing decision to provide information, the potential speculative profits cannot be too large.

With respect to the impact of network externalities, as γ increases, condition (10) is more easily satisfied, which means that firms in such industries are more likely to go public. In addition, from equation (12), the required equity retention on going public must be greater for such firms. This occurs because with network externalities the potential benefits of misrepresenting quality by going public are greater than in the absence of such effects.

Finally, we examine the impact of risk aversion in the equilibrium. As in Leland and Pyle (1977), risk aversion affects both high and low types in similar ways. Risk-averse entrepreneurs who sell equity through the IPO are able to diversify their holdings. This provides a benefit. However, when selling equity in the market, the retained equity is subjected to market risks, such as the noise traders in the model. Since this affects consumer perceptions and, thereby, second-period profits, going public also carries a cost. Which one of these two offsetting aspects dominates depends on the required level of equity retention. Since the impact of risk aversion is identical for both types for a given level of equity retention, the nature of the equilibrium is driven by the other benefits and costs. The only major difficulty introduced by the existence of risk aversion is that if the retained equity required to prevent mimicking by the low type is too costly for the high type because of lack of portfolio diversification, then the separating equilibrium would fail to exist. Conditions (10) and (11) ensure that this is not the case.

In Section III, we turn to a model of competition in the product market. This allows us to derive results on stock price reactions of competitive firms and to study possible “hot issue” markets and correlation of IPO decisions among firms in the same industry.

III. Product Market Competition

We now extend the previous results to consider product market competition. The model of competition we use is a simple market share model, which assumes that consumers trade off quality against a search cost based on their location. As a result, the higher-quality firm will obtain higher market share. Profits are an increasing function of both market share and market size. An alternative model using Bertrand competition is analyzed in Section IV.

Suppose that there are two firms (indexed by I and E) competing on the line segment [0, 2]. Firm E is the entrant located at zero, and firm I is the incumbent located at two.[18] Consumers are uniformly distributed on the line segment, and each of them demands one unit of a good produced by either firm E or firm I. Consumers incur a transportation cost, T, per unit distance traveled. To simplify the exposition, we assume that $T = 1/2$.[19] Market structure is captured by monopolistic competition such that the firms produce differentiated products and take prices as given. Given monopolistic competition, prices can be normalized to one without loss of generality. In Section IV, a related model is developed in which prices are strategically chosen by the entrant and incumbent firms.

Market size in periods 1 and 2, respectively, is represented by the magnitude or density of consumers, M_1 and M_2. In accordance with Section II, we assume that M_1 is known to both the entrant and the incumbent firm, but not to the outside financial market, ex ante. As a result, the IPO process may communicate some information about market size as well as quality to the financial market. This will enable the model to make richer predictions about the stock price reactions of the incumbent firm when it is publicly traded. For the second period only the expected market size, M_2, is known by both the financial market and the firms.

Information about the first-period market size is characterized as follows. Before the IPO the financial market regards the consumer density to be uniformly distributed with mean $\bar{M}_1$ and support $[\bar{M}_1 - s(n), \bar{M}_1 + s(n)]$, where n is the number of firms that will be publicly traded after the IPO. Thus $s(n)$ represents the incremental information associated with revelation of information about market size in the nth firm's prospectus. The support variable, $s(n)$ can depend on the number of firms that have gone public. This assumption embodies the viewpoint that the financial market expects no increase in market size from the IPO process itself on an ex ante basis. However, the resolution of uncertainty, as represented by the variance of the ex ante distribution, may depend on the number of firms that are publicly listed. For example, if the initial prospectus reveals more information about market size than do sub-

18. Although we describe E as an entrant, this is mainly for the purpose of distinguishing it from the incumbent. The entrant firm always competes with the incumbent. The distinction is that the entrant has the discretionary decision on whether to undergo an IPO or not, in contrast to the incumbent, which has already decided.

19. We have also solved the model for general T and discuss this in Sec. V.

sequent prospectuses, $s(1) > s(2)$. By contrast, there may be certain industries in which confirming information in the second prospectus may convey more incremental information than the first prospectus. In such a case, $s(1) < s(2)$. Although the market size variable is private information to both firms, we shall not consider strategic implications in revealing this variable as part of the IPO process; rather, we shall assume that the market size is revealed truthfully at the time of the IPO process.

As before, the entrant has expected product quality $\overline{q}_i^E$ drawn from the same discrete distribution as before: $\overline{q}_i^E \in \{\overline{q_L}, \overline{q_H}\}$. The true product quality of the entrant is normally distributed with mean $\overline{q}_i^E$ and variance σ_q^2. Because the incumbent firm has been in existence for some time and because the product is an experience good, we assume that the incumbent firm's product quality, q^I, is known to all.[20] There are two cases to be considered depending on whether the incumbent is a publicly listed firm or not.

A. *Incumbent Is Publicly Listed*

Suppose that the entrant goes public. All agents update their beliefs to $\overline{q}^E = E\left(q^E|\text{public}\right)$. The market size in this case becomes known to be M_1. In the first period, the true quality of the entrant is not known, but consumers can observe the stock price, p_1^E, from which the true product quality of the entrant is inferred to be $\hat{q}^E$. To derive the respective market shares, consider the consumer at some point along the line segment that is exactly indifferent between purchasing from the incumbent with quality q^I or from the entrant with expected quality $\hat{q}^E$. Define the location of this consumer to be equal to $\pi_1 \in [0, 2]$. Then π_1 must satisfy

$$\hat{q}^E - \frac{1}{2}\pi_1 = q^I - \frac{1}{2}(2 - \pi_1).$$

Solving for π_1 yields

$$\pi_1 = 1 - q^I + \hat{q}^E.$$

Throughout the article we focus on the case in which both firms' market shares are strictly positive, that is, $0 < \pi_1 < 2$. Because prices are normalized to one, $M_1\pi_1$ represents the first-period profit of the entrant. That is, it is equal to the market size less the difference between the quality of the incumbent and the perceived quality of the entrant.

