IPO Waves, Product Market Competition, and the Going Public Decision: Theory and Evidence

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ABSTRACT

We develop a new rationale for IPO waves based on product market considerations, and empirically test the implications of our theory. We model an industry with two competing firms, one of which has higher productivity of capital compared to the other. The two firms assess a significant probability of a positive productivity shock affecting their industry in the near future. Going public, though costly, not only allows each firm to raise external capital at a lower cost compared to a private firm, but also allows it to grab market share from its competitor if the latter remains private. In the above setting, we solve for the decision of each firm whether to go public or remain private, and if it chooses to go public, the optimal timing of going public. We show that, in equilibrium, even firms with sufficient internal capital to optimally fund their investment may go public, driven by the possibility of their product market competitors going public. We also show that IPO waves may arise in equilibrium even in industries which do not experience a positive productivity shock. Our model develops several testable predictions for IPO waves and post-IPO profitability, two of which are as follows. First, firms going public during an IPO wave will have lower post-IPO profitability than those going public off the wave. Second, firms going public earlier in an IPO wave will have higher post-IPO profitability than those going public later in the wave. We empirically test these and other predictions of our model and find supporting evidence.

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1 Introduction

The existence of IPO waves, otherwise known as "hot" IPO markets, has been widely documented, starting with Ibbotson and Jaffe (1975) and Ritter (1984). The reasons for the existence of such IPO waves, however, are less widely understood. Two recent theoretical models of IPO waves or the clustering of IPOs are Pastor and Veronesi (2005) and Alti (2005). Pastor and Veronesi (2005) argue that IPO waves are generated due to the "real option" effect of going public: entrepreneurs possess a real option to take their firms public, invest part of the IPO proceeds, and begin producing, and, in a setting of time varying market conditions, choose the best time to exercise this option. When stock market conditions are sufficiently favorable (expected market return is low, expected aggregate profitability is high, and prior uncertainty is high), many entrepreneurs exercise their options to go public, thus generating an IPO wave. In contrast to the above, Alti (2005) focuses on information spillovers across IPOs to generate the clustering of IPOs. He considers a setting in which IPOs are sold to institutional investors, who are asymmetrically informed about a valuation factor that is common across private firms. Since IPO offer prices are set based on investors' indications of interest, the outcome of an IPO (a high versus low IPO offer price) reflects information that was previously private, reducing information asymmetry across investors and reducing valuation uncertainty for future issuers, thereby triggering a cluster of subsequent IPOs.

While the above two theoretical analyses have driving forces quite different from each other, they also have one feature in common: they are both driven by considerations of stock market valuation and stock returns: the aggregate stock market in the case of Pastor and Veronesi (2005), and stock valuation in the IPO market in the case of Alti (2005). As such, neither model directly analyzes many other interesting questions regarding the relationship between IPO waves and various features of the product market: First, which industries are most likely to have an IPO wave? Second, what are the differences between firms that go public "on the wave" (i.e., as part of an IPO wave) versus "off the wave" (i.e., either individually, or part of a cold IPO market) both in terms of pre-IPO productivity and post-IPO product market performance?[1] Third, within the set of firms going public as part of an IPO wave, does timing matter: i.e., is there a difference in productivity and post-IPO performance (as well as other firm characteristics) between firms that go public earlier in an IPO wave versus those that go public later?[2] Our

[1] Helwege and Liang (2004) conclude that there is no difference in the quality of firms going public in hot and cold IPO markets. In contrast to their findings, our empirical analysis indicates that there is indeed a significant difference in post-IPO operating performance between firms going public during an IPO wave versus those going public off the wave.

[2] While we are not aware of any prior empirical analyses of this question, there is some anecdotal evidence that higher quality firms go public earlier in an IPO wave: see, e.g., the Harvard Business School Case ImmuLogic Pharmaceutical Corporation (B-2). To quote: "The one certainty about the current open window for biotechnology initial public offerings (IPOs) was that sooner or later it would shut again. Furthermore, he (Henry McCance) has observed that in past periods of intense IPO activity, the best firms tended to go public early in the cycle, while lower-quality firms went public later."

objective in this paper is to develop a new theoretical rationale for the timing of a firm's going public decision and for IPO waves based on product market considerations that allow us to answer these and related questions, and empirically test the implications of our theory.

The point of departure for our theory from existing analyses is the assumption that going public not only allows a firm to raise capital at a lower cost than if it were a private firm, but also allows it to grab market share from competitors who remain private. It is particularly interesting to examine, both theoretically and empirically, the implications of the notion that going public enables a firm to grab market share from competitors in the product market, since there is some anecdotal evidence from practitioners that this is indeed the case in many real-world situations. To quote Killian, Smith, and Smith (2001): "An IPO can establish its brand and gain loyal customers ahead of competitors. Palm established itself as the leader with a suite of spiffy handheld devices and great marketing, grabbing 80 percent of market share. Then Handspring, founded by Palm alums, created a device with a twist: add-on modules that allow Handspring users to download and play music or to access the Internet. Handspring priced its PDAs aggressively and captured most of the remaining (market) share. With these two aggressive players dominating PDA sales, it was very difficult for a new entrant to compete. Even Microsoft, with its billions of dollars of marketing clout, retreated from the field."[3] We do not make any assumptions regarding the precise mechanisms through which firms going public early are able to grab market share from their competitors: possible mechanisms include gaining additional credibility with customers and suppliers; being able to hire higher quality employees as a public firm and rewarding them more efficiently using stock and stock options; and being able to acquire related firms in the same industry (holding patents valuable for introducing various product innovations) through takeovers paid for using their own (publicly traded) stock.

We consider an industry with two firms: firm 1 and firm 2, both of which are private to begin with. Each firm has a scalable project with decreasing returns to scale, which it proposes to implement. Firm 1 has higher productivity of capital compared to firm 2, so that its equilibrium scale of investment is higher than that of firm 2. Each firm has a certain amount of internal capital available to it as a private firm. However, if the amount of capital required for investment exceeds the above internal capital, the firm needs to either scale back its investment (i.e. operate at a scale smaller than its optimal level) or go public by issuing equity in the stock market.[4] Thus, going public has two benefits in our setting: it allows the firm to raise external financing if necessary, and, as discussed before, allows it to grab market share from other firms in the industry that are private. On the other hand, going public is costly: we assume that each firm has to incur a significant issuing cost if it chooses to go public.

[3] Killian, Smith, and Smith (2001) give a number of examples from other industries where firms that went public earlier were able to grab significant market share in their industry. Examples include Affymetrix, the maker of microchips that identify and analyze gene sequences; Petsmart, the pet superstore, which went public ahead of its competitor, pets.com, and grabbed significant market share; and Capstone Turbine, the maker of microturbines, which was the first to introduce such turbines for commercial use.

[4] Thus, for simplicity, we assume that it is prohibitively costly for the firm to raise external financing as a private firm. However, note that all our results go through as long as the cost of external financing is significantly cheaper for a public firm compared to that for a private firm.

Each firm knows its own productivity. However, each firm also knows that their industry may soon experience a positive productivity shock with a certain probability (and no productivity shock with the complementary probability).[5] We assume that, in the absence of a productivity shock, the available internal capital will be enough to fund the projects of both firm 1 and firm 2 at their optimal scale. If, however, a productivity shock is realized, firm 1 (which has higher productivity to begin with) needs to go public to raise external financing in order to operate at its new optimal scale while firm 2 will continue to have enough internal capital to operate at its new optimal scale (since, given its lower level of initial productivity, its new optimal scale will be smaller than its available internal capital even after the productivity shock is realized). We allow a firm to go public either early (before uncertainty about whether or not there is a productivity shock is resolved) or late (after such uncertainty is resolved). We assume that there will be two rounds of competition for market share between the two firms in the product market: one before the resolution of uncertainty about the productivity shock, and one afterward.

In the above setting, we solve for the equilibrium time at which each firm goes public (if at all), which in turn determines whether or not there is an IPO wave (we define an IPO wave as a situation where both firms in the industry go public). There are five possible equilibria in the model. Which of these occur depends on the following four parameters of this model: the magnitude of a potential productivity shock; the probability of a productivity shock; the deadweight cost of going public; and the levels of initial productivity of each firm in the industry. It is useful to first discuss the benchmark equilibrium, where going public merely allows a firm to raise external financing (and does not give it any advantage in terms of competing for market share). In the benchmark case, both firms remain private until the uncertainty about the productivity shock is resolved. Assuming that the cost of going public is not prohibitive, firm 1 goes public in the event of a shock, and remains private if there is no productivity shock. Firm 2 remains private throughout, regardless of whether or not there is a productivity shock. The intuition here is straightforward. In the absence of product market considerations, each firm behaves optimally purely from the perspective of raising capital. Since going public is costly, it is not optimal for firm 2 to go public at all, since it has adequate capital to fund its project at its optimal scale even in the event of a productivity shock. Firm 1 waits till all uncertainty about the shock is resolved, and will go public only if a productivity shock is realized. Note that there is no benefit for firm 1 to go public early in this benchmark setting, since going public does not yield any advantage to it in terms of competition for market share, so that the only reason for going public is to raise external financing (which becomes necessary if and only if a productivity shock is realized).

We now describe the equilibria of the full-fledged model, where going public enables a firm to grab market share from competitors. There are three categories of equilibria occurring in our setting, depending upon the model parameters discussed earlier. The first category of equilibria (characterized in Proposition 1) involves an IPO wave

[5] While in the basic model we assume that these productivity shocks are perfectly positively correlated (i.e., industry wide), we allow for firm-specific shocks in our extended model (section 3.2.2).

occurring even without the realization of a productivity shock: i.e., both firms go public early without waiting to see whether a productivity shock is realized or not. The second category of equilibria (characterized in Proposition 2) involves both firms going public, but at least one of the two firms in the industry goes public only if a productivity shock is realized: in other words, an IPO wave occurs only in the event of a productivity shock. The third category of equilibria (characterized in Proposition 3) involves firms going public off the wave: i.e., only one of the two firms goes public, and the other remains private throughout.

To understand the intuition behind the above equilibria, it is useful to discuss the costs and benefits of going public versus remaining private for each firm, as well as the advantages and disadvantages of going public early versus late. Consider first firm 1. This firm has two benefits from going public. First, in the event of a productivity shock, its internal capital is not sufficient to fund its investment to its optimal level, so that it needs to raise additional capital by going public. Second, by going public, it can grab market share from firm 2, in the event that the latter remains private. Its cost of going public is the deadweight cost discussed before. Now consider firm 2. Since its productivity is lower, its only benefit from going public is to prevent firm 1 from grabbing market share from it (and to grab market share from firm 1 in the event that it does not go public); recall that we have assumed that its initial productivity is low enough that, even after the shock, it can still fund its investment to its optimal level using internal capital. Note, however, that a productivity shock nevertheless increases its benefit of going public, since its profits from additional market share will be greater if its productivity is greater. For either firm, the trade-off between going public early versus late is as follows. The advantage of going public early is that the firm is able to grab market share from the other firm (and to prevent the other firm from grabbing market share from it) in two rounds of product market competition. The disadvantage of going public early is that it incurs the cost of going public before it knows for sure whether a productivity shock is realized (so that the firm may end up being public in a situation where no shock is realized, and it would have been better off remaining private). Note that the benefit of going public early versus late is always greater for firm 1 than for firm 2 (since it has multiple reasons for going public, while firm 2 has only the benefit of grabbing market share); on the other hand, the cost of going public is the same for both firms. To illustrate the above intuition, consider the equilibrium characterized in Proposition 2 (ii), where firm 1 goes public early (before a productivity shock is realized) and firm 2 goes public late, if and only if there is a productivity shock (i.e., there is an IPO wave only in the event of a productivity shock). This equilibrium occurs only when the magnitude of a potential productivity shock is large, firm 1's existing productivity is high, while firm 2's productivity is much smaller. Here firm 1 chooses to go public early since its expected total benefit of going public early (arising from the ability to grab market share as well as from raising external financing) dominates the cost. Firm 2, on the other hand, does not find it optimal to go public early since given its low existing productivity (which reduces the benefit from having additional market share), its benefit of going public is smaller than the cost of doing so. It finds it optimal to go public only if a productivity shock is realized, at which point its benefit of going public rises above the cost of doing so.

We now briefly discuss the remaining four equilibria of the full-fledged model. The intuition behind the behavior of the two firms in these equilibria remains similar to that discussed above. These equilibria arise as the magnitude of the benefits versus costs of going public, and of the benefits versus costs of going public early rather than late to the two firms change with variations in the four model parameters discussed earlier. The equilibrium characterized in Proposition 1, involving both firm 1 and firm 2 going public early, occurs when the magnitude of a potential productivity shock is large and firm 2's productivity (as well as that of firm 1) is high. The intuition here is that, given its high existing level of productivity, firm 1 chooses to go public early since its benefit of going public dominates the cost of doing so even in the absence of a shock. Given that firm 1 goes public early in equilibrium, firm 2 also chooses to go public early in order to compete better for market share. The equilibrium characterized in Proposition 2 (i), involving both firms remaining private until uncertainty about the productivity shock is resolved, and going public if (and only if) a productivity shock is realized, occurs when the magnitude of a potential productivity shock is large, but both firms' existing productivity is relatively low. The intuition here is that the benefit of going public does not rise above the cost of doing so at the existing level of productivity for either firm, and rises above this cost only if a productivity shock is realized. The two equilibria characterized in Proposition 3, where firm 2 remains private throughout while firm 1 either goes public only in the event of a productivity shock (Proposition 3 (i)) or goes public early: i.e. even in the absence of a shock (Proposition 3 (ii)), occur when the magnitude of the productivity shock is not too large, with firm 2's existing productivity relatively small. The former equilibrium occurs when firm 1's existing productivity is low so that its benefit rises above its cost of doing so if and only if there is a shock; the latter equilibrium occurs when firm 1's existing productivity is high, so that its benefit of going public is higher than the cost of doing so even in the absence of a productivity shock.

Our theoretical analysis yields several testable predictions. The first prediction is that, on average, firms going public outside an IPO wave (i.e. in a cold market) will have higher post-IPO profitability than those that go public in an IPO wave (after controlling for industry conditions, firms' post-IPO capital stock and market share, and other characteristics of the offerings). Second, our model predicts that everything else equal, firms going public earlier in an IPO wave will be characterized by higher post-IPO profitability than those that go public later in the wave. Since our model predicts that firms going public outside an IPO wave typically have higher average pre-IPO productivity and considering the fact that higher-productivity firms in general use more capital for expansion, our third prediction is that everything else equal, firms that go public in an IPO wave will on average hold more cash on hand (since they use less of the cash raised through their offerings for investment) than firms that go public off the wave. Similarly, our model predicts that everything else equal, firms that go public later in an IPO wave will on average hold more cash on hand (or, use less of the cash raised through their offerings for investment) than firms that go public earlier in the wave.

We test the above predictions of our model, using a sample of 6647 IPO firms from the Thomson Financial Securities Data Corporation (SDC) new issues database. To test the first hypothesis, which compares the post-IPO operating performance of on-the-wave IPO firms versus off-the-wave ones in the same industry, we define the "hotness" of an IPO market as the total number of IPOs in the same Fama-French industry within a 90-day window symmetrically surrounding the issuance date for any given IPO and use this number as a raw measure of the hotness of the IPO market in that industry for the particular issuance date under consideration. Consistent with our first prediction, we find that, even after controlling for industry and time effects as well as various firm and IPO characteristics, a firm that goes public within a hot period of 8 other same-industry IPOs will on average have a post-issuance ROA 1.1% less than a firm that goes public within a cold period of only 1 other same-industry IPO. Given that the mean of post-IPO ROA in our sample is 5%, this represents a 20% difference in post-issuance operating performance, which is economically significant. We also use two refinements of the above measure for hotness and find similar results, consistent with the first prediction of our model.

To test the second prediction, which compares the post-IPO operating performance of leaders and followers in an IPO wave for a particular industry, we first identify and define IPO waves within that industry and then rank the IPOs in our sample within each wave by the order of their issuance dates. Consistent with our second prediction, we find that even after controlling for industry and time effects as well as various firm and IPO characteristics, a firm that goes public earlier in an IPO wave (among the first 25% of firms going public in this IPO wave) will on average have an ROA 2.3% more than a firm that goes public later in the wave (among the last 25% of firms going public in this wave). Given that the mean of ROA in our sample is 5%, this represents a 46% difference in post-issuance ROA. Similar results hold if we use alternative measures of how early an IPO takes place within a wave.

We also find supporting evidence for the third and fourth predictions. Specifically, our results show that, on average, firms that go public in an IPO wave will hold more cash balance on hand after the IPO or experience a larger increase in cash and cash equivalents around the IPO date than firms that go public off the wave (consistent with the third prediction of our model). Similarly, we find that firms going public later in an IPO wave will on average hold more cash balance on hand after the IPO or experience a larger increase in cash and cash equivalents around the IPO date than firms that go public earlier in the wave (consistent with the fourth prediction of our model).

Finally, since our model argues that product market competition is an important factor driving firms' going public decisions, we test whether and how industry concentration affects the relationship between post-issuance operating performance and IPO timing ("on the wave" versus "off the wave", and "early in a wave" versus "late in a wave"). We find that a higher level of industry concentration tends to weaken the difference in post-IPO performance between firms that go public on the wave versus those that go public off the wave, and between firms going public earlier in a wave versus those going public later in the wave. This suggests that going public adds little to a firm's product market competitiveness in highly concentrated industries and thus fail to induce it to go public purely out of competition concerns.

Our paper is related to several strands in the theoretical and empirical literature. Apart form the two theoretical analyses (Pastor and Veronesi 2005 and Alti 2005) of IPO waves discussed earlier, the theoretical literature most directly related to this paper is the literature on the going public decision: Chemmanur and Fulghieri (1999) model the going public decision as a trade-off between the duplication in information production inherent in the public equity market versus the risk (or negotiating power) premium demanded by private financiers. They, however, do not focus directly on product market considerations. In a recent paper, Spiegel and Tookes (2007) develop a model of the relationship between product market innovation, product market competition, and the public versus private financing decision in an infinite horizon model. In their model (as well as in the two-period model of Maksimovic and Pichler 2001), the advantage of going public is the ability to obtain cheaper financing; the disadvantage is that the disclosure requirements associated with going public allow competitors in the firm's industry to copy the innovation (in other words, remaining private allows a firm to hide its innovation). Apart from the fact that the trade-offs modeled in these two papers are unrelated to those in our paper, neither paper focuses on IPO waves, which is the primary focus of this paper. Other related theoretical analyses of the going public decision include Pastor, Taylor, and Veronesi (2007) and Stoughton, Wong, and Zechner (2001), who develop models of going public. The former paper develops a model in which an entrepreneur trades off the diversification benefits of going public against the cost of doing so (arising from the loss of his benefits of control), in the presence of Bayesian learning about the average productivity of his firm; and the latter paper argues that the decision of a firm to go public may serve to signal high quality to the product market.[6] In terms of empirical literature, this paper is most directly related to the papers studying hot and cold IPO markets (see, e.g., Helwege and Liang 2004) and the literature studying fluctuations in IPO volume (see, e.g., Lowry 2003, Lowry and Schwert 2002, or Benveniste, Ljungqvist, Wilhelm, and Yu 2003). The empirical literature on the going public decision (see, e.g., Pagano, Panetta, and Zingales 1998 or Chemmanur, He and Nandy 2005) is also indirectly related to this paper.[7]

The rest of the paper is organized as follows: In section 2, we describe the essential features of our model, and in section 3 we characterize its equilibrium. In section 4, we describe the testable predictions of our model. In section 5, we provide evidence consistent with some of our main predictions. We conclude in section 6. The proofs of all propositions are confined to the appendix.

[6] Our paper is broadly related to the extensive literature on product and financial market interactions. In addition to the papers discussed earlier, see, e.g., Chemmanur and Yan (2008), who analyze the relationship between product market advertising and new equity issues (IPOs and SEOs).

[7] Our paper is also broadly related to the large theoretical and empirical literature on IPOs: see, e.g., Chemmanur (1993), Allen and Faulhaber (1989), Welch (1989), and Grinblatt and Hwang (1989), for theoretical IPO models. See Ritter and Welch (2002) for a review of the theoretical and empirical IPO literature.

2 The Model

This section considers the going public decision of two competing private firms in an industry. For simplicity, we assume that the two firms are duopolies who split the total product market between them. The model has four dates (time 0, 1, 2, and 3). At time 0, the two private firms are endowed with the same amount of initial capital, the same form of cash-flow-generating technology, different productivity, and different market share. Firm 1 has a market share of m and firm 2 gets the rest $(1-m)$.[8] Without loss of generality, we assume firm 1 to have the higher productivity A_1 and firm 2 to have the lower one A_2 ($A_1 > A_2$). As we shall see in section 2.1, both firms' long-term (time 3) valuation increases with their market share and production efficiency (which depends on their productivity as well as their available capital).

At time 1, each firm knows that a productivity shock may take place at time 2 in which case its productivity may increase by amount ΔA (> 0) with probability p. We denote the enhanced productivity of firm i as $A_{iH} \equiv A_i + \Delta A$. Given this distribution of potential shocks, the firms will calculate their expected optimal capital level and may go public in case of expected funding shortage. Going public, at a fixed cost of B, has two benefits. First, it can provide cheaper capital for the firm's production than debt or private placements (in the current model we assume the alternative financing methods are too costly to be feasible). Second, it can improve the firm's efficiency in grabbing market share from its competitors by enhancing its credibility, attracting better managers, and allowing it to implement strategic plans such as predation or acquisition. After the firms make their going public decisions, they will start the first round of product market competition in terms of grabbing market share from each other. The details of the competition will be discussed in section 2.2.

At time 2, the productivity shock takes place and a firm can go public at this stage if it hasn't done so at time 1. The capital raised at this stage and the enhancement in its market-share-grabbing ability will also help the firm increase long-term (time 3) cash flows thus raise its market valuation. The second round of product market competition takes place and the total market share is redivided between the two rivals.

At time 3, the long-run cash flows are realized and distributed to shareholders, and the firms liquidate. We assume that all agents (firm managers, shareholders, and investors) are risk-neutral and the risk free rate is zero. Everything in the model is publicly observable (i.e., no asymmetric information). The sequence of events is depicted in figure 1.

[8] Since firms already gone public play no role in our model, we simply assume that they own zero market share. As a result, the sum of market share for the two private firms is assumed to be 1. Alternatively, we can specify the sum of market share to be δ ($0 < \delta < 1$), and all our following analysis goes through unaffected.

