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Do Underwriters Compete in IPO Pricing?

Fangjian FU
Singapore Management University, fjfu@smu.edu.sg

Evgeny Lyandres
Boston University

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Fangjian Fu[†], Evgeny Lyandres[‡]

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Abstract

We propose and implement, for the first time, a direct test of the hypothesis of oligopolistic competition in the U.S. underwriting market against the alternative of implicit collusion in IPO price setting. We construct two models of an IPO underwriting market: in the first one IPO underwriters set their fees competitively, while in the second one they coordinate (collude) in setting fees. The two models lead to different equilibrium relations between market shares and compensation of underwriters of different quality on one hand, and the state of the IPO market on the other hand. We use 39 years' worth U.S. IPO data to examine which of the two models is better aligned with the data. Our empirical results are generally consistent with the implicit collusion hypothesis – underwriters, especially the larger ones, do not seem to always engage in price competition for underwriting business.

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†Singapore Management University, fjfu@smu.edu.sg.

‡Boston University and IDC, lyandres @bu.edu.

1 Introduction

In this paper we propose and implement a direct test of the hypothesis of implicit collusion among underwriters of U.S. initial public offerings (IPOs) against the alternative of oligopolistic competition among them. Our goal is to contribute to the debate regarding the competitive environment of the underwriting market in the U.S.

The U.S. IPO underwriting market is highly profitable. IPO gross spreads, most of which cluster at 7%, seem high in absolute terms and are high relative to other countries (e.g., Chen and Ritter (2000), Torstila (2003), Abrahamson, Jenkinson and Jones (2011), and Kang and Lowery (2014)). In addition, returns on IPO stocks on the first day of trading (i.e. IPO underpricing) tend to be even higher (e.g., Ritter and Welch (2002), Aggarwal, Prabhala and Puri (2002), Ljungqvist and Wilhelm (2003), Loughran and Ritter (2004), and Liu and Ritter (2011)). Underwriters are likely to be rewarded by investors who benefit from this money left on the table, in the form of "soft dollars", for example, abnormally high trading commissions (e.g., Reuter (2006), Loughran and Ritter (2004), Nimalendran, Ritter and Zhang (2007), and Goldstein, Irvine and Puckett (2011)), spinning (e.g., Liu and Ritter (2010)), and other forms of kickbacks.

There is an ongoing debate as to whether the high profitability of the U.S. IPO underwriting market is suggestive of implicit collusion in price setting among underwriters or, alternatively, consistent with efficient contracting and competition among underwriters. On one side of the debate, Chen and Ritter (2000) show that IPO underwriting spreads in the U.S. cluster at an exact 7% and argue that the U.S. IPO underwriting market is likely to be characterized by "strategic price setting"(i.e. implicit collusion). Similarly, Abrahamson, Jenkinson and Jones (2011) find no evidence that the high gross spreads in the U.S. can be justified by non-collusive reasons – such as legal expenses, retail distribution costs, litigation risk, high cost of research analysts, and the possibility that higher fees may be offset by lower underpricing – and also attribute the high profitability of IPO underwriting in the U.S. to implicit collusion. Kang and Lowery (2014) estimate a structural model of IPO pricing and conclude that the observed underwriting spreads and underpricing are consistent with underwriter collusion with imperfect information.

On the other side of the debate, Hansen (2001) finds that the U.S. IPO underwriting market is characterized by low concentration and high degree of entry, that IPO spreads did not decline following the SEC announcements of allegations of collusion, and that the average spread in IPOs that do not belong to the 7% cluster is higher than 7%. He interprets this and other evidence as supporting the competition hypothesis. This interpretation is consistent with investment banks competing for IPO underwriting business on dimensions other than pricing, for example, underwriter prestige (e.g., Beatty and Ritter (1986), Carter and Manaster (1990), and Chemmanur and Fulghieri (1994)), providing analyst coverage and investment recommendations (e.g., Dunbar (2000), Krigman, Shaw and Womack (2001), Cliff and Denis (2004), and Liu and Ritter (2011)), and aftermarket price support (e.g., Ellis, Michaely, and O'Hara (2000) and Lewellen (2006)).

In this paper we attempt to contribute to this debate by proposing and implementing a new test of the hypotheses of competition/implicit collusion in prices in the U.S. IPO underwriting market. Our test is based on a "horse race" between the two hypotheses and does not favor any of them ex-ante. Our strategy consists of two steps. In the first step, we construct two models of the underwriting market. In the first one, characterized by oligopolistic competition, we assume that each underwriter sets the price for its services with the objective of maximizing its own expected profit, while taking into account the optimal responses of other underwriters. In the second model, characterized by implicit collusion, we assume that underwriters cooperate in price setting, i.e. they choose underwriting fees that maximize their joint expected profit. In constructing these models we are agnostic ex-ante regarding the structure of the market. It is important to note that our term "implicit collusion" refers to lack of price competition and does not preclude the possibility that underwriters compete for IPO business via other channels such as providing (star) analyst coverage and/or aftermarket price support, getting access to favorable investor clientele, etc.

Both models yield equilibrium relations between market shares and absolute and proportional fees of higher-quality and lower-quality underwriters on one hand and the state of the IPO market (i.e. firms' demand for IPOs) on the other hand. The comparative statics of the oligopolistic competition model are, in many cases, different from those of the implicit collusion model. These differences in comparative statics allow us to test the two hypotheses in a "horse race" framework.

Our second step is to employ U.S. IPO data during the period 1975 – 2013 to test the two models' predictions. We compute measures of direct and indirect compensation of underwriters for their services, underwriters' market shares, and the state of the IPO market. We then examine which of the two models fits the data better. Our exercise is in the spirit of Rotemberg and Woodford (1992), who solve an industry equilibrium model under the collusion scenario and, alternatively, under the competitive scenario, and examine empirically which of the two settings fits more closely the effects on the economy of U.S. military spending.

Our models feature investment banks of heterogenous quality that provide underwriting services to heterogeneous firms: Higher-quality underwriters provide higher value-added to firms whose IPOs they underwrite. Providing underwriting services entails increasing marginal costs. Firms choose whether to go public or stay private and, in case they decide to go public, which underwriter to employ for their IPO, with the objective of maximizing the benefits of being public net of IPO costs. The resulting equilibrium outcome is an assortative matching of firms and underwriters – higher-quality underwriters charge higher fees, firms with relatively high valuations employ higher-quality underwriters, medium-valued firms are taken public by lower-quality underwriters, and low-valued firms stay private, since for them the costs of going public outweigh the benefits of public incorporation.

The models' main comparative statics are as follows. First, in the competitive setting, in which each bank maximizes its own expected profit, the relation between the higher-quality underwriters' market share and the state of the IPO market depends on the degree of heterogeneity among underwriters. When underwriter qualities are similar, the relation is negative because the competition resembles a Bertrand competition in nearly homogeneous goods. With increasing marginal costs of underwriting, higher-quality banks capture most of cold markets, in which marginal costs are relatively flat, but a lower share of hot markets, in which marginal costs are relatively steep. When underwriter qualities are sufficiently different, the relation between the higher-quality underwriters' market share and the state of the IPO market becomes positive. This is because lower-quality underwriters are forced to set very low fees in cold markets in order to get business and end up underwriting relatively many (low-valued) IPOs. The incentive to set low underwriting fees diminishes in hot IPO markets due to the increasing marginal costs of underwriting, which leads to higher market share of higher-quality banks in hot markets.

In the collusive setting – in which underwriters maximize their joint expected profit – the market share of higher-quality underwriters is predicted to be decreasing in the state of the IPO market. This is because when underwriters coordinate their pricing strategies, in cold markets, in which marginal costs of underwriting are low, banks prefer to channel more IPOs to higher-quality underwriters, which can justify charging higher fees. In hot markets, both higher-quality and lower-quality underwriters get IPO business. The increasing marginal costs of providing underwriting services result in higher-quality banks reaching their capacity and firms turning to lower-quality banks for IPO services.

Second, in the competitive scenario, the ratio of equilibrium dollar compensation received by higher-quality underwriters to that received by lower-quality underwriters is predicted to be decreasing in the state of the IPO market. The reason is related to the one discussed above: In cold markets, lower-quality underwriters have to set fees that are significantly lower than those of higher-quality underwriters to get some share of the underwriting business. This relative difference declines, however, as the state of the IPO market improves.

The relation between the ratio of fees charged by higher-quality banks to those charged by lower-quality banks and the state of the IPO market is shown to be hump-shaped in the collusive scenario, because in cold markets, joint profit is maximized by channelling most IPOs to the higher-quality banks. As argued above, this leads the colluding banks to set high fees of lower-quality banks relative to those of higher-quality ones. This pricing strategy effectively results in channeling most IPOs to the higher-quality banks. This channeling incentive gradually weakens as the state of the IPO market improves, because of the increasing marginal costs of underwriting. As the state of the underwriting market improves further, banks effectively become local monopolists, which leads to a negative relation between the state of the IPO market and the ratio of fees charged by higher-quality banks to those charged by lower-quality banks. The reasons are similar to those in the competitive scenario: In hot IPO markets, fees are determined mostly by the banks' value-added and not by strategic pricing.

Third, in the competitive scenario, the mean equilibrium proportional underwriter compensation (i.e. compensation relative to IPO proceeds) is predicted to be increasing in the state of the IPO market for both higher-quality and lower-quality underwriters, because in hot IPO markets, banks are more selective in the choice of IPO firms. This selectivity leads to higher average value of firms going public in hot markets, empowering underwriters to charge higher (direct and indirect) fees.

In the collusive setting, the relation between the mean proportional fees and the state of the market is positive for higher-quality banks, due to reasons similar to those in the competitive case. On the other hand, the relation is U-shaped for lower-quality underwriters. The reason for the decreasing part of the relation is that in cold IPO markets, banks are collectively better off channeling most IPOs to the higher-quality banks. This is achieved by the lower-quality banks setting relatively high fees in cold markets, which leads to the overall U-shaped relation between the lower-quality underwriters' proportional fees and the state of the IPO market.

Importantly, we demonstrate that our models' conclusions are robust to a conceivable situation in which only a subset of larger, more reputable underwriters consider coordinating IPO fees, while not colluding with smaller, fringe underwriters. Our model is robust to an inclusion of fringe underwriters because in equilibrium they do not end up competing fiercely with higher-quality underwriters. This is due to the assortative matching result, according to which better banks underwrite larger IPOs, leaving smaller, less profitable IPOs to lower-quality banks.

The vast majority of our empirical results are in line with the implicit collusion model, and are less consistent with the oligopolistic competition model. First, consistent with the collusive model and inconsistent with the competitive model, the mean proportional compensation of relatively low-quality underwriters exhibits a U-shaped relation with proxies for the state of the IPO market, both when we focus exclusively on the direct component of underwriter compensation, i.e. underwriting spread, and when we account for its potential indirect component, i.e. kickbacks to underwriters for underpricing IPOs.

Second, consistent with the collusive model and inconsistent with the competitive model, the relation between the ratio of higher-quality banks' compensation for underwriting services to that of lower-quality banks' compensation on one hand and proxies for the state of the IPO market on the other hand is clearly hump-shaped. In most specifications, this relation is significant economically and statistically.