In the second period, the true quality, q^E, of the entrant becomes publicly known as in the single-firm model. Analogous to the model in Section II, we assume that because of a network externality effect, the consumer in the second period also values the market share from the first period. This is represented

20. Actually it does not matter whether the incumbent firm's quality is perfectly known, in the case where it is either public or private. The critical assumption is that no information about the incumbent firm's quality is revealed by the decision of the entrant to go public.

as an increase in willingness to pay via a coefficient, $\gamma/2$, times the market share from the previous period, π_1.[21]

The location of the marginal consumer, π_2, who is indifferent between buying from the entrant and the incumbent is now given by

$$q^E + \frac{\gamma}{2}\pi_1 - \frac{1}{2}\pi_2 = q^I + \frac{\gamma}{2}(2 - \pi_1) - \frac{1}{2}(2 - \pi_2).$$

Solving for π_2 yields

$$\pi_2 = 1 - q^I + q^E + \gamma(\hat{q}^E - q^I).$$

The entrant's expected second-period profit is equal to the expected market size times the unit profit, or $M_2\pi_2$.

Therefore, by comparison with the single-firm case, the product market competition case has a similar entrant profit structure in both the first and second periods, with the addition of the terms $1 - q^I$ in the first period and $1 - (1 + \gamma)q^I$ in the second period, representing the market size minus the amount captured by the incumbent. Thus, essentially the same analysis as in Section II can be used to derive the functional form of the analogous stock market equilibrium. Further, since the incumbent's quality is always known when it is publicly traded, this does not affect the decision of the entrant to go public. Following an almost identical approach to the analysis of the single-firm case, we can therefore derive existence of separating equilibria. In order to simplify the exposition at this point, we assume risk neutrality on the part of the entrepreneur.

Proposition 3. If the entrepreneur is risk neutral, there exists a family of separating signaling equilibria in which the high-type firm goes public with equity retention, $\alpha \geq \alpha^*$, while the low type remains private if and only if

$$(M_1 + M_2\gamma)\Delta q \geq R \tag{14}$$

and

$$\frac{1}{2}(M_1 + M_2\gamma)\Delta q < R, \tag{15}$$

where $\Delta q = \bar{q}_H - \bar{q}_L$ and

$$\alpha^* = 1 - \frac{R - (M_1 + M_2\gamma)\Delta q/2}{[M_1/2 + M_2(1 + \gamma/2)]\Delta q.} \tag{16}$$

21. In this formulation, the network externality occurs with a lag of one period. Thus, the model does not contain the typical sort of coordination problems encountered in models with rational expectations. We have investigated alternative specifications in which network externalities are simultaneous. One such specification is where some consumers buy in the first period but enjoy benefits for 2 periods, and other consumers only purchase and enjoy benefits for the second period.

Proof. See Section III of the appendix.

Therefore, the qualitative features of the separating equilibrium are identical to those in the single-firm case. However, because of the assumption of risk neutrality, we are able to derive a somewhat sharper prediction about the existence of a separating equilibrium as compared to that in proposition 2. Conditions (14) and (15), analogous to conditions (10) and (11), are both necessary and sufficient for an equilibrium to exist. Also the threshold α^* for retained equity given by equation (16) can be solved for analytically.

B. Announcement Effects

The preceding analysis can be used to consider the impact on the stock price of the incumbent firm when the entrant decides to make an IPO. Let us begin by solving for the ex ante probability that the entrant decides to go public. We make the following assumption on the support, $s(2)$, of the uniform distribution on M_1:

$$\bar{M}_1 + M_2\gamma + \frac{2R}{\Delta q} > s(2) > \bar{M}_1 + M_2\gamma - \frac{R}{\Delta q}. \qquad (17)$$

The lower bound on the support, $s(2)$, ensures that the support is wide enough so that there is some probability that the market size realization is sufficiently low that the high-type entrant decides not to go public for certain states of nature from condition (14). The upper bound ensures that the support is not so large that the retained equity in a separating equilibrium would be larger than unity.

Given this assumption, the probability, p^*, that the high-type entrant goes public is equal to the probability that the market sizes are not too small, that is,

$$p^* = \text{prob}[(M_1 + M_2\gamma)\Delta q \geq R].$$

Using the uniform support, it can be shown that

$$p^* = \frac{1}{2} - \frac{R - (\bar{M}_1 + M_2\gamma)\Delta q}{2s(2)\Delta q}. \qquad (18)$$

For the incumbent firm, it is of interest to look at announcement effects associated with a declaration of the entrant to go public. Before the entrant makes any decision, the expected value of the entrant's quality and the first-period expected market size are $E(q^E) = (\bar{q}_L + \bar{q}_H)/2$ and $\bar{M}_1$, respectively. Therefore, the incumbent's ex ante profits are given by

$$U^I = \bar{M}_1[1 + q^I - E(q^E)] + M_2\{1 + (1 + \gamma)[q^I - E(q^E)]\}. \qquad (19)$$

When the entrant decides to go public, the incumbent's profits become

$$U^I(\text{public}) = E(M_1|\text{public})(1 + q^I - \bar{q}^E) + M_2[1 + (1 + \gamma)(q^I - \bar{q}^E)]. \tag{20}$$

Subtracting equation (19) from equation (20) yields

$$U^I(\text{public}) - U^I = [E(M_1|\text{public}) - \bar{M}_1](1 + q^I - \bar{q}^E) + [\bar{M}_1 + M_2(1 + \gamma)][E(q^E) - \bar{q}^E]. \tag{21}$$

Substituting the form of the separating equilibrium, $\bar{q}^E = \bar{q}_H$, and $E(q^E) = (\bar{q}_H + \bar{q}_L)/2$ and simplifying equation (21) gives the following condition on the profits of the incumbent firm:

$$U^I(\text{public}) - U^I = [E(M_1|\text{public}) - \bar{M}_1](1 + q^I - \bar{q}_H) - [\bar{M}_1 + M_2(1 + \gamma)]\frac{\Delta q}{2}. \tag{22}$$

Therefore, the impact on profits of the incumbent depends on two offsetting effects. First, the fact that the entrant goes public implies that the expected market size in the first period is larger. This affects the incumbent's profits in a positive direction in the first term of equation (22). By contrast, the entrant is now known to have a high-quality product, and this causes a negative impact on the incumbent's first- and second-period profits as indicated by the second term on the right-hand side of equation (22). The net impact depends on which effect outweighs the other.