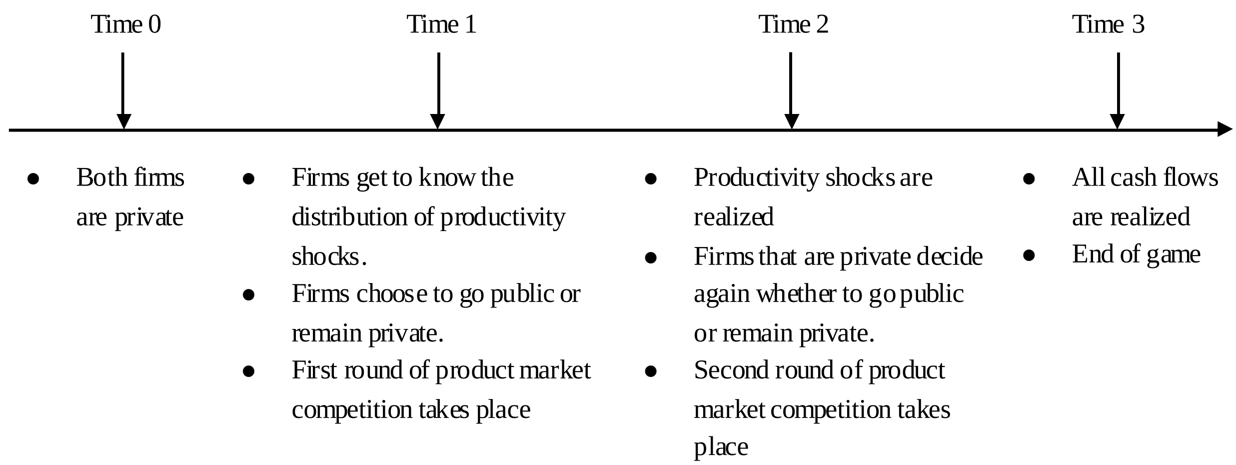

Figure 1: Sequence of Events

2.1 The firm's problem

Each firm's objective is to maximize its long-term cash flows at time 3, which depends on the amount of capital it uses to generate cash flows as well as its market share in the product market. Specifically, firm i's cash flow at time 3 is given as follows:

$$V_i^{III} = k_i^{II} + m_i^{II}(A_i^{II}(k_i^{II*})^{\gamma} - ck_i^{II*}),\ 0 < k_i^{II*} < k_i^{II},\ i = 1, 2, \tag{1}$$

where k_i^{II} is the amount of capital firm i possesses at time 2. If the firm remains private for the two periods, then k_i^{II} is simply k_0, its original capital endowment (which is assumed to be the same for both firms). If, on the other hand, firm i goes public in any period (time 1 or 2), k_i^{II} will become $k_0 + E_i$, where E_i denotes the amount of capital raised in the offering. m_i^{II} is firm i's market share at the end of time 2 (i.e., after two rounds of product market competition), whose level depends on both firms' going public decisions. The details of product market competition are provided in section 2.2. A_i^{II} is firm i's productivity at time 2. If it experiences the productivity shock at time 2, then A_i^{II} becomes A_{iH}. Otherwise A_i^{II} remains to be A_i. k_i^{II*}, the capital firm i uses to generate cash flows, cannot exceed the total amount of capital it owns at time 2, k_i^{II}. c is the constant marginal cost of deploying capital. As in standard finance literature, we assume $0 < \gamma < 1$ so that the cash-flow generating technology exhibits decreasing returns to scale. All parameters are publicly known.

Given the above conditions, it is straightforward to calculate the optimal level of capital chosen by firm i, k_i^{II*}, which is given by:

$$k_i^{II*} = Min\left[k_i^*, k_i^{II}\right], \quad \text{where} \quad k_i^* \equiv \left(\frac{c}{\gamma A_i^{II}}\right)^{\frac{1}{\gamma-1}}. \tag{2}$$

2.2 Product market competition

The current model specifies one form of product market competition, which is the firms' campaign to gain market share by attracting each other's customers.[9] There are two successive rounds of competition in our model, during which each firm relies on its own market power to launch marketing campaigns and to attract customers away from its rival. Specifically the evolution of market share for firm i is given by:

$$m_i^{t+1} = m_i^t + (1 - m_i^t)s_i^{t+1} - m_i^t s_j^{t+1}, \quad i \neq j \ \text{ and } \ t = 0, 1, \tag{3}$$

where m_i^t is firm i's market share at the end of time t and s_i^{t+1} is its ability of grabbing rivals' market share during the round of competition at time $t+1$ ($t = 0, 1$). Here, $m_1^0 = m$ and $m_2^0 = 1 - m$. s_i^{t+1} denotes the effectiveness of marketing efforts made by firm i at time $t+1$. While firm i can grab its competitor's time-t market share ($m_j^t \equiv 1 - m_i^t$) with intensity s_i^{t+1}, the other firm (firm j) can also attract consumers away from firm i at the same time. Thus its final market share depends on both players' relative marketing abilities.

To make the model realistic yet tractable, we assume that a public firm's ability to grab market share after its IPO is linear in its existent market share. Moreover, a private firm's ability to grab market share from competitors is normalized to be zero. Specifically, we assume:

$$s_i^{t+1} = \begin{cases} s m_i^t, & \text{if firm } i \text{ is public} \\ 0, & \text{if firm } i \text{ is private} \end{cases}, \quad 0 < s < 1. \tag{4}$$

Hence, s denotes the advantage that a public firm enjoys relative to a private firm in terms of product market competition. If firm i goes public early (i.e. before the first round of competition at time 1), it can grab market share from firm j for two rounds (at time 1 and 2). In other words, a late IPO may be costly due to the loss in market share at time 1. This point is most clearly illustrated by figure 2, the evolution path of market share distribution.

[9] The market share competition is a variant of the Lanchester (1916) battle model, which has been widely adopted in the marketing literature. Some recent finance papers such as Spiegel and Tookes (2006) also make use of this model to describe product market competition.

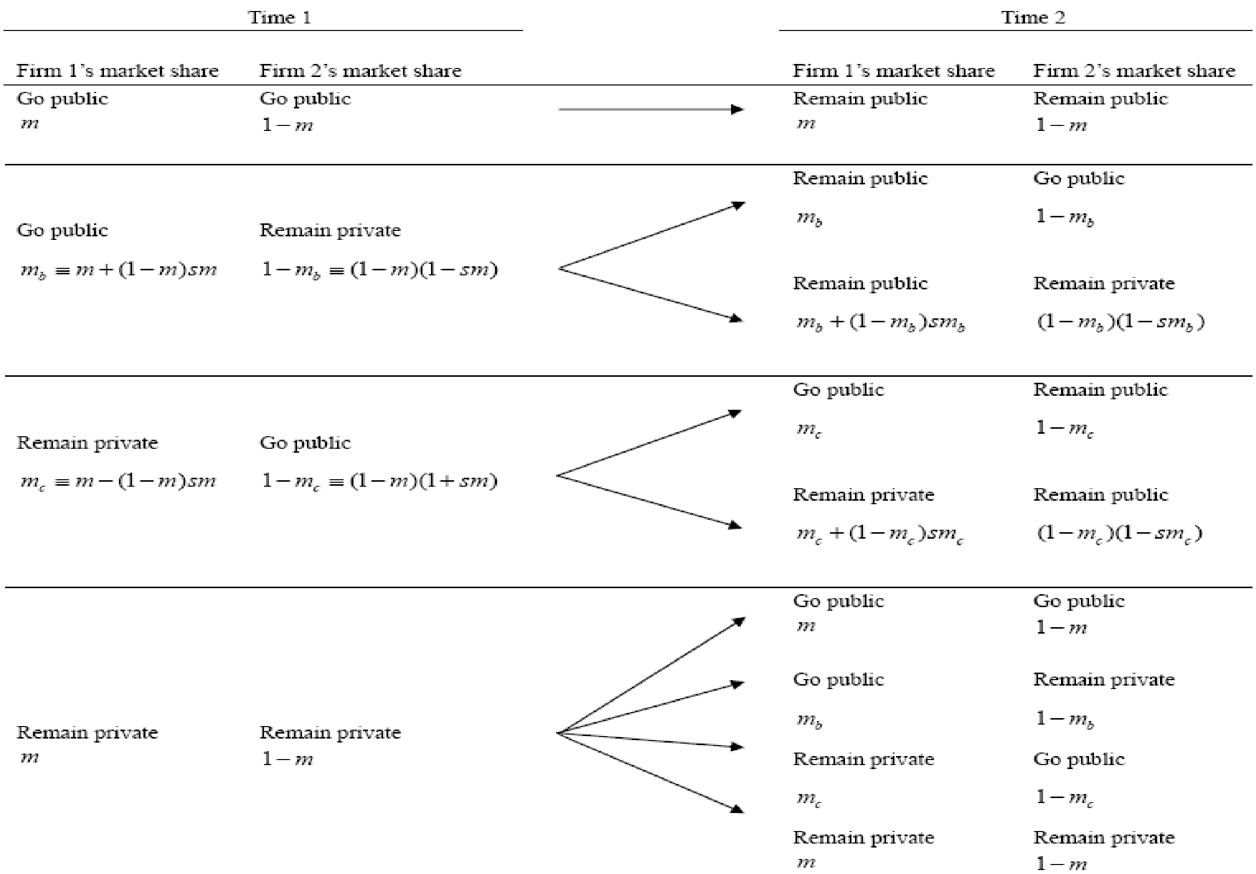

Figure 2: Evolution of market share of both firms and its relationship to their going public decisions

As can be seen, if a firm wants to go public, it is better off doing so at time 1 rather than delaying it to time 2. Let's use firm 1 as an illustration. If the final industry outcome is that both firms go public, then for firm 1, IPO at time 1 weakly dominates IPO at time 2 ($m_b > m > m_c$). This is due to the fact that going public at time 1 will give it immediate competitive edge while deferring IPO will result in a loss of this opportunity and may even subject the firm to more aggressive competition from rival firms. Likewise if the final industry outcome is that only firm 1 goes public, IPO at time 1 is still weakly dominant $(m_b(1 + s(1 - m_b)) > m_b)$ This means that the IPO decision at time 1 is a real option driven by both capital concerns and competitive forces. While deferring IPO decision may save the issuing cost if productivity turns out not to increase and it is unnecessary for the firm to raise external financing, doing so may sacrifice the precious business opportunity of enlarging its market share at an earlier date. As we will see in the next section, this new trade-off prompts many firms to go public purely out of product market competition concerns and drives industry-wide IPO waves.

3 Equilibrium

Given the two-period structure of the model, the equilibrium concept adopted in the current paper is Perfect Bayesian Equilibrium (PBE). At time 1, both firms choose to either go public or remain private. If they go public at time 1, they make no choice at time 2. Otherwise they can choose to go public at time 2 after observing the realization of the potential productivity shock. Therefore a PBE is a complete characterization of all contingent strategies of the two firms in the two periods. First, we will analyze the benchmark case where IPO does not affect product market competition. The PBE in this case is trivially determined. Then we will proceed to solve the full model where IPO enhances a firm's competitiveness on the product market.

3.1 Benchmark case: IPO does not affect product market competition

Given the level of newly raised capital, E_i, and the rational expectation of the firm's long-run market value, $E_t(V_i^{III})$, the sharing rule between existing owners and new stock holders during an IPO is determined as follows: the investors will acquire $E_i/E_t(V_i^{III})$ fraction of the firm and the remaining shares belong to the existing owners. Thus, whoever owning the firm will try his best to maximize the whole firm's market value (because his stake in the firm is $E_t(V_i^{III}) - E_i$) and to choose best investment policies. Thus we do not model agency problems in the current setting. The managers can always use only a fraction of capital in its cash-flow generation but unlike physical production which exhausts the raw materials and other inputs, the capital used here is nonperishable.[10] As we can see in equation (2), the firm will not use capital beyond the optimal level (k_i^*) which in turn depends on its productivity at time 2 (A_i^{II}). Depending on whether firm i experiences the productivity shock at time 2, k_i^* can be expressed as:

$$k_i^* = \begin{cases} \left(\frac{c}{\gamma A_i}\right)^{\frac{1}{\gamma-1}} \equiv k_{iL}^* & \text{without productivity shock} \\ \left(\frac{c}{\gamma A_{iH}}\right)^{\frac{1}{\gamma-1}} \equiv k_{iH}^* & \text{with productivity shock} \end{cases}. \quad (5)$$

For simplicity, we assume that $E_1 = E_2 \equiv E >> Max(k_i^* - k_0, 0)$, $\forall\ i = 1, 2$, so that once a firm accesses the external financial market, it is no longer subject to capital constraint and will always have adequate funds for its future cash-flow generation. The investor's participation constraint has to be satisfied so the fraction of equity sold to new investors is $E/E_t(V_i^{III})$. Given large enough E, the public firm i's long-run (time 3) value V_i^{III} is given by:

$$V_i^{III} = k_0 + E + m_i^{II}(A_i^{II}(k_i^*)^\gamma - ck_i^*) - B, \quad i = 1, 2. \quad (6)$$

Without product market concerns, a firm will go public if and only if its current capital level (k_i^t, $t = I, II$) is lower than its efficient level (k_i^*) and the efficiency gain from raising new capital exceeds the issuing cost B. By

[10] This assumption is innocuous. As long as the capital depreciation rate is the same for both firms, all our results are unaffected.

examining the expression for efficient capital level, we have:

$$k_0 < k_i^* \Leftrightarrow A_i^{II} > \frac{ck_0^{1-\gamma}}{\gamma} \equiv \overline{A}. \tag{7}$$

Recall that firm 1 is assumed to have higher productivity. Without loss of generality, we further assume that the productivity shock raises firm 1's productivity above the threshold level ($\overline{A}$) but not that of firm 2. Specifically, the conditions we operate on are:[11]

$$\begin{cases} A_2 < A_1 < \overline{A} < A_{1H} \\ A_2 < A_{2H} < \overline{A} < A_{1H} \end{cases}. \tag{8}$$

Given (8), we know that both firms will operate at their efficient capital levels if they do not experience the productivity shock, whether or not they go public. Likewise firm 2 will always use its efficient level of capital whether or not its productivity increases. However, firm 1, if experiencing a productivity shock, will need fresh capital, though it may also choose to remain private if the issuing cost is too large. To make the notations simpler, we define the following operating profit functions:

$$\begin{aligned} &\pi_1 \equiv A_1 k_{1L}^{*\gamma} - ck_{1L}^* = (A_1)^{\frac{1}{1-\gamma}} c^{\frac{\gamma}{\gamma-1}} \gamma^{\frac{\gamma}{1-\gamma}} (1-\gamma) \\ &\pi_2 \equiv A_2 k_{2L}^{*\gamma} - ck_{2L}^* = (A_2)^{\frac{1}{1-\gamma}} c^{\frac{\gamma}{\gamma-1}} \gamma^{\frac{\gamma}{1-\gamma}} (1-\gamma) \\ &\pi_{2H} \equiv A_{2H} k_{2H}^{*\gamma} - ck_{2H}^* = (A_{2H})^{\frac{1}{1-\gamma}} c^{\frac{\gamma}{\gamma-1}} \gamma^{\frac{\gamma}{1-\gamma}} (1-\gamma) \\ &\pi_{1H}^{IPO} \equiv A_{1H} k_{1H}^{*\gamma} - ck_{1H}^* = (A_{1H})^{\frac{1}{1-\gamma}} c^{\frac{\gamma}{\gamma-1}} \gamma^{\frac{\gamma}{1-\gamma}} (1-\gamma) \\ &\pi_{1H}^{PR} \equiv A_{1H} k_0^{\gamma} - ck_0 \end{aligned}, \tag{9}$$

where π_1 and π_2 are the gross operating profits (without market share considerations) for firm 1 and firm 2 respectively if they do not experience the productivity shock; π_{2H} is the gross operating profit for firm 2 if it gets the shock (whether or not it is public); π_{1H}^{IPO} is the gross operating profit for firm 1 if it gets the shock and goes public; and π_{1H}^{PR} is firm 1's gross operating profit if it gets the shock but chooses to remain private.

To simplify computations, we also assume that if firm 1 gets the productivity shock but chooses to remain private, its profit is still greater than that of firm 2 who also experiences the shock. (8) then determines the following relationship:

$$\begin{cases} \pi_2 < \pi_1 < \pi_{1H}^{PR} < \pi_{1H}^{IPO} \\ \pi_2 < \pi_{2H} < \pi_{1H}^{PR} < \pi_{1H}^{IPO} \end{cases}. \tag{10}$$

This section mainly deals with the case where IPO has no impact on product market competition so that going

[11] Note that this assumption is not as restrictive as it looks. What we really need is that firm 1 has higher productivity ex ante. The assumption that firm 1 needs new capital after the productivity shock whereas firm 2 does not even after the productivity can be relaxed without affecting the central intuition of the paper, although such relaxation may lead to uninteresting equilibria where both firms always want to do IPO at time 1 or both remain private throughout the two periods.

public will not enhance a firm's market-share-grabbing ability (i.e. $s = 0$ for both public and private firms). As long as $B > 0$, (8) means that without productivity shocks, both firms will never want to go public and even with productivity shock, firm 2 will not go public. To make the model interesting, we assume that the issuing cost B is not too large so that firm 1, upon the productivity shock, will go public:

$$m\pi_{1H}^{IPO} - m\pi_{1H}^{PR} > B, \tag{11}$$

where the left handside denotes the benefit of going public and the right handside is the cost.[12] Hence, in the benchmark case, only higher-productivity firms (like firm 1 here) go public under the productivity shock. These IPOs are solely driven by capital shortage.

3.2 Full Model: IPO enhances product market competitiveness

However, going public is attractive not just because it can provide necessary funding, but also because it enhances the firms' competitiveness on the product market. Hence a fuller characterization of firms' optimal IPO decisions needs to take market share competition into consideration.

Before analyzing the full model, we also impose stability conditions for time 0 to ensure that without productivity shocks (i.e. $p = 0$), remaining private is a Nash equilibrium. Without productivity shocks, a firm's benefit of going public purely comes from the enhancement in its competitiveness on the product market. As we can see from Figure 2, the maximum additional market share firm 1 can gain by its IPO (when firm 2 remains private throughout) is $m_b + sm_b(1 - m_b) - m$. Likewise, the maximum benefit of firm 2 to go public (when firm 1 remains private throughout) in terms of long-run cash flows is $[(1 - m_c)(1 + sm_c) - (1 - m)]\pi_2$. Hence, the sufficient conditions for remaining private to be a Nash equilibrium at time 0 are:

$$B > [m_b + sm_b(1 - m_b) - m]\pi_1. \tag{12}$$

$$B > [(1 - m_c)(1 + sm_c) - (1 - m)]\pi_2. \tag{13}$$

Given these two conditions, both firms will optimally choose to remain private without productivity shocks.[13]

[12] The violation of this assumption does not change the main results because even though B is so big that both firms will not go public without product market concerns, firm 1 still has a relatively stronger incentive to go public due to its superior exisitn productivity. This leads to similar results as those derived under the current assumption.

[13] These sufficient conditions are in fact stronger than a standard Nash equilibrium requires. They make remaining private a strictly dominant strategy for each firm. This is purely out of computational concerns. If we use weaker conditions to make remaining private only the best response to rival's equilibrium moves, all results in the current paper remain intact.

3.2.1 Industry-wide productivity shocks

At time 1, the two firms, under the common belief that productivity shocks may take place in the future with probability $p > 0$, consider their going public choice. We first analyze the case where the productivity shocks are industry-wide (perfectly correlated), which means that with probability p, both firm 1 and firm 2 will experience an increase in productivity at time 2 and with probability $1 - p$ they will not. Given the rapid advancement in modern information technology and the high mobility of personnel across companies within the same industry, competing firms on the same product market not only keep a close eye on their rivals' change in production and management, but also react quickly by adopting the same technology if it turns out to be efficient. Therefore this assumption seems to fit the current industry situation well. However, to make the picture more complete, we also analyze the scenario where either firm's productivity shock is purely idiosyncratic in the next subsection.

For firm 1, if the productivity shock occurs at time 2 which raises its productivity to a higher level, it will definitely go public even if doing so has no product market effects.[14] An IPO will also increase firm 1's ability to grab market share from its competitor. Knowing this, firm 2 may also wish to go public at time 2 because staying private may put it in a much worse product market position than paying the issuing cost to go public and improve its competitiveness. This strategic concern of firm 2 gives firm 1 an additional incentive to go public even at time 1 when actual productivity shocks are not realized. If firm 2's threat of going public is credible enough and the likelihood of productivity shock is high, then going public right away at time 1 dominates waiting for the arrival of actual productivity shocks at time 2. Of course, if firm 1 commits to go public (either at time 1 or 2), firm 2 may also be prompted to go public at time 1 in order to establish its competitive status in the industry as early as possible. Therefore, with product market competition, both firms (the whole industry) may go public around the possible arrival of productivity shocks, creating an IPO wave that would not be likely to happen in the benchmark case. To be precise, we define an IPO wave in our model to be the situation where both firms go public either at time 1 or time 2 so that by the end of the game both are public.

After solving this dynamic game, we find a total of five possible Perfect Bayesian Equilibria (PBEs) under the current parametric setting: Proposition 1 describes the equilibrium in which IPO waves occur even without actual productivity shocks, Proposition 2 gives two equilibria that may yield IPO waves upon the realization of a productivity shock, and Proposition 3 delineates two equilibria that can only have off-the-wave IPOs whether or not a productivity shock take place.[15] To make our notations easy to follow, we define the following two boundaries for

[14] This is due to equation (11) and the fact that $m_b > m > m_c$. See Appendix for more details.

[15] To save space, all propositions given in the main text only describe on-equilibrium-path strategies and omit the off-equilibrium-path ones, which will be outlined in the Appendix.

the magnitude of the shock (ΔA):

$$\begin{aligned} \Delta A_L &\equiv \left(\frac{c}{\gamma}\right)^{\gamma}\left(\frac{B}{(1-\gamma)Max\{sm(1-m), sm_b(1-m_b)\}}\right)^{1-\gamma} - A_2. \\ \Delta A_H &\equiv \left(\frac{c}{\gamma}\right)^{\gamma}\left(\frac{B}{(1-\gamma)Min\{sm(1-m), sm_b(1-m_b)\}}\right)^{1-\gamma} - A_2. \end{aligned} \tag{14}$$

Proposition 1 ***(IPO waves even without a productivity shock)*** *When the magnitude of the shock is moderate ($A_1 - A_2 < \Delta A \leq \Delta A_L$), the probability of the shock is large, the issuing cost is small, and the existing productivity levels of firm 1 and firm 2 are high, both firms will go public before the realization of a productivity shock (at time 1).*

The intuition behind the above proposition is straightforward: when both firms' existing productivity levels are high (close to the threshold level $\overline{A}$), a highly probable industry-wide shock with a moderate magnitude is very likely to render the firms' current production scales inefficient, making them eager to obtain fresh capital through IPOs. Since the productivity shock is likely and both firms are close to their efficient operating scales, firm 2 knows for sure that firm 1 will become public by the end of the game (by conducting its IPO at time 1 or 2), which means that if it does not go public, it will lose market share at least in the second round of product market competition. The benefit of additional market share depends on the magnitude of one's productivity level. Hence, the high existing productivity level of firm 2 makes it care much about the potential loss of market share due to firm 1's strengthening competitive position after the IPO. When this potential loss exceeds the issuing cost of going public, firm 2 will go public. Inferring this, firm 1's incentive to go public is also enhanced. The only reason for firm 1's hesitation to go public at time 1 is that it wants to avoid paying the "unnecessary" issuing cost should the shock not be realized at time 2. Therefore, when the cost of going public is significantly smaller than the expected gain in profits (due to its high existing productivity) and given firm 2's aggressive going-public strategy, firm 1 will be prompted to go public at time 1 itself, even without the realization of a productivity shock. Knowing this, firm 2 will also hasten to go public to combat firm 1 in the product market as early as possible. Consequently, both firms end up going public at time 1, creating an IPO wave without waiting for the actual realization of a productivity shock.