Third, consistent with the collusive model and inconsistent with the competitive model, the share of IPOs underwritten by higher-quality banks is in general negatively related to proxies for the state of the IPO market, especially when underwriters are relatively heterogeneous in quality.

Fourth, the relations discussed above tend to be stronger when we restrict the sample to the largest, most reputable underwriters. This is consistent with implicit collusion being more plausible among large banks, which are less interested in coordinating prices with their fringe rivals.

The static nature of our model, coupled with time-series empirical predictions, is a potential limitation of our setting. In a dynamic setting, underwriters' incentives to collude may be time-varying. In particular, since the benefits of deviating from implicit collusion are higher when the (IPO) market is hot (e.g, Rotemberg and Saloner (1986) and Rotemberg and Woodford (1992)), it is possible that underwriters would implicitly collude in relatively cold IPO markets and compete in relatively hot markets. As the comparative statics of the collusive and competitive models differ mostly in relatively low states of the IPO market, our evidence can be interpreted as consistent with a dynamic setting in which underwriters tend to engage in implicit collusion in prices in relatively cold IPO markets.

To summarize, our paper's contribution is threefold. First, we propose a novel direct test of the hypothesis of oligopolistic competition in the U.S. IPO underwriting market against the alternative hypothesis of implicit collusion in setting IPO underwriting fees. This test is based on matching the directional predictions derived from two models – one in which underwriters compete in setting underwriting fees and one in which they set their fees cooperatively – to the relations observed in the data. Second, the empirical estimation of the models' predictions contributes to the debate regarding the structure of the U.S. IPO underwriting market. Our empirical results are more consistent with the hypothesis of implicit collusion in IPO underwriting fee setting. Our third contribution is theoretical: ours is among the first papers to model interaction among heterogeneous underwriters and to derive competitive and collusive equilibria in a simple industrial organization setting.

The paper procedes as follows. The next section presents the competitive and collusive models and derives two sets of empirical predictions that follow from the models. In Section 3 we conduct empirical tests of the two models' predictions. Section 4 concludes. Appendix A provides proofs of theoretical results. Appendices B and C contain extensions of the baseline model.

2 Model

In this section we first describe the general setup of the model, which features multiple banks and multiple firms that may use banks' underwriting services. Then, to simplify the exposition and highlight the intuition, we solve in closed form the most parsimonious version of the model with two restrictive assumptions. First, we assume that there are two heterogeneous underwriters. Second, we assume a fixed underwriting fee structure.

We provide two solutions to the model, corresponding to two distinct scenarios. The first is the competitive scenario, in which each underwriter sets its fee with the objective of maximizing its own expected profit while disregarding the effects of its choice on other underwriters' expected profits. The second is the collusive scenario, in which the two underwriters set their fees cooperatively, with the objective of maximizing their combined expected profit – i.e. they internalize the effects of each bank's fee on firms' demand for the other bank's underwriting services.

The model's solutions under these two scenarios allow us to derive comparative statics of underwriters' equilibrium market shares, absolute and proportional fees with respect to the state of the IPO market, and the degree of heterogeneity among underwriters for both competitive and collusive cases. We summarize the contrasting empirical predictions that follow from the comparative statics of the two models at the end of this section.

The assumptions of the simplified model are restrictive. First, in reality there are multiple underwriters. In Appendix B, therefore, we ensure that increasing the number of underwriters does not affect the models' qualitative conclusions. While it is possible to solve the model analytically for any number of underwriters, comparative statics become prohibitively algebra-intensive. Thus, we examine the robustness of the results in the baseline model by solving analytically the case of three underwriters.

In addition to the cases in which all underwriters collude or all of them compete, as in the baseline model, we examine the case of "partial collusion,"in which two highest-quality underwriters collude and they compete with the third underwriter. It is important to contrast the comparative statics under the competitive scenario with the "partial collusion" scenario, because it is possible that larger (higher-quality) underwriters collude among themselves but compete with smaller (lower-quality) underwriters.[1] In Appendix B, we verify by solving numerically the model that features three underwriters, that even if only the two highest-quality banks collude, the comparative statics of underwriting fees and market shares within the subset of the two highest-quality banks are similar to 1) those obtained in a model in which only two banks collude, and 2) those obtained in a model in which there

[1]Bain (1951) shows that it is easier to maintain collusion when the number of colluding firms is small. Barla (1998) demonstrates that it is harder to maintain tacit price coordination in the presence of large firm-size asymmetry.

are three underwriters, all of which coordinate fees.

Second, underwriting fees charged by a given bank are not constant and depend, among other factors, on IPO size. In the baseline model we assume, for analytical tractability, that the underwriters' only choice variable is their fixed underwriting fees. However, this assumption implies that the total fee paid by each firm to a given underwriter is independent of the size of its IPO. This implication is inconsistent with the empirical evidence that while the proportional underwriting fee decreases in IPO size, total fees paid in larger IPOs tend to be higher than those paid in smaller IPOs (e.g., Ritter (2000), Hansen (2001), and Torstila (2003)). Thus, in Appendix C we solve numerically a model in which we allow each of the two underwriters to choose not only its fixed fee but also its variable fee and show that the comparative statics are robust to this more realistic assumption.

2.1 General setup

Assume that there are N firms, which are initially private and are considering going public.[2] Firm i's pre-IPO value is denoted by V_i. Firms' pre-IPO values are assumed to be drawn from a uniform distribution with bounds equaling zero and one:

$$V_i \sim \mathbb{U}(0,1). \tag{1}$$

In what follows, we assume that all of the firms' shares are sold to the public and no new shares are issued. This assumption, which is common in the literature (e.g., Gomes (2000), Bitler, Moskowitz and Vissing-Jørgensen (2005), and Chod and Lyandres (2011)), does not drive any of the results, but allows us to equate firm value to IPO size.

Each firm may decide to go public or to stay private, and firms make these decisions simultaneously and non-cooperatively. We assume that going public increases firm value due to various reasons, such as subjecting a firm to outside monitoring (e.g., Holmström and Tirole (1993)), improving its liquidity (e.g., Amihud and Mendelson (1986)), lowering the costs of subsequent seasoned equity offerings (e.g., Derrien and Kecskés (2007)), improving the firm's mergers and acquisitions policy (e.g., Zingales (1995) and Hsieh, Lyandres, and Zhdanov (2010)), loosening financial constraints and providing financial intermediary certification and knowledge capital (e.g., Hsu, Reed, and Rocholl (2010)), and improving

[2] Similar to Chod and Lyandres (2011), and following a large body of industrial organization literature, we treat the total number of firms and the number of firms that decide to go public as continuous variables (see, for example, Ruffin (1971), Okuguchi (1973), Dixit and Stiglitz (1977), Loury (1979), von Weizsäcker (1980), and Mankiw and Whinston (1986)). See Suzumura and Kiyono (1987) for a discussion of the effect of departure from a continuous number of firms on equilibrium conditions. Seade (1980) justifies the practice of treating the number of firms as a continuous variable by arguing that it is always possible to use continuous differentiable variables and restrict attention to the integer realizations of these variables.

operating and investment decision making (e.g., Rothschild and Stiglitz (1971), Shah and Thakor (1988), and Chod and Lyandres (2011)).

Going and being public also entails costs. Two direct costs are the compensation to be paid to the IPO underwriter (i.e. IPO spread) and the money left on the table at the time of the IPO (i.e. IPO underpricing), part of which is argued to accrue to underwriters (e.g., Reuter (2006), Nimalendran, Ritter and Zhang (2006), and Goldstein, Irvine and Puckett (2011)). In what follows, we refer to all the (direct and indirect) compensation a bank receives in exchange for providing underwriting services as an underwriting fee (or IPO fee).[3] If firm i decides to go public using underwriter j, its post-IPO value equals

$$V_{i_{IPO}\text{-}j} = V_i(1+\alpha_j) - F_{i,j} = V_i(1+\alpha_j) - (\lambda_j + \mu_j V_i), \tag{2}$$

where α_j is bank j's "value-added" parameter, i.e. the (expected) proportional value increase following the IPO underwritten by bank j, and $F_{i,j}$ is the total compensation received by bank j for underwriting firm i's IPO.

Consistent with existing empirical evidence (e.g., Altinkiliç and Hansen (2000)), we assume that underwriter compensation has two components: a fixed fee, λ_j, which is identical for all firms underwritten by bank j, and a variable component, $\mu_j V_i$, which increases in the size of the firm going public. We assume that underwriters are potentially heterogeneous in their quality, i.e. in the value they add to the firms whose issues they underwrite. For example, higher-quality underwriters may have an advantage at marketing an issue through a road show, selling the issue to longer-term investors, stabilizing stock prices in the aftermarket, and providing analyst coverage of a newly issued stock. Empirically, underwriter quality is positively related to post-IPO long-run performance (e.g., Nanda, Yi and Yun (1995) and Carter, Dark and Singh (1998)). In our model, underwriter j is said to be of a "higher quality" than underwriter k if $\alpha_j > \alpha_k$.

An immediate result that follows from the assumed underwriter fee structure is that for all IPOs underwritten by a given bank, the *proportional* underwriting fee (i.e. total underwriting fee divided by the value of shares issued at IPO) is decreasing in the IPO size.

Lemma 1 *The relative underwriting fee for all IPOs underwritten by bank j, $\frac{\lambda_j+\mu_j V_i}{V_i(1+\alpha_j)}$, is decreasing in V_i.*

Lemma 1 is consistent with existing empirical evidence that the proportional underwriting fee is decreasing in IPO size, while the absolute fee is increasing in IPO size (e.g., Ritter (1987), Beatty and Welch (1996), and Torstila (2003)).

[3] There are additional, indirect costs of being public, such as the loss of private benefits of control (e.g., Benninga, Helmantel and Sarig (2005)) and the release of valuable information to competitors (e.g., Spiegel and Tookes (2009)).

Assume that there are K underwriters (banks), indexed B_1 through B_K. Each bank chooses the fixed and variable components of its fee, denoted λ_j and μ_j, respectively, for bank j. Assume, without loss of generality, that $\alpha_i \geq \alpha_j \ \nabla \ i < j$, i.e. that underwriters are sorted by quality from high to low. The banks face increasing marginal costs of providing underwriting services. This assumption is in line with Khanna, Noe and Sonti's (2008) model of an inelastic supply of labor in investment banking and is consistent with empirical estimates of the shape of underwriters' cost function (e.g., Altinkiliç and Hansen (2000)) and with empirical evidence in Lowry and Schwert (2002), who find that in hot IPO markets investment banks struggle to provide service to all firms interested in going public. In particular, we assume that for underwriter j, the total cost of underwriting n IPOs, $TC_{j,n}$, is

$$TC_{j,n} = cn^2. \tag{3}$$

The assumption that the total cost is quadratic and the marginal cost is linear in the number of IPOs underwritten by a bank simplifies the solution considerably, as it precludes any corner solutions in which a bank chooses not to underwrite any IPOs.