We can now use the above relation, equation (22), along with ex ante expectations by the financial market to solve for the announcement effect from the entrant's decision. This is recorded in the following proposition.

PROPOSITION 4. Suppose that the support of the market size distribution is sufficiently wide, that is, equation (17) is satisfied. Then the expected stock price reaction of the incumbent firm to the announcement that the entrant plans to go public is positive if and only if

$$\left[\frac{s(2)}{2} + \frac{R}{2\Delta q}\right]\left(1 + q^I - \bar{q}_H\right) - \frac{\bar{M}_1 + M_2\gamma}{2}\left(1 + q^I - \bar{q}_L\right) - \frac{M_2\Delta q}{2} > 0. \tag{23}$$

Proof. Using the information that the entrant has gone public, the financial market will compute conditional expectations of the market size as follows:

$$E(M_1|\text{public}) = \frac{1}{2}\left[\bar{M}_1 + s(2) + \frac{R}{\Delta q} - M_2\gamma\right]. \tag{24}$$

Substituting this term into equation (22) yields the condition in the proposition. Q.E.D.

Proposition 4 shows that average announcement effects depend critically on the variance of the market size increment distribution, measured by $s(2)$, the respective market shares of the incumbent firm conditional on the two types of firms, and the separation between the two expected qualities, Δq.[22] If the support of the market size distribution is sufficiently wide, then we will observe positive announcement effects on the incumbent firm. This happens because the fact that the entrant goes public indicates that the lower tail of the prior distribution on market size has been truncated, and thus beliefs are revised in a positive direction. By contrast, if the support is narrow, then there is relatively little positive information communicated by the entrant's decision to go public, and the incumbent is worse off because of the revelation about the entrant's quality.

This analysis is consistent with the empirical results of Ward (1997), who observed a correlation between the announcement effect of a rival (incumbent) and the extent of underpricing at the onset of secondary trading. In fact, the stock price reaction of a competitor firm on announcement of the IPO was strongly negatively correlated with the extent of eventual underpricing. If greater underpricing is associated with the competitive strength of the IPO firm (entrant), then this could be an indication that the market share effect dominates the market size effect. By contrast, when underpricing is nonexistent, this may indicate a weak entrant, and, therefore, the market size impact dominates.

Another way of testing proposition 4 might be to differentiate among IPOs by the length of time the incumbent has been publicly held. One might expect long-term incumbents to have communicated most of the information about market size, so that most of the announcement effect would be associated with changes in market share. However, we would expect a greater likelihood of positive announcement effects on the rival firm when it has been listed for a shorter period of time.

C. Incumbent Is Privately Held

We now turn to the analysis when the incumbent is a privately held firm and the entrant can decide whether to go public. This case is similar to the previous case with the following change. The major effect is that the distribution of the market size increment may be different from the situation when the incumbent is publicly traded. We use this difference to develop a theory of how the entrant's incentives to go public are correlated with the incumbent's presence as a publicly traded or privately held firm.

Suppose that the entrant goes public. All agents update their beliefs to $\bar{q}^E = E(q^E|\text{public})$. In the first period, the true quality of the entrant is not known, but consumers can observe the stock price, p_1^E, from which the true product quality of the entrant is inferred to be $\hat{q}^E$. Given these inferences, the market shares of the incumbent and entrant can be derived and used to define

22. Note that we have assumed that each firm's expected market share is strictly positive, which requires $1 + q^I - \bar{q}_H > 0$, from the incumbent's point of view. Thus, the first term on the right-hand side in eq. (23) is positive.

a stock market equilibrium. The functional form of the stock market equilibrium is exactly the same as in the case of the publicly traded incumbent. Similarly, the incentives of the entrepreneur and the conditions for existence of a separating signaling equilibrium can be derived.

The only difference between the going public decision of the entrant when the incumbent is privately held as opposed to being public is dependent on whether the prior distribution of the market size differs from the case in which the incumbent firm is public. The support of the distribution if the incumbent firm is private is defined by $[\bar{M}_1 - s(1),\ \bar{M}_1 + s(1)]$. As before we assume that

$$\bar{M}_1 + M_2\gamma + \frac{2R}{\Delta q} > s(1) > \bar{M}_1 + M_2\gamma - \frac{R}{\Delta q}.$$

Using this fact the probability that the high-type entrant goes public when the incumbent is private, p^{**}, is equal to

$$p^{**} = \frac{1}{2} - \frac{R - (\bar{M}_1 + M_2\gamma)\Delta q}{2s(1)\Delta q}. \tag{25}$$

Considering the difference between p^{**} and p^{*} and substituting for R from proposition 3 leads to the following proposition on the likelihood of the entrant to go public as related to the status of the incumbent.

PROPOSITION 5. Suppose that the support of the market size distribution is smaller when the incumbent firm is publicly traded than when it is not, that is, $s(1) > s(2)$. Then, if the prior belief on initial market size is sufficiently large relative to the second period market size,

$$\bar{M}_1 + M_2\gamma > \frac{M_2\sigma_q\sigma_u}{2\Delta q}, \tag{26}$$

the entrant is more likely to go public given that the incumbent has gone public.