Proposition 2 ***(IPO waves only with a productivity shock)*** *When the magnitude of a potential shock is large ($\Delta A > \Delta A_L$), in addition to the PBE in Proposition 1, we have two more possible equilibria:*

(i) When the existing market share of firm 1 is moderately large ($m \geq (2 + s - \sqrt{s^2 + 4})/(2s)$), and the existing productivity levels of firm 1 and firm 2 are low, both firms will remain private before the realization of a productivity shock (at time 1) and go public only upon the realization of a shock (at time 2).

(ii) When the existing market share of firm 1 is small ($m < (2 + s - \sqrt{s^2 + 4})/(2s)$), the existing productivity of firm 1 is high, and the existing productivity of firm 2 is low, firm 1 will go public before the realization of a productivity shock (at time 1) and firm 2 will go public only upon the realization of a shock (at time 2).

When the magnitude of a potential productivity shock is large ($\Delta A > \Delta A_L$) but not too large ($\Delta A < \Delta A_H$), the initial distribution of market share between the two firms matters in deciding what kind of PBE may occur. If the existing market share of firm 1 is small enough ($m < (2 + s - \sqrt{s^2 + 4})/(2s)$), PBE (ii), rather than PBE (i), will occur when the other parametric conditions specified above are met. The intuition is as follows. The additional market share each firm can gain by product market competition depends on two things: the available market share to grab from rivals (i.e. rivals' existing market share), and its own market-share-grabbing ability, which in turn relies on its own existing market share. When firm 1's existing market share is much smaller than that of firm 2, the latter's additional gain in market share by going public at time 2 would be $sm_b(1 - m_b)$ if firm 1 goes public at time 1, which is larger than $sm(1 - m)$, the increase in market share for firm 2 if firm 1 remains private at time 1 and goes public only upon the realization of a productivity shock at time 2. The reason is that when firm 1 is currently a small player in the product market, firm 2, despite its strong market-share-grabbing ability ($s(1 - m)$), has little to grab by going public, so that its gain from an IPO is small. On the other hand, when firm 1 goes public at time 1, its market share will increase by $sm(1-m)$ in the first round of product market competition, which in turn arouses firm 2's interest to compete for market share in the second round of competition. Thus, firm 2's incentive to go public at time 2 will be stronger if firm 1 goes public at time 1 than if firm 1 delays its IPO decision. Mathematically, the above argument means that $sm_b(1 - m_b)\pi_{2H} > B > sm(1 - m)\pi_{2H}$, which can be equivalently expressed as $\Delta A_L < \Delta A < \Delta A_H$. Therefore, when ΔA falls between ΔA_L and ΔA_H, and the market share of firm 1 is small, PBE (i) cannot occur because even if the productivity shock is realized, firm 2 will not go public as the benefit it derives from an IPO does not cover its issuing cost.

When firm 1's existing market share is larger than $(2 + s - \sqrt{s^2 + 4})/(2s)$ and the magnitude of a potential shock ΔA is between ΔA_L and ΔA_H, we have $sm(1 - m)\pi_{2H} > B > sm_b(1 - m_b)\pi_{2H}$. Under this circumstance, the benefit of firm 2's going public upon a productivity shock dominates its issuing cost if firm 1 remains private at time 1, but falls short of the issuing cost if firm 1 chooses to go public one period earlier. Thus PBE (ii) cannot occur whereas PBE (i) can. When the magnitude of the productivity shock is very large ($\Delta A > \Delta A_H$), the initial market share distribution between the two firms does not matter in determining whether PBE (i) or PBE(ii) occurs.

Apart from the existing market share distribution, the difference in the two firms' existing productivity levels also determines which PBE might occur when the magnitude of the shock is at least ΔA_L. Note that in both PBE (i) and (ii), the existing productivity of firm 2 is so low that it has no desire to go public before a productivity shock is realized. When the existing productivity of firm 1 is high, it has a strong incentive to go public earlier (i.e. at time 1) because each unit of additional market share gained through more effective product market competition will bring it larger time 3 cash flows. This leads to PBE (ii), the most interesting "sequential IPO wave equilibrium", in which higher-productivity firms' IPOs are followed one period later by IPOs conducted by lower-productivity ones (if an industry-wide productivity shock takes place). On the other hand, if the existing productivity level of firm 1 is also low (as that of firm 2), it will also choose to wait until the realization of a productivity shock because the marginal benefit of additional market share by going public earlier does not outweigh the expected "unnecessary" issuing costs. In this scenario, we will observe PBE (i), where both firms adopt exactly the same strategy: remain private at time 1 and go public if and only if the productivity shock actually occurs at time 2.

The fact that there does not exist a "symmetric" equilibrium to PBE (ii) where firm 2 goes public earlier at time 1 followed by firm 1 at time 2 can be explained by the differing degree of going public incentives of the two firms. Since firm 1 has a more intense incentive to go public (arising from both a desire to increase production efficiency and also to grab market share) whereas firm 2 only wants to grab market share, there exists an equilibrium (PBE (ii)) where the issuing cost is larger than firm 2's incremental benefit due to going public at time 1 but smaller than that of firm 1's.

Proposition 3 ***(IPOs off the wave)*** *When the magnitude of a potential shock is not too large ($\Delta A < \Delta A_H$), we have two additional equilibria besides the above three PBEs:*

(i) When the probability of a potential shock is low, the existing market share of firm 1 is small ($m < (2 + s - \sqrt{s^2 + 4})/(2s)$), the existing productivity of firm 1 is low, and the issuing cost is large, firm 1 will go public only upon the realization of a shock (at time 2) and firm 2 will remain private throughout.

(ii) When the probability of a potential shock is high, the existing market share of firm 1 is moderately large ($m \geq (2 + s - \sqrt{s^2 + 4})/(2s)$), the existing productivity of firm 1 is high, and the issuing cost is small, firm 1 will go public before the realization of a productivity shock (at time 1) and firm 2 will remain private throughout.

When the magnitude of the productivity shock, ΔA, is not very large ($< \Delta A_H$), we have two additional PBEs as listed above where there is no IPO wave (i.e., only one of the two firms go public).[16] In fact, when ΔA is small enough (below the threshold level $A_1 - A_2$), we can only observe these two equilibria, in which firm 2 will remain private throughout the two periods because its marginal cash flow benefit from additional market share by going public is just too small compared to the issuing cost. Even though a productivity shock may improve its operating efficiency at time 2, firm 2's incentive to go public is still small as the shock is not large enough to make it deviate from its initial state (i.e., being private) after taking into account the issuing cost. Remaining private is still the dominant strategy for firm 2, just as in the benchmark case. Hence, the only difference between PBE (i) and (ii) is the timing of firm 1's going public.

PBE (i) of Proposition 3 is just the benchmark equilibrium: only the higher-productivity firm will go public after a productivity shock actually occurs. When firms go public only for the sake of raising capital, firms closer to their optimal operating scale (firm 1 here) will go public after a productivity shock because productivity shocks create a wedge between current working capital and its optimal level. On the contrary, firms with lower existing productivity (firm 2) will not go public because they don't need additional capital to improve production efficiency. This equilibrium continues to be possible if firms take product market competition into consideration when making their IPO decisions. A careful inspection of parametric conditions for this PBE reveals that it will become more possible if the issuing cost is very large, and when the existing productivity level of firm 1 is low. The former factor

[16] See Figure 3 in Appendix for a more complete list of possible PBEs in different parametric ranges.

increases firm 1's direct cost of going public, while the latter lowers its expected benefit of going public earlier to grab market share.

PBE (ii) occurs due to product market concerns. This equilibrium becomes possible when the issuing cost is not too large and the existing productivity level of firm 1 is high. In this case, firm 1 has stronger incentives to go public earlier and grab market share from firm 2, even though it may not need fresh capital (since the magnitude of the productivity shock is really low). Similar to Proposition 2, the existing market share distribution affects the occurrence of PBE (i) versus (ii) when $\Delta A_L < \Delta A < \Delta A_H$. Since firm 2 remains private throughout the two periods in both PBEs, we only need to analyze firm 1's incentive to go public. Given firm 2's equilibrium strategy, firm 1 will gain additional market share of $sm(1-m)+sm_b(1-m_b)$ if it goes public earlier at time 1 and gain $sm(1-m)$ if it goes public later at time 2. The difference in market share gained under both equilibria, $sm_b(1-m_b)$, determines firm 1's incentive to go public earlier (at time 1) and is non-monotonic in its existing market share. When the existing market share of firm 1 is small ($m < (2+s-\sqrt{s^2+4})/(2s)$), this incentive is weaker because with a low existing market share of its own, firm 1's market-share-grabbing ability is so low that even if firm 2 has a large market share available for grabbing, firm 1 cannot effectively take over much. When firm 1's existing market share is high ($m \geq (2+s-\sqrt{s^2+4})/(2s)$), its incentive to go public earlier is stronger because it now possesses enough ability to grab firm 2's market share.

It is important to understand why the probability of a potential productivity shock, p, influences the occurrence of the PBEs in Propositions 1 and 3, but not those of Proposition 2. Its effect on the PBE in Proposition 1 is clear: if p is larger, both firms will be more likely to go public at time 1. This is because given the rival firm going public at time 1, there is no uncertainty with respect to the rival's strategy at time 2, so each firm's benefit of going public earlier (at time 1) purely depends on the probability of getting a productivity shock. Even firm 2's incentive to go public increases with p, since the shock has enough magnitude to make the additional market share from going public early and competing with firm 1 profit-enhancing.

The effect of p on the distinction between PBE (i) and (ii) in Proposition 2, however, is ambiguous. For these two equilibria to be possible, the magnitude of the shock must be large enough so that firm 2, in addition to firm 1, will also find it desirable to go public at time 2 if the shock actually occurs. The difference between the two equilibria is firm 1's choice of IPO timing. On the one hand, a higher p gives firm 1 stronger incentives to go public at time 1 because it knows there is a big chance that it will need additional capital after the shock occurs. This concern tends to make PBE (ii) more likely than PBE (i). On the other hand, a higher p means that firm 2 is more likely to go public at time 2 when the shock actually takes place, reducing the additional market share that firm 1 expects to grab by going public before the shock is actually realized (at time 1). Given this, firm 1 may wish to delay its IPO decision until time 2, leading to PBE (i).

The effect of the probability of a shock on the occurrence of PBE (i) versus (ii) in Proposition 3 is also clear:

when p is larger, firm 1 will be more likely to benefit from the additional market share grabbed from firm 2 if it goes public at time 1. Firm 2 will remain private throughout in both these equilibria (because the benefit of going public is too small compared to the issuing cost), so firm 1 does not have to be concerned about the possible loss of market share due to firm 2's going public at time 2. Thus, its incentive to go public at time 1 monotonically increases with p. When p is large, we are more likely to observe PBE (ii) whereas a small p leads to PBE (i).

The above three propositions directly lead to the following proposition, which can form the basis of testable hypotheses.

Proposition 4 ***(Average pre-IPO productivity and IPO timing)*** *Consider an industry with parameter values such that all five possible PBEs in Propositions 1, 2, and 3 occur with positive probabilities. Then:*

(i) firms that go public in an IPO wave will have lower average pre-IPO productivity than those that go public off the wave.

(ii) firms that go public earlier in an IPO wave will have higher average pre-IPO productivity than those that go public later in the wave.

Part (i) of the proposition follows from inspecting the five possible PBEs in our model. We can see that an IPO wave (defined as two firms going public at time 1 or/and 2) can result from PBEs in Proposition 1 and 2, and that stand-alone IPOs can happen in the two PBEs of Proposition 3 and PBE (ii) in Proposition 2. Under all circumstances the lower-productivity firm (firm 2 here) never goes public alone, but rather conducts its IPO either following or together with its higher-productivity rival (firm 1). This leads to the implication that in general, stand-alone IPOs are mostly conducted by higher-productivity firms but IPOs in an IPO wave involve both high and low productivity firms. The intuition is simple: besides product market concerns, higher productivity firms need more capital to approach their efficient operating scales thus have much stronger incentives to go public than lower-productivity ones who merely go public under the pressure from product market competition. Hence, higher-productivity firms will go public even at times when doing so brings no additional market power.

Part (ii) of the proposition comes directly from the result that we do not have an equilibrium in which firm 2 goes public at time 1 and firm 1 follows suit at time 2 (thus creating a "sequential IPO wave"). In fact, firm 2 will never go public alone at time 1. PBE (ii) of Proposition 2 is the only equilibrium that may generate an IPO wave that spans both time 1 and 2, given that an industry-wide productivity shock actually takes place. The intuition why firms with superior pre-IPO productivity are more eager to go public early on in a given wave is as follows. Both types of firms need to evaluate the benefits and costs of waiting in an IPO wave. On the one hand, the cost of waiting, which is the loss of precious business opportunity to gain market power, is larger for firm 1, the higher-productivity one, due to its superior cash-flow generating ability. For example, if each firm is able to gain 1 percent additional market share by IPO at time 1, the long-term cash flow of firm 1 will rise by π_1 percent whereas that of firm 2 will only increase by π_2 percent, which is less than π_1 percent. On the other hand, the benefit of waiting until time 2, which is to avoid the unnecessary issuing cost if the productivity shock does not take place, is larger for firm 2, the lower-productivity firm. The reason is clearest if we think of benefits of waiting as avoiding costs of making "mistakes". Whether or not the productivity shock occurs, firm 2 does not need extra capital for production, so if it goes public at time 1, it pays the full issuing cost for nothing. On the contrary, firm 1 only pays partial costs of making "mistakes" because there is a positive probability that it may need the extra capital provided by IPO, the efficiency gain from which covers some of the issuing cost. Hence, the cost of "wrongly" going public earlier (at time 1) is bigger for firm 2, which implies that the benefit of waiting is also larger for these lower-productivity firms. Comparing both the costs and benefits of waiting for the two types of firms will give rise to the prediction that firms with higher pre-IPO productivity are more "impatient" in making their IPO decisions at time 1.

In practice, however, it is difficult to observe or measure a firm's pre-IPO productivity level, because doing so requires data on the firm's operations when it is still private and thus not subject to the usual rules of disclosure. To get around this problem, the following proposition compares the post-IPO operating performance for firms that go public on a wave, off a wave, earlier in a wave, and latter in a wave, and hence offers more direct hypotheses for empirical tests.

Proposition 5 ***(Average post-IPO operating performance and IPO timing)*** *Consider an industry with parameter values such that all five possible PBEs in Propositions 1, 2, and 3 occur with positive probabilities. Then, conditional on whether an industry-wide productivity shock has occurred:*

(i) an average firm that goes public in an IPO wave will have lower post-IPO operating performance than an average firm that goes public off the wave.

(ii) an average firm that goes public earlier in an IPO wave will have higher post-IPO operating performance than an average firm that goes public later in the wave.

The proof of the proposition is straightforward (with details in Appendix). If two average firms in an industry have an identical initial capital level (k_0), raise the same amount of equity (E), and have the same post-IPO market share (m_i^{II}), then the one that goes public alone (i.e. outside an IPO wave) will yield more post-IPO profits than the one that goes public within an IPO wave. Given the occurrence of an industry-wide productivity shock, the average productivity for a firm that goes public in an IPO wave will be $(A_{1H} + A_{2H})/2$, whereas the average productivity for a firm that does a stand-alone IPO will be A_{1H}, which is higher. Similarly, if the productivity shock does not take place, an average firm going public on an IPO wave will have an average productivity of $(A_1 + A_2)/2$, still lower than that of a firm going public off the wave, A_1. If the on-the-wave firm has the same post-IPO market share as the off-the-wave one, then the difference in average post-IPO productivity will directly translate into the difference in average post-IPO operating performance (given our assumption on the cash-flow generating process). Hence, everything else equal, an average firm that goes public in an IPO wave will have lower post-IPO operating performance than an average stand-alone IPO firm.

The intuition for part (ii) of this proposition is similar to that for part (ii) of Proposition 4. The fact that firms with stronger pre-IPO productivity go public earlier in an IPO wave due to their stronger incentives to raise capital determines that these firms will perform better than those that go public later in the wave, if they have the same level of post-IPO capital stock and market share. To observe a "sequential wave" equilibrium that spans both time 1 and 2 in our model, the industry-wide productivity shock has to take place at time 2 and the resulting productivity levels for the earlier issuer (firm 1) and the latter one (firm 2) will be A_{1H} and A_{2H}, respectively. Consequently, the post-IPO productivity for firms going public earlier in a wave will be higher than that for firms going public later in the wave, resulting in a gap between their post-IPO operating profitability.

The current model also yields several cross-industry implications, which are summarized in Proposition 6.

Proposition 6 ***(Industry characteristics and IPO waves)***
(i) Industries whose productivity shocks have large magnitudes ($\Delta A > A_1 - A_2$) tend to have more IPOs and more IPO waves than industries whose shocks have smaller magnitudes ($\Delta A < A_1 - A_2$).
(ii) Industries with more innovation opportunities (large p) will have more IPOs and more IPO waves than industries with fewer or no innovations ($p \simeq 0$).
(iii) IPO waves in industries whose higher-productivity firms have a smaller market share will last longer than IPO waves in industries whose higher-productivity firms also have a larger market share.
(iv) IPO waves in industries whose firms have larger gaps in productivity levels will last longer than IPO waves in industries whose firms have more homogeneous productivity levels.

Part (i) of the proposition can be easily obtained by comparing the PBEs in Proposition 1, 2, and 3. As we can see, the magnitude of the productivity shock (ΔA) has to be large enough to shake a firm away from the initial state (without productivity shocks) and to prompt it to go public. When ΔA is small so that $\pi_{2H} < \pi_1$ (due to $A_{2H} < A_1$), the only PBE different from the baseline one (PBE (i) in Proposition 3) is the equilibrium in which higher-productivity firms go public alone at time 1 (PBE (ii) in Proposition 3). Firms with lower productivity still choose to remain private even after getting the productivity shock. However, when ΔA is sufficiently large so that $\pi_{2H} > \pi_1$, the same industry may witness more IPOs and IPO waves due to the going-public efforts by firm 2 such as those in the PBEs of Proposition 1 and 2. This is because productivity shock is one of the driving forces of going public in our model and we need it to have sufficiently meaningful magnitudes to generate clustering of IPOs.

Part (ii) of Proposition 6 also follows naturally from our discussion of Proposition 1, 2, and 3. The stability conditions (12) and (13) ensure that without productivity shocks, firms will optimally choose to remain private. Hence, the larger the probability of productivity shock in an industry is, the more likely that firms in this industry will go public and initiate IPO waves. This is true for both high and low productivity firms in the same industry. For high productivity ones, the higher chance of an industry-wide productivity shock also means a larger probability of experiencing capital shortage, which will prompt them to do IPOs even without product market concerns. For low productivity ones, on the contrary, the greater chance of productivity shock will not make them in more need of capital. However, the conjecture that their higher-productivity rivals will be more likely to go public and take away more market share will give these low productivity firms an incentive to go public as well, thus creating an IPO wave that would not result in the absence of product market concerns.

Part (iii) of this proposition mainly compares the conditions for PBE (ii) of Proposition 2 (the "sequential wave equilibrium") versus those for the other two equilibria in Proposition 1 and 2 (the "simultaneous wave equilibrium"). As our discussion of Proposition 2 shows, if the higher-productivity firms in an industry also happen to possess larger market share, it is more likely for these firms to delay their IPO decisions until the uncertainty involving the productivity shocks is resolved. In such industries, both higher and lower productivity firms are more likely to go public together after actual productivity shocks are realized. If the higher productivity firms in such industries, after weighing the costs and benefits of waiting, decide to go public early, then the lower productivity firms in these industries will optimally choose to remain private and do not go public at all (as in PBE (ii) of Proposition 3), resulting in no IPO waves. Therefore, IPO waves in such industries tend to span a shorter period of time than industries whose higher-productivity firms possess little market share. In the latter type of industries, higher-productivity firms are more likely to go public earlier, followed by IPOs conducted by lower-productivity firms. The intuition why market share distribution matters is given in our previous discussion of Proposition 2 and 3.

Part (iv) of Proposition 6 also compares the length of IPO waves across the three PBEs in the first two propositions. According to our previous discussion, if the existing productivity levels of both firms are high, they are more likely to go public together at time 1; if both of their productivity levels are low, they are more likely to delay their IPOs until productivity shocks actually take place at time 2. Only when the gap between higher and lower productivity firms is huge may we observe a "sequential wave equilibrium". The intuition is simple: if firms in an industry are more homogeneous, they are more likely to act together in terms of financing activities because they face virtually the same situations. Thus IPO waves in such industries tend to span a shorter period of time than industries whose productivity distribution is more unequal.

The current model has three flexible features regarding the nature and timing of productivity shocks. First, we don't need actual productivity shocks to take place to initiate IPO waves. The mere conjecture of possible productivity shock at time 1 will prompt firms to go public right away (before the realization of shocks) because under competition pressure, waiting may be too costly. Second, the results of our model do not rely on the sequence of shocks. Both the higher-productivity firms (firm 1) or lower ones (firm 2) get the shocks at the same time, so those going public earlier in a wave are not necessarily the ones that experience earlier shocks. Moreover, if we think of time 2 as a long period where productivity shocks take place in turns, the implications of our model are still unchanged because under the assumption of symmetric information, all firms will choose to make decisions until the end of time 2 when all possible shocks have realized. As a result, the structure of our model remains unaltered. Third, the current model does not require the productivity shock to be systematic in the sense that it hits every firm in the whole industry at the same time (what the current subsection analyzes). Each firm may get idiosyncratic productivity shocks via its own research activities and the improvement of productivity can be independent across firms. The scenario of independent productivity shocks will be studied in the next subsection.

3.2.2 Idiosyncratic productivity shocks

This subsection analyzes another extreme case where the productivity shock is purely idiosyncratic, i.e. one firm's shock is independent of the other one's. In this case, we can solve for equilibrium as before and the results are summarized below.