After observing the fees charged by all underwriters, each firm can pursue one of $K+1$ mutually exclusive strategies: it can remain private or it can perform an IPO underwritten by one of K banks. Firm i's maximized value, V_i^*, is thus

$$V = \sup\{V_i, \max_j (V_i(1+\alpha_j) - (\lambda_j + \mu_j V_i)\}. \tag{4}$$

As discussed above, in this section, we present an analytical solution of the model under two restrictive assumptions. First, we assume two underwriters: $K = 2$. Second, we assume that each bank charges a fixed underwriting fee (which may be different across banks), λ_j, but no variable component, $\mu_j = 0 \ \nabla \ j$. Appendix B presents a numerical solution of the model in which we relax the first assumption, while in Appendix C we relax the second assumption.

2.2 Two underwriters

In the case of two potentially heterogeneous underwriters (B_1 and B_2, $\alpha_1 \geq \alpha_2$) and zero variable underwriting fees ($\mu_1 = \mu_2 = 0$), it follows from (4) that each firm's optimal strategy can be summarized as follows:

Lemma 2 *Firm i's optimal strategy as a function of the two underwriters' value-added parameters,*

α_1 and α_2, and of their underwriting fees, λ_1 and λ_2, is to

$$\textit{remain private if } V_i \leq \min\left\{\frac{\lambda_1}{\alpha_1}, \frac{\lambda_2}{\alpha_2}\right\},$$
$$\textit{perform an IPO underwritten by } B_1 \textit{ if } V_i > \max\left\{\frac{\lambda_1}{\alpha_1}, \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2}\right\},$$
$$\textit{perform an IPO underwritten by } B_2 \textit{ if } V_i \in \left[\frac{\lambda_2}{\alpha_2}, \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2}\right].$$

As a result, depending on the fixed fees set by the two banks, the following situations are possible.
1) No IPOs. This happens if $\frac{\lambda_1}{\alpha_1} \geq 1$ and $\frac{\lambda_2}{\alpha_2} \geq 1$.
2) No IPOs underwritten by B_1. B_2 underwrites IPOs of firms with $V_i > \frac{\lambda_2}{\alpha_2}$. This happens if $\frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2} \geq 1$ and $\frac{\lambda_2}{\alpha_2} < 1$.
3) No IPOs underwritten by B_2. B_1 underwrites IPOs of firms with $V_i > \frac{\lambda_1}{\alpha_1}$. This happens if $\frac{\lambda_2}{\alpha_2} > \frac{\lambda_1}{\alpha_1}$ and $\frac{\lambda_1}{\alpha_1} < 1$.
4) B_2 underwrites IPOs of firms with $V_i \in (\frac{\lambda_2}{\alpha_2-\mu}, \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}]$. B_1 underwrites IPOs of firms with $V_i > \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}$. This happens if $\frac{\lambda_1}{\alpha_1-\mu} > \frac{\lambda_2}{\alpha_2-\mu}$ and $\frac{\lambda_1}{\alpha_1-\mu} < 1$.

The first case above is trivial. If the fixed fees charged by both banks are too high to induce even the highest-valued firm (which would benefit the most from an IPO) to go public, then no firm would choose to do so. In the second scenario, the higher-quality bank's (B_1) fee is too high; therefore even the most valuable firm, which could benefit the most from its IPO being underwritten by B_1 prefers to perform an IPO with the lower-quality bank (B_2) despite the lower value increase brought by B_2. In the third case, the benefit of an IPO with B_1 net of its underwriting fee exceeds the net benefit of IPO with B_2 even for the least valuable firm that would still benefit from an IPO with B_2. Therefore, all IPOs are underwritten by B_1. Finally, in the fourth case, both banks underwrite IPOs: B_1 underwrites IPOs of companies whose valuations are sufficiently high, so that the higher benefit of an IPO underwritten by B_1 outweighs its higher fee, while IPOs of firms with lower valuations (that are still sufficiently high to go through an IPO with B_2) are underwritten by B_2.

The next result establishes that in equilibrium, only the fourth scenario, in which both banks underwrite some IPOs, is possible.

Lemma 3 *In equilibrium, underwriters' fees, λ_1^* and λ_2^*, satisfy $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1} < 1$. Firms with values $V_i \leq \frac{\lambda_2^*}{\alpha_2}$ remain private. Firms with values $\frac{\lambda_2^*}{\alpha_2} < V_i \leq \frac{\lambda_1^*}{\alpha_1}$ go public and have their IPOs underwritten by B_2. Firms with values $V_i \geq \frac{\lambda_1^*}{\alpha_1}$ go public and have their IPOs underwritten by B_1.*

The intuition is simple. Since the marginal cost of underwriting the first IPO (i.e. the first "infinitesimal unit of IPO", since we treat the number of firms going public as a continuous variable) approaches zero, a bank would always prefer underwriting that first IPO at any fee greater than zero to underwriting no IPOs. Thus, in equilibrium both underwriters set fees in such a way that both get a positive share of the IPO underwriting market. Lowest-valued firms stay private, highest-valued firms' IPOs are underwritten by the higher-quality bank, while lower-valued firms' IPOs are underwritten by the lower-quality bank. This outcome is consistent with anecdotal evidence suggesting that more reputable underwriters tend to underwrite larger IPOs and with Fernando, Gatchev and Spindt's (2005) assortative matching model of firms and underwriters, in which firm quality and underwriter quality are positively correlated.

An immediate result that follows from Lemma 3 is that for a firm that is indifferent between its IPO underwritten by the two banks, the proportional fee of the higher-quality bank (B_1) is higher than that of the lower-quality bank (B_2):

Lemma 4 *If* $V_i = \frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha_2}$, $\frac{\lambda_1^*}{V_i(1+\alpha_1)} > \frac{\lambda_2^*}{V_i(1+\alpha_2)}$.

In other words, ceteris paribus, an IPO underwritten by a higher-quality bank commands higher proportional underwriting fee than an IPO underwritten by a lower-quality bank.

2.3 Equilibrium fees under competitive and collusive scenarios

2.3.1 Oligopolistic competition

Assume first that the underwriting market is competitive in the sense that each of the two banks sets its fixed fee simultaneously and non-cooperatively, with the objective of maximizing its own profit, π_j for bank j, while taking into account the optimal response of the rival bank. Using the result in Lemma 3, we can write bank j's optimization problem as

$$\pi_j = \max_{\lambda_j} \left(\lambda_j \left(N \left(\overline{V_j} - \underline{V_j} \right) \right) - c \left(N \left(\overline{V_j} - \underline{V_j} \right) \right)^2 \right), \tag{5}$$

$$\underline{V_1} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2} \text{ and } \overline{V_1} = 1, \tag{6}$$

$$\underline{V_2} = \frac{\lambda_2}{\alpha_2} \text{ and } \overline{V_2} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2}, \tag{7}$$

where the number of IPOs underwritten by bank j, $N\left(\overline{V_j} - \underline{V_j}\right)$, is determined by the two "indifference"thresholds: $\underline{V_1} = \overline{V_2}$ determines the marginal firm that is indifferent between having its IPO underwritten by bank 1 or bank 2, and $\underline{V_2}$ determines the marginal tim that is indifferent between having its IPO underwritten by bank 2 and staying private. Solving the system of two first-order conditions following from (5) results in equilibrium fee levels of each bank under the competitive scenario, λ_{jComp}^* for bank j:

$$\lambda^*_{1_{Comp}} = \frac{2\alpha_1(2cN+\alpha_1-\alpha_2)(cN\alpha_1+(\alpha_1-\alpha_2)\alpha_2)}{\Phi_{Comp}}, \tag{8}$$

$$\lambda^*_{2_{Comp}} = \frac{\alpha_2((2cN)^2\alpha_1+(\alpha_1-\alpha_2)^2\alpha_2+2cN(\alpha_1^2-\alpha_2^2))}{\Phi_{Comp}}, \tag{9}$$

$$\Phi_{Comp} = (2cN)^2\alpha_1+2cN(2\alpha_1^2+\alpha_1\alpha_2-\alpha_2^2)+\alpha_2(4\alpha_1^2-5\alpha_1\alpha_2+\alpha_2^2). \tag{10}$$

The resulting equilibrium number of IPOs underwritten by each of the two banks, $N^*_{1_{Comp}}$ and $N^*_{2_{Comp}}$, are

$$N^*_{1_{Comp}} = \frac{2\alpha_1 N(cN\alpha_1+(\alpha_1-\alpha_2)\alpha_2)}{\Phi_{Comp}}, \tag{11}$$

$$N^*_{2_{Comp}} = \frac{\alpha_1\alpha_2 N(2cN+\alpha_1-\alpha_2)}{\Phi_{Comp}}. \tag{12}$$

2.3.2 Implicit collusion

Assume now that the underwriting market is collusive in the sense that the two banks coordinate their fees, i.e. they set their fees with the objective of maximizing their combined profit, $\pi_{joint} = \pi_1 + \pi_2$. The banks' joint optimization problem is:

$$\pi_{joint} = \max_{\lambda_1,\lambda_2}\left(\sum_{j=1}^{2}\left(\lambda_j\left(N\left(\overline{V_j}-\underline{V_j}\right)\right)-c\left(N\left(\overline{V_j}-\underline{V_j}\right)\right)^2\right)\right), \tag{13}$$

where $\overline{V_j}$ and $\underline{V_j}$ for the two banks are given in (6) and (7), respectively. Solving the system of two first-order conditions that follow from (13) results in equilibrium fees under the collusive scenario, λ^*_{jColl} for bank j:

$$\lambda^*_{1_{Coll}} = \frac{2(cN)^2\alpha_1+\alpha_1\alpha_2(\alpha_1-\alpha_2)+cN(\alpha_1^2+2\alpha_1\alpha_2-\alpha_2^2)}{\Phi_{Coll}}, \tag{14}$$

$$\lambda^*_{2_{Coll}} = \frac{(2cN+\alpha_1-\alpha_2)\alpha_2(cN+\alpha_2)}{\Phi_{Coll}}, \tag{15}$$

$$\Phi_{Coll} = 2((cN)^2+\alpha_2(\alpha_1-\alpha_2)+cN(\alpha_1+\alpha_2)), \tag{16}$$

and the equilibrium number of IPOs underwritten by the two banks, $N^*_{1_{Coll}}$ and $N^*_{2_{Coll}}$,

$$N^*_{1_{Coll}} = \frac{2\alpha_1 N(cN\alpha_1+(\alpha_1-\alpha_2)\alpha_2)}{\Phi_{Coll}}, \tag{17}$$

$$N^*_{2_{Coll}} = \frac{cN^2\alpha_2}{\Phi_{Coll}}. \tag{18}$$

The first intuitive result is that the number of IPOs underwritten by each bank, as well as the total number of underwritten IPOs, is increasing in the number of firms considering going public, N, in both the competitive and collusive scenarios:

Lemma 5 *The numbers of IPOs underwritten by each bank under the competitive scenario,* $N^*_{1_{Comp}}$ *and* $N^*_{2_{Comp}}$*, and under the collusive scenario,* $N^*_{1_{Coll}}$ *and* $N^*_{2_{Coll}}$ *for* B_1*, are increasing in* N*.*

The monotonic relation between the equilibrium number of IPOs and N in both the competitive and collusive settings is useful, because it enables us to translate various comparative statics of the model with respect to N into empirical predictions regarding the relations between observable quantities in the IPO market and the "hotness" of the market, i.e. the number of firms going public in a particular time period. In what follows, we will refer to both N and the total equilibrium number of IPOs, $N^*_{1_{Comp}} + N^*_{2_{Comp}}$ and $N^*_{1_{Coll}} + N^*_{2_{Coll}}$, under the competitive and collusive scenarios, respectively – which are monotonic functions of N – as the state of the IPO market.