This proposition shows that the critical difference between a privately held incumbent and one whose stock is publicly traded relates to the amount of residual uncertainty about market size and about the relative sizes of the first-period and second-period market. If the prior on the first-period market size, $\bar{M}_1$, is large relative to M_2, then if $s(1) > s(2)$ we get hot issue markets. This corresponds to a situation where the initial prospectus reveals more information about initial market size than a subsequent prospectus. We believe this assumption to be reasonable whenever the marginal amount of information declines with the issuance of a subsequent prospectus.[23]

The analysis of this subsection may indicate why in some industries hot issue markets occur, while in other industries there is a lack of correlation

23. By contrast, it can be shown that, whenever the above condition on information is reversed, then hot issue markets obtain only if the initial market size is small relative to the second-period market size.

between IPOs. We can interpret equation (26) in proposition 5 as applying whenever the expected gain of the high-type entrant from going public is greater than the loss because of underpricing of the IPO. From this condition, investors will expect the high-type entrant to go public. Such an expectation will be more likely to be true the more precise the information held by investors (i.e., the narrower the support of the market size). Thus, we would see a hot issue market if investors initially expect firms to go public and the information contained in various prospectuses confirms investors' expectations. By contrast, if beliefs about initial market size are pessimistic, investors do not expect the high-type entrant to go public. In order for a hot issue market to occur, these expectations would have to be reversed. This could only happen if there is relatively more information contained in a subsequent prospectus.

The result of proposition 5 also indicates that network externality effects imply a greater tendency toward hot issue markets. This happens because the gains from signaling product quality are larger because of the importance of initial consumer perceptions in future consumption purchase decisions.

IV. A Model of Competitive Dynamics

In Section IV we develop a model of competitive dynamics between the incumbent and entrant firm in which the alternative to going public involves communicating quality through prices. Although the model features a "reduced form" specification of the stock market equilibrium considered in previous sections, the basic features are preserved. Specifically, we assume now that if a firm goes public, the presence of market analysts ensures that the quality is revealed *perfectly* through the stock price.

In the model in this section, we compare two alternatives. In the first alternative, an entrant can go public, and, since its quality is then known to consumers through the stock price, a high-quality entrant can choose its first-best (full-information) profit-maximizing price. In the second alternative, if the entrant does not go public, a high-quality firm must signal by charging a higher price for its product in the first period. We compare the two alternatives from the standpoint of the high-quality entrant and determine under what market conditions the IPO method leads to higher 2-period profits than does the price-signaling method.

A. Model Structure

Consider, as in Section III, an entrant and an incumbent firm, whose quality, q^I, is already known. We define $\hat{q}^E$ as the perceived product quality of the entrant and q^E as the true product quality of the entrant. An entrant firm is either of quality q^E_H (high) or q^E_L. That is, there is no remaining uncertainty in quality levels once q^E_H or q^E_L is known.

Preferences over product quality are specified in a manner consistent with

Bagwell and Riordan (1991). Consumers purchase at most one unit and are of heterogeneous types, uniformly distributed with preferences given by

$$V_1^E = \bar{V} + \theta \hat{q}^E - p_1^E, \tag{27}$$

if the product is purchased from the entrant in the first period, where θ is uniformly distributed in the [0, 1] interval; p_1^E is the price paid; and $\bar{V}$ is a constant. In this formulation, consumers have varying degrees of preference for product quality depending on θ. If the product is purchased from the incumbent firm, preferences are given by

$$V_1^I = \bar{V} + \theta q^I - p_1^I, \tag{28}$$

where p_1^I is the price charged by the incumbent firm.

In the second period, consumer preferences depend, as in Section II, on the true quality, q^E, and on the quality as perceived by consumers in the first period. That is,

$$V_2^E = \bar{V} + \theta q^E + \frac{\gamma}{2}(\hat{q}^E - q^I) - p_2^E, \tag{29}$$

where p_2^E is the price charged by the entrant in the second period. Similarly, preferences over products purchased from the incumbent are described by

$$V_2^I = \bar{V} + \theta q^I + \frac{\gamma}{2}(q^I - \hat{q}^E) - p_2^I. \tag{30}$$

The interpretation is that there is a network externality effect represented by the term involving γ. If the perceived quality of the entrant is higher in the first period, consumers have a greater propensity to purchase from the entrant in the second period.

We consider the following assumptions on firm costs and qualities. The incumbent produces with constant marginal cost, equal to c. The high-quality entrant has constant marginal cost equal to 0, while the low-quality entrant has constant marginal cost equal to c, the same as for the incumbent firm.[24] In addition, we assume that the quality of the incumbent's product and that of the low-quality entrant are identical, $q_L^E = q^I$. This implies that under full-information Bertrand competition and without a network externality effect, if the entrant firm is of low quality, the incumbent and entrant both earn zero profits. By contrast, when the entrant's quality is high, then they compete as a differentiated Bertrand duopoly, with the entrant charging a higher price than the incumbent and also getting a higher market share. Define the dif-

24. The assumption that marginal costs of the low-quality entrant and incumbent are equal simplifies the analysis greatly without compromising the implications. With this cost structure, pricing below marginal cost is a signal of quality. Alternatively, if costs for the high-quality entrant were greater than those for the low-quality entrant, then signaling with prices above marginal cost would be optimal.

ference in quality between the high- and low-quality entrant as $\Delta q = q_H^E - q_L^E$.

B. Quality Communication through the IPO

With the IPO method, quality is revealed perfectly through the secondary stock market price. Section IV of the appendix derives the functional form of prices and profits for the entrant of type t in period i, π_{ti}^E, in a Bertrand equilibrium.

Using the profit functions, equations (A22) and (A24) in Section IV of the appendix, the necessary conditions can be derived for a separating equilibrium in which the high-quality entrant goes public and the low-quality entrant remains private. Consistent with the analysis of Section II, we assume that there is a fixed cost, R, of going public. As in equation (7), the utility of the entrant that goes public is equal to

$$U(\text{public}) = (1-\alpha)p_0 + \alpha(\pi_{t1}^E + \pi_{t2}^E) - R, \tag{31}$$

where $t = H, L$, the true type of the entrant, and p_0 is the conjectured 2-period profit of the type that goes public. If, as will be investigated below, the market conjectures that the high-quality firm goes public, then

$$p_0 = \pi_{H1}^E + \pi_{H2}^E. \tag{32}$$

We show in the following proposition that there exists a separating equilibrium in which the high-quality entrant goes public and the low-quality entrant remains private.