Proposition 7 ***(IPOs and IPO waves when productivity shocks are purely idiosyncratic)*** *When the shocks of firms in an industry are perfectly uncorrelated, we have five possible PBEs similar to those listed in Proposition 1, 2, and 3:*

i. When the magnitude of the shock is small ($\Delta A \leq A_1 - A_2$), then depending upon parameter values, we have two possible PBEs:

(ia) ***(IPOs off the wave only with productivity shocks)*** *Both firms will remain private before the realization of productivity shocks (at time 1) and firm 1 will go public only upon its shock (at time 2).*

(ib) ***(IPOs off the wave even without productivity shocks)*** *Firm 1 will go public before the realization of productivity shocks (at time 1) and firm 2 will remain private throughout in equilibrium.*

ii. When the magnitude of the shock is at least moderate ($\Delta A > A_1 - A_2$), then in addition to the above two PBEs, there are three more possible equilibria:

(iia) ***(IPO waves even without productivity shocks)*** *Both firms will go public before the realization of any productivity shocks (at time 1).*

(iib) ***(IPO waves only with firm 2's productivity shock)*** *Firm 1 will go public before the realization of productivity shocks (at time 1) and firm 2 will go public only upon the realization of its shock (at time 2).*

(iic) ***(IPO waves only with two productivity shocks)*** *Both firms will remain private before the realization of productivity shocks (at time 1) and go public only upon the realization of their own shocks (at time 2).*

The intuition for how the five PBEs occur in our model is similar to what has been outlined in the last section. However, unlike PBE (i) in Proposition 2, PBE (iic) in Proposition 7 now yields four (rather than two) possible equilibrium outcomes: either both firms go public together in the case of two productivity shocks, one firm goes public in the case of its own productivity shock (can be either firm), or both remain private in the case of no shocks. This creates the possibility that a stand-alone IPO is conducted by a firm with lower pre-IPO productivity because it is lucky enough to get the productivity shock while its rival does not. Hence, part (i) of Proposition 4 fails to hold on the surface. However, if we consider an industry where all five possible PBEs can occur with positive probability, then it continues to hold. The probability that a firm's average pre-IPO productivity is low (A_2) conditional on a stand-alone IPO is less than 0.5 while the conditional probability that its average pre-IPO productivity is high (A_1) is bigger than 0.5, and thus the average is higher than $(A_1 + A_2)/2$, the average productivity of a firm that goes public within an IPO wave. This is because given the industry is in PBE (iic) of Proposition 7, the conditional probability that an "off-the-wave" firm has high pre-IPO productivity (A_1) is 0.5 ($= \frac{p(1-p)}{2p(1-p)}$), whereas if the industry is in any other four equilibrium, this conditional probability will increase to 1. At the same time, the average pre-IPO productivity for a firm that goes public within an IPO wave is always $(A_1 + A_2)/2$. Therefore, as long as PBE (iic) in Proposition 7 is not the only equilibrium that the given industry can fall into (i.e. there's positive probability for other equilibria as we assume in Proposition 4), the average pre-IPO productivity for firms going public on a wave will be lower than that for firms going public off the wave. Moreover, part (ii) of Proposition 4 continues to hold trivially because firm 1 still goes public earlier in an IPO wave than firm 2 does, as described in PBE (iib) of Proposition 7.

In the case of idiosyncratic shocks, our previous results with regard to post-IPO operating performance need to be modified. Let's continue to consider an industry where all five possible PBEs in Proposition 7 will occur with probability $q_i > 0$, $(i = 1, 2, 3, 4, 5)$ for PBEs (ia), (ib), (iia), (iib), and (iic), respectively.

Proposition 8 ***(Post-IPO operating performance for on-the-wave and off-the-wave IPOs when the productivity shock is purely idiosyncratic)*** *When the shocks of firms in an industry are perfectly uncorrelated:*

(i) conditional on the occurrence of zero or two productivity shocks, an average firm that goes public in an IPO wave will have lower post-IPO operating performance than an average firm that goes public off the wave.

(ii) conditional on the occurrence of only one shock, the above conclusion holds if and only if

$$\frac{(A_{1H} + A_{2H})q_5/2 + A_{1H}(q_1 + q_4) + A_1 q_2}{q_1 + q_2 + q_4 + q_5} > \frac{(A_1 + A_{2H})(q_4 + q_3/2) + (A_{1H} + A_2)q_3/2}{2(q_3 + q_4)}. \tag{15}$$

After the IPO, the firm that has just gone public will have adequate capital to pursue its most efficient scale in cash-flow generation (k_i^*, $i = 1, 2$), so given a certain level of post-IPO market share and total capital, the post-IPO operating profitability for the firm really depends on its post-IPO productivity. When the productivity shocks are purely idiosyncratic and no shocks actually take place, the average post-IPO productivity for a firm going public on a wave and off a wave will be $(A_1 + A_2)/2$ and A_1 respectively (note that without any shocks, PBE (iic) of Proposition 7 only results in no IPOs). When both firms experience the productivity shock, the average post-IPO productivity for the two types of firms will be $(A_{1H} + A_{2H})/2$ and A_{1H} respectively (because in this case the equilibrium cannot be PBE (iic) of Proposition 7). In both scenarios, an average firm that goes public in an IPO wave will have lower post-IPO operating performance than a similar firm that goes public outside the wave.

However, when only one of the productivity shocks actually occurs, it could be the case that the firm with stronger pre-IPO productivity does not receive the shock but its rival does (as in PBE (iic) of Proposition 7). Under such circumstances, the post-IPO productivity for a firm that goes public outside a wave may be A_{2H}, which might be higher or lower than the average post-IPO productivity of a similar firm that goes public in an IPO wave $(A_1 + A_{2H})/2$ or $(A_{1H} + A_2)/2$. Moreover, PBE (ib) of Proposition 7 may lead to an equilibrium outcome that the productivity only hits firm 2 but still fails to prompt it to go public. In this case, the post-IPO productivity for the firm that goes public alone outside an IPO wave is A_1, which may be lower than $(A_1 + A_{2H})/2$ or $(A_{1H} + A_2)/2$.

The left handside of condition (15) denotes the average post-IPO productivity for a firm that goes public off the wave whereas the right handside is the average post-IPO productivity for a firm that goes public in an IPO wave, conditional on only one occurrence of the productivity shock. As we can see, when $q_2 = 0$ but $q_i \neq 0$, $i = 1, 3, 4, 5$, the left handside becomes a weighted average of $(A_{1H} + A_{2H})/2$ and A_{1H} whereas the right handside becomes a weighted average of $(A_1 + A_{2H})/2$ and $(A_{1H} + A_2)/2$. As a result, the inequality holds for sure at all levels of q_i, $i = 1, 3, 4, 5$. A closer inspection of the conditions for different PBEs (available upon request) suggests that a necessary condition for PBE (ib) in Proposition 7 to occur is $B > sm_b(1-m_b)\pi_{2H}$, so if π_{2H} is large enough to reverse this condition, q_2 will be zero and (15) will hold. This implies that in industries where the magnitude of productivity shocks is large (large ΔA thus large π_{2H}), we are more likely to conclude that conditional on any number of occurring productivity shocks, an average firm that goes public in an IPO wave will have lower post-IPO operating performance than an average firm that goes public outside the wave.

Proposition 9 ***(Post-IPO operating performance for earlier-in-the-wave and later-in-the-wave IPOs when the productivity shock is purely idiosyncratic)*** *When the shocks of firms in an industry are perfectly uncorrelated:*

(i) conditional on the occurrence of two productivity shocks, an average firm that goes public earlier in an IPO wave will have higher post-IPO operating performance than an average firm that goes public later in the wave.

(ii) conditional on the occurrence of only one productivity shock, an average firm that goes public earlier in an IPO wave will have lower post-IPO operating performance than an average firm that goes public later in the wave.

(iii) if the probability of productivity shocks is large enough ($p > (A_{2H}-A_1)/\Delta A$) for this industry, then conditional on observing an IPO wave that spans both time 1 and 2, an average firm that goes public earlier in this wave will have higher average post-IPO operating performance.

When the productivity shock in a given industry is purely idiosyncratic, the occurrence of an IPO wave that spans both time 1 and 2 can only result from PBE (iib) in Proposition 7 when the presumed shocks actually take place. Conditional on observing two shocks in such an industry, we can infer that the post-IPO productivity of a firm going public earlier in the "sequential wave" is A_{1H} while that of a firm going public later in the wave is A_{2H}. Hence it is straightforward to conclude that an average firm that goes public earlier in an IPO wave will have higher post-IPO operating performance than a similar firm that goes public later in the wave.

However, conditional on only one occurrence of the productivity shock, the existence of such a "sequential IPO wave" requires that the shock is for firm 2 and not for firm 1. Thus, the post-IPO productivity for a firm that goes public earlier is A_1, which is smaller than that of a firm that goes public later (A_{2H}). This is because such an equilibrium (PBE (iib) in Proposition 7) takes place only in the case of $A_1 < A_{2H}$ (i.e., $\Delta A > A_1 - A_2$).

Part (iii) of the Proposition argues that when the productivity shock for an industry is very likely (i.e. the probability of it happening is greater than a certain threshold level), then conditional on observing an IPO wave that spans both time 1 and 2, a firm that goes public earlier in this wave will have higher average post-IPO operating performance than an average firm that goes public later in the wave. This is because under such conditions ($p > (A_{2H} - A_1)/\Delta A$), people's posterior belief for one productivity shock to occur will be lower than their belief for two shocks to occur. In the case of idiosyncratic productivity shocks, the prior probability for only firm 2's shock to occur is $p(1-p)$ while the prior probability for both firm 1 and firm 2's shocks to occur is p^2. Thus the posterior probability for one and two shocks to occur will be $1-p$ and p, respectively. Therefore, the average post-IPO productivity for a firm that goes public earlier in the wave will be $pA_{1H} + (1-p)A_1$, which is greater than $pA_{2H} + (1-p)A_{2H} = A_{2H}$ if and only if $p > (A_{2H} - A_1)/(A_{1H} - A_1) = (A_{2H} - A_1)/\Delta A$. This proposition implies that in industries with plenty of productivity shocks (large p), we are more likely to conclude that conditional on observing an IPO wave that spans a long period of time (both time 1 and 2 in the model), an average firm that goes public earlier in this wave will have higher average post-IPO operating performance, even if the shocks are uncorrelated across firms.

4 Implications and Testable Hypotheses

Our model generates several testable predictions, which we describe below. We will test the first five implications in the empirical section of this paper.

1. *Post-IPO operating performance for firms going public on the wave versus off the wave*: Our model predicts that, on average, firms going public outside an IPO wave (i.e. in a cold market) will yield more post-IPO profitability than those going public within an IPO wave (after controlling for industry conditions, firms' post-IPO capital stock and market share, and other characteristics of IPOs such as the total amount of money raised in the offerings and the issuing costs). This implication, following directly from part (i) of Proposition 5 and Proposition 8, will be the first hypothesis ($\mathbf{H}_1$) that we test here.

2. *Post-IPO operating performance for firms going public earlier in an IPO wave versus later in the wave*: Our model predicts that, on average, firms going public earlier in an IPO wave will yield more post-IPO profitability than those going public later in the wave (after controlling for industry conditions, firms' post-IPO capital stock and market share, and other characteristics of IPOs). This implication, following directly from part (ii) of Proposition 5 and Proposition 9, will be the second hypothesis ($\mathbf{H}_2$) that we test here.

3. *Usage of cash raised in IPOs for firms that go public on the wave versus those that go public off the wave*: Proposition 4 of our model implies that firms going public in an IPO wave will have lower average pre-IPO productivity than those going public outside the wave. Since higher-productivity firms in general need more capital for expansion and thus go public both on and off IPO waves, we expect these firms to spend more of the cash raised in their IPOs for investment in various projects than those lower-productivity firms that go public only in an IPO wave. This leads to the third hypothesis ($\mathbf{H}_3$) that we test: everything else equal, firms that go public in an IPO wave will on average hold more cash on hand (or, use less cash raised through their offerings) than firms that go public off the wave.

4. *Usage of cash raised in IPOs for firms that go public earlier in an IPO wave versus those that go public later in the wave*: Part (ii) of Proposition 4 also implies that firms going public earlier in an IPO wave will have lower average pre-IPO productivity than those going public later in the wave. Following the same logic we used to derive $\mathbf{H}_3$, we will arrive at the following hypothesis ($\mathbf{H}_4$) that we test here: everything else equal, firms that go public earlier in an IPO wave will on average hold less cash on hand (or, use more cash raised through their offerings for investment) than firms that go public later in the wave.

5. *Industry concentration and the difference in post-IPO operating performance for firms that go public on the wave versus off the wave, and earlier in a wave versus later in the wave*: Our model argues that one important factor driving firms' going public decision is product market competition. In the benchmark case where IPOs yield no product market advantages ($s = 0$), firm 2 will never go public, even with a productivity shock. Therefore, no IPO waves will occur. However, as $s > 0$ and becomes larger, IPOs will give a greater competitive edge to public firms in grabbing private rivals' market share, leading to more IPOs conducted by lower productivity firms. Although industry concentration is one measure of the intensity of product market competition, it is unclear whether IPOs in more concentrated industries yield greater or smaller product market benefits (bigger s). On the one hand, for an industry characterized by a few large players (high concentration), any competitor's IPO will exert a large product market pressure on the rest of the firms in the industry, which may then go public, thereby creating an IPO wave. This leads to the prediction that greater industry concentration will amplify the difference in post-IPO operating performance for firms that go public on the wave versus those that go public off the wave, and the difference between those going public earlier in a wave versus those going public later in the wave. On the other hand, it may be the case that larger firms that already have significant market share in an industry as private firms do not have too much to gain by going public, since they may carry significant credibility with potential employees, customers, and suppliers even as private firms; in other words, the benefits of going public may be greater for smaller firms with relatively smaller current market share. In the latter scenario, it may be firms in less concentrated industries that are more likely to go public out of product market concerns, sharpening the difference in post-IPO performance between firms that go public on the wave versus those that go public off the wave, and firms going public earlier in a wave versus those going public later in the wave. In sum, the effect of industry concentration on the difference in post-IPO operating performance for firms that go public on the wave versus off the wave and earlier in a wave versus later in the wave is an empirical question, and will be the fifth hypothesis we test ($\mathbf{H}_5$).

6. *Pre-IPO productivity and firms' incentives to go public on the wave versus off the wave, and earlier in a wave versus later in the wave*: A direct empirical test of Proposition 4 is to measure the difference in pre-IPO productivity between firms that go public on an IPO wave and those that go public off the wave, and between firms that go public earlier in an IPO wave and those that go public later in the wave. Our model predicts that firms that go public in an IPO wave will have lower average pre-IPO productivity than those that go public outside the wave; and firms that go public earlier in an IPO wave will have higher average pre-IPO productivity than those that go public later in the wave. While the difficult part of such a test is the availability of data on private firms' operational and financial performance, this implication is testable: some recent papers such as Chemmanur, He, and Nandy (2007) make use of the Longitudinal Research Database (LRD), maintained by the Center of Economic Studies at the U.S. Census Bureau, to gauge the productivity of private firms at the plant level.

7. *Long-term stock returns for firms that go public on the wave versus off the wave, and earlier in a wave versus*

later in the wave: If we assume that all investors are fully rational and correctly infer the type of equilibria that bring about an IPO wave, then our model does not generate any prediction for the long-term stock returns of firms that go public on the wave versus off the wave, and earlier in a wave versus later in the wave. This is because, with perfect foresight, the market will incorporate the difference in long-run operating performance for IPO firms into their first day trading price. If, however, the market only gradually infers the implication of IPO timing on firms' long-term profitability and incorporates it into stock valuations only over a longer period, then our model predicts superior long-term stock return performance for firms that go public off the wave relative to those that go public on the wave, and superior long-term stock return performance for firms that go public earlier in an IPO wave relative to those that go public later in the same wave (as the superior operating performance of off-wave issuers and early movers in a wave gets reflected in stock prices over time).

8. *The magnitude and frequency of productivity shocks in an industry, the occurrence of IPO waves, and the difference in Post-IPO operating performance between firms that go public on the wave versus off the wave, and earlier in a wave versus later in the wave*: The first two parts of Proposition 6 predict that everything else equal, industries with more innovation opportunities and whose productivity shocks have bigger magnitudes will have more IPOs and more IPO waves. Proposition 8 and 9 also imply that everything else equal, industries with more innovation opportunities and whose productivity shocks have larger magnitudes tend to have sharper difference in post-IPO performance for firms that go public on the wave versus those that go public off the wave, and firms going public earlier in a wave versus those going public later in the wave. This prediction is also an interesting hypothesis to test.

9. *Product homogeneity in an industry, the occurrence of IPO waves, and the difference in Post-IPO operating performance for firms that go public on the wave versus off the wave, and earlier in a wave versus later in the wave*: Our model predicts that everything else equal, industries whose IPOs yield greater product market benefits (bigger s) will witness more IPO waves. In particular, such industries are characterized by a higher level of product homogeneity. As we have shown before, in the benchmark equilibrium where product market competition is not influenced by IPOs, only firms with higher productivity go public in the event that a productivity shock is realized. In other words, when s, the ability of public firms to grab market share relative to private ones, is zero, firms' going public decision will not be affected by the product market concerns. In practice, this situation occurs when firms within an industry produce heterogeneous goods or services that have little substitutability with each other. In such cases, even if a firm improves its credibility with potential emplyees, customers, and suppliers by going public, it cannot grab much additional market share from competitors because the cross-product consumption elasticities are low. Hence, in this situation, firms' incentives to go public out of product market concerns will be low, resulting in fewer IPO waves. On the other hand, in an industry where products are more homogeneous, more firms will be prompted to go public purely out of product market concerns, giving rise to a larger number of IPO waves and sharper differences in post-IPO operating performance between firms going public on the wave versus those going

public off the wave, and firms going public earlier in a wave versus those going public later in the wave.

5 Empirical Evidence

5.1 Data and Sample Selection

The data used in this study comes from a variety of sources. We obtain our initial sample from the Thomson Financial Securities Data Corporation (SDC) new issues database. We exclude from our initial IPO sample spin-offs, ADRs, unit offerings, reverse LBOs, foreign issues, REITS, close-end funds, offerings in which the offer price is less than $5, finance and utilities (with Fama French 49 industry code 31, 45, 46, and 48), and those offerings whose industries are unidentified (with Fama French 49 industry code 49 or missing).[17] To minimize the effect of wrong data entries on our study, we corrected for several mistakes and typos in SDC's database following Jay Ritter's "Corrections to Security Data Company's IPO database" (http://bear.cba.ufl.edu/ritter/ipodata.htm).[18] Thus, our final sample contains 6647 IPOs between 1970 and 2006. We then extract financial statement information for the IPO firms in our sample from Standard & Poor's Compustat files, stock price and shares outstanding data from CRSP, institutional investors' positions in new stocks from the Thomson Financial 13f Institutional Holdings database, and IPO firms' founding years as well as their underwriter reputation from Jay Ritter's database. Due to missing observations for various variables, we may lose up to 55% of the sample when we conduct empirical analysis.

To test the first hypothesis ($\mathbf{H}_1$), which compares the post-IPO operating performance of on-the-wave IPO firms versus off-the-wave ones in the same industry, we define the clusteredness ("hotness") of a certain industry's IPO market for the period within which a firm goes public. For each IPO in the sample, we count the total number of IPOs in the same FF-49 industry within a 90-day window symmetrically surrounding the issuance date for the given IPO and use this number (*IPONUM*) as a raw measure of the clusteredness of the IPO market in that industry for the particular issuance date under consideration. We also use two refinements for this raw measure (*IPONUM*). First, to control for the relative frequency of IPOs across different industries, we deflate *IPONUM* by the total number of IPOs over the entire sample period in the same industry as the particular IPO under consideration (*IPONUM*/Same Industry Vol.). Second, to control for overall hotness of the IPO market such as in a stock market boom, we deflate *IPONUM* by the total number of IPOs done in all industries within the same 90-day window surrounding that particular issue date (*IPONUM*/Same Window Vol.).[19]

[17] The definition of Fama French 49 industries (based on 4-digit historical SIC codes) is obtained from Ken French's website (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html).

[18] Moreover, due to duplicated entries, we checked Factiva and modified the observation for Wynn Resorts Ltd (CUSIP "983134", issue date "Oct. 25, 2002") whose proceeds and shares offered should be the sum of two entries in the database: "449.8" and "34.6 million", respectively.

[19] Alternatively, one can do the two deflations by using the number of new business formations gathered from Dun and Bradstreet (Helwege and Liang 2004) or the number of outstanding public firms in that industry one day before the issuance date (Lowry 2003 and Pastor and Veronesi 2005).

To test the second hypothesis ($\mathbf{H}_2$), which compares the post-IPO operating performance of leaders and followers in an IPO wave for a particular industry, we first identify and define IPO waves and then rank the IPOs in our sample within each wave by the order of their issuance dates. Using a procedure similar to that of Helwege and Liang (2004) as well as Pastor and Veronesi (2005), we first compute the three-month moving averages of IPO volume in a particular industry for each month. Then we define "hot periods" as those in which the moving average falls into the top quartile of that industry's IPO months. Lastly, we define IPO waves as all sequences of consecutive "hot periods" that begin and end with non-zero number of issuances. To minimize the possibility of misclassifying concurrent stand-alone IPOs as a tiny wave (such as those waves consisting of only two offerings), we reclassify IPO waves by dropping those with a total number of five offerings or lower.[20] Once the waves are defined, we then identify leaders and followers in a particular wave according to issue dates. If more than one IPOs take place on the same date, we rank these IPOs according to their filing dates (if possible) or we randomize if the filing dates are missing (there are 32 such cases). A naive measure of how early an IPO takes place in a wave is just the order of that IPO's appearance within its wave (*ORDER*). However, this measure has two limitations. First, waves with a larger size will carry undue weights in our analysis. For example, the last IPO in a wave with five offerings will get "5" as its score for *ORDER* whereas the last IPO in a wave with fifty offerings will get "50", even though they are both the last one in a given wave. Second, the relationship between post-IPO operating performance (or other accounting measures) and *ORDER* may not be linear, especially considering the fact that *ORDER* can only take positive integer values that can be as huge as 300: those extremely large integers will be unduly influential in our regression analysis. In light of the above two limitations, we propose three refinements to *ORDER* in our analysis. First, to make this measure robust to the size of a wave and to control for the possible nonlinear relationship between post-IPO operating performance and *ORDER*, we chop *ORDER* for a given wave into four quartiles and assign "0", "1", "2", and "3" to each of them with larger numbers meaning later appearance in a wave. We call this measure *EARLINESS*. Second, to make the measure comparable across all waves, we divide *ORDER* by the median of it for a given wave (*ORDER* / Median *ORDER*) so that the order measure for all waves will be centered around 1 and have an approximate range between 0 and 2. Third, just to control for the possible concave relationship between post-IPO variables and *ORDER*, we take the natural logarithm of *ORDER* and use it (Log (*ORDER*)) as a crude measure of how early a firm goes public within a hot-issue market.

Our basic measure for a firm's post-IPO operating performance is its return on assets (ROA) for the first fiscal year after the IPO date (Compustat item DATA13/DATA6).[21] To test the third and fourth hypotheses ($\mathbf{H}_3$ and $\mathbf{H}_4$), we

[20] We repeated our analysis by either keeping all of the originally defined IPO waves (with number of offerings within a wave greater than or equal to two) or using a stricter filtering rule by dropping all waves with number of IPOs fewer than ten. All our results remain unchanged.