2.4 Comparative statics

We now turn to examining the comparative statics of the equilibria obtained under the two scenarios with the objective of designing empirical tests of the implicit underwriter collusion hypothesis against the alternative of oligopolistic competition. We begin by examining the relations between the two banks' equilibrium absolute and proportional underwriting fees and the state of the market and then analyze the relation between the banks' equilibrium shares of the IPO market and the state of the market.

2.4.1 Proportional underwriting fees

We define the weighted average proportional fee of bank j as the ratio of the combined fees collected by bank j from all firms whose IPOs it underwrites to the combined pre-IPO value of these firms:

Definition 1 *The weighted average proportional fee of bank* j*,* $\overline{RF_j}$*, equals* $\frac{\lambda^*_j\left(\overline{V_j}-\underline{V_j}\right)}{\int_{V=\underline{V_j}}^{\overline{V_j}} V dV}$.

The relation between the two banks' proportional fees and the state of the IPO market is summarized in the following two propositions.

Proposition 1 *In a competitive underwriting market, the weighted average proportional fee of the higher-quality bank* (B_1) *and that of the lower-quality bank* (B_2) *are increasing in* N*.*

This result is consistent with the empirical evidence in Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004) among many others, who find that the indirect component of underwriter compensation, i.e. IPO underpricing, tends to be higher in hot IPO markets. The intuition behind the positive relation between the average proportional fees of the two banks and the state of the IPO market in the competitive case is as follows. Because of the banks' increasing marginal costs, the set of firms that the banks choose to underwrite becomes more selective as the number of firms considering an IPO increases. This also means that the range of values of firms underwritten by each of the banks narrows as N increases (i.e. as the state of the IPO market improves). The proportional fee paid by the lowest-valued firm that the lower-quality bank (B_2) underwrites equals α_2, since for that firm the bank extracts the whole surplus obtained at the time of the IPO. As follows from Lemma 1, the proportional fee paid by a firm to a given bank is decreasing in firm's quality; thus, the average proportional fee paid to B_2 is lower than α_2. However, since the range of values of firms whose IPOs are underwritten by B_2 is decreasing in N, the average proportional fee approaches the highest proportional fee (α_2) as N increases. While the higher-quality bank (B_1) does not extract the full surplus from the lowest-valued firm among those it underwrites (because that firm has the option of its IPO being underwritten instead by B_2), similar logic holds for B_1: The higher the state of the IPO market, the narrower the range of values of firms underwritten by B_1. This implies that B_1's average proportional fee approaches the highest relative fee charged by B_1 as N increases.

Proposition 2 *In a collusive underwriting market:*
a) the weighted average proportional fee of the higher-quality bank (B_1) is increasing in N;
b) the weighted average proportional fee of the lower-quality bank (B_2) exhibits a U-shaped relation with N: it is decreasing in N for sufficiently low N and it is increasing in N for sufficiently high N.

The intuition behind the positive relation between the average proportional fee of a higher-quality bank and N in the collusive scenario is similar to that in the competitive scenario: Higher N leads to a smaller range of values of firms underwritten by the higher-quality bank, raising its average proportional fee. The U-shaped relation between the average proportional fee of a lower-quality bank and the state of the IPO market in the collusive case is a little subtler, as it is driven by a combination of two effects. First, as with the higher-quality bank, higher N leads to a smaller range of values of firms underwritten by the lower-quality bank, raising its average proportional fee.

Second, for low levels of N, the two banks' joint expected profit is maximized when most IPOs are performed by B_1. This is because if the banks collude with the objective of maximizing their combined profit, then for low levels of N – for which the marginal cost structure is relatively flat – it is optimal to channel most of the IPOs to the higher-quality bank, which can charge a higher underwriting fee. Allocating IPOs to the lower-quality bank would reduce the number of IPOs underwritten by the higher-quality bank and the two banks' combined profit. To channel most of the IPOs to the higher-quality bank, the lower-quality bank's fee is set high, leading to a decreasing relation between the lower-quality bank's fee and the state of the IPO market in relatively low states of the IPO market.

As N continues to increase, the higher-quality bank becomes constrained by its increasing marginal cost of underwriting, making it optimal to allocate more IPOs to the lower-quality bank. Thus, when N is high, the incentives to set high fees for the lower-quality bank are weaker, making the first (positive) effect of the state of the IPO market on the lower-quality bank's fee dominant. The combination of these two effects leads to the U-shaped relation between the state of the IPO market and the average proportional fee charged by the lower-quality underwriter.

2.4.2 Absolute (dollar) underwriting fees

Next, we examine the relation between equilibrium absolute (dollar) fees charged by each of the two banks and the state of the IPO market.

Proposition 3 *In a competitive underwriting market, the ratio of the absolute (dollar) fee charged by the higher-quality bank (B_1), $\lambda^*_{1_{Comp}}$, to the fee charged by the lower-quality bank (B_2), $\lambda^*_{2_{Comp}}$, is decreasing in N.*

The intuition behind the negative relation between the ratio of the two banks' fees and the state of the IPO market in the competitive case is as follows. When N is low, marginal costs of both underwriters are close to zero and the only way for the lower-quality bank to grab market share is to charge fees that are substantially lower than those of the higher-quality bank. As N increases, marginal costs increase as well and each underwriter's situation begins to resemble a local monopoly. Therefore, as N increases, the lower-quality bank is able to increase its fees relative to the higher-quality bank and still capture part of the IPO market. As a result, the relation between the state of the IPO market and the ratio of the fee charged by the higher-quality bank to that of the lower-quality bank is negative in the competitive scenario.

Proposition 4 *In a collusive underwriting market, the ratio of the absolute (dollar) fee charged by the higher-quality bank (B_1), $\lambda^*_{1_{Coll}}$, to the fee charged by the lower-quality bank (B_2), $\lambda^*_{2_{Coll}}$, has a hump-shaped relation with N: It is increasing in N for sufficiently low N and is decreasing in N for sufficiently high N.*

The intuition behind this hump-shaped relation is as follows. When the two banks maximize their combined expected profit, they internalize the effect that each bank's fee has on the demand for the other bank's underwriting services. When N is low, the marginal costs of underwriting are also low, and the banks are better off channeling most IPOs to the higher-quality bank, which can extract higher fees. Thus, when N is low, the fee of the lower-quality bank is set relatively high in order to not grab market share from the higher-quality bank. As N increases, the marginal costs of the two banks increase as well, leading the lower-quality bank to reduce its fee relative to that of the higher-quality bank in order to channel more IPOs to the former. As N increases further, the two banks effectively become local monopolists. In such a situation, the effects of each bank's fee on the other bank's expected profit are minimal and, in the extreme, each bank's fee is determined in isolation. This leads to the negative relation between the state of the IPO market and the ratio of the two banks' fees – similar to the competitive scenario – for relatively high N, and overall to a hump-shaped relation between N and the ratio of the two underwriters' absolute fees.

2.4.3 Underwriters' market shares

Proposition 5 *In a competitive underwriting market,*
a) if the difference between the two banks' qualities, $\alpha_1 - \alpha_2$, is sufficiently small, then the share of IPOs underwritten by the higher-quality bank (B_1), $\frac{N^*_{1_{Comp}}}{N^*_{1_{Comp}}+N^*_{2_{Comp}}}$, is decreasing in N;
b) if the difference between the two banks' qualities, $\alpha_1 - \alpha_2$, is sufficiently large, then the share of IPOs underwritten by B_1 is increasing in N.

The intuition for Proposition 5 is as follows. When the two banks maximize their separate expected profits from underwriting, the difference between the banks' qualities is crucial in determining the effects of the state of the IPO market on their market shares. When the difference between the two underwriters' qualities is relatively small, then in low states of the IPO market (i.e. small N), the competition between the two banks resembles Bertrand competition in homogeneous goods with close-to-zero marginal costs. In such a situation, the market share of the higher-quality bank is large.

In high states of the IPO market (i.e. large N), the situation resembles a monopolistic competition in which the two underwriters operate as local monopolists. This happens because in the presence of increasing marginal costs of underwriting, as N becomes large, the higher-quality bank starts underwriting only the highest-valued IPOs, while not challenging the lower-quality bank's ability to underwrite IPOs of lower-valued firms. In the extreme, each bank's underwriting fee and the number of underwritten IPOs is determined by that bank in isolation from the optimal strategy of the other bank. Thus, when N is high, the ratio of the numbers of IPOs underwritten by the two banks converges to the ratio of the numbers of IPOs at which each bank's marginal cost of underwriting equals the value added by that bank to the highest-valued firm. As a result, when the difference between the two underwriters' qualities is relatively small, the higher-quality (lower-quality) underwriter's market share is decreasing (increasing) in the state of the IPO market.

When the difference between the two banks' qualities is relatively large, then in the low states of the IPO market (i.e. close-to-zero marginal costs of underwriting), the only way for the lower-quality underwriter to generate any revenues (and profits) is to charge lower underwriting fees and underwrite more (low-valued) IPOs. As N increases, the marginal costs of underwriting increase as well, limiting the ability of the lower-quality bank to charge low underwriting fees. This leads the lower-quality bank to lose market share as the state of the IPO market improves and, as a result, to a positive (negative) relation between the state of the IPO market and the higher-quality (lower-quality) bank's share of the market.

Proposition 6 *In a collusive underwriting market, the share of IPOs underwritten by the higher-quality bank (B_1), $\frac{N^*_{1_{Coll}}}{N^*_{1_{Coll}}+N^*_{2_{Coll}}}$, is decreasing in N.*

As argued above, in the collusive scenario it is optimal to channel most IPOs to the higher-quality bank in the low states of the IPO market, when the marginal costs of underwriting are relatively flat. In higher states of the market, the marginal costs of underwriting start driving the allocation of IPOs to the two banks, leading to an increased market share for the lower-quality bank. In the extreme, when $N \to \infty$, each bank underwrites only the highest-valued firms, and the only constraint on the number of underwritten IPOs is the two banks' marginal costs of underwriting. Thus, in the extreme, each bank's fee has no effect on the number of IPOs underwritten by the other bank, leading to more equal equilibrium market shares as N becomes large. The resulting relation between the market share of the higher-quality (lower-quality) bank and the state of the IPO market is negative (positive) under the collusive scenario.

The results in this section demonstrate that in a situation in which there are two underwriters, the relation between these underwriters' equilibrium fees and market shares, on one hand, and the state of the IPO market, on the other hand, depends crucially on whether the banks implicitly collude or compete in setting underwriting fees. The comparative statics in the competitive and collusive scenarios lead to the following empirical predictions.