PROPOSITION 6. There exists a family of separating equilibria in which the high-quality entrant goes public with retained equity $\alpha \geq \alpha^*$, while the low-quality firm remains private if and only if

$$\frac{1}{9\Delta q}(2\Delta q + c)^2(M_1 - M_2) + \frac{1}{9\Delta q}[(2+\gamma)\Delta q + c]^2 M_2 - cM_1 \geq R, \tag{33}$$

where

$$\alpha^* = 1 - \frac{R}{\pi_{H1}^E + \pi_{H2}^E}. \tag{34}$$

Proof. See Subsection IV*A* of the appendix.

Proposition 6 is similar in nature to proposition 3. If sufficient equity is retained, the low-quality firm has no incentive to go public since the gain from possible mispricing is limited to only a small fraction of the firm. Equation (33) is the analog of condition (14). As long as the cost of going public is not too large, the high-quality firm will have an incentive to do so in order to avoid having to choose too low a price in the first period, and, in addition, giving up the network externality benefits in the second period. Based on the comparative static effects discussed earlier, it is easy to see that the amount of equity retained to support the separating equilibrium is increasing in the quality difference, Δq, as well as the network externality parameter, γ.

Moreover, the critical condition for existence of a separating equilibrium provides further support for the competitive models of the previous sections. From examination of condition (33), it can be shown that the comparative static effect of decreases in marginal cost, c, makes condition (33) easier to satisfy. That is, as the marginal cost distribution becomes more uniform in the industry, separation by going public is more easily accomplished. One would expect that industries characterized by low marginal costs have, therefore, greater tendencies to go public. Second, it is apparent that growth in market size interacts with the degree of network externalities. If $\gamma = 0$, the size of the market in the second period does not affect the ability of the high-quality firm to use an IPO to signal quality. However, the larger γ is, the easier is condition (33) to satisfy, and, therefore, growth in the market becomes more important.

C. Signaling through Price

As has been discussed above, high-quality firms may be motivated to go public despite having to pay the costs of doing so, such as flotation costs, transaction fees, and underpricing of the new issue. Alternatively, we explore the consequences of high-quality firms using product price, itself, to signal quality. The analysis of this situation is based on Saloner (1987).

In a separating equilibrium with price as a signal, the low-type firm must be precluded from choosing the price selected by the high-type firm in the first period. In the second period, we assume that quality has been revealed. Along the equilibrium path, the price charged by the low-quality firm is therefore $p^E_{L1} = p^E_{L2} = c$, and profits are $\pi^E_{L1} = \pi^E_{L2} = 0$. Along the separating equilibrium path, the high-quality firm will choose a price in the second period, p^E_{H2}, equal to the full information price, and will obtain profit given by equation (A22) in Section IV of the appendix. In the first period, the high-quality firm must charge a price, p^E_{H1}, that deters the low-quality firm from mimicking. Proposition 7 determines the pricing policy of the high-quality firm under these assumptions.

PROPOSITION 7. The high-quality firm charges a price equal to

$$p^E_{H1} = c - \frac{\gamma M_2}{M_1}\Delta q, \tag{35}$$

and it achieves 2-period realized profit of

$$\pi^E_H = \left(c - \frac{\gamma M_2}{M_1}\Delta q\right)M_1 + \frac{1}{9\Delta q}[(2+\gamma)\Delta q + c]^2 M_2. \tag{36}$$

Proof. See Subsection IV*B* of the appendix.

Proposition 7 shows that in a price-signaling equilibrium the high-quality firm will price below marginal cost, thereby making it costly for the low-quality firm to mimic since its first-period profits will be negative. In this case it is apparent from equation (35) that the high-quality firm suffers a negative externality from the presence of the low-quality firm that is exacerbated by the inclusion of the network externality effect. This occurs because when network externalities are present, the low type is more willing to suffer a negative profit in order to capture a higher profit in the subsequent period. Further, the growth in the market size also affects the high-quality firm in a negative manner, as does the degree of information asymmetry (Δq).

D. Comparison of the Signaling Methods

We now compare the IPO and price-signaling equilibria. It is first worth noting that, if the difference in marginal costs between the high-quality entrant and incumbent, c, is low, the high-quality firm may wind up with a negative profit in equation (36). Thus, the IPO represents the obvious alternative in such cases.

When both separating equilibria exist, the welfare comparison of the two methods of signaling quality is simplified since in both equilibria the low-quality firm obtains zero profits in both periods. Moreover, the high-quality firm obtains the full-information profit level given by equation (A22) in the second period. Therefore, from the entrant's standpoint, the only difference between the methods is represented in the initial profit levels.[25] Proposition 8 indicates the conditions under which the entrant is better off by signaling quality through the IPO as opposed to using a pricing strategy.

PROPOSITION 8. The high-quality entrant is better off using an IPO than by competing against an incumbent in a Bertrand duopoly with asymmetric information whenever

$$\frac{1}{9\Delta q}(2\Delta q + c)^2 M_1 - R \geq \left(c - \frac{\gamma M_2}{M_1}\Delta q\right)M_1. \tag{37}$$

Proof. Equation (37) is obtained using propositions 6 and 7. Q.E.D.

First, proposition 8 shows that if both an IPO and a price-separating equilibrium exist, the high-quality entrant is more likely to be better off in the IPO equilibrium whenever the network externality effect is larger. This is because network externalities make it more difficult for the low type to signal through the public offer but make it more willing to misrepresent through pricing in the price-signaling situation.

Second, proposition 8 indicates that higher-quality firms are better off when the growth in market size, M_2/M_1 is larger, or if the costs of going public are smaller.

Third, the cost difference in the industry also plays an important role in determining which method would be preferred. It is easy to see that when c

25. The incumbent always prefers the IPO separating equilibrium because it obtains positive profits in both periods in a Bertrand equilibrium if the entrant is of high type, but zero profits always in the price-signaling equilibrium.

is reduced, the IPO method is better. Once again, this points to the notion that for industries that are characterized by strong degrees of asymmetric information, but for which marginal costs are relatively less important than fixed costs, going public is a viable method of communicating product quality to consumers.