[21] We have also tried different measures including post-IPO operating cash flows over assets (DATA13-DATA128 divided by DATA6), return on equity (ROE: DATA172/DATA60), and the profit margin (DATA172/DATA12), which all yield similar results to the ones reported here. To gauge the impact of IPO timing on firms' long-term operating performance, we also repeated our study by using the two-year and three-year averages of post-IPO ROA, operating cash flow over assets, ROE, and profit margin, and obtain similar results.

also construct two variables to measure firms' usage of cash raised in the IPO: (1) the increase in cash and cash equivalents in the IPO year scaled by total net assets at the first fiscal year-end after the IPO (DATA274/DATA6); and (2) cash and short-term investments at the first fiscal year-end after the IPO scaled by total net assets (DATA1/DATA6). To test the fifth hypothesis ($\mathbf{H}_5$), we need to come up with a measure for industry concentration. Following previous literature, we calculate the Herfindahl-Hirschman Index (HHI) based on public firms' market share in total book assets within the FF-49 industries.[22]

We construct other control variables in our study following standard procedures in the literature. These include: (1) Firms' financial statement variables (from Compustat): logarithm of firm's market capital (DATA199*DATA25) at the first fiscal year end after the IPO; capital expenditure scaled by firm's net property, plant, and equipment (DATA128/DATA8); research & development expenses scaled by total net assets (DATA46/DATA6); and firms' market share within the FF-49 industries based on all Compustat firms' net sales (DATA12). (2) IPO characteristics (from SDC and Jay Ritter's database): IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock price (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; logarithm of firm's age at IPO date (the number of years between the firm's founding year (from Jay Ritter's database) and the IPO year); and the reputation for underwriters.[23] (3) Institutional investors' holdings for a company's stock (from the Thomson Financial 13*f* Institutional Holdings database): percentage of shares owned by all types of institutional investors right after the IPO but before the first fiscal year-end for the firm as a fraction of the total number of shares outstanding in the firm reported in CRSP. In case there are more than one disclosure for the holdings, we use the first one. To reduce the effect of outliers, all financial ratios in our study are winsorized at their 1% and 99% values.

Table 1 reports descriptive statistics of IPO waves and IPO characteristics in our sample. Panel A gives the distribution of IPOs and IPO waves across different decades. As we can see, the 1990's have the most number of IPOs (3304) and the highest proportion of "on-the-wave" IPOs among all decades (more than 75% of the IPOs done between 1990 and 1999 occurred during a hot market). Based on our classification of IPO waves (or "hot periods") (with the number of IPOs greater than or equal to five), 4180 IPOs took place during industry-based waves while the remaining 2467 offerings occurred during a "cold" period. Except for the 1990's, the number of "off-the-wave" IPOs seems to exceed the number of "on-the-wave" IPOs for all decades, suggesting that the "hot-issue" market for

However, due to loss of observations (some firms are acquired or delisted within three years after the IPO), the results are slightly less significant but still remain to be statistically significant at 90% confidence level. For brevity, we do not include those robustness checking results in the paper but they are available upon request.

[22] The market share is calculated by using data for all public firms' net assets (DATA6) available in Compustat, thus may have not incorporated the impact of private firms. However, given the unavailablity of private firms' data, this is the best we can do. This limitation also applies to our measure of market share based on total net sales (DATA12) used as a control variable. For robustness, we also calculated HHI based on firms' market share in total net sales and book equity and obtain similar results.

[23] This variable, obtained from Jay Ritter's database, has a range from 0 to 9.1, with the higher values indicating better reputation. For simplicity, we only use the reputation for bookrunners of the offerings.

IPOs mainly took place in the 90's when productivity shocks hit many industries.

Panel B presents the distribution of IPO waves across the FF-49 industries. As we see, both the "Electronic Equipment" and "Wholesale" industry have sixteen IPO waves over the sample period, but the waves for the former have a larger magnitude: on average an IPO wave in the "Electronic Equipment" industry has approximately 25 offerings while a wave in the "Wholesale" industry has approximately 15. The industries ranked the third to the fifth are: "Computer Hardware", "Retail", and "Medical Equipment", with 15, 14, and 13 IPO waves, respectively.

Panel C of Table 1 lists the five largest IPO waves in our sample. The "Computer Software" industry has the two biggest waves with 334 and 278 IPOs, respectively, within each hot-issuing period; the "Business Services" industry has the two next largest waves with 185 and 104 offerings, respectively; and the "Electronic Equipment" industry has the fifth largest wave with 81 IPOs. As we can see, three out of five of these giant waves took place during the tech bubble period (from 1998 to 2000). The wave from Nov., 1998 to Nov., 2000 in the "Computer Software" industry is the most "condense" hot-issuing period because on average 15 firms in this industry went public per month during this wave and the maximum number of offerings within one month can be as high as 27.

Panel D gives summary statistics of our measures for the industry IPO clusteredness (*IPONUM*, *IPONUM* / Same Industry Vol., and *IPONUM* / Same Window Vol.) as well as the order of going public in a wave (*EARLINESS*, *ORDER* / Median *ORDER*, and Log (*ORDER*) multiplied by 100). Note that a maximum of 100 percent for *IPONUM* / Same Window Vol. denotes that the IPOs occurred in the 90-day window centering an offering are all in the same industry as the given offering. Panel E presents summary statistics of IPO characteristics in our sample, which are by and large in line with what have been reported by previous literature.

5.2 Empirical Tests and Results

In this section, we discuss the empirical methodology used to test our hypotheses and report the results from our univariate and multivariate analyses.

5.2.1 Post-IPO Operating Performance, Industry IPO Clusteredness, and the Order of Going Public in a Wave: Univariate Analysis

In this subsection, we carry out a univariate analysis of the differential post-issuance operating performance between firms that go public in an IPO wave and those that go public outside it ($\mathbf{H}_1$), and between firms that go public earlier in an IPO wave and those that go public later in the wave ($\mathbf{H}_2$).

Table 2 presents the mean and median post-IPO ROA in various ranges of the three measures of industry clusteredness and the three measures of the order of going public within an IPO wave. As is shown in Panel A, there is a big difference of mean post-IPO ROA for firms that go public in a hot period versus those that go public in a cold period. There is a clear monotonically decreasing pattern in mean ROA for IPO firms in different quartiles of the measures. The average post-issuance ROA for "on-the-wave" firms (top quartile) can be 15% less than that for "off-the-wave" firms (bottom quartile) based on *IPONUM* and this difference remains to be economically large if we use alternative definitions of clusteredness (8% for *IPONUM* / Same Industry Vol. and 14% for *IPONUM* / Same Window Vol.).[24] The difference in mean ROA between the two groups is also statistically significant: both the two-sample t-tests assuming unequal variance and the Wilcoxon Ranksum tests for unmatched pairs of observations show p-values close to 0. This lends some support to $\mathbf{H}_1$. The difference in mean post-issuance ROA for firms that go public earlier in an IPO wave versus those that go public later is also both economically and statistically significant, which is at approximately 95% confidence level (by using *EARLINESS* and *ORDER* / Median *ORDER*).[25] These results support $\mathbf{H}_2$.

Considering the possible skewness of the distribution for operating performance measures, Panel B of Table 2 repeats the univariate analysis by examining the median post-IPO ROA in different ranges of the three measures of industry clusteredness and the three measures of the order of going public within an IPO wave. We used a non-parametric median test to gauge the degree of differential post-IPO operating performance for "on-the-wave" issuers, "off-the-wave" issuers, leaders in a wave, and followers in a wave. The results remain qualitatively similar, though the economic magnitudes are smaller. Overall, the univariate results are consistent with our first two hypotheses.

5.2.2 Post-IPO Operating Performance and Industry IPO Clusteredness: Multivariate Analysis

In this subsection, we carry out a multivariate analysis of the differential post-issuance operating performance between firms that go public in an IPO wave and those that go public outside it ($\mathbf{H}_1$), after controlling for various confounding factors.

Table 3 summarizes the results of multiple regressions of post-issuance ROA on measures of industry IPO clusteredness. To control for unobservable macroeconomic shocks that affect all firms in a given year, we put a dummy for IPO year in all our model specifications. Similarly, we use an industry dummy throughout our regressions to control for unobservable industry-invariant characteristics that may affect the operating performance of all firms in a certain industry. For each of the three measures of clusteredness, we present four different specifications to demonstrate the robustness of our results.

Panel A provides results with respect to the measure *IPONUM*. As we can see, the post-IPO ROA for firms that go public in a hot period (with larger *IPONUM*) is significantly less than those that go public in a cold period, and the negative relationship between ROA and *IPONUM* holds for all specifications. This is consistent with our first

[24] Considering the fact that ROA here has already been winsorized at its 1 and 99 percentile values, the actually mean difference can be even larger.

[25] Note that the difference using Log (*ORDER*) may be over-stated since it incorporates some effects from the difference between "on-the-wave" and "off-the-wave" firms: those IPO waves with smaller number of IPOs, which are more likely to happen in a period with little industry clusteredness, are also more likely to fall into the bottom quartile of Log (*ORDER*), and vice versa.

hypothesis ($\mathbf{H}_1$). The coefficient of -0.0016 for *IPONUM* in the full specification (model 4) tells us that even after controlling for industry and time effects as well as various firm and IPO characteristics, a firm that goes public within a hot period of 8 other same-industry IPOs (75% quantile of *IPONUM*) will on average have an ROA 1.1% less than a firm that goes public within a cold period of only 1 other same-industry IPO (25% quantile of *IPONUM*). Given the mean of ROA in our sample is 5%, this represents a 20% difference in post-issuance ROA, which is economically significant.

Panel B provides results with respect to the measure *IPONUM* / Same Industry Vol. As in Panel A, the coefficient of *IPONUM* / Same Industry Vol. is statistically significant at 1% level in all model specifications. This is also consistent with $\mathbf{H}_1$. The coefficient of -0.6741 for *IPONUM* / Same Industry Vol. in the full specification (model 4) implies that even after controlling for all other independent variables, a firm that goes public within a hot period where 3% of all IPOs in the given industry take place within the 90-day window surrounding this particular offering (75% quantile of *IPONUM* / Same Industry Vol.) will on average have an ROA 1.4% less than a firm that goes public within a cold period where only 1% of all IPOs in the given industry take place in the given window (25% quantile of *IPONUM* / Same Industry Vol.).

Panel C provides results with respect to the measure *IPONUM* / Same Window Vol. As in the previous two panels, the coefficient of *IPONUM* / Same Window Vol. is statistically significant at 1% level in all model specifications. This is again consistent with $\mathbf{H}_1$. The coefficient of -0.234 for *IPONUM* / Same Window Vol. in the full specification (model 4) implies that even after controlling for all other independent variables, a firm that goes public within a hot period where 10% of all IPOs in the given 90-day window are conducted by firms in this particular industry (75% quantile of *IPONUM* / Same Window Vol.) will on average have an ROA 16.4% less than a firm that goes public within a cold period where only 3% of all IPOs in the given 90-day window are conducted by firms in this particular industry (25% quantile of *IPONUM* / Same Window Vol.).

In all our regressions using post-IPO ROA as independent variables (Table 3, 4, and 6), the coefficient for firm size as proxied by logarithm of market capital is significantly positive, which holds true if we use total net assets as an alternative measure. Firm age as proxied by logarithm of the number of years between a firm's founding year and its IPO year also exerts a significantly positive impact on firms' post-IPO operating performance. These results, consistent with the findings of previous studies such as Mikkelson, Partch, and Shah (1997), suggest that smaller and younger firms may be still in their early years of operations thus need to incur greater setup costs or charge lower product prices to attract customers (thus earn smaller profit margins). In line with these findings, firms' capital expenditure and R&D intensity both significantly reduce the profitability of the same fiscal year because they represent a form of investment that would pay off only in the long run. Similarly, Firms' market share calculated based on net sales does not show up as statistically significant, which might be the result of two offsetting forces. On the one hand, higher market share may boost sales thus increase total cash flows. On the other, the expenditures to increase one's market share may lead to high operating costs, lowering the profits for the current fiscal year (but may benefit long-term profits).

Everything else equal, IPOs with larger total proceeds exhibit lower post-issuance ROA, which is consistent with the finding that larger firms (in terms of post-IPO market cap) tend to have better ROA. This is because conditional on the level of post-IPO market cap, larger total proceeds implies smaller pre-IPO firm size, indicating a lower profitability after the IPO.[26] We also find that the offer price of an IPO is positively related to the issuer's post-IPO operating performance, which is consistent with the information spillover story proposed by Alti (2005) that a higher offer price reveals better news about firm quality. The fact that our measures for IPO timing (clusteredness as well as the order of going public) remain significant even after controlling for offer price also indicates that the empirical evidence provided in the current paper cannot be fully explained by market valuation stories such as Alti (2005). The dummy for VC backing shows a moderately significant negative impact on post-IPO ROA, which might be due to the consequence of VC's optimal timing in exiting their investments. When VCs suspect a drop in entrepreneurial firms' operating performance in the near future, they may fasten the pace of realizing their investment returns through either IPOs or acquisitions, whereas for non-VC-backed firms such concerns do not exist. Thus, conditional on the occurrence of an IPO, firms backed by VCs might have worse future prospects. We also find a significantly negative relationship between initial returns (underpricing) and post-IPO operating performance, which is consistent with Ritter (1991) who finds that initial returns are negatively correlated with long-run stock return performance. Our results show that the percentage of secondary shares sold in an offering is positively related to its post-IPO ROA, which is consistent with the finding of Mikkelson, Partch, and Shah (1997) but contradicts that of Jain and Kini (1994). This positive relationship might be the outcome of both issuers' and investment banks' efforts to reduce the unfavorable information conveyed by offerings with secondary share sales (suggested by previous literature such as Leland and Pyle 1977): in order to successfully complete such an offering, the IPO firm must have better future prospects and an average higher level of post-issuance operating profits. Lastly, we find that IPO firms with more shares held by institutional investors and those underwritten by more reputable investment banks have a higher post-IPO ROA, which is consistent with the common intuition that institutional investors and higher reputation underwriters are associated with higher quality private firms.

[26] In fact, the variable Log (IPO proceeds) is highly correlated with the size variable Log (market cap) (with Pearson correlation coefficient of 0.85), suggesting some problem of multicollinearity. However, in unreported work, we run regressions with either one of them and obtain both qualitatively and quantitatively similar coefficients of IPO timing variables (measures for clusteredness and the order of going public). If we exclude Log (market cap), then IPO proceeds will have a significantly positive effect on post-IPO ROA if not controlling for firm age and underwriter reputation but a significantly negative effect after we control for firm age and underwriter reputation. If we exclude Log (proceeds), then Log (market cap) continues to have a significantly positive impact on post-IPO ROA in all specifications. To avoid omitted variable bias, we thus include both of them in our current model specifications.

5.2.3 Post-IPO Operating Performance and the Order of Going Public in an IPO Wave: Multivariate Analysis

In this subsection, we carry out a multivariate analysis of the differential post-issuance operating performance between firms going public earlier in an IPO wave and those going public later in it ($\mathbf{H}_2$), after controlling for various confounding factors. IPOs conducted in a cold period (2467 of them) are excluded in our tests of $\mathbf{H}_2$.

Table 4 summarizes the results of multiple regressions of post-issuance ROA on measures of the order of going public within a hot period. Panel A provides results with respect to the measure *EARLINESS*. As we can see, the post-IPO ROA for "on-the-wave" firms that go public earlier in a hot period (with smaller *EARLINESS*) is in general larger than those that go public later in the wave (at 95% confidence level), and the negative relationship between ROA and *EARLINESS* holds more significantly for specifications (3) and (4) when we include more control variables. This is consistent with our second hypothesis ($\mathbf{H}_2$). The coefficient of -0.0076 for *EARLINESS* in the full specification (model 4) tells us that even after controlling for industry and time effects as well as various firm and IPO characteristics, a firm that goes public earlier in a hot period (among the first 25% of firms going public in this IPO wave) will on average have an ROA 2.3% more than a firm that goes public later in the wave (among the last 25% of firms going public in this hot period). Given the mean of ROA in our sample is 5%, this represents a 46% difference in post-issuance ROA, which is economically significant.

Panel B provides results with respect to the measure *ORDER* / Median *ORDER*. As in Panel A, the coefficient of *ORDER* / Median *ORDER* is statistically significant at 5% level in all model specifications and at 1% significance level in some specifications. This is also consistent with $\mathbf{H}_2$. The coefficient of -0.016 for *ORDER* / Median *ORDER* in the full specification (model 4) implies that even after controlling for all other independent variables, a firm that goes public earlier in a wave (at 25% quantile of *ORDER* / Median *ORDER,* 0.55) will on average have an ROA 1.5% more than a firm that goes public later in the hot period (at 75% quantile of *ORDER* / Median *ORDER,* 1.46).

Panel C provides results with respect to the measure Log (*ORDER*). The coefficient of Log (*ORDER*) is statistically significant at 1% level in all model specifications, much stronger than the previous two measures. This is again consistent with $\mathbf{H}_2$. The coefficient of -0.0086 for Log (*ORDER*) in the full specification (model 4) implies that even after controlling for all other independent variables, a firm that goes public earlier in a hot period (when it is the 4th in the wave, the 25% quantile of Log (*ORDER*)) will on average have an ROA 1.8% more than a firm that goes public later in a hot period (when it is the 33th in the wave, the 75% quantile of Log (*ORDER*)). However, since this measure (Log (*ORDER*)) is not readily comparable across waves of different sizes, we should treat the results with care.

Taken together, all empirical results presented in this subsection support the hypothesis that on average, firms going public earlier in an IPO wave will yield more post-IPO profitability than those going public later in a hot-issuing period, even after controlling for industry conditions, firms' post-IPO capital stock and market share, and other characteristics of IPOs.

5.2.4 Cash Usage, Industry IPO Clusteredness, and the Order of Going Public in a Wave: Multivariate Analysis

In this subsection, we carry out a multivariate analysis of the different cash usage intensities between firms that go public in an IPO wave and those that go public outside it ($\mathbf{H}_3$), and between firms that go public earlier in an IPO wave and those that go public later in the wave ($\mathbf{H}_4$), after controlling for various confounding factors.

Table 5 presents the results of multiple regressions of post-IPO cash balance and cash increases on measures of IPO timing (industry clusteredness and the order of going public within a hot period). Panel A provides results with respect to the first cash usage measure: the post-IPO increase in cash and cash equivalents scaled by total net assets. As we can see, the increase in cash balance for firms that go public in a hot period (with larger clusteredness measures) is in general more than those that go public in a cold period, and this positive relationship is statistically significant at 10% level for *IPONUM* and at 5% for *IPONUM* / Same Industry Vol. This is consistent with our third hypothesis ($\mathbf{H}_3$). The results with respect to the order of going public in an IPO wave are much stronger: "on-the-wave" firms that go public later in a hot period (with larger measures for the order of going public) in general have greater increases in cash balance than those that go public later in the wave, and the positive relationship is significant at 1% level for all three measures for the earliness of going public. This lends strong support to our fourth hypothesis ($\mathbf{H}_4$). An examination of other control variables shows that younger firms with larger post-IPO market capital, smaller IPO size (in terms of total proceeds), lower underwriter reputation, and those backed by venture capital will have more increases in cash and cash equivalents.

Panel B provides results with respect to the second cash usage measure: the cash and short-term investments after the IPO scaled by total net assets. As in Panel A, the post-IPO cash balance for firms that go public in a hot period (with larger clusteredness measures) is in general more than those that go public in a cold period, and this positive relationship is statistically significant at 1% level for *IPONUM* and *IPONUM* / Same Industry Vol. This is consistent with our third hypothesis ($\mathbf{H}_3$). The results with respect to the order of going public in an IPO wave are weaker: "on-the-wave" firms that go public later in a hot period (with larger measures for the order of going public) in general have greater balance in cash and short-term investments than those that go public later in the wave, but the positive relationship is significant at 1% level only for Log (*ORDER*). However, although the coefficients for *EARLINESS* and *ORDER* / Median *ORDER* are not statistically significant, the t-values are not terribly smaller (both bigger than 1.3), which lends weak support to our fourth hypothesis ($\mathbf{H}_4$). The impact of other control variables is similar to that reported in Panel A, except that in this case, firms with higher offer price and initial return and those with lower institutional holdings will sit on more cash balance and that underwriter reputation does not influence the post-IPO cash balance significantly.

In sum, the empirical results presented in this subsection, though not very strong, support the hypothesis that firms that go public in a hot-issuing market will on average hold more cash on hand (or, use less cash raised through their offerings) than firms that go public off the wave, and the hypothesis that firms going public earlier in an IPO wave will on average hold more cash on hand than firms going public later in the wave. By defining hot and cold periods according to total monthly IPO volume (for all industries), Alti (2005) also finds that hot-market issuers raise more equity than needed, adding more of the IPO proceeds to their cash and short-term investments than to other long-term assets. However, he does not examine the cash usage for leaders and followers within an IPO wave.

5.2.5 Post-IPO Operating Performance, Industry Concentration, and IPO Timing: Multivariate Analysis

In this subsection, we carry out a multivariate analysis of the influence that industry concentration exerts on the relationship between post-issuance operating performance and IPO timing variables (clusteredness as well as the order of going public within a hot period). We test whether higher industry concentration intensifies or weakens the superior post-IPO profitability of firms that go public in a cold period or earlier in a wave, which is our fifth hypothesis ($\mathbf{H}_5$).

Table 6 summarizes the results of multiple regressions of post-issuance ROA on measures of IPO timing (clusteredness or the order of going public), the Herfindahl-Hirschman Index (HHI), and the interaction of HHI and IPO timing measures. If industry concentration amplifies the difference in post-IPO operating performance for firms that go public on the wave versus those that go public off the wave and for firms going public earlier in a wave versus those going public later in the wave, then we expect the coefficients before the interaction of HHI and timing variables to be significantly negative. If, on the other hand, industry concentration weakens the relationship between post-IPO ROA and the timing of IPO, then we expect the interaction variable to be significantly positive. If industry concentration cannot adequately proxy for how IPOs enhance firms' product market competitiveness or the two effects that concentration has on the performance-timing relationship cancel each other, then the coefficient before the interaction term should be insignificant.

Panel A provides results with respect to industry IPO clusteredness. As we can see, the interaction of HHI and clusteredness measures is positive in all three models and statistically significant when we use the measure *IPONUM* / Same Window Vol. Even for the models (1) and (2) where the interaction term is not statistically significant at 10% level, the t-statistics are still greater than 1, showing weak evidence for the conclusion that industry concentration weakens the relationship between post-IPO ROA and the timing of IPO. The main effect of clusteredness measures on post-issuance operating performance remains to be significantly negative, consistent with our findings in Table 3 ($\mathbf{H}_1$). Nevertheless, the Herfindahl-Hirschman Index itself has a weak negative impact on firms' post-IPO ROA, contradicting the common intuition that less competition (or more concentration) renders more opportunities to manipulate price and earn higher monopoly rents. A possible explanation for this result is that IPOs yield more product market advantages in a more competitive industry with lots of small firms than in a highly concentrated one. Thus, if we compare new IPO firms' post-issuance profitability, we will be more likely to find better performance for IPO firms in competitive industries because the public debuts have added more edges to these firms than the ones in a more concentrated industry. This explanation is also consistent with our finding that industry concentration weakens the relationship between post-IPO ROA and the timing of IPO, as we argued in section 4.

Panel B presents results with respect to the order of going public within a given IPO wave. Similar to Panel A, the interaction of HHI and earliness measures is positive in all three models. Moreover, the positive effect is much more significant than in Panel A, with all three t-values exceeding 2.29. This finding strongly supports the conclusion that industry concentration weakens the relationship between post-IPO ROA and the timing of IPO. The main effect of measures for the order of going public in a wave on post-issuance operating performance remains to be significantly negative, consistent with our findings in Table 4 ($\mathbf{H}_2$). In addition, the Herfindahl-Hirschman Index itself has a strong negative impact on firms' post-IPO ROA, consistent with our findings in Panel A as well as the sign of interaction variables in Panel B.