2.5 Empirical predictions

2.5.1 Validation of the model setting

Before proceeding to predictions that contrast the collusion hypothesis with the competition hypothesis, we discuss ways to validate empirically the models' main assumptions. Lemma 1 – and the extension of the model to the case in which both the fixed fee and relative fee are chosen optimally in equilibrium, presented in Appendix C – leads to the following empirical prediction:

Prediction 1 *For IPOs underwritten by a given bank, the proportional underwriting fee is expected to be decreasing in the market value of IPO shares.*

Lemma 4 implies that controlling for IPO size, IPOs underwritten by higher-quality underwriters are expected to be associated with higher proportional fees than those underwritten by lower-quality underwriters.

Prediction 2 *The proportional underwriting compensation is expected to be higher for IPOs underwritten by higher-quality banks, ceteris paribus.*

While Predictions 1 and 2 enable partial validation of the model's setup, the core empirical predictions follow from the comparative statics under the competitive and collusive scenarios described in Propositions 1-6. These predictions, which allow us to potentially test the implicit collusion hypothesis against the alternative of competition among underwriters, are as follows.

2.5.2 Tests of the implicit collusion and oligopolistic competition hypotheses

Propositions 1 and 2 result in empirical predictions regarding the effects of the state of the IPO market on the average proportional fee paid to underwriters.

Prediction 3a (Competition) *Average proportional underwriter compensation is expected to be increasing in the state of the IPO market.*

Prediction 3b (Implicit collusion) *Average proportional underwriter compensation of low-quality underwriters is expected to exhibit a U-shaped relation with the state of the IPO market. Average proportional underwriter compensation of higher-quality underwriters is expected to be increasing in the state of the IPO market.*

Propositions 3 and 4 lead to the empirical predictions regarding the effects of the state of the IPO market on the ratio of dollar compensation received by higher-quality underwriters to compensation received by lower-quality underwriters.

Prediction 4a (Competition) *The ratio of average absolute (dollar) compensation paid to higher-quality underwriters by firms whose IPOs they underwrite to average compensation paid to lower-quality underwriters is expected to be decreasing in the state of the IPO market.*

Prediction 4b (Implicit collusion) *The ratio of average absolute (dollar) compensation paid to higher-quality underwriters by firms whose IPOs they underwrite to average compensation paid to lower-quality underwriters is expected to have a hump-shaped relation with the state of the IPO market.*

Propositions 5 and 6 lead to empirical predictions regarding the effects of the state of the IPO market on the market share of higher-quality underwriters.

Prediction 5a (Competition) *The market share of higher-quality underwriters is expected to be decreasing in the state of the IPO market if the heterogeneity in underwriter quality is relatively low and to be increasing in the state of the IPO market if the heterogeneity in underwriter quality is relatively high.*

Prediction 5b (Implicit collusion) *The market share of higher-quality underwriters is expected to be decreasing in the state of the IPO market.*

3 Empirical tests

3.1 Data

The IPO sample used in this paper is drawn from the Securities Data Company IPO database and supplemented by data provided to us by Jay Ritter on IPO underwriting spreads, underwriter reputation scores, and whether an IPO was syndicated and/or backed by venture capital funds. Following prior studies examining underwriting fees and IPO underpricing (e.g., Chen and Ritter (2000), Hansen (2001), and Abrahamson, Jenkinson and Jones (2011)), we exclude from our sample IPOs by banks and utilities, closed-end funds, REITs, ADRs, reverse LBOs, unit offerings, IPOs with offer price lower than \$5, and offerings that result from spinoffs. Finally, to include an IPO in our sample, we require that the information on underwriting spread and post-IPO first-day return be available.

Our final sample consists of $6,917$ firm-commitment IPOs by U.S. firms between 1975 and 2013. Panel A of Table 1 presents summary statistics of the IPO market by calendar year.

Insert Table 1 here

Columns $2-5$ in Panel A contain annual statistics related to the state of the IPO market, stock market, and economy in general. The second column in Panel A of Table 1 shows that the number of IPOs varies between 12 in 1975 and 603 in 1996. The third column presents IPO proceeds in millions of dollars, adjusted by the Consumer Price Index (CPI) to 2010 dollars. In aggregate, U.S. firms have raised more than \$600 billion (2010) dollars through IPOs during the 39 years of our sample. Annual CPI-adjusted IPO proceeds also vary considerably throughout our sample period, from \$501 million in 1977 to \$44 billion in 2000. The early 1980s and the 1990s are the two hottest periods for IPOs. The fourth column reports the mean value-weighed market return in each of the 39 years of our sample. Annual market returns range from -38% in 2008 to 37% in 1975, with an average of 13.8%. The fifth column presents annual growth in private nonresidential fixed investment (PNFI), which ranges from -16% in 2009 to 21% is 1978. Overall, our sample includes periods of both hot and cold markets in general and IPO markets in particular.

The next three columns present mean annual underwriting spreads and first day post-IPO returns (aka underpricing). Similar to past studies (e.g., Chen and Ritter (2000) and Hansen (2001)), the mean underwriting spread is 7.4% and has been on a declining trajectory over the last three decades. Mean underpricing, calculated as the percentage difference between the newly public stock's closing price at the first trading day and its offer price, is 19%. Mean annual underpricing varies over time, ranging from -0.2% for 12 IPOs underwritten in 1975 to 73% for 397 IPOs underwritten in 1998. Consistent with past studies (e.g., Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004)), underpricing tends to be positively correlated with the hotness of the IPO market: The correlation between mean annual underpricing and the number of IPOs in that year is 45%. Since it is conceivable that underwriters receive indirect compensation from IPO investors only when underpricing is positive, the next column presents mean underpricing, in which we replace negative first day returns with zeros.

The next four columns present annual IPO statistics. In particular, 40% of IPOs in our sample are backed by venture capital funds, 46% of IPOs are by firms in the high-tech or biotech sectors, 13% of IPO proceeds are secondary, and 10% of IPOs are syndicated, i.e. involve multiple book runners. The percentage of syndicated IPOs has been increasing over time: There were no syndicated IPOs up to year 1991, while in each of the last five years of the sample, more than 90% of IPOs are syndicated. It is important to note that the fact that underwriters tend to form syndicates now much more than in the past does not necessarily suggest that they also collude more than previously in setting IPO fees. While underwriters do set fees jointly in IPOs that they underwrite jointly, collusion would imply coordination of fees across IPOs, not within a single IPO.

In Panel B of Table 1 we report additional statistics for the variables described above. The standard deviation of underwriting spread is about 1% and the median is exactly 7%, consistent with the clustering pattern documented by Chen and Ritter (2000). In contrast, there is a significant variation in IPO underpricing. The standard deviation of underpricing across $6,917$ IPOs is 39%.

In our model, we show that the comparative statics of underwriter compensation with respect to the state of the IPO market may depend on underwriter quality. Panel C of Table 1 presents statistics on the number and volume of IPOs underwritten by banks of various quality, as proxied by the underwriter reputation score first proposed by Carter and Manaster (1990) and extended by Loughran and Ritter (2004). The highest score, 9, is given to the 15 most reputable underwriters, including Goldman Sachs, Morgan Stanley, Merrill Lynch, JP Morgan, Deutsche Bank, Citigroup, and Credit Suisse. These banks underwrite one third of all deals in our sample in terms of numbers. Also, IPOs underwritten by high-quality banks tend to be larger: There is an almost perfect monotonic relation between underwriter reputation score and mean value of IPO proceeds, as follows from the last column in Panel C.

3.2 Model validation

We begin by testing Predictions 1 and 2 of the model, according to which the proportional compensation for underwriting an IPO is expected to be decreasing in the size of the IPO and to be increasing in the quality of the IPO underwriter. To test these predictions, we estimate a regression in which the dependent variable is underwriter compensation and the main independent variables are IPO size and a measure of underwriter quality:

$$Comp_{i,j,t} = \alpha + \beta_1 HQ_{i,t} + \beta_2 IPO\_size_{j,t} + \overrightarrow{\theta}\overrightarrow{X_{i,t}} + YearFE_t + \varepsilon_{i,t}. \quad (19)$$

Bank i's proportional compensation for underwriting IPO of firm j in year t, $Comp_{i,j,t}$, consists of a direct component and, possibly, an indirect one. The direct component is the underwriting fee (gross spread) paid to the underwriter by the issuing firm. We consider a certain percentage of IPO underpricing as the indirect component of the underwriter's compensation, following the evidence that suggests that institutional investors in IPOs indirectly reward underwriters for allocating them underpriced IPO shares. For example, Reuter (2006) finds a positive relation between trading commissions paid by a mutual fund family to an underwriter and the fund family's holding of recent profitable IPO shares allocated by that underwriter, and interprets his findings as underwriters profiting from discretionary allocations of IPO shares. Nimalendran, Ritter, and Zhang (2007) find abnormally intensive trading in the 50 most liquid stocks before allocations of significantly underpriced IPO shares and suggest that institutional investors trade liquid stocks to generate excessive commissions to lead underwriters in order to get favorable allocations of underpriced IPO shares. Goldstein, Irvine, and Puckett (2011) provide numerical estimates of the share of IPO underpricing that is returned to underwriters in the form of increased trading commissions. While there is wide variation in the proportion of underpricing captured by underwriters, they estimate that on average, lead underwriter receives between 2 and 5 cents in abnormal commission revenue for every $1 left on the table.

We use two measures of underwriter compensation:

1) $Direct\_comp_{i,j,t}$ is the IPO spread. This measure may understate the overall underwriter compensation, but it is not plagued by problems in estimating the indirect component of compensation.

2) $Direct\&indirect\_comp_{i,j,t}$ is the combination of IPO spread and a certain proportion of IPO underpricing. Following Goldstein, Irvine and Puckett (2011), we use 5% of underpricing as a measure

of indirect compensation. (In cases in which underpricing is negative, we set it to zero.) The results are robust to the use of other proportions of underpricing as a measure of indirect underwriter compensation, ranging between 0% and 10%.

The first independent variable, $HQ_{i,t}$, is an indicator variable that equals one if underwriter i is of high quality in year t and zero otherwise. According to Prediction 1, we expect to observe a positive coefficient on the higher-quality indicator, $\beta_1 > 0$. We use two measures of underwriter quality:

1) $CM\_score_{i,t}$ is bank i's Carter-Manaster (1990) reputation score, updated by Loughran and Ritter (2004). In particular, if an underwriter's score is 9 in a given year, it is defined as a high-quality underwriter in that year.[4]

2) $Top\_ten_{i,t}$ is based on bank i's market share of the underwriting market, i.e. the proportion of IPOs underwritten by bank i in year t out of all IPOs in year t. Specifically, high-quality underwriters are those with top 10 market shares.[5] The correlation between the two measures of underwriter quality is 59%.

3) $IPO\_size_{j,t}$ is measured as the natural logarithm of the issue proceeds, i.e. of the product of the number of shares offered by firm j in its IPO and the final offer price. We use the logarithmic transformation of IPO size, because this variable exhibits high skewness. According to Prediction 2, we expect a negative coefficient on IPO size, $\beta_2 < 0$.