V. Conclusions and Empirical Implications

In this article, we have examined the implications of the going-public decision on the product and financial markets. An important aspect that we have considered is the interaction between the two markets: the financial market price incorporates information about potential profits arising from consumer demand, and the product market relies on information communicated through the stock price.

As this article bridges the large literature between quality in product markets and firm valuation in financial markets, a number of specific empirical implications are generated. Our model provides a new interpretation of the well-known underpricing phenomenon as an indication of unexpected high product quality. Thus, firms that experience a large initial return should gain larger market share in the product market than those firms that experience low initial returns. Further, our article predicts that an IPO generates a positive price impact on rival firms when the uncertainty about market sizes is sufficiently large.

Our analysis also demonstrates that IPOs motivated by product market benefits are characterized by a significant equity retention by the entrepreneur. The prediction of our model is that for firms in high technology industries, we should observe smaller fractions of inside equity sold at the time of the IPO. This seems to be broadly consistent with recent observations.

The nature of cross-sectional differences across industries affects the propensity to go public. We find that signaling through IPOs is more viable when there exists a greater difference between expected product qualities. This ought to be true in high technology industries. We also should expect to observe greater tendencies to go public for industries where the firms themselves have greater confidence about their private information regarding their own product quality, as opposed to requiring outside verification by security analysts. When network externalities are significant, procyclical growth becomes more important, that is, high growth rates make a firm more likely to go public.

Our model also contains a number of implications about the existence of hot issue IPO markets and cyclical behavior. We found that the critical factor is how much uncertainty is resolved concerning the overall size of the market. If priors are that initial market size is important and the initial prospectus of the first firm going public reveals relatively more information than the subsequent IPOs, then we predict that IPOs in such industries will occur in "waves." The article also proposes an explanation for the interesting puzzle documented in Ritter (1998) concerning the positive association between initial IPO returns and subsequent hot issue markets. From proposition 3, going public in the face of large underpricing implies that the prospective benefits in terms of signaling quality are high. This then implies that the condition in proposition 5 for existence of hot issue markets is more likely to hold.

The extent of competition can also affect firms' decisions to become publicly traded. The model of Section III can be easily extended to allow for differential search costs. We have found that as search costs go down, representing greater competition between the incumbent and an entrant, it is more likely that an equilibrium exists in which high-quality firms go public. Thus, product market competition acts in a manner similar to network externalities.

Further, we have examined the alternative of using product price directly, instead of IPOs, in conveying information to consumers. We find that large growth opportunities as well as network externalities imply a greater tendency to use the IPO method instead of product price signaling. Moreover, IPOs should be more frequent in industries characterized by small differences in marginal production costs. For example, in the software industry the marginal cost of "producing" an extra copy of a program may be negligible. Thus, the marginal cost of production will be similar for all competitors. As a result, if two software companies have developed similar products, they may be unable to signal by pricing. For such industries the information revelation through the stock market is therefore particularly important.

The analysis of the interaction between listing decisions and product market considerations seems to be a fruitful direction for future research in corporate finance. Especially in industries such as the Internet, software, pharmaceuticals, and other high-tech industries, the informational role of market prices and the resulting industrial organization effects may be particularly important. The relevance of these issues is emphasized not only by the numbers of recent IPOs but also by the rapid growth of international listings on stock exchanges.

Appendix

I. Proof of Proposition 1

Conjecture the following:

Conjecture 1. There exists an equilibrium demand schedule by the speculator, which is linear in the true product quality, q:

$$x = a + bq.$$

Conjecture 2. There exists an equilibrium price function that is linear in the total demand by the speculator and the uninformed investors:

$$p_1 = c + d(x - v + u).$$

Conjecture 3. Consumers employ a linear function that maps the stock price into expected quality

$$\hat{q} = e + fp_1.$$

To verify conjecture 1, we assume that conjectures 2 and 3 hold. In this case, the firm's expected liquidation value given q and x is

$$E[(M_1 + \gamma M_2)\hat{q} + M_2 q | q, x] = (M_1 + \gamma M_2)[e + fc + fd(x - v)] + M_2 q.$$

Also, the expected price is given by

$$E(p_1 | q, x) = c + d(x - v).$$

The speculator's expected profits are

$$\prod = E\{[(M_1 + \gamma M_2)\hat{q} + M_2 q - p_1]x | q, x\}.$$

Substituting for $E[(M_1 + \gamma M_2)\hat{q} + M_2 q | q, x]$ and $E(p_1 | q, x)$, differentiating with respect to x, and setting the resulting expression equal to zero yields

$$x = \frac{v}{2} + \frac{1}{2d[1 - f(M_1 + \gamma M_2)]}\{e(M_1 + \gamma M_2) - c[1 - f(M_1 + \gamma M_2)] + M_2 q\}.$$

This is consistent with $x = a + bq$ if

$$b = \frac{M_2}{2d[1 - f(M_1 + \gamma M_2)]} \tag{A1}$$

and

$$a = \frac{v}{2} + \frac{1}{2d[1 - f(M_1 + \gamma M_2)]}\{e(M_1 + \gamma M_2) - c[1 - f(M_1 + \gamma M_2)]\}. \tag{A2}$$

Thus, conjecture 1 is verified given the other two conjectures.