In sum, our tests of $\mathbf{H}_5$ suggest that a public debut will add little to a firm's product market competitiveness in highly concentrated industries and thus fail to induce it to go public purely out of competition concerns. Consequently, a higher level of industry concentration will tend to weaken the difference in post-IPO performance for firms that go public on the wave versus those that go public off the wave, and firms going public earlier in a wave versus those going public later in the wave, as is found in this subsection.

6 Conclusion

We develop a new rationale for IPO waves based on product market considerations, and empirically test the implications of our theory. We model an industry with two competing firms, one of which has higher productivity of capital compared to the other. The two firms assess a significant probability of a positive productivity shock affecting their industry in the near future. Going public not only allows each firm to raise external capital at a cheaper cost compared to a private firm, but allows it to grab market share from its competitor if the latter remains private. In the above setting, we solve for the decision of each firm whether to go public or remain private, and if it chooses to go public, the optimal timing of going public. We show that, in equilibrium, even firms with sufficient internal capital to optimally fund their investment may go public, driven by the possibility of their product market competitors going public. We also show that IPO waves may arise in equilibrium even in industries which do not experience a positive productivity shock. Our model develops several testable predictions for IPO waves and post-IPO profitability, two of which are as follows. First, firms going public during an IPO wave will have lower post-IPO profitability than those going public off the wave. Second, firms going public earlier in an IPO wave will have higher post-IPO profitability than those going public later in the wave. We empirically test these and other predictions of our model and find supporting evidence.

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Appendix: Proofs of Propositions

Proof of Proposition 1, 2, 3, and 7. Since these four propositions all involve solving the perfect Bayesian equilibrium (PBE) for the model, we put the proofs of them together. We first prove the more complicated case of purely idiosyncratic productivity shocks (Proposition 7) and then generalize the proofs to the case of industry-wide productivity shocks. After solving for the possible PBEs, we characterize the conditions under which they can occur (Propositions 1, 2, and 3).

Part (a): Solving for all the PBEs in the model.

To solve for PBE, we use backward induction. Let (a_1, a_2) denote the strategies adopted by firm 1 and firm 2 respectively. a_i can be either "IPO" (meaning "go public" or "remain public") or "PR" (meaning "remain private"). Then the strategy profile at time 1 can be one of the following four: $(IPO, IPO), (IPO, PR), (PR, IPO), (PR, PR)$. According to Figure 2, if the time 1 strategy profile is (IPO, IPO), then the market share for firm 1 and 2 is $(m, 1-m)$ at time 2 and the game is over because both firms cannot switch back to the private status. If the time 1 strategy profile is (IPO, PR), then at time 2, firm 2's market share will be $(1-m_b)(1-sm_b)$ if it stays private and $1-m_b$ if it goes public. The incremental market share it gets by IPO is $(1-m_b)sm_b$. Similarly, if the time 1 strategy profile is (PR, IPO), the incremental market share for firm 1 to go public rather than remaining private at time 2 is $(1-m_c)sm_c$. Lastly, if the time 1 strategy profile is (PR, PR), then either firm 1 or firm 2's incremental market share by IPO (given rival's strategy) at time 2 is $(1-m)sm$. Hence, the firms will compare the incremental profit by IPO (the additional market share gained through IPO times their efficient-scale cash-flow generation levels) to the issuing cost, B, to make their going public decision. Since we will make use of these incremental market share, we need to rank them. Simple calculation yields

$$\begin{cases} (1-m_b)m_b > (1-m)m \Leftrightarrow m < \frac{2+s-\sqrt{s^2+4}}{2s} (< \frac{1}{2}) \\ (1-m_c)m_c > (1-m)m \Leftrightarrow m > \frac{s-2+\sqrt{s^2+4}}{2s} (> \frac{1}{2}) \\ (1-m_b)m_b > (1-m_c)m_c \Leftrightarrow m < \frac{1}{2} \end{cases} . \tag{A1}$$

Since this model involves discrete choice of firms, we need to examine the parameter values in several ranges.

Case (i) $\Delta A < A_1 - A_2 \Rightarrow \pi_2 < \pi_{2H} < \pi_1 < \pi_{1H}^{PR} < \pi_{1H}^{IPO}$

(I) $0 < m < \frac{2+s-\sqrt{s^2+4}}{2s} \Rightarrow (1-m_b)m_b > (1-m)m > (1-m_c)m_c$

By stability conditions (12) and (13) in the main text, we then have:

$$B > (1-m)sm\pi_{2H} > (1-m)sm\pi_1 > (1-m)sm\pi_2, \tag{A2}$$

which means that if the time 1 strategy profile is (PR, PR), firm 2 will continue to remain private at time 2. Firm 1 will not go public at time 2 if it does not get the productivity shock. However, if firm 1 gets the productivity shock, it pays off to go public. This is because given firm 2 IPO at time 2, firm 1 with higher productivity will gain net profit $m\pi_1^{IPO} - m_c\pi_1^{PR}$ by also going public. Similarly, given firm 2 remaining private at time 2, firm 1 with higher productivity will gain $m_b\pi_1^{IPO} - m\pi_1^{PR}$ by going public. Since we make assumption (11) in the main text and $m_b > m > m_c$, it directly follows that going public is a strictly dominant strategy for firm 1 at time 2 once it gets the productivity shock. Similarly, since $\pi_{2H} < \pi_1$ and $[m_b + sm_b(1-m_b) - m]\pi_1 < B$, we have:

$$B > (1-m_b)sm_b\pi_{2H} > (1-m_b)sm_b\pi_2, \tag{A3}$$

which shows that remaining private is also dominant for firm 2 at time 2 if firm 1 has already gone public at time 1. The only uncertainty we have in this case is how firm 1 will behave at time 2 if the time 1 strategy profile is (PR, IPO). So we have two cases:

(1) $m_c\pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR} > B > sm_c(1-m_c)\pi_1$

In this case, if the time 1 strategy profile is (PR, IPO) and firm 1 has the productivity shock at time 2, it will go public. Otherwise it will remain private. Therefore, the expected payoffs for the four time 1 strategy profiles can be written as:

$$\begin{cases} (IPO, IPO)\text{: } (x_1, y_1) \\ (IPO, PR)\text{: } (x_2, y_2) \\ (PR, IPO)\text{: } (x_3, y_3) \\ (PR, PR)\text{: } (x_4, y_4) \end{cases} , \tag{A4}$$

where

$$\begin{cases} x_1 = m(p\pi_{1H}^{IPO} + (1-p)\pi_1) - B \\ x_2 = (m_b + sm_b(1-m_b))(p\pi_{1H}^{IPO} + (1-p)\pi_1) - B \\ x_3 = pm_c\pi_{1H}^{IPO} + (1-p)[m_c - sm_c(1-m_c)]\pi_1 - pB \\ x_4 = p[m + sm(1-m)]\pi_{1H}^{IPO} + (1-p)m\pi_1 - pB \\ y_1 = (1-m)(p\pi_{2H} + (1-p)\pi_2) - B \\ y_2 = (1-m_b)(1-sm_b)(p\pi_{2H} + (1-p)\pi_2) \\ y_3 = (p\pi_{2H} + (1-p)\pi_2)[p(1-m_c) + (1-p)(1-m_c)(1+sm_c)] - B \\ y_4 = (p\pi_{2H} + (1-p)\pi_2)[p(1-m_b) + (1-p)(1-m)] \end{cases} . \tag{A5}$$

Now, given parametric conditions, it is easy to show that

$$\begin{cases} y_1 < y_2 \\ y_3 < y_4 \end{cases} , \tag{A6}$$

which means that remaining private is dominant for firm 2 at time 1. And the final PBE depends on

$$x_2 - x_4 = sm_b(1-m_b)(p\pi_{1H}^{IPO} + (1-p)\pi_1) + (1-m)sm(1-p)\pi_1 - (1-p)B. \tag{A7}$$

When this condition is greater than 0, the PBE is that firm 1 goes public at time 1 and firm 2 remains private for both periods. When this condition is less than 0, the PBE is that both firms remain private at time 1 and firm 1 will go public at time 2 if the productivity shock is realized.

(2) $B > m_c\pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR} > sm_c(1-m_c)\pi_1$

In this case, if the time 1 strategy profile is (PR, IPO), firm 1 will always choose to remain private at time 2. Solving the model backwards follows the same procedure, and the results are similar. We can show that under the current conditions, $x_1 - x_3 > y_3 - y_4$, which says that (PR, IPO) is not part of a PBE because if $x_1 < x_3$, then $y_3 < y_4$ as well. If we analyze all possible parameter ranges, we find that this result holds throughout. Hence regardless of parametric restrictions, (PR, IPO) is never an equilibrium move at time 1. In this case, we still have $y_1 < y_2$ and have the same result as the last case: if $x_2 - x_4 > 0$, the PBE is that firm 1 goes public at time 1 and firm 2 remains private for both periods; if $x_2 - x_4 < 0$, the PBE is that both firms remain private at time 1 and firm 1 will go public at time 2 if it experiences the productivity shock. Similar analysis can be applied to the following three cases as well:

(II) $\frac{2+s-\sqrt{s^2+4}}{2s} < m < \frac{1}{2} \Rightarrow (1-m)m > (1-m_b)m_b > (1-m_c)m_c$

(III) $\frac{1}{2} < m < \frac{s-2+\sqrt{s^2+4}}{2s} \Rightarrow (1-m)m > (1-m_c)m_c > (1-m_b)m_b$

(IV) $\frac{s-2+\sqrt{s^2+4}}{2s} < m < 1 \Rightarrow (1-m_c)m_c > (1-m)m > (1-m_b)m_b$

The calculations are tedious but straightforward. If we use the following notations,

$$\begin{cases} x_1 - x_3 \equiv (*1) \\ y_3 - y_4 \equiv (*2) \\ x_2 - x_4 \equiv (*3) \\ y_1 - y_2 \equiv (*4) \end{cases} , \tag{A8}$$

the results for case (i) can be succinctly presented below:

If $(*3) > 0$ or $\begin{cases} (*3) < 0 \\ (*2) > 0 \\ m > \frac{2+s-\sqrt{s^2+4}}{2s} \\ m_c\pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR} > B > sm_c(1-m_c)\pi_1 \end{cases}$, the time 1 equilibrium strategy is (IPO, PR) and the time 2 equilibrium strategy is (IPO, IPO, PR, PR).[27] Otherwise, the time 1 equilibrium strategy is (PR, PR) and the time 2 equilibrium strategy is (IPO, PR, PR, PR). We should note that (*1), (*2), (*3) and (*4) bear different forms and values under different parametric conditions, which means that x's and y's do not necessarily look like those given in (A5).

Case (ii) $\Delta A \geq A_1 - A_2 \Rightarrow \pi_2 < \pi_1 \leq \pi_{2H} < \pi_{1H}^{PR} < \pi_{1H}^{IPO}$

Basically we follow the same steps to solve the model. This time the results are more complicated yet more

[27] The equilibrium strategy at time 1 is given in the form of (a_1, a_2, a_3, a_4) which correspond to the strategies adopted by firm 1 with shock, firm 1 without shock, firm 2 with shock, and firm 2 without shock, respectively.

interesting as well. Since there are many parametric ranges that lead to the same PBE, we do not provide the long list of those conditions here. The general form of solutions can be described as:[28]

If $(*1) > 0$ and $(*4) > 0$, the time 1 equilibrium strategy is (PR, PR) and the time 2 equilibrium strategy is (IPO, PR, IPO, PR).

If $\begin{cases} (*3) > 0 \\ (*4) < 0 \\ (1-m_b)sm_b\pi_{2H} > B > (1-m_b)sm_b\pi_2 \end{cases}$, the time 1 equilibrium strategy is (IPO, PR) and the time 2 equilibrium strategy is (IPO, IPO, IPO, PR).

If $\begin{cases} (*3) > 0 \\ (*4) < 0 \\ B > (1-m_b)sm_b\pi_{2H} > (1-m_b)sm_b\pi_2 \end{cases}$, the time 1 equilibrium strategy is (IPO, PR) and the time 2 equilibrium strategy is (IPO, IPO, PR, PR).

If $\begin{cases} (*3) < 0 \\ (*2) < 0 \\ (1-m)sm\pi_{2H} > B > (1-m)sm\pi_1 > (1-m)sm\pi_2 \end{cases}$, the time 1 equilibrium strategy is (PR, PR) and the time 2 equilibrium strategy is (IPO, PR, IPO, PR).

If $\begin{cases} (*3) < 0 \\ (*2) < 0 \\ B > (1-m)sm\pi_{2H} > (1-m)sm\pi_1 > (1-m)sm\pi_2 \end{cases}$, the time 1 equilibrium strategy is (PR, PR) and the time 2 equilibrium strategy is (IPO, PR, PR, PR).

There may be rare cases where we have no PBEs or two PBEs (whose time 1 strategies are (IPO, IPO) and (PR, PR), respectively). For brevity, we do not provide detailed descriptions of these cases here. Last but not least, we can prove that when $x_1 > x_3$, we always have $y_3 < y_4$. This means that regardless of parameter values, (PR, IPO) is never a time 1 equilibrium strategy.

When the productivity shock is industry-wide, the analysis is very similar to the case of idiosyncratic shocks. The only difference is that when the time 1 strategy profile is (PR, PR), the uncertain situations faced by the two firms are reduced to two rather than four as before. With probability p, both firms' technology parameters $A_i's$ will increase by ΔA and with probability $1-p$ the parameters $A_i's$ will remain unchanged for the whole industry. All other analysis follows the same procedure as outlined above. To save space, we do not present the detailed list of all possible equilibria here, but they are available upon request.

Part B: Characterize the conditions under which different PBEs may occur.

After solving for all five possible PBEs in the model, we continue to characterize them in this section. For brevity, we only illustrate the case of industry-wide productivity shocks (Propositions 1, 2, and 3). The characterization of PBEs in the case of idiosyncratic productivity shocks (Proposition 7) is similar. Figure 3 lists all possible PBEs under different ranges of market share distribution and the magnitude of the productivity shock. As we can see, when the magnitude of the shock is very large ($\Delta A \geq \Delta A_H$), we only observe IPO-wave equilibria (those in Propositions 1 and 2), whereas when the magnitude of the shock is small ($\Delta A \leq A_1 - A_2$), only off-the-wave IPOs may occur in equilibrium (PBEs in Proposition 3). PBE in Proposition 1 may occur only when the magnitude of the shock is greater than $A_1 - A_2$ (i.e., at least moderate), while PBEs in Proposition 2 may occur only when ΔA is at least large ($\Delta A > \Delta A_L$). When the magnitude of the shock is large but not very large ($\Delta A_L < \Delta A < \Delta A_H$), the market share distribution matters: if m is below $\frac{2+s-\sqrt{s^2+4}}{2s}$, only PBE (ii) in Proposition 2 and PBE (i) in Proposition 3 may occur rather than PBE (i) in Proposition 2 or PBE (ii) in Proposition 3.

[28] A complete list of all parametric conditions that lead to different PBEs can be provided to interested readers upon request.

	Market Share Distribution			
Magnitude of shock	Case I ($m < \frac{2+s-\sqrt{s^2+4}}{2s}$)	Case II ($\frac{2+s-\sqrt{s^2+4}}{2s} < m < \frac{1}{2}$)	Case III ($\frac{1}{2} < m < \frac{s-2+\sqrt{s^2+4}}{2s}$)	Case IV ($m > \frac{s-2+\sqrt{s^2+4}}{2s}$)
Very Large $\Delta A \geq \Delta A_H$	PBE(i) of Prop.2 PBE(ii) of Prop.2 PBE of Prop.1	PBE(i) of Prop.2 PBE(ii) of Prop.2 PBE of Prop.1	PBE(i) of Prop.2 PBE(ii) of Prop.2 PBE of Prop.1	PBE(i) of Prop.2 PBE(ii) of Prop.2 PBE of Prop.1
Large $\Delta A_L < \Delta A$ $< \Delta A_H$	PBE(i) of Prop.3 PBE(ii) of Prop.2 PBE of Prop.1	PBE(ii) of Prop.3 PBE(i) of Prop.2 PBE of Prop.1	PBE(ii) of Prop.3 PBE(i) of Prop.2 PBE of Prop.1	PBE(ii) of Prop.3 PBE(i) of Prop.2 PBE of Prop.1
Moderate $A_1 - A_2 <$ $\Delta A \leq \Delta A_L$	PBE(i) of Prop.3 PBE(ii) of Prop.3 PBE of Prop.1	PBE(i) of Prop.3 PBE(ii) of Prop.3 PBE of Prop.1	PBE(i) of Prop.3 PBE(ii) of Prop.3 PBE of Prop.1	PBE(i) of Prop.3 PBE(ii) of Prop.3 PBE of Prop.1
Small $\Delta A \leq A_1 - A_2$	PBE(i) of Prop.3 PBE(ii) of Prop.3	PBE(i) of Prop.3 PBE(ii) of Prop.3	PBE(i) of Prop.3 PBE(ii) of Prop.3	PBE(i) of Prop.3 PBE(ii) of Prop.3

Figure 3: Distribution of Possible Equilibria over Different Parameter Ranges

To differentiate the PBEs within each category of market share distribution and the magnitude of productivity shock, we need to look at the specific conditions for them to occur. From our proof in part (A), we know that the general rule is that the PBE of Proposition 1 will occur when both $(*1) > 0$ and $(*4) > 0$; PBE (i) of Proposition 2 and 3 will occur when both $(*3) < 0$ and $(*2) < 0$; and PBE (ii) of Proposition 2 and 3 will occur when $(*3) > 0$ & $(*4) < 0$. A complete analysis of $(*1)$, $(*2)$, $(*3)$, and $(*4)$ shows that all these four conditions increase with ΔA and decrease with B. $(*1)$ and $(*3)$ increase with A_1, while $(*2)$ and $(*4)$ increase with A_2. $(*1)$ and $(*4)$ always increase with p, but $(*2)$ and $(*3)$ may increase or decrease with p. When p is close to 1 and $m < \frac{2+s-\sqrt{s^2+4}}{2s}$, $(*3)$ will decrease with p; and when p is close to 1 and $m > \frac{s-2+\sqrt{s^2+4}}{2s}$, $(*2)$ will decrease in p. In all other situations, both $(*2)$ and $(*3)$ increase in p. We find out these results by listing $(*1)$, $(*2)$, $(*3)$, and $(*4)$ for each parameter range and calculate their derivatives with respect to model parameters, ΔA, B, A_1, A_2, and p. For brevity, the specific calculations case by case will not be presented here, but they are available upon request.

Q.E.D.

Proof of Proposition 4. Part (i) of the proposition is straightforward to prove. Consider an industry where all five possible PBEs in Propositions 1, 2, and 3 will occur with positive probabilities, then if we observe a stand-alone IPO, it must be conducted by firm 1 (possibly from the PBE (i) and (ii) of Proposition 3 or PBE (ii) of Proposition 2). That's why the pre-IPO productivity of such a firm is A_1. Similarly, if we observe an IPO wave in the sense that two IPOs occur during the period of time 1 and 2, then it must be the case that both firm 1 and 2 have gone public so the average pre-IPO productivity for such a firm is $(A_1 + A_2)/2$, which is lower than A_1.

Part (ii) of the proposition follows from the observation that if an IPO wave spans both time 1 and 2, then it must be from the PBE (ii) of Proposition 2, which says that firm 1 will go public at time 1 and firm 2 will do so at time 2 when the productivity shock occurs. That's why the pre-IPO productivity for a firm that goes public earlier in such a wave (A_1) is higher than that for a later comer in the IPO wave (A_2).

Q.E.D.

Proof of Proposition 5. We also consider an industry where all five possible PBEs in Propositions 1, 2, and 3 will occur with positive probabilities. The post-IPO operating performance for firm i is defined as:

$$ROA_i^{III} \equiv \frac{m_i^{III}(A_i^{II})^{\frac{1}{1-\gamma}} c^{\frac{\gamma}{\gamma-1}} \gamma^{\frac{\gamma}{1-\gamma}} (1-\gamma) - B}{k_0 + E}, \tag{A9}$$

where A_i^{II} can be either A_i or A_{iH}, depending on whether the industry-wide shock occurs. If two firms have identical initial capital level (k_0), raise the same amount of equity (E), pay the same issuing costs (B), and have the same average post-IPO market share ($m_i^{III} = \overline{m}$, $i = 1, 2$), then their post-IPO operating performance (ROA_i^{III}) depends mainly on their post-IPO productivity (A_i^{II}). If these two average firms go public at different times of "market hotness", then the one that goes public alone will have an average post-IPO productivity of A_{1H} if the industry-wide productivity shock takes place (PBE (i) and (ii) in Proposition 3) and an average post-IPO productivity of A_1 if the productivity shock does not occur (PBE (ii) of Proposition 3, and PBE (ii) of Proposition 2). Thus the average post-IPO productivity for a stand-alone IPO firm based on the above updated posterior belief will be $pA_{1H} + (1-p)A_1$, where p is the ex ante belief that the industry-wide productivity shock will occur. Similarly, the average post-IPO productivity for an on-the-wave IPO firm based on updated posterior belief will be $p(A_{1H} + A_{2H})/2 + (1-p)(A_1 + A_2)/2$. This completes the proof for part (i) of the proposition.

Part (ii) of the proposition can be proved in a similar fashion. Conditional on the occurrence of the productivity shock, the post-IPO productivity for a firm that goes public earlier in a "sequential IPO wave" (firm 1 in the model) will be A_{1H} whereas the post-IPO productivity for a firm that goes public later in the wave will be A_{2H}. Similarly, conditional on no occurrence of the productivity shock, the post-IPO productivity for a firm that goes public earlier in a "sequential IPO wave" (firm 1 in the model) will be A_1 whereas the post-IPO productivity for a firm that goes public later in the wave will be A_2. In both cases, the equilibrium that results in such a sequential wave is PBE (ii) of Proposition 2, and the post-IPO productivity for a firm that goes public earlier in a wave is higher than that of a firm that goes public later in that same wave. Therefore, if these two firms have the same level of post-IPO capital stock and market share, the post-IPO operating performance for the early issuer will be better than that of the late one.

Q.E.D.

Proof of Proposition 6. Part (i) of the proposition compares industries with a small magnitude of productivity shocks ($\Delta A < A_1 - A_2$) and those with a large magnitude ($\Delta A > A_1 - A_2$). When ΔA is small so that $\pi_{2H} < \pi_1$, we have the situation as in Proposition 3 where the only equilibria (PBE (i) and (ii)) involve at most one IPO (by firm 1) and no IPO waves can occur. However, when ΔA is sufficiently large ($\pi_{2H} > \pi_1$), the same industry may witness more IPOs and IPO waves due to the going-public efforts by firm 2 such as those in the PBE of Proposition 1 and PBE (i) and (ii) of Proposition 2.