We follow Hansen (2001), Torstila (2003), and Abrahamson, Jenkinson and Jones (2011) in defining the vector of control variables, $\overrightarrow{X_{i,t}}$, in (19). It includes post-IPO 12-month daily stock return volatility, the percentage of secondary shares in the offering, hi-tech dummy variable equaling one if the issuing firm operates in the high-tech sector, as defined in Loughran and Ritter (2004), VC dummy variable equaling one if the issue is backed by a venture capital fund, and syndicate dummy that equals one if there are multiple book runners in the issue.

We estimate the regression in (19) using OLS, while including year fixed effects and clustering standard errors at the underwriter level. The regression results are reported in Table 2. In the first two columns in Table 2, we define high-quality underwriters according to their Carter and Manaster (1990) score. In the next two columns, high-quality underwriters are defined based on IPO underwriting market share. In the first and third columns we use direct compensation (i.e. IPO spread)

[4]Most of the results are robust to defining underwriters with Carter-Manaster scores of 8 and 9 as high-quality underwriters.

[5]The results are robust to defining the top five underwriters based on market share as high-quality.

as the dependent variable. In the second and fourth columns, we use the combination of direct and indirect compensation, where for the latter we assume that the share of IPO underpricing captured by underwriters equals 5%.

Insert Table 2 here

The first result in Table 2 is that there is clear evidence of a positive relation between underwriter quality and underwriter compensation. The coefficients on the high-quality dummy are positive and significant for both definitions of high-quality underwriters and for both measures of underwriter compensation. Controlling for IPO size and other relevant variables, high-quality underwriters' mean spread is 0.1 percentage point higher than that of low-quality banks. The combination of direct and indirect compensation received by high-quality banks is $0.4 - 0.5$ percentage points higher than that of low-quality banks, ceteris paribus.

The second important result in Table 2 is the negative and significant relation between underwriter compensation and IPO size that is obtained in all four regression specifications. This result is also economically significant: a tenfold increase in IPO proceeds is associated with a roughly 1 percentage point decrease in IPO spread.

The coefficients on control variables are generally consistent with past literature. More volatile issues are associated with higher underwriter compensation, consistent with Hansen (2001). Offerings in the high-tech industry tend to have higher underpricing, while VC-backed offerings are associated with lower spreads. Consistent with Hu and Ritter (2007), IPOs underwritten by syndicates tend to have higher spreads. While the results in Table 2 do not allow us to separate the implicit collusion hypothesis from the oligopolistic competition hypothesis, they provide a validation of the model's settings. In the next subsection, we present the results of tests of Predictions $3 - 5$, which are aimed at distinguishing between the two hypotheses.

3.3 Testing the collusion versus oligopolistic competition hypotheses

Testing Prediction 3

Prediction 3 of the model concerns the relation between the average proportional underwriter compensation and the state of the IPO market. The oligopolistic competition hypothesis suggests that this relation is positive. The implicit collusion hypothesis also suggests a positive relation for higher-quality underwriters, but for lower-quality underwriters it predicts a U-shaped relation. To test this hypothesis we estimate the following regression:

$$Avg\_comp_{i,t} = \alpha + \beta_1 Mkt\_state_t * HQ_{i,t} + \beta_2 Mkt\_state_t * LQ_{i,t} + \beta_3 Mkt\_state_t^2 + \overrightarrow{\theta}\overrightarrow{X_{i,t}} + \varepsilon_{i,t}. \quad (20)$$

$Avg\_comp_{i,t}$ is the average compensation (direct and/or indirect) of underwriter i in year t.

Mkt_state_t is the state of the IPO market. We use three measures of the IPO market state:

1) $\#IPOs_t$ is the annual number of IPOs in year t. This measure is motivated by the model. As we show in Lemma 5, the equilibrium number of underwritten IPOs is increasing by the state of the IPO market in the model, i.e. in the number of firms considering going public.[6]

2) $PNFI\_gr_t$ is the annual growth in private nonresidential fixed investment (PNFI). Growth in PNFI is shown to be related to firms' demand for capital (e.g., Lowry (2003), Pastor and Veronesi (2005), and Yung, Çolak, and Wang (2008)) and the resulting desire to raise funds using an IPO.

3) VW_mktret_t is the value-weighted market return in year t. Firms are more likely to issue equity in general and go public in particular in bull markets (e.g., Lucas and McDonald (1990), Lerner (2004), and Ritter and Welch (2002)).

$HQ_{i,t}$ and $LQ_{i,t}$ are high-quality and low-quality underwriter dummies, defined in the same way as in the previous section, i.e. based on the Carter-Manaster (1990) score or on the share of the IPO underwriting market. The control variables are the underwriter-year means of the control variables used in (19). The regression in (20) is estimated at the underwriter-year level.

Both the implicit collusion and oligopolistic competition hypotheses predict a positive relation between underwriter compensation and the state of the IPO market for high-quality underwriters. Thus, both hypotheses predict that $\beta_1 \geq 0$ and $\beta_3 > 0$. However, the two hypotheses lead to different predictions for low-quality banks: the competition hypothesis predicts a positive relation between underwriter compensation and the state of the IPO market, while the implicit collusion hypothesis predicts a U-shaped relation. Hence, the important difference between the competition hypothesis and the collusion hypothesis is that the former predicts that $\beta_2 \geq 0$, while the latter predicts that $\beta_2 < 0$.

Unlike (19), we do not include year fixed effects in (20), since we are interested in the association between the state of the IPO market – which is measured on an annual basis – and average underwriter compensation. Similar to (19), we cluster standard errors at the underwriter level. The results of estimating (20) are reported in Table 3, which has 12 columns. In the first four columns $\#IPOs_t$ is used as a measure of the state of the IPO market, in columns 5 – 8 we use $PNFI\_gr_t$ as a measure of IPO market state, and in columns 9 – 12 we use VW_mktret_t. In columns 1, 2, 5, 6, 9, and 10,

[6]Lowry and Schwert (2002) and Pastor and Veronesi (2005) document that the number of IPOs in a given year is, to a large extent, predictable. Thus, we use the realized number of IPOs as a proxy for the expected number of IPOs, which in turn proxies for the state of the IPO market.

high-quality and low-quality underwriters are defined based on their Carter-Manaster (1990) scores, while in columns 3, 4, 7, 8, 11, and 12, they are defined based on previous-year market shares. In odd columns, only direct underwriter compensation is considered, while in even columns we also account for estimated indirect compensation.

Insert Table 3 here

The results for high-quality underwriters are generally consistent with both the competition and collusion hypotheses: The coefficient on $Mkt\_state_t * HQ_{i,t}$ is generally insignificantly different from zero (it is significantly positive in two specifications out of 12), while the coefficient on $Mkt\_state_t^2$ is positive and significant in all 12 specifications. The important finding, however, is that the results for the low-quality underwriters support the implicit collusion hypothesis and are inconsistent with the competition hypothesis: The coefficients on $Mkt\_state_t * LQ_{i,t}$ are negative in all 12 specifications and are statistically significant at the 5% level in 10 of them, suggesting a U-shaped relation between the state of the IPO market and compensation of lower-quality underwriters. The inflection point of this U-shaped relation (i.e. $-\frac{\beta_2}{2\beta_3}$) ranges between 236 and 387 IPOs per year in columns $1-4$, between 9.7% and 12.6% annual PNFI growth in columns $5-8$, and between 5.7% and 12.7% annual market return in columns $9-12$. All these values are in the range of the distributions of respective measures of the state of the IPO market (although in the high end of this range, in the case of $\#IPOs_t$ and $PNFI\_gr_t$). This implies that the documented relation between the state of the IPO market and the compensation of lower-quality underwriters is indeed U-shaped, consistent with the implicit collusion hypothesis and inconsistent with the competition hypothesis.

Testing Prediction 4

Prediction 4 concerns the relation between the ratio of absolute (dollar) compensation received by higher-quality underwriters to compensation received by lower-quality ones, on one hand, and the state of the IPO market, on the other hand. To test this prediction, we estimate the following regression:

$$\log\left(\frac{Avg\_\$Comp_{i\in HQ,t}}{Avg\_\$Comp_{LQ,t}}\right) = \alpha + \beta_1 Mkt\_state_t + \beta_2 Mkt\_state_t^2 + \overrightarrow{\theta}\,\overrightarrow{X_{i,t}} + \varepsilon_{i,t}. \tag{21}$$

The dependent variable in (21) is the natural logarithm of the ratio of the following two quantities. The one in the numerator is the average dollar compensation of high-quality underwriter i in year t, $Avg\_\$Comp_{i\in HQ,t}$, computed as the mean dollar compensation per IPO, which in turn is the product of proportional compensation, $Comp_{i,j,t}$, and IPO proceeds. The one in the denominator, $Avg\_\$Comp_{LQ,t}$, is the average dollar compensation of low-quality underwriters in year t. We take the logarithm of the dependent variable because of the high skewness of this ratio. Similar to (20),

Mkt_state_t refers to one of the three proxies for the state of the IPO market. The control variables are based on those in (20) and measured as the differences between the underwriter-year average of the respective variable for a high-quality underwriter (e.g., logarithm of IPO proceeds) and the annual average of that variable for the low-quality underwriters.

The prediction for both the competitive and collusive cases is of a positive coefficient on the state of the IPO market, $\beta_1 > 0$. In the competitive case, the coefficient on the quadratic term of the state of the IPO market, $Mkt\_state_t^2$, is expected to be either insignificant or positive, $\beta_2 \geq 0$. In the collusive case, the relation between the state of the IPO market and the ratio of high-quality underwriters' compensation to low-quality banks' compensation is expected to be hump-shaped, i.e. the coefficient on the squared measure of the state of the IPO market, $Mkt\_state_t^2$ is expected to be negative, $\beta_2 < 0$.

The results of estimating (21) are presented in Table 4. The table has 12 columns, which correspond to the same measures of the state of the IPO market, definitions of high-quality underwriters, and measures of underwriter compensation as in Table 3.

Insert Table 4 here

The results in Table 4 are generally consistent with the collusion hypothesis and inconsistent with the oligopolistic competition hypothesis. In particular, in all twelve specifications, the coefficients on Mkt_state_t are positive, and are statistically significant in half the cases. The coefficients on $Mkt\_state_t^2$ are negative in all specifications and significant in seven out of twelve. In the specifications in which β_2 is statistically significant, the inflection point of the hump-shaped relation lies inside the range of values of the three measures of the state of the IPO market in all the cases except for two of the specifications that employ $PNFI\_gr_t$ as a measure of the state of the IPO market. These results suggest that the relation between the ratio of compensation of high-quality banks relative to that of lower-quality ones is hump-shaped, in line with the implicit collusion model.