To verify conjecture 2, we assume that conjectures 1 and 3 hold. Market efficiency from the standpoint of the market maker requires

$$p_1 = E[(M_1 + \gamma M_2)\hat{q} + M_2 q | y] = (e + fp_1)(M_1 + \gamma M_2) + M_2 E(q|y).$$

By Bayes's rule, we know that

$$E(q|y) = \bar{q} + \frac{\text{cov}(q, y)}{\text{var}(y)}[y - E(y)].$$

Note that $x = a + bq$ and $y = x - v + u$; we have

$$\text{cov}(q, y) = b\sigma_q^2, \ \text{var}(y) = b^2\sigma_q^2 + \sigma_u^2, \quad E(y) = a + b\bar{q} - v.$$

Therefore, market efficiency requires that

$$p_1 = \frac{1}{1 - f(M_1 + \gamma M_2)}\left[e(M_1 + \gamma M_2) + M_2\bar{q} + \frac{M_2 b\sigma_q^2}{b^2\sigma_q^2 + \sigma_u^2}(y - a - b\bar{q} + v)\right].$$

This is consistent with $p_1 = c + dy$ if

$$d = \frac{M_2 b\sigma_q^2}{[1 - f(M_1 + \gamma M_2)](b^2\sigma_q^2 + \sigma_u^2)} \tag{A3}$$

and

$$c = \frac{(M_1 + \gamma M_2)e + M_2\bar{q}}{1 - f(M_1 + \gamma M_2)} - d(a + b\bar{q} - v). \tag{A4}$$

This verifies conjecture 2 given the other two conjectures. Substituting equation (A3) into equation (A1) yields

$$b = \frac{\sigma_u}{\sigma_q}. \tag{A5}$$

Substituting this into equation (A3) yields

$$d = \frac{M_2\sigma_q}{2[1 - f(M_1 + \gamma M_2)]\sigma_u}. \tag{A6}$$

The last step is to prove conjecture 3 given conjectures 1 and 2. For consumers' beliefs to be rational, we require that $\hat{q} = E(q|p_1)$. Since $p_1 = c + d(a + bq - v + u)$, applying Bayes's rule yields

$$E(q|p_1) = \bar{q} + \frac{b\sigma_q^2}{d\left(b^2\sigma_q^2 + \sigma_u^2\right)}[p_1 - c - d(a + b\bar{q} - v)].$$

This is consistent with $\hat{q} = e + fp_1$ if

$$f = \frac{b\sigma_q^2}{d\left(b^2\sigma_q^2 + \sigma_u^2\right)} \tag{A7}$$

and

$$e = \bar{q} - f[c + d(a + b\bar{q} - v)]. \tag{A8}$$

This verifies conjecture 3 given the other two conjectures. Substituting equations (A5) and (A6) into equation (A7) yields

$$f = \frac{1}{(M_1 + \gamma M_2) + M_2}. \tag{A9}$$

Finally, the ex ante revenue, R, of the speculator is given by

$$\begin{aligned} R &= E(E\{[(M_1 + \gamma M_2)\hat{q} + M_2 q - p_1]x|q\}) \\ &= M_2 E\left[(q - \bar{q})x - \frac{\sigma_q}{2\sigma_u}(x + u)x\right] \\ &= \frac{M_2}{2}\sigma_q\sigma_u. \end{aligned}$$

Q.E.D.

II. Proof of Proposition 2

The equilibrium is derived by considering the incentive compatibility conditions that the high-quality firm has an incentive to go public and the low-quality firm has an incentive to remain private. First, the high-quality firm will have an incentive to go public whenever

$U(\text{public}) \geq U(\text{private})$, as given in equations (8) and (9), with $\bar{q} = \bar{q}_i = \bar{q}_H$ and $\underline{q} = \bar{q}_L$. This condition is expressed as

$$IC_H(\alpha) \equiv (M_1 + M_2\gamma)\Delta q - R - \frac{\rho}{4}(K\alpha^2 - 2M_2^2)\sigma_q^2 \geq 0. \tag{A10}$$

Likewise, the incentive compatibility constraint for the low-quality firm is also given by comparing equations (8) and (9) with $\bar{q} = \bar{q}_H$ and $\underline{q} = \bar{q}_i = \bar{q}_L$:

$$IC_L(\alpha) \equiv IC_H(\alpha) + M_2\Delta q - \frac{\alpha}{2}[M_1 + M_2(2+\gamma)]\Delta q \leq 0. \tag{A11}$$

Equations (12) and (13) define α^* and α_H, respectively, such that $IC_H(\alpha_H) = IC_L(\alpha^*) = 0$. It is easily shown that $IC_H(\alpha)$ and $IC_L(\alpha)$ are both strictly decreasing and concave functions of α such that $IC_L(\alpha)$ is always steeper than $IC_H(\alpha)$. Condition (10) in the statement of the proposition is a sufficient condition for existence of α_H. Further, a sufficient condition for existence of α^* is that $IC_L(1) < 0$. This is condition (11) in the statement of the proposition. Since $IC_L(\alpha)$ and $IC_H(\alpha)$ cross at only a single point, which is $\hat{\alpha}$, it follows from condition (10) in the statement of the proposition that $\hat{\alpha} < \alpha^* < \alpha_H$. Therefore the incentive compatibility conditions that support an equilibrium imply that the high-quality firm is better off by going public whenever $\alpha \leq \min(\alpha_H, 1)$ and that the low-quality firm is better by remaining private whenever $\alpha \geq \alpha^*$. Q.E.D.

III. Proof of Proposition 3

Proposition 3 is a corollary of proposition 2. Using equation (10) with $\rho = 0$ yields

$$(M_1 + M_2\gamma)\Delta q - R \geq 0. \tag{A12}$$

This is condition (14) in the proposition. Similarly using condition (11) gives condition (14) in the proposition. Notice that as these conditions are independent of α, they are both necessary and sufficient for existence of a separating equilibrium. Setting $\rho = 0$ in equation (12) yields equation (16) in the proposition. Q.E.D.

IV. Derivation of the Equilibrium in the Dynamic Model

We begin by identifying consumer demand for both periods. In the first period, suppose that perceived quality $\hat{q}^E = q_L^E = q^I$. Then it is clear by comparing equations (27) and (28) that all consumers purchase from the firm that charges the lower price. If they charge the same price, they divide the market in an arbitrary fashion. Therefore, the equilibrium prices are $p_{L1}^E = p_1^I = c$. If $\hat{q}^E = q_H^E$, then once again comparing equations (27) and (28) and using the assumption of the uniform distribution, aggregate demand for the entrant's products will be given by

$$D_1^E = \left(1 - \frac{p_{H1}^E - p_1^I}{\Delta q}\right)M_1, \tag{A13}$$

where M_1 is the market size in the first period and $\Delta q = q_H^E - q^I$ is the difference in product quality. The aggregate demand for the incumbent's products in this case is

$$D_1^I = M_1 - D_1^E. \tag{A14}$$

In the second period, if the entrant is of low quality, there are two cases to consider. If the entrant's perceived quality equals the true quality in the first period, then the analysis of aggregate demand is identical to the first period; hence, both the entrant and incumbent price at marginal cost and earn zero profits. However, if the low-quality entrant has managed to misrepresent its quality in the first period as a high-quality firm, then analysis of equations (29) and (30) shows that as long as the entrant charges a price $p_{L2}^E \leq \gamma\Delta q + c$, it can capture the entire market, that is, $D_2^E = M_2$.