Even within an industry with either $\Delta A < A_1 - A_2$ or $\Delta A > A_1 - A_2$, a greater ΔA will contribute to stronger incentives to go public. For example, in an industry with $\Delta A < A_1 - A_2$, we may observe either PBE (i) or (ii) in Proposition 3. PBE (ii) yields stronger going-public incentives because in this equilibrium firm 1 will go public at time 1 before the realization of any productivity shocks. On the contrary, in PBE (i) of Proposition 3, firm 1 will wait until time 2 to do its IPO when the industry-wide productivity shock actually occurs. Thus we may compare the likelihood of PBE (i) and that of PBE (ii) to see the effect of ΔA on going-public concerns. As we show in the proof of Proposition 1, 2, 3, and 7, the conditions for PBE (ii) to occur rather than PBE (i) is:

$$(*3) > 0 \text{ or } \begin{cases} (*3) < 0 \\ (*2) > 0 \\ m > \frac{2+s-\sqrt{s^2+4}}{2s} \\ m_c \pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR} > B > sm_c(1-m_c)\pi_1 \end{cases} . \tag{A10}$$

In the case of $0 < m < \frac{2+s-\sqrt{s^2+4}}{2s}$ and $m_c \pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR} > B > sm_c(1-m_c)\pi_1$, we have shown that $(*3) > 0$ is equivalent to

$$x_2 - x_4 = sm_b(1-m_b)(p\pi_{1H}^{IPO} + (1-p)\pi_1) + (1-m)sm(1-p)\pi_1 - (1-p)B > 0, \tag{A11}$$

the left handside of which is clearly increasing in ΔA (because π_{1H}^{IPO} increases with ΔA). In fact, as ΔA decreases to 0, $(*3) < 0$ for sure. Similarly, $(*2) > 0$ is equivalent to

$$y_3 - y_4 = (p\pi_{2H} + (1-p)\pi_2)[(1+p)(1-m)sm + (1-p)(1-m_c)sm_c] - B > 0, \tag{A12}$$

whose left handside also increases with ΔA as π_{2H} rises with ΔA. As ΔA decreases to 0, $(*2) < 0$ for sure. Lastly, the expression $m_c \pi_{1H}^{IPO} - (m_c - sm_c(1-m_c))\pi_{1H}^{PR}$ itself is increasing in π_{1H}^{IPO} (which in turn increases in ΔA). Combining the above results, we can see that a larger ΔA tends to increase the likelihood that PBE (ii) occurs, even if it is smaller than $A_1 - A_2$. We have repeated the analysis in all other possible cases and shown that the conclusion is true for all of them. (For brevity the detailed proofs are not listed here.)

Part (ii) of Proposition 6 also follows from Proposition 1, 2, and 3. The stability conditions (12) and (13) ensure that without productivity shocks ($p \simeq 0$), firms will optimally choose to remain private. Hence, an industry with large enough probability of productivity shocks will tend to witness more IPOs and IPO waves. Similar to the proof for part (i), we can show that within an industry with either $\Delta A < \Delta A_L$ or $\Delta A > \Delta A_H$, a greater p will always contribute to stronger incentives to go public. For example, in an industry with $\Delta A < A_1 - A_2$, we may observe either PBE (i) or (ii) in Proposition 3. PBE (ii) yields stronger going-public incentives thus we may compare the likelihood of PBE (i) and that of PBE (ii) to see the effect of p on going-public concerns. As we show in the proof of part (i) of Proposition 6, the condition for PBE (ii) to occur rather than PBE (i) is (A10). Since $x_2 - x_4$ is linear in p, it's easy to show that $x_2 - x_4$ increases with p by comparing its value when p is 0 and 1. When $p = 0$, $x_2 - x_4 < 0$ for sure and vice versa when $p = 1$. Hence, p increases $x_2 - x_4$. Similarly, it is straightforward to show that $y_3 - y_4$ increases with p as well. Combining the above results, we can see that a larger p tends to increase the likelihood that PBE (ii) occurs, even if ΔA is smaller than $A_1 - A_2$. We can repeat the analysis in other possible cases when either $\Delta A < \Delta A_L$ or $\Delta A > \Delta A_H$. However, when ΔA is moderate, p's effect on going-public incentives may be ambiguous (with intuition given in the main text). Hence, part (ii) of Proposition 6 only compares industries with very high p and those with $p \simeq 0$. Then regardless of the magnitude of ΔA, industries with higher p will unambiguously have more IPOs and IPO waves.

Part (iii) of this proposition follows Proposition 1 and 2. As we can see in Figure 3, among the three IPO-wave equilibria, the occurrence of the PBE in Proposition 1 is not affected by the market share distribution while PBE (i) and (ii) in Proposition 2 do. When the higher-productivity firm, firm 1, has small enough existing market share ($m < \frac{2+s-\sqrt{s^2+4}}{2s}$), only PBE (ii) can occur, resulting in a longer wave period (both time 1 and time 2) than when firm 1's market share is larger than $\frac{2+s-\sqrt{s^2+4}}{2s}$, in which case only PBE (i), whose wave takes place at time 2, may occur.

Part (iv) follows Proposition 1 and 2 as well. When the existing productivity level of firm 1 is high while that of firm 2 is low, PBE (ii) of Proposition 2 is more likely to occur than when both firms' productivity levels are similar (either both high as in PBE of Proposition 1, or both low as in PBE (i) of Proposition 2). In PBE (ii) of Proposition 2, the IPO wave will span the whole period of time 1 and 2, while in the latter two cases any IPO waves will only take place simultaneously, either at time 1 or 2.

Q.E.D.

Proof of Proposition 8. As the proof for Proposition 5 shows, if two firms have identical initial capital level (k_0), raise the same amount of equity (E), pay the same issuing costs (B), and have the same average post-IPO market share ($m_i^{III} = \overline{m}$, $i = 1, 2$), then their post-IPO operating performance (ROA_i^{III}) depends mainly on their post-IPO productivity (A_i^{II}). When the productivity shock in the industry is purely idiosyncratic, we may observe either none, one, or two actual shocks. Conditional on the occurrence of zero productivity shocks, the average post-IPO productivity for a firm going public on a wave (from PBE (iia) of Proposition 7) and off a wave (from PBE (ib) and (iib) of Proposition 7) will be $(A_1 + A_2)/2$ and A_1 respectively. Conditional on the occurrence of two productivity shocks, the average post-IPO productivity for a firm going public on a wave (from PBE (iia), (iib), and (iic) of Proposition 7) and off a wave (from PBE (ia) and (ib) of Proposition 7) will be $(A_{1H} + A_{2H})/2$ and A_{1H} respectively. In both scenarios, an average firm that goes public in an IPO wave will have lower post-IPO operating performance than a similar firm that goes public outside the wave. This proves part (i) and (ii) of Proposition 8.

Conditional on the occurrence of only one productivity shock, a stand-alone IPO may be the outcome of PBE (ia) (when firm 2 gets the shock), PBE (ib) (when firm 2 gets the shock), PBE (iib) (when firm 1 gets the shock), or PBE (iic) (when either firm 1 or firm 2 gets the shock). Thus if we use the probability q_i, ($i = 1, 2, 3, 4, 5$) to denote the ex ante chance of observing PBEs (ia), (ib), (iia), (iib), and (iic), respectively, then the posterior average post-IPO productivity for a firm that goes public in a cold period will be:

$$\frac{(A_{1H} + A_{2H})q_5/2 + A_{1H}(q_1 + q_4) + A_1 q_2}{q_1 + q_2 + q_4 + q_5}. \tag{A13}$$

Similarly, an IPO wave may be the outcome of PBE (iia) (when either firm 1 or firm 2 gets the shock), or PBE (iib) (when firm 2 gets the shock). Hence, the posterior average post-IPO productivity for a firm that goes public in a hot market will be:

$$\frac{(A_1 + A_{2H})(q_4 + q_3/2) + (A_{1H} + A_2)q_3/2}{2(q_3 + q_4)}. \tag{A14}$$

As a result, the sufficient and necessary condition for an off-the-wave firm to have better average post-IPO operating performance than an on-the-wave firm is $(A13) > (A14)$. This proves part (iii) of the proposition.

Q.E.D.

Proof of Proposition 9. When the productivity shock in a given industry is purely idiosyncratic, the occurrence of an IPO wave that spans both time 1 and 2 can only result from PBE (iib) in Proposition 7 when the presumed shocks actually take place. Conditional on observing two shocks in such an industry, we can infer that the post-IPO productivity of a firm that goes public earlier in the "sequential wave" is A_{1H} while that of a firm conducting its IPO later in the hot issuing period is A_{2H}. Hence it is straightforward to prove part (i) of the proposition.

However, conditional on only one occurrence of the productivity shock, the "sequential IPO wave" of PBE (iib) in Proposition 7 requires that the shock is for firm 2 and not for firm 1. Thus, the post-IPO productivity for a firm that goes public earlier is A_1, which is smaller than that of a firm that goes public later (A_{2H}). But we know that $A_1 < A_{2H}$ in the scenario where PBE (iib) can occur, thus part (ii) of the proposition is proved.

Part (iii) of the Proposition can be proved as follows. In the case of independent productivity shocks, the prior probability for only firm 2's shock to occur is $p(1-p)$ while the prior probability for both firm 1 and firm 2's shocks to occur is p^2. Thus the posterior probability for one and two shocks to occur will be $1-p$ and p, respectively. Therefore, the average post-IPO productivity for a firm that goes public earlier in the wave will be $pA_{1H} + (1-p)A_1$, which is greater than $pA_{2H} + (1-p)A_{2H} = A_{2H}$ (the average post-IPO productivity for a firm that goes public later in the wave) if and only if $p > (A_{2H} - A_1)/(A_{1H} - A_1) = (A_{2H} - A_1)/\Delta A$.

Q.E.D.

Table 1: Descriptive Statistics on IPOs and IPO Waves, 1970-2006

This table presents descriptive statistics on IPOs and IPO waves between 1970 and 2006, as listed on SDC. IPOs in which the offer price is less than $5, ADRs, units, REITS, spin-offs, reverse LBOs, foreign issues, close-end funds, finance and utilities (with FF-49 industry code 31, 45, 46, and 48), and those offerings whose industries are unidentified (with FF-49 industry code 49 or missing) are excluded. The three industry IPO clusteredness measures are defined as follows: "*IPONUM*" is the total number of IPOs in the same Fama-French 49 industry within the 90-day window symmetrically surrounding each IPO issuance date; "*IPONUM*/Same Industry Vol." is *IPONUM* scaled by the total number of IPOs in the same FF-49 industry during the whole sample period; and "*IPONUM*/Same Window Vol." is *IPONUM* scaled by the total number of IPOs in all FF-49 industries during the same 90-day window used to calculate *IPONUM*. The three measures for the order of going public within an IPO wave are defined as follows. For any FF-49 industry, we define all IPO waves within it (according to the procedure outlined in the main text of the paper) and rank the offerings in a particular wave in terms of their sequence of issuances. Waves whose number of IPOs is less than 5 are deleted. We denote the rank by an integer variable *ORDER*, whose larger values indicate late occurrence in a wave. We then divide the ranked offerings in a given wave into four groups of equal size and use a dummy variable (*EARLINESS*) to denote whether an IPO takes place "early" or "late" in the wave it belongs to. *EARLINESS* equals "3" if the IPO belongs to the latest batch of offerings, equals "0" if it falls into the earliest category, and "1" and "2" if in the middle. "*ORDER* / Median *ORDER*" is *ORDER* scaled by its median in the given wave; and "Log (*ORDER*)" is the logarithm of *ORDER*. The IPO characteristics include: IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; logarithm of firm's age at IPO date (number of years between the firm's founding year and the IPO year); and the reputation for underwriters.

Panel A: Number of IPOs in the sample

	Number of IPOs		
Year	Whole Sample	On-the-Wave	Off-the-Wave
1970-1979	189	71	118
1980-1989	1534	756	778
1990-1999	3304	2551	753
2000-2006	861	405	456
Total	6647	4180	2467

Panel B: Distribution of IPO waves across the Fama-French 49 industries

	Industry Name	Number of Waves	Percentage	Mean Number of IPOs in the Wave	Median Number of IPOs in the Wave	Std of IPO Volume in the Wave	Minimum Number of IPOs in the Wave	Maximum Number of IPOs in the Wave
1st	Electronic Equipment	16	7.51	24.7	9.5	26.3	6	81
2nd	Wholesale	16	7.51	14.7	15.0	9.7	5	46
3rd	Computers (Hardware)	15	7.04	13.6	10.0	12.8	5	49
4th	Retail	14	6.57	27.5	23.5	18.3	8	71
5th	Medical Equipment	13	6.10	14.9	8.0	16.3	5	63
Rest		139	65.26	20.7	10.0	40.3	5	334
Total		213	100	20.1	10.0	34.2	5	334

Panel C: The five largest IPO waves in the sample

	Industry Name	Number of IPOs	Beginning Month of Wave	Ending Month of Wave	Mean No. of IPOs per month	Median No. of IPOs per month	Std of IPO Volume across month	Minimum No. of IPOs per month	Maximum No. of IPOs per month
1st	Computer Software	334	Oct., 1994	Aug., 1998	9.0	9	3.9	0*	18
2nd	Computer Software	278	Nov., 1998	Nov., 2000	15.2	15	6.2	1	27
3rd	Business Services	185	Jun., 1995	Aug., 1998	6.0	6	2.3	0**	10
4th	Business Services	104	Feb., 1999	Aug., 2000	7.2	6	3.2	1	13
5th	Electronic Equipment	81	Apr., 1999	Nov., 2000	5.5	6	2.9	1	11

* The only month that has zero IPOs in the wave is Nov., 1994.
** The only month that has zero IPOs in the wave is Jan., 1998

Panel D: Summary statistics for measures of Industry IPO clusteredness and the order of going public in a wave

	Measure	No. of Obs.	Mean	Median	Std	Min	Max
Industry Clusteredness	*IPONUM*	6647	8.0	5.0	10.1	1.0	72.0
	IPONUM/Same Industry Vol. (%)	6647	2.3	1.8	2.0	0.1	40.0
	IPONUM/Same Window Vol. (%)	6647	8.2	5.5	8.2	0.5	100.0
Order in a Wave	*ORDER* / Median *ORDER* (%)	4180	99.9	100.0	55.1	1.2	199.4
	Log (*ORDER*) (multiplied by 100)	4180	286.1	270.8	128.5	69.3	581.4
	EARLINESS	Category	Number	Percentage			
		0	972	23.25			
		1	1174	28.09			
		2	1055	25.24			
		3	979	23.42			
		Total	4180	100			

Panel E: Summary statistics for IPO characteristics

Measure	No. of Obs.	Mean	Median	Std	Min	Max
Offer Price ($)	6647	12.1	12.0	5.7	5.0	189.6
Initial Return (%)	4182	25.6	11.4	50.0	-96.0	697.5
IPO proceeds ($ million)	6646	54.5	24.0	173.2	0.3	7322.4
Secondary Shares (%)	6646	14.5	0.0	22.8	0.0	100.0
Firm Age at IPO Date (Years)	5455	13.6	7.0	18.5	0.0	165.0
Underwriter Reputation (0-9.1)	5442	7.2	8.1	2.2	0.0	9.1
Dummy for VC backing (Yes=1)	Category	Number	Percentage			
	0	4008	60.3			
	1	2639	39.7			
	Total	6647	100			

Table 2: Univariate Analysis of Post-IPO Operating Performance, Industry IPO Clusteredness, and the Order of Going Public in a Wave

This table presents mean and median of post-IPO operating performance in various ranges of the three measures of industry IPO clusteredness and the three measures of the order of going public within an IPO wave. The post-IPO operating performance measure is defined as the return on assets (*ROA*) for the first fiscal year after the IPO date (COMPUSTAT DATA13/DATA6). The three industry IPO clusteredness measures and the three measures for the order of going public within an IPO wave are defined as in Table 1. T-test is the two-sample t-test for the equality of means assuming unequal variance. Wilcoxon Ranksum test is a nonparametric test for the equality of means. The Median test is a nonparametric test for the equality of medians. T-statistics for the t-test, z-statistics for the Wilcoxon Ranksum test, and Pearson Chi-squared statistic for the Median test are reported with p-values in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Mean ROA in different ranges of measures for industry IPO clusteredness and the order of going public in a wave

		Mean ROA (%)						
		Range*				Difference	T-test	Wilcoxon
	Measure	0%-25% (1)	25%-50% (2)	50%-75% (3)	75%-100% (4)	(1)-(4)	t-statistic (p-value)	z-statistic (p-value)
Industry Clusteredness	*IPONUM*	12.1	9.1	4.7	-3.0	15.1	15.9***(0.00)	17.0***(0.00)
	IPONUM/Same Industry Vol.	8.6	5.7	5.2	0.5	8.1	9.4***(0.00)	10.4***(0.00)
	IPONUM/Same Window Vol.	11.0	6.6	5.9	-3.2	14.2	16.8***(0.00)	16.9***(0.00)
Order in a Wave	*EARLINESS*	4.1	2.2	2.1	-0.7	4.8	4.2***(0.00)	2.7***(0.01)
	ORDER / Median *ORDER*	4.1	1.6	2.5	-0.5	4.6	4.1***(0.00)	2.6***(0.01)
	Log (*ORDER*)	8.4	5.3	0.7	-5.6	14.0	13.2***(0.00)	13.1***(0.00)

Panel B: Median ROA in different ranges of measures for industry IPO clusteredness and the order of going public in a wave

		Median ROA (%)					
		Range*				Difference	Median Test
	Measure	0%-25% (1)	25%-50% (2)	50%-75% (3)	75%-100% (4)	(1)-(4)	Pearson Chi-2 (p-value)
Industry Clusteredness	*IPONUM*	15.9	13.2	10.9	4.1	11.8	253.2***(0.00)
	IPONUM/Same Industry Vol.	13.4	12.3	11.1	7.0	6.4	97.3***(0.00)
	IPONUM/Same Window Vol.	14.1	11.9	11.9	3.5	10.6	238.4***(0.00)
Order in a Wave	*EARLINESS*	10.2	8.4	8.9	7.9	2.3	2.2 (0.14)
	ORDER / Median *ORDER*	10.0	8.0	8.9	8.5	1.5	1.8 (0.18)
	Log (*ORDER*)	12.7	10.7	8.0	1.7	11.0	129.3***(0.00)

* Note: for *EARLINESS*, the four ranges represent “0”, “1”, “2”, and “3”, respectively.

Table 3: Post-IPO Operating Performance and Industry Clusteredness of IPOs

This table presents OLS regressions of post-IPO operating performance on three measures of industry IPO clusteredness ("hotness" of the IPO market) and other firm-level characteristics. The post-IPO operating performance measure is defined as the return on assets (*ROA*) for the first fiscal year after the IPO date (COMPUSTAT DATA13/DATA6). The three industry IPO clusteredness measures are defined as in Table 1: Panel A uses the total number of IPOs in the same Fama-French 49 industry within the 90-day window symmetrically surrounding each IPO issuance date (*IPONUM*); Panel B uses *IPONUM* scaled by the total number of IPOs in the same FF-49 industry during the whole sample period; and Panel C presents results with regards to *IPONUM* scaled by the total number of IPOs in all FF-49 industries during the same 90-day window used to calculate *IPONUM*. The other independent variables include: logarithm of firm's market capital (DATA199*DATA25) at the first fiscal year end after the IPO; IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; firms' market share within the FF-49 industries based on all Compustat firms' net sales (DATA12); percentage of shares owned by institutional investors right after the IPO; logarithm of firm's age at IPO date (number of years between the firm's founding year and the IPO year); capital expenditure scaled by firm's net property, plant, and equipment (DATA128/DATA8); research & development expenses scaled by total net assets (DATA46/DATA6); and the reputation for underwriters. All models control for industry (FF-49 level) and IPO-year fixed effect. All standard errors are robust to industry clustering. Heteroskedasticity-robust *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Industry IPO clusteredness as measured by *IPONUM*, the total number of IPOs in the same industry within the 90-day window symmetrically surrounding each IPO issuance date

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
IPONUM	-0.0022***	-0.0022***	-0.0016***	-0.0016***
	(-4.92)	(-4.94)	(-4.12)	(-4.16)
Log (market cap)	0.0582***	0.0583***	0.0618***	0.0579***
	(6.03)	(6.03)	(9.21)	(8.61)
Offer Price	0.0050***	0.0050***	0.0038***	0.0033**
	(4.68)	(4.69)	(3.25)	(2.59)
Dummy for VC backing	-0.0523***	-0.0529***	-0.0170	-0.0254**
	(-3.92)	(-3.97)	(-1.53)	(-2.41)
Initial Return (percent)	-0.0006***	-0.0006***	-0.0004***	-0.0004***
	(-8.83)	(-8.81)	(-5.09)	(-4.89)
Log (IPO proceeds)	-0.0348***	-0.0334***	-0.0662***	-0.0747***
	(-3.51)	(-3.37)	(-7.23)	(-7.72)
Percent of Secondary Shares	0.2284***	0.2273***	0.2065***	0.2032***
	(8.22)	(8.15)	(7.72)	(7.14)
Market share		-0.4604*	-0.3843	-0.2182
		(-1.71)	(-1.67)	(-1.00)
Percent of Institutional Holding			0.1126***	0.1165***
			(5.25)	(5.83)
Log (firm age at IPO date)			0.0318***	0.0317***
			(5.61)	(5.58)
CapEx/PPE			-0.0609***	-0.0618***
			(-5.05)	(-4.76)
R&D/Assets			-1.0544***	-1.0463***
			(-8.82)	(-8.84)
Underwriter Reputation				0.0095***
				(4.93)
Constant	-0.1125***	-0.0825***	-0.0667*	-0.0795**
	(-4.25)	(-2.77)	(-1.79)	(-2.15)
Observations	4003	4003	3419	3259
R-squared	0.414	0.414	0.563	0.556

Panel B: Industry IPO clusteredness as measured by *IPONUM* scaled by the total number of IPOs in the same industry during the whole sample period

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
IPONUM/Same Industry Vol.	-0.6662***	-0.6859***	-0.6560***	-0.6741***
	(-3.00)	(-3.07)	(-2.95)	(-3.09)
Log (market cap)	0.0572***	0.0574***	0.0611***	0.0573***
	(5.98)	(5.99)	(9.18)	(8.58)
Offer Price	0.0050***	0.0050***	0.0038***	0.0033**
	(4.60)	(4.61)	(3.20)	(2.56)
Dummy for VC backing	-0.0548***	-0.0554***	-0.0186	-0.0270**
	(-4.07)	(-4.13)	(-1.67)	(-2.56)
Initial Return (percent)	-0.0006***	-0.0006***	-0.0004***	-0.0004***
	(-8.63)	(-8.62)	(-5.27)	(-5.05)
Log (IPO proceeds)	-0.0336***	-0.0321***	-0.0650***	-0.0732***
	(-3.44)	(-3.29)	(-7.31)	(-7.68)
Percent of Secondary Shares	0.2272***	0.2260***	0.2061***	0.2031***
	(7.97)	(7.89)	(7.57)	(7.00)
Market share		-0.4848*	-0.4088*	-0.2513
		(-1.77)	(-1.69)	(-1.08)
Percent of Institutional Holding			0.1150***	0.1196***
			(5.29)	(5.91)
Log (firm age at IPO date)			0.0314***	0.0312***
			(5.70)	(5.64)
CapEx/PPE			-0.0627***	-0.0638***
			(-5.26)	(-4.96)
R&D/Assets			-1.0612***	-1.0528***
			(-8.98)	(-8.98)
Underwriter Reputation				0.0092***
				(4.81)
Constant	-0.0921***	-0.0597**	-0.0483	-0.0595*
	(-4.06)	(-2.22)	(-1.39)	(-1.72)
Observations	4003	4003	3419	3259
R-squared	0.411	0.411	0.562	0.555