Testing Prediction 5

Prediction 5 relates the market share captured by high-quality underwriters to the state of the IPO market. According to Prediction 5, if IPO underwriters collude in setting fees for underwriting services, we should expect a negative relation between the market share of high-quality underwriters and the state of the IPO market. If, on the other hand, the IPO market structure is best described as oligopolistic competition, we should expect a negative relation within the subsample in which underwriters are relatively heterogeneous and a positive relation within the subsample in which the underwriters are sufficiently homogeneous. To test this hypothesis, we estimate the following regression:

$$MS\_high_t = \alpha + \beta_1 Mkt\_state_t * High\_hetero_t + \beta_2 Mkt\_state_t * Low\_hetero_t + \varepsilon_{i,t}. \qquad (22)$$

MS_high_t is the market share of high-quality underwriters in year t, computed as the ratio of total dollar proceeds in IPOs underwritten by high-quality underwriters in year t to total proceeds in IPOs in year t.[7]

$Hetero_t$ refers to the degree of heterogeneity in underwriter quality in year t. We measure this heterogeneity as the standard deviation of the Carter-Manaster (1990) reputation score of banks that have underwritten at least one IPO in year t. $High\_hetero_t$ (Low_hetero_t) equals one in years in which the standard deviation of underwriters' reputation scores is above (below) its time-series median. Regression (22) is estimated at a year level (as opposed to underwriter-year level in (19) and (20)). Since we are interested in the time-series relation between the state of the IPO market and the market share of high-quality underwriters, we do not include year fixed effects in (22).

The results of estimating (22) are presented in Table 5, which has six columns. In columns 1 – 2 (3 – 4, 5 – 6), the state of the IPO market is proxied by $\#IPOs_t$ ($PNFI\_gr_t$, VW_mktret_t). In odd columns, we define high-quality underwriters based on Carter-Manaster (1990) reputation scores, while in even columns, high-quality underwriters are those with top-10 market shares in the IPO underwriting market.

Insert Table 5 here

Under both the oligopolistic competition and implicit collusion hypotheses, we expect a negative relation between the market share of high-quality underwriters and the interaction between the state of the IPO market and the low underwriter heterogeneity indicator, $\beta_2 < 0$. We may be able to distinguish between the two hypotheses by observing the coefficient on the interaction between the state of the IPO market and the high underwriter heterogeneity indicator, β_1. We expect $\beta_1 < 0$ in the collusive case and $\beta_1 > 0$ in the competitive case.

The results in Table 5 are more consistent with the collusion hypothesis than with the oligopolistic competition hypothesis. The estimate of β_2 is negative and significant in just one specification out of six, and insignificant in the other specifications. More importantly, however, the estimate of β_1 is negative in all specifications and significant at the 1% level in four of them. This relation is also economically sizable. For example, a one standard deviation increase in $PNFI\_gr_t$ (7.2%) is associated with a drop of $8 - 12$ percentage points in the market share of high-quality underwriters in years when the heterogeneity in underwriter quality is high.

Tests Using a Subsample of the Largest Underwriters

[7] The results are similar when we define market shares based on the number of underwritten IPOs instead of total IPO proceeds.

As mentioned above, it is conceivable that larger (higher-quality) underwriters implicitly collude among themselves but compete with smaller (lower-quality) underwriters. We show in Appendix B that the predictions of our two models hold within a subset of colluding underwriters, even in the presence of other, non-colluding, ones. In what follows, we examine empirically the predictions of the two models while concentrating on a sample that consists of the largest 10 underwriters in a given year, with the idea that these banks are ex-ante more likely to collude among themselves than they are with their smaller peers.

Table 6 reports results of re-estimating the regressions reported in Tables 3–5 within the subsample of the largest underwriters. While the set of control variables in the regressions in Table 6 is identical to those in (20)–(22), to conserve space we do not report the coefficients on control variables. In addition, in Table 6 we report results using only one proxy for the state of the IPO market, the annual number of IPOs.[8] High-quality underwriters in Table 6 are defined differently than in Tables 3–5. In particular, given that the vast majority of top-10 underwriters have a Carter-Manaster reputation score of 9, we cannot use reputation score to define the highest-quality underwriters. Thus, we define underwriters with the highest three (or highest five) previous-year market shares as those possessing the highest quality.

Insert Table 6 here

In Panel A, we re-estimate the regression in (20) for the sample of top-10 banks in each year. Similar to the results in Table 3, the results for highest-quality underwriters are generally consistent with both the competition and collusion hypotheses: The coefficient on $Mkt\_state_t * HQ_{i,t}$ is insignificant in all specifications, while the coefficient on $Mkt\_state_t^2$ is positive and significant in two specifications out of four. Importantly, the results for the lower-quality underwriters are consistent with the collusion hypothesis and inconsistent with the competition hypothesis, as the coefficients on $Mkt\_state_t * LQ_{i,t}$ are significantly negative in all four specifications, suggesting a U-shaped relation between the state of the IPO market and the lower-quality underwriters' compensation.

Panel B reports estimates of the regression in (21) for the top-10 underwriter sample. The results in Panel B are strongly supportive of the collusion hypothesis – more so than the full-sample results in Table 4 – and are inconsistent with the competition hypothesis. In all four specifications, the coefficients on the annual number of IPOs, which proxies for the state of the IPO market, are positive and highly significant. The coefficients on the squared number of IPOs are negative and highly significant in all specifications, suggesting a hump-shaped relation between the state of the IPO market and the ratio of the top underwriters' compensation to the lower-quality underwriters' compensation.

[8] Unreported results using the other two measures of the IPO market state – PNFI growth and value-weighted market return – are generally similar to those reported in Table 6.

In Panel C, we report the results of re-estimating (22) while concentrating on the subsample of top-10 banks. Since we cannot use the standard deviation of Carter-Manaster reputation score to measure underwriter heterogeneity within the subsample of top underwriter, we use the standard deviation of underwriters' IPO market shares instead. The results in Panel C are again consistent with the collusion hypothesis and inconsistent with the competition hypothesis. The relation between the market share of the highest-quality underwriters and the state of the IPO market is significantly negative, both when underwriters are relatively heterogeneous in their market shares and when they are relatively homogeneous.

Overall, the results reported in Tables 3 – 6 are generally consistent with the implicit collusion hypothesis for the U.S. IPO underwriting market, and are inconsistent with the hypothesis according to which underwriters engage in oligopolistic competition in setting underwriter spread and offer price.

4 Conclusions

In this paper we try to shed light on an elusive question: Do IPO underwriters in the U.S. compete for IPO business by setting competitive spreads and offer prices? To answer this question, we construct two models of interaction among heterogeneous IPO underwriters. In the first, a model of oligopolistic competition, each bank sets its fee for underwriting services separately, with the objective of maximizing its own expected profit while accounting for the optimal response of other underwriters. In the second, a model of implicit collusion, underwriters cooperate and set their fees in a way that maximizes their joint expected profit.

The two models generate different comparative statics and empirical predictions regarding the effects of the state of the IPO market on equilibrium market shares and on compensation of underwrites of various quality. Unlike existing studies of underwriting market structure that separately test the implications of either the implicit collusion hypothesis or the competition hypothesis, we examine both hypotheses simultaneously. In other words, we provide a framework for a "horse race" between the two hypotheses. We test the contrasting empirical implications of the competitive and collusive models using U.S. IPOs data from 1975 to 2013. Most of our evidence lends support to the implicit collusion hypothesis and is less consistent with the oligopolistic competition hypothesis.

Our conclusion that underwriters do not compete fiercely in IPO fee setting complements recent studies that provide indirect evidence on the lack of competition in the IPO underwriting market. Liu and Ritter (2011) argue that by differentiating their services, e.g., providing all-star analyst coverage, underwriters effectively mitigate the extent of price competition. Hu and Ritter (2007) focus on the recent phenomenon of IPO underwriting syndication and show that IPOs underwritten by multiple book runners have become increasingly popular since the turn of the century. Syndication reduces coordination costs and makes implicit collusion more sustainable as it overcomes the issue of the legality of side payments among underwriters. However, the short history of syndicated IPOs limits our ability to conduct meaningful time-series empirical tests of this phenomenon.

Overall, our results demonstrate that empirically testing predictions that follow from industrial organization models of interactions among underwriters and between underwriters and issuing firms and investors may lead to better understanding of the competitive structure of the IPO underwriting market.

While beyond the scope of this paper, it would be interesting to examine the model's predictions using data from non-U.S. markets with sufficient time-series IPO data, such as the U.K., Japan, and Canada, in order to test the claim that non-U.S. underwriting markets are more competitive than the U.S. underwriting market (e.g., Abrahamson, Jenkinson and Jones (2011)). In addition, our model could also be used to investigate the structure of additional markets in which heterogeneous intermediaries interact with heterogeneous firms. Immediate examples include the market for underwriting seasoned equity offerings and the market for M&A advising.

5 Appendix

A Proofs

Proof of Lemma 1 Differentiating the proportional underwriting fee, $\frac{\lambda_j+\mu_j V_i}{V_i(1+\alpha_j)}$, with respect to V_i results in

$$\frac{\partial \frac{\lambda_j+\mu_j V_i}{V_i(1+\alpha_j)}}{\partial V_i} = -\frac{\lambda_j}{V_i^2(1+\alpha_j)} < 0. \blacksquare$$

Proof of Lemma 2 Firm i's value if private, $V_{i,private}$, is V_i. Firm i's value after an IPO underwritten by B_1 or B_2 is

$$\begin{aligned} V_{i,IPO(B_1)} &= V_i(1+\alpha_1) - \lambda_1, \\ V_{i,IPO(B_2)} &= V_i(1+\alpha_2) - \lambda_2. \end{aligned}$$

$V_{i,private} \geq V_{i,IPO(B_1)}$ if $V_i \leq \frac{\lambda_1}{\alpha_1}$. $V_{i,private} \geq V_{i,IPO(B_2)}$ if $V_i \leq \frac{\lambda_2}{\alpha_2}$. Thus, $V_{i,private} \geq \max\{V_{i,IPO(B_1)}, V_{i,IPO(B_2)}\}$ if $V_i \leq \min\{\frac{\lambda_1}{\alpha_1}, \frac{\lambda_2}{\alpha_2}\}$. $V_{i,IPO(B_1)} \geq V_{i,IPO(B_2)}$ if $V_i \geq \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}$. $V_{i,IPO(B_1)} \geq V_i$ if $V_i \geq \frac{\lambda_1}{\alpha_1}$. Thus, $V_{i,IPO(B_1)} \geq \max\{V_{i,private}, V_{i,IPO(B_2)}\}$ if $V_i \geq \max\{\frac{\lambda_1}{\alpha_1}, \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}\}$. $V_{i,IPO(B_2)} \geq V_{i,IPO(B_1)}$ if $V_i \leq \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}$. $V_{i,IPO(B_2)} \geq V_i$ if $V_i \geq \frac{\lambda_2}{\alpha_2}$. Thus, $V_{i,IPO(B_2)} \geq \max\{V_{i,private}, V_{i,IPO(B_1)}\}$ if $V_i \in \left[\frac{\lambda_2}{\alpha_2}, \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}\right]$. $\blacksquare$