In the second period, if the entrant is of high quality, and the perceived quality equals the actual quality in the first period, equations (29) and (30) show that the aggregate demand is

$$D_2^E = \left(1 - \frac{p_{H2}^E - p_2^I - \gamma\Delta q}{\Delta q}\right) M_2. \tag{A15}$$

We now consider the form of equilibrium prices and market shares over the 2 periods under full information with Bertrand competition. As has already been discussed, if the entrant is of low quality, both the entrant and incumbent price at marginal cost and earn zero profit in the first and second period. We now derive the prices and profit for the Bertrand equilibrium when the entrant is of high quality.

Since consumer preferences in the first period are a special case of those in the second period with $\gamma = 0$, it suffices to derive the prices and profit functions in a Bertrand equilibrium for the second period only. The problem of the high-quality entrant in the second period taking the price of the incumbent as given for the second period is as follows:

$$\max_{p_{H2}^E} \ \pi_{H2}^E = p_{H2}^E D_2^E, \tag{A16}$$

where D_2^E is the demand for the entrant from equation (A15). This gives the reaction function for the entrant as

$$p_{H2}^E = (1/2)(\Delta q + \gamma\Delta q + p_2^I). \tag{A17}$$

Similarly, the problem of the incumbent firm is

$$\max_{p_2^I} \ \pi_2^I = \left(p_{H2}^I - c\right)\left(M_2 - D_2^E\right). \tag{A18}$$

The reaction function for the incumbent is

$$p_2^I = (1/2)(p_{H2}^E - \gamma\Delta q + c). \tag{A19}$$

Solving equations (A17) and (A19) yields the following set of equilibrium prices:

$$p_{H2}^E = (1/3)[(2 + \gamma)\Delta q + c] \tag{A20}$$

and

$$p_2^I = (1/3)[(1 - \gamma)\Delta q + 2c]. \tag{A21}$$

In order to avoid the interior price being below marginal cost, we assume that $(1 - \gamma)\Delta q - c > 0$. Substituting equations (A20) and (A21) into equations (A16) and (A18) yields the following profit functions:

$$\pi_{H2}^{E} = \frac{1}{9\Delta q}[(2+\gamma)\Delta q + c]^2 M_2 \tag{A22}$$

and

$$\pi_{2}^{I} = \frac{1}{9\Delta q}[(1-\gamma)\Delta q - c]^2 M_2. \tag{A23}$$

Setting $\gamma = 0$ gives the following profit functions for the first period:

$$\pi_{H1}^{E} = \frac{1}{9\Delta q}(2\Delta q + c)^2 M_1 \tag{A24}$$

and

$$\pi_{1}^{I} = \frac{1}{9\Delta q}(\Delta q - c)^2 M_1. \tag{A25}$$

A. Proof of Proposition 6

In order to derive existence of a separating equilibrium, the low-quality firm must have an incentive to remain private. Obviously if the low-type firm were to go public, then its price would be determined by equation (32). However, the firm recognizes that its true profits will be zero since going public reveals quality to consumers. Therefore, the low-type firm remains private whenever

$$(1-\alpha)p_0 - R \leq 0.$$

Equation (34) gives the minimal value of α such that the low-type firm remains private.

The high-quality entrant achieves utility of

$$U(\text{public}) = \pi_{H1}^{E} + \pi_{H2}^{E} - R$$

by going public in a separating equilibrium, where the profits are determined as in equations (A22) and (A24). If it remains private, there is no information that reveals its quality to consumers in the first period. Hence, with the incumbent pricing at marginal cost, the entrant can capture the entire market by pricing at slightly below c. Therefore, profits of the high-quality entrant that remains private are equal to cM_1 in the first period. In the second period, quality is revealed, but there is no benefit of network externalities. Hence, the profits are given by π_{H2}^{E}, with $\gamma = 0$. Equation (33) is a straightforward algebraic simplification of the condition that U (public) is greater than by remaining private and earning the 2-period profits as described above. Q.E.D.

B. Proof of Proposition 7

In the separating equilibrium, the profit of the low-quality firm is zero in both periods. Therefore, we need to compute the profit if it should misrepresent itself, by charging a price equal to p_{H1}^{E} in the first period. In the second period, the low-quality firm will not have an incentive to set price at marginal cost because of the market share generated in the first period. In fact, it will set price equal to

$$p_{L2}^{E} = \gamma\Delta q + c.$$

This means that its second period profit from misrepresentation in the first period is

$$\pi_{L2}^{E} = \gamma \Delta q M_2.$$

Now moving back to the first period, if the low-quality entrant chooses a price below marginal cost, it will attract all of the consumers since the incumbent will never select a price less than its marginal cost. Thus, the first-period profit (loss) from misrepresentation is

$$\pi_{L1}^{E} = \left(p_{H1}^{E} - c\right)M_1.$$

The condition that guarantees that the low-quality firm will not have an incentive to mimic the high-quality firm becomes $\pi_{L1}^{E} + \pi_{L2}^{E} \leq 0$, or

$$\left(p_{H1}^{E} - c\right)M_1 + \gamma \Delta q M_2 \leq 0.$$

The Pareto dominant separating equilibrium price is given by equation (35). Equation (36) is then obtained by adding this first-period profit, $p_{H1}^{E}M_1$, to the full-information profit of equation (A22). Q.E.D.

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