Panel C: Industry IPO clusteredness as measured by *IPONUM* scaled by the total number of IPOs in all industries during the same 90-day window

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
IPONUM/Same Window Vol.	-0.3359***	-0.3377***	-0.2390***	-0.2340***
	(-4.80)	(-4.83)	(-4.84)	(-4.72)
Log (market cap)	0.0582***	0.0584***	0.0617***	0.0579***
	(6.02)	(6.03)	(9.23)	(8.64)
Offer Price	0.0050***	0.0050***	0.0038***	0.0034**
	(4.71)	(4.72)	(3.19)	(2.56)
Dummy for VC backing	-0.0519***	-0.0525***	-0.0173	-0.0256**
	(-3.98)	(-4.03)	(-1.58)	(-2.48)
Initial Return (percent)	-0.0005***	-0.0006***	-0.0004***	-0.0004***
	(-8.96)	(-8.95)	(-4.99)	(-4.80)
Log (IPO proceeds)	-0.0353***	-0.0339***	-0.0665***	-0.0749***
	(-3.56)	(-3.42)	(-7.19)	(-7.71)
Percent of Secondary Shares	0.2279***	0.2267***	0.2059***	0.2025***
	(8.17)	(8.10)	(7.62)	(7.04)
Market share		-0.4686*	-0.3837	-0.2185
		(-1.69)	(-1.65)	(-1.00)
Percent of Institutional Holding			0.1136***	0.1176***
			(5.37)	(6.00)

Log (firm age at IPO date)			0.0316***	0.0315***
			(5.66)	(5.62)
CapEx/PPE			-0.0605***	-0.0614***
			(-5.03)	(-4.71)
R&D/Assets			-1.0474***	-1.0394***
			(-8.86)	(-8.88)
Underwriter Reputation				0.0094***
				(5.01)
Constant	-0.1108***	-0.0802**	-0.0634*	-0.0768**
	(-4.23)	(-2.69)	(-1.71)	(-2.11)
Observations	4003	4003	3419	3259
R-squared	0.416	0.417	0.564	0.557

Table 4: Post-IPO Operating Performance and the Order of Going Public in an IPO Wave

This table presents OLS regressions of post-IPO operating performance on three measures of an IPO's order within a given hot issuing period (an IPO wave) and other firm-level characteristics. The post-IPO operating performance measure is defined as the return on assets (*ROA*) for the first fiscal year after the IPO date (COMPUSTAT DATA13/DATA6). The three measures for the order of going public within an IPO wave are defined as in Table 1: Panel A uses the dummy variable (*EARLINESS*) to denote whether an IPO takes place "early" or "late" in the wave it belongs to. Panel B uses *ORDER* scaled by its median in the given wave; and Panel C uses the logarithm of *ORDER*. Other independent variables include: logarithm of firm's market capital (DATA199*DATA25) at the first fiscal year end after the IPO; IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; firms' market share within the FF-49 industries based on all Compustat firms' net sales (DATA12); percentage of shares owned by institutional investors right after the IPO; logarithm of firm's age at IPO date (number of years between the firm's founding year and the IPO year); capital expenditure scaled by firm's net property, plant, and equipment (DATA128/DATA8); research & development expenses scaled by total net assets (DATA46/DATA6); and the reputation for underwriters. All models control for industry (FF-49 level) and IPO-year fixed effect. All standard errors are robust to industry clustering. Heteroskedasticity-robust *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Panel A: The order of going public in a wave as measured by *EARLINESS*, a dummy variable whose larger integer values denote "lateness" in the wave

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
EARLINESS	-0.0078*	-0.0076*	-0.0075**	-0.0076**
	(-1.83)	(-1.78)	(-2.51)	(-2.40)
Log (market cap)	0.0528***	0.0530***	0.0590***	0.0543***
	(5.01)	(5.02)	(8.91)	(8.20)
Offer Price	0.0050***	0.0049***	0.0039**	0.0035**
	(3.90)	(3.89)	(2.47)	(2.13)
Dummy for VC backing	-0.0664***	-0.0669***	-0.0291**	-0.0373***
	(-5.09)	(-5.15)	(-2.66)	(-3.51)
Initial Return (percent)	-0.0004***	-0.0004***	-0.0003***	-0.0003***
	(-5.22)	(-5.19)	(-3.64)	(-3.42)
Log (IPO proceeds)	-0.0310**	-0.0299**	-0.0699***	-0.0815***
	(-2.56)	(-2.45)	(-6.01)	(-6.90)
Percent of Secondary Shares	0.2687***	0.2681***	0.2357***	0.2367***
	(7.39)	(7.38)	(6.98)	(7.19)
Market share		-0.6038	-0.0130	0.2956
		(-1.08)	(-0.023)	(0.51)
Percent of Institutional Holding			0.1449***	0.1392***
			(4.68)	(4.37)
Log (firm age at IPO date)			0.0321***	0.0316***
			(5.41)	(5.33)
CapEx/PPE			-0.0814***	-0.0827***
			(-5.99)	(-5.76)
R&D/Assets			-1.0630***	-1.0647***
			(-8.81)	(-8.82)
Underwriter Reputation				0.0111***
				(4.85)
Constant	-0.1261***	-0.1282***	0.0340	-0.1616**
	(-2.88)	(-2.95)	(0.77)	(-2.69)
Observations	2736	2736	2366	2321
R-squared	0.431	0.431	0.586	0.581

Panel B: The order of going public in a wave as measured by *ORDER* scaled by its median in the same wave

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
ORDER / Median *ORDER*	-0.0190***	-0.0186**	-0.0157***	-0.0160**
	(-2.78)	(-2.72)	(-2.89)	(-2.71)
Log (market cap)	0.0529***	0.0531***	0.0591***	0.0544***
	(5.02)	(5.03)	(8.93)	(8.21)
Offer Price	0.0049***	0.0049***	0.0039**	0.0035**
	(3.86)	(3.85)	(2.47)	(2.12)
Dummy for VC backing	-0.0665***	-0.0670***	-0.0292**	-0.0374***
	(-5.12)	(-5.18)	(-2.67)	(-3.52)
Initial Return (percent)	-0.0004***	-0.0004***	-0.0003***	-0.0003***
	(-5.26)	(-5.23)	(-3.67)	(-3.45)
Log (IPO proceeds)	-0.0312**	-0.0301**	-0.0700***	-0.0817***
	(-2.57)	(-2.47)	(-6.05)	(-6.93)
Percent of Secondary Shares	0.2682***	0.2676***	0.2355***	0.2365***
	(7.43)	(7.42)	(7.00)	(7.22)
Market share		-0.5995	-0.0168	0.2926
		(-1.08)	(-0.029)	(0.50)
Percent of Institutional Holding			0.1448***	0.1391***
			(4.67)	(4.36)
Log (firm age at IPO date)			0.0321***	0.0315***
			(5.38)	(5.30)
CapEx/PPE			-0.0816***	-0.0829***
			(-6.01)	(-5.78)
R&D/Assets			-1.0627***	-1.0644***
			(-8.76)	(-8.76)
Underwriter Reputation				0.0111***
				(4.84)
Constant	-0.1228***	-0.1249***	0.0362	-0.1550**
	(-2.81)	(-2.88)	(0.83)	(-2.61)
Observations	2736	2736	2366	2321
R-squared	0.431	0.432	0.586	0.581

Panel C: The order of going public in a wave as measured by the logarithm of *ORDER*.

Dependent Variable:	ROA			
	(1)	(2)	(3)	(4)
Log (*ORDER*)	-0.0156***	-0.0155***	-0.0083***	-0.0086***
	(-5.38)	(-5.38)	(-2.90)	(-3.00)
Log (market cap)	0.0526***	0.0527***	0.0589***	0.0542***
	(4.85)	(4.86)	(8.73)	(8.07)
Offer Price	0.0050***	0.0050***	0.0040**	0.0036**
	(3.95)	(3.94)	(2.61)	(2.25)
Dummy for VC backing	-0.0650***	-0.0655***	-0.0288**	-0.0370***
	(-5.02)	(-5.08)	(-2.61)	(-3.46)
Initial Return (percent)	-0.0004***	-0.0004***	-0.0003***	-0.0003***
	(-5.07)	(-5.04)	(-3.55)	(-3.32)
Log (IPO proceeds)	-0.0314**	-0.0301**	-0.0702***	-0.0818***
	(-2.55)	(-2.43)	(-6.05)	(-6.90)
Percent of Secondary Shares	0.2722***	0.2715***	0.2374***	0.2382***
	(7.60)	(7.60)	(7.11)	(7.32)
Market share		-0.6539	-0.0684	0.2398
		(-1.20)	(-0.12)	(0.41)
Percent of Institutional Holding			0.1453***	0.1396***
			(4.73)	(4.42)

Log (firm age at IPO date)			0.0324***	0.0318***
			(5.42)	(5.34)
CapEx/PPE			-0.0799***	-0.0812***
			(-5.72)	(-5.52)
R&D/Assets			-1.0529***	-1.0539***
			(-8.70)	(-8.71)
Underwriter Reputation				0.0111***
				(4.90)
Constant	-0.0761**	-0.0788**	0.0391	-0.1592**
	(-2.07)	(-2.16)	(0.87)	(-2.61)
Observations	2736	2736	2366	2321
R-squared	0.434	0.434	0.586	0.581

Table 5: Post-IPO Cash Balance, Industry Clusteredness of IPOs, and the Order of IPO in a Wave

This table presents OLS regressions of post-IPO cash balance on the three measures of industry IPO clusteredness and the three measures of the order of going public within an IPO wave. The post-IPO cash balance is measured in two ways: Panel A uses the increase in cash and cash equivalents scaled by total net assets (DATA274/DATA6) as the dependent variable; and Panel B uses cash and short-term investments scaled by total net assets (DATA1/DATA6). The three industry IPO clusteredness measures and the three measures for the order of going public within an IPO wave are defined as in Table 1. The other independent variables include: logarithm of firm's market capital (DATA199*DATA25) at the first fiscal year end after the IPO; IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; firms' market share within the FF-49 industries based on all Compustat firms' net sales (DATA12); percentage of shares owned by institutional investors right after the IPO; logarithm of firm's age at IPO date (number of years between the firm's founding year and the IPO year); and the reputation for underwriters. All models control for industry (FF-49 level) and IPO-year fixed effect. All standard errors are robust to industry clustering. Heteroskedasticity-robust *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Panel A: The increase in cash and cash equivalents after the IPO scaled by total net assets

Dependent Variable:	Increase in cash and cash equivalents after the IPO scaled by assets					
	(1)	(2)	(3)	(4)	(5)	(6)
IPONUM	0.0013*					
	(1.83)					
IPONUM/Same Industry Vol.		0.4190**				
		(2.12)				
IPONUM/Same Window Vol.			0.0319			
			(0.40)			
EARLINESS				0.0201***		
				(3.42)		
ORDER / Median *ORDER*					0.0387***	
					(3.53)	
Log (*ORDER*)						0.0182***
						(4.09)
Log (market cap)	0.0212***	0.0216***	0.0214***	0.0214***	0.0211***	0.0214***
	(5.56)	(5.52)	(5.41)	(4.88)	(4.82)	(5.02)
Offer Price	0.0020**	0.0020**	0.0021**	0.0022	0.0021	0.0018
	(2.15)	(2.17)	(2.20)	(1.52)	(1.52)	(1.31)
Dummy for VC backing	0.0323***	0.0339***	0.0335***	0.0339***	0.0341***	0.0322***
	(3.65)	(3.94)	(3.81)	(3.21)	(3.23)	(3.10)
Initial Return (percent)	0.0003*	0.0003*	0.0003*	0.0002	0.0002	0.0002
	(1.73)	(1.71)	(1.75)	(1.19)	(1.21)	(1.15)
Log (IPO proceeds)	-0.0426***	-0.0436***	-0.0429***	-0.0423***	-0.0420***	-0.0412***
	(-6.09)	(-6.39)	(-6.15)	(-4.38)	(-4.36)	(-4.40)

Percent of Secondary Shares	0.0054	0.0060	0.0054	-0.0085	-0.0082	-0.0133
	(0.32)	(0.36)	(0.33)	(-0.37)	(-0.35)	(-0.60)
Market share	-0.5441	-0.5264	-0.5640	-1.7897***	-1.7628***	-1.6637***
	(-1.09)	(-1.05)	(-1.11)	(-3.91)	(-3.92)	(-3.77)
Percent of Institutional Holding	0.0083	0.0055	0.0058	0.0116	0.0116	0.0110
	(0.45)	(0.29)	(0.32)	(0.54)	(0.54)	(0.53)
Log (firm age at IPO date)	-0.0273***	-0.0271***	-0.0272***	-0.0173***	-0.0173***	-0.0178***
	(-6.54)	(-6.49)	(-6.48)	(-3.88)	(-3.86)	(-3.94)
Underwriter Reputation	-0.0134***	-0.0132***	-0.0132***	-0.0104***	-0.0104***	-0.0105***
	(-5.30)	(-5.26)	(-5.29)	(-3.58)	(-3.61)	(-3.52)
Constant	0.3419***	0.3316***	0.3464***	0.1936***	0.1832***	0.1970***
	(8.83)	(8.50)	(8.79)	(5.34)	(5.01)	(5.05)
Observations	3315	3315	3315	2362	2362	2362
R-squared	0.208	0.207	0.206	0.194	0.194	0.194

Panel B: The cash and short-term investments after the IPO scaled by total net assets

Dependent Variable:	Cash and short-term investments after the IPO scaled by assets					
	(1)	(2)	(3)	(4)	(5)	(6)
IPONUM	0.0021***					
	(2.93)					
IPONUM/Same Industry Vol.		0.8378***				
		(2.74)				
IPONUM/Same Window Vol.			0.1948**			
			(2.07)			
EARLINESS				0.0104		
				(1.37)		
ORDER / Median *ORDER*					0.0218	
					(1.60)	
Log (*ORDER*)						0.0220***
						(3.38)
Log (market cap)	0.0168***	0.0175***	0.0170***	0.0114*	0.0113*	0.0121*
	(2.82)	(2.92)	(2.84)	(1.75)	(1.74)	(1.83)
Offer Price	0.0043**	0.0043**	0.0043**	0.0044**	0.0044**	0.0042**
	(2.44)	(2.42)	(2.47)	(2.03)	(2.04)	(2.04)
Dummy for VC backing	0.0998***	0.1024***	0.1007***	0.1000***	0.1001***	0.0982***
	(8.27)	(8.65)	(8.29)	(8.19)	(8.20)	(7.96)
Initial Return (percent)	0.0004***	0.0004***	0.0004***	0.0003**	0.0003**	0.0003**
	(3.20)	(3.09)	(3.11)	(2.29)	(2.32)	(2.22)

Log (IPO proceeds)	-0.0637***	-0.0656***	-0.0636***	-0.0604***	-0.0603***	-0.0594***
	(-6.08)	(-6.67)	(-6.11)	(-3.96)	(-3.97)	(-3.91)
Percent of Secondary Shares	0.0005	0.0017	0.0010	-0.0084	-0.0081	-0.0125
	(0.019)	(0.063)	(0.037)	(-0.23)	(-0.23)	(-0.36)
Market share	-0.6013	-0.5579	-0.6163	-2.1010***	-2.0927***	-2.0575***
	(-0.95)	(-0.88)	(-0.97)	(-3.04)	(-3.03)	(-3.00)
Percent of Institutional Holding	-0.0734***	-0.0780***	-0.0758***	-0.0726**	-0.0724**	-0.0718**
	(-2.90)	(-3.08)	(-3.00)	(-2.19)	(-2.19)	(-2.16)
Log (firm age at IPO date)	-0.0453***	-0.0450***	-0.0451***	-0.0407***	-0.0406***	-0.0407***
	(-6.64)	(-6.65)	(-6.61)	(-5.91)	(-5.87)	(-5.86)
Underwriter Reputation	-0.0021	-0.0018	-0.0020	0.0030	0.0030	0.0025
	(-0.56)	(-0.49)	(-0.52)	(0.78)	(0.78)	(0.64)
Constant	0.4603***	0.4377***	0.4613***	0.4564***	0.4478***	0.4173***
	(8.72)	(8.26)	(8.68)	(8.23)	(7.94)	(7.73)
Observations	3315	3315	3315	2362	2362	2362
R-squared	0.481	0.479	0.479	0.475	0.475	0.479

Table 6: Industry Concentration, Post-IPO Operating Performance, Industry Clusteredness of IPOs, and the Order of IPO in a Wave

This table presents OLS regressions of post-IPO operating performance on industry concentration, the three measures of industry IPO clusteredness, the three measures of the order of going public within an IPO wave, and the interaction between concentration and IPO clusteredness and order measures. The post-IPO operating performance measure is defined as the return on assets (*ROA*) for the first fiscal year after the IPO date (COMPUSTAT DATA13/DATA6). Industry concentration is the Herfindahl-Hirschman Index (*HHI*) calculated based on all Compustat firms' post-IPO total net assets within a certain FF-49 industry. The three industry IPO clusteredness measures and the three measures for the order of going public within an IPO wave are defined as in Table 1. The other independent variables include: logarithm of firm's market capital (DATA199*DATA25) at the first fiscal year end after the IPO; IPO's offer price; a dummy variable showing whether the issuer is backed by venture capitalists (equals 1 if yes); the initial return of the IPO firm's stock (difference between the first closing price and the offer price, divided by the offer price); logarithm of total IPO proceeds; percentage of secondary shares sold in the IPO; firms' market share within the FF-49 industries based on all Compustat firms' net sales (DATA12); percentage of shares owned by institutional investors right after the IPO; logarithm of firm's age at IPO date (number of years between the firm's founding year and the IPO year); capital expenditure scaled by firm's net property, plant, and equipment (DATA128/DATA8); research & development expenses scaled by total net assets (DATA46/DATA6); and the reputation for underwriters. All models control for industry (FF-49 level) and IPO-year fixed effect. All standard errors are robust to industry clustering. Heteroskedasticity-robust *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Industry concentration and IPO clusteredness

Dependent Variable:	ROA		
	(1)	(2)	(3)
IPONUM	-0.0020***		
	(-3.33)		
Herfindahl Index * *IPONUM*	0.0064		
	(1.37)		
IPONUM/Same Industry Vol. (*IPONUM_1*)		-0.8502**	
		(-2.58)	
Herfindahl Index * *IPONUM_1*		1.5138	
		(1.07)	
IPONUM/Same Window Vol. (*IPONUM_2*)			-0.3086***
			(-4.49)
Herfindahl Index * *IPONUM_2*			1.1343***
			(3.02)
Herfindahl Index	-0.0730*	-0.0657	-0.0966**
	(-1.84)	(-0.92)	(-2.34)
Log (market cap)	0.0580***	0.0572***	0.0581***
	(8.60)	(8.56)	(8.61)
Offer Price	0.0033**	0.0033**	0.0034**
	(2.60)	(2.57)	(2.58)
Dummy for VC backing	-0.0253**	-0.0270**	-0.0258**
	(-2.44)	(-2.56)	(-2.50)
Initial Return (percent)	-0.0004***	-0.0004***	-0.0004***
	(-5.21)	(-5.01)	(-5.12)
Log (IPO proceeds)	-0.0748***	-0.0733***	-0.0752***
	(-7.76)	(-7.64)	(-7.73)
Percent of Secondary Shares	0.2019***	0.2028***	0.2012***
	(7.13)	(7.10)	(7.04)
Market share	-0.2280	-0.2478	-0.2374
	(-1.06)	(-1.09)	(-1.10)
Percent of Institutional Holding	0.1162***	0.1194***	0.1171***
	(5.95)	(6.02)	(6.13)
Log (firm age at IPO date)	0.0317***	0.0312***	0.0315***
	(5.56)	(5.63)	(5.61)

CapEx/PPE	-0.0623***	-0.0639***	-0.0618***
	(-4.81)	(-4.94)	(-4.75)
R&D/Assets	-1.0484***	-1.0527***	-1.0413***
	(-8.94)	(-9.03)	(-9.01)
Underwriter Reputation	0.0095***	0.0092***	0.0095***
	(4.96)	(4.82)	(5.11)
Constant	-0.0627*	-0.0476	-0.0557
	(-1.78)	(-1.59)	(-1.64)
Observations	3259	3259	3259
R-squared	0.556	0.555	0.557

Panel B: Industry concentration and the order of going public in an IPO wave

Dependent Variable:	ROA		
	(1)	(2)	(3)
EARLINESS	-0.0152***		
	(-3.62)		
Herfindahl Index * *EARLINESS*	0.0750***		
	(3.40)		
ORDER / Median *ORDER* (*ORDER_N*)		-0.0271***	
		(-3.46)	
Herfindahl Index * *ORDER_N*		0.1092**	
		(2.57)	
Log (*ORDER*)			-0.0143***
			(-2.91)
Herfindahl Index * Log (*ORDER*)			0.0633**
			(2.29)
Herfindahl Index	-0.1827***	-0.1809**	-0.2266***
	(-2.96)	(-2.50)	(-4.05)
Log (market cap)	0.0541***	0.0543***	0.0542***
	(8.13)	(8.17)	(7.96)
Offer Price	0.0034**	0.0034**	0.0037**
	(2.08)	(2.07)	(2.32)
Dummy for VC backing	-0.0373***	-0.0374***	-0.0370***
	(-3.54)	(-3.54)	(-3.48)
Initial Return (percent)	-0.0003***	-0.0003***	-0.0003***
	(-3.39)	(-3.40)	(-3.50)
Log (IPO proceeds)	-0.0808***	-0.0810***	-0.0818***
	(-6.90)	(-6.94)	(-6.96)
Percent of Secondary Shares	0.2380***	0.2376***	0.2384***
	(7.21)	(7.24)	(7.34)
Market share	0.2341	0.2381	0.1824
	(0.41)	(0.42)	(0.32)
Percent of Institutional Holding	0.1370***	0.1371***	0.1383***
	(4.26)	(4.26)	(4.38)
Log (firm age at IPO date)	0.0317***	0.0316***	0.0319***
	(5.33)	(5.28)	(5.33)
CapEx/PPE	-0.0825***	-0.0830***	-0.0818***
	(-5.78)	(-5.81)	(-5.60)
R&D/Assets	-1.0615***	-1.0619***	-1.0519***
	(-8.96)	(-8.85)	(-8.79)
Underwriter Reputation	0.0110***	0.0110***	0.0112***
	(4.90)	(4.85)	(4.97)
Constant	-0.1461**	-0.1400**	-0.1438**
	(-2.46)	(-2.40)	(-2.31)
Observations	2321	2321	2321
R-squared	0.582	0.582	0.582