Proof of Lemma 3 The lowest-valued firm for which $V_{i,IPO(B_2)} > V_{i,private}$ is $\underline{V_2} = \frac{\lambda_2}{\alpha_2}$. Assume $\frac{\lambda_1}{\alpha_1} \leq \frac{\lambda_2}{\alpha_2}$. Then for firm with value $\underline{V_2}$, $V_{i,IPO(B_1)} \geq V_{i,IPO(B_2)}$, and $V_{i,IPO(B_1)} > V_{i,IPO(B_2)}$ for any $V_i > \underline{V_2}$. As a result, B_2 would not underwrite any IPOs. Since the marginal cost of underwriting the first infinitesimal unit of IPOs is zero, in equilibrium B_2 would set α_2 such that $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$. The highest-valued firm for which $V_{i,IPO(B_1)} > V_{i,private}$ is $\overline{V_1} = 1$. Assume $\frac{\lambda_1}{\alpha_1} \geq 1$. Then for firm with value $\overline{V_1}$, $V_{i,private} \geq V_{i,IPO(B_1)}$, and $V_{i,private} > V_{i,IPO(B_1)}$ for any $V_i < \overline{V_1}$. As a result, B_1 would not underwrite any IPOs. Since the marginal cost of underwriting the first infinitesimal unit of IPOs is zero, in equilibrium B_1 would set α_1 such that $\frac{\lambda_1^*}{\alpha_1} < 1$. $\blacksquare$

Proof of Lemma 4 Since, according to Lemma 3, $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$, and $\alpha_1 \geq \alpha_2$ by assumption, $\lambda_1^* > \lambda_2^*$. Therefore,

$$\frac{\lambda_1^*}{\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}(1+\alpha_1)} - \frac{\lambda_2^*}{\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}(1+\alpha_2)} = \frac{(\lambda_1^*-\lambda_2^*)+(\lambda_1^*\alpha_2-\lambda_2^*\alpha_1)}{\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}(1+\alpha_1)(1+\alpha_2)} > 0. \blacksquare$$

Proof of Lemma 5 Differentiating $N^*_{1_{Comp}}$, $N^*_{2_{Comp}}$, $N^*_{1_{Coll}}$, and $N^*_{2_{Coll}}$in (11), (12), (17), and (18) respectively with respect to N leads to

$$\frac{\partial N^*_{1_{Comp}}}{\partial N} = \frac{2\alpha_1(N^2\left(2c^2\alpha_1\left(2\alpha_1^2+\alpha_2^2-\alpha_1\alpha_2\right)\right)) + N\left(2c\alpha_1\alpha_2\left(\alpha_1-\alpha_2\right)\left(4\alpha_1-\alpha_2\right)\right) + \left(\alpha_2^2\left(4\alpha_1-\alpha_2\right)\left(\alpha_1-\alpha_2\right)^2\right))}{\left(4c^2N^2\alpha_1+4cN\alpha_1^2+2cN\alpha_1\alpha_2+4\alpha_1^2\alpha_2-2cN\alpha_2^2-5\alpha_1\alpha_2^2+\alpha_2^3\right)^2} > 0,$$

$$\frac{\partial N^*_{2_{Comp}}}{\partial N} = \frac{\alpha_1\alpha_2(N^2\left(4c^2(\alpha_1^2-\alpha_2^2)+8c^2\alpha_1\alpha_2\right) + N\left(4c\alpha_2\left(\alpha_1-\alpha_2\right)\left(4\alpha_1-\alpha_2\right)\right) + \alpha_2\left(4\alpha_1-\alpha_2\right)\left(\alpha_1-\alpha_2\right)^2)}{\left(4c^2N^2\alpha_1+4cN\alpha_1^2+2cN\alpha_1\alpha_2+4\alpha_1^2\alpha_2-2cN\alpha_2^2-5\alpha_1\alpha_2^2+\alpha_2^3\right)^2} > 0,$$

$$\frac{\partial N^*_{1_{Coll}}}{\partial N} = \frac{N^2c^2(\alpha_1^2+\alpha_2^2)+2Nc\alpha_1\alpha_2(\alpha_1-\alpha_2)+\alpha_2^2(\alpha_1-\alpha_2)^2}{2(c^2N^2+cN\alpha_1+cN\alpha_2+\alpha_1\alpha_2-\alpha_2^2)^2} > 0,$$

$$\frac{\partial N^*_{2_{Coll}}}{\partial N} = \frac{Nc\alpha_2(Nc(\alpha_1+\alpha_2)+2\alpha_2(\alpha_1-\alpha_2))}{2(c^2N^2+cN\alpha_1+cN\alpha_2+\alpha_1\alpha_2-\alpha_2^2)^2} > 0.$$

It follows that $\frac{\partial\left(N^*_{1_{Comp}}+N^*_{2_{Comp}}\right)}{\partial N} > 0$ and $\frac{\partial\left(N^*_{1_{Coll}}+N^*_{2_{Coll}}\right)}{\partial N} > 0$. ■

Proof of Proposition 1 Weighted average proportional fees of B_1 and B_2 in the competitive scenario, $\overline{RF_1}^*$ and $\overline{RF_2}^*$ in Definition 1 can be rewritten as

$$\overline{RF_{1_{comp}}}^* = \frac{2\alpha_1(2Nc+\alpha_1-\alpha_2)(Nc\alpha_1+\alpha_2(\alpha_1-\alpha_2))}{(1+\alpha_1)\left(N^2(4c^2\alpha_1)+N(3c\alpha_1^2+2c\alpha_1\alpha_2-2c\alpha_2^2)+\left(\alpha_2\left(\alpha_1-\alpha_2\right)\left(3\alpha_1-\alpha_2\right)\right)\right)}, \quad (23)$$

$$\overline{RF_{2_{comp}}}^* = \frac{2\alpha_2\left(2Nc\alpha_1+\alpha_2\left(\alpha_1-\alpha_2\right)\right)}{(1+\alpha_2)\left(4Nc\alpha_1+3\alpha_1\alpha_2-2\alpha_2^2\right)}. \quad (24)$$

Differentiating (23) and (24) with respect to N leads to

$$\frac{\partial\overline{RF_{1_{comp}}}^*}{\partial N} = \frac{2c\alpha_1^2\left(N^2c^2(2\alpha_1^2+4\alpha_2^2)+4Nc\alpha_2(c\alpha_1^2-c\alpha_2^2)+\left(3\alpha_2^2\left(\alpha_2+\alpha_1^2-2\alpha_1\alpha_2\right)\right)\right)}{(1+\alpha_1)\left(N^2(4c^2\alpha_1)+N(3c\alpha_1^2+2c\alpha_1\alpha_2-2c\alpha_2^2)+\left(\alpha_2\left(\alpha_1-\alpha_2\right)\left(3\alpha_1-\alpha_2\right)\right)\right)^2} > 0,$$

$$\frac{\partial\overline{RF_{2_{comp}}}^*}{\partial N} = \frac{4c\alpha_1^2\alpha_2^2}{(1+\alpha_2)\left(4Nc\alpha_1+3\alpha_1\alpha_2-2\alpha_2^2\right)^2} > 0. ■$$

Proof of Proposition 2 Weighted average proportional fees of B_1 and B_2 in the collusive scenario, $\overline{RF_1}^*$ and $\overline{RF_2}^*$ in Definition 1 can be rewritten as

$$\overline{RF_{1_{c\,oll}}}^* = \frac{2\left(2N^2c^2\alpha_1+N(c\alpha_1^2+2c\alpha_1\alpha_2-c\alpha_2^2)+(\alpha_1^2\alpha_2-\alpha_1\alpha_2^2)\right)}{(1+\alpha_1)(4N^2c^2+N(3c\alpha_1+4c\alpha_2-2c\alpha_2^2)+3\alpha_2\left(\alpha_1-\alpha_2\right))}, \quad (25)$$

$$\overline{RF_{2_{c\,oll}}}^* = \frac{\alpha_2\left(2Nc+\alpha_1-\alpha_2\right)\left(Nc+\alpha_2\right)}{(1+\alpha_2)\left(4N^2c^2\alpha_1+N(3c\alpha_1+4c\alpha_2)+3\alpha_2\left(\alpha_1-\alpha_2\right)\right)}. \quad (26)$$

Differentiating (25) and (26) with respect to N leads to

$$\frac{\partial\overline{RF_{1_{c\,oll}}}^*}{\partial N} = \frac{2c\left(2N^2c^2(\alpha_1^2+2\alpha_2^2)+4Nc(\alpha_1^2\alpha_2-\alpha_1\alpha_2^2)+\left(\alpha_2^2\left(2\alpha_1-3\alpha_2\right)\left(\alpha_1-\alpha_2\right)\right)\right)}{(1+\alpha_1)(4N^2c^2+N(3c\alpha_1+4c\alpha_2-2c\alpha_2^2)+3\alpha_2\left(\alpha_1-\alpha_2\right))^2} > 0,$$

$$\frac{\partial\overline{RF_{2_{c\,oll}}}^*}{\partial N} = \frac{2c\alpha_2^2\left(2N^2c^2-\alpha_2\left(\alpha_1-\alpha_2\right)\right)}{(1+\alpha_2)\left(4N^2c^2\alpha_1+N(3c\alpha_1+4c\alpha_2)+3\alpha_2\left(\alpha_1-\alpha_2\right)\right)^2}. \quad (27)$$

The expression in (27) is positive for $N > \sqrt{\frac{\alpha_2(\alpha_1-\alpha_2)}{2c^2}}$ and is negative for $N < \sqrt{\frac{\alpha_2(\alpha_1-\alpha_2)}{2c^2}}$. ■

Proof of Proposition 3 Differentiating $\frac{\lambda^*_{1_{Comp}}}{\lambda^*_{2_{Comp}}}$ with respect to N leads to

$$\frac{\partial\left(\frac{\lambda^*_{1_{Comp}}}{\lambda^*_{2_{Comp}}}\right)}{\partial N} = -\frac{2c(\alpha_1-\alpha_2)\alpha_1^2}{\left(2Nc\alpha_1+\alpha_2(\alpha_1-\alpha_2)\right)^2} < 0. \blacksquare$$

Proof of Proposition 4 Differentiating $\frac{\lambda^*_{1_{Coll}}}{\lambda^*_{2_{Coll}}}$ with respect to N leads to

$$\frac{\partial\left(\frac{\lambda^*_{1_{Coll}}}{\lambda^*_{2_{Coll}}}\right)}{\partial N} = -\frac{c(\alpha_1-\alpha_2)\left(2N^2c^2-\alpha_2(\alpha_1-\alpha_2)\right)}{\left(2Nc+\alpha_1-\alpha_2\right)^2(Nc+\alpha_2)^2}. \tag{28}$$

The expression in (28) is positive for $N < \sqrt{\frac{\alpha_2(\alpha_1-\alpha_2)}{2c^2}}$ and is negative for $N > \sqrt{\frac{\alpha_2(\alpha_1-\alpha_2)}{2c^2}}$. ■

Proof of Proposition 5 Differentiating $\frac{N^*_{1_{Comp}}}{N^*_{1_{Comp}}+N^*_{2_{Comp}}}$ with respect to N leads to

$$\frac{\partial\left(\frac{N^*_{1_{Comp}}}{N^*_{1_{Comp}}+N^*_{2_{Comp}}}\right)}{\partial N} = \frac{2c(\alpha_1-2\alpha_2)(\alpha_1-\alpha_2)\alpha_2}{2Nc(\alpha_1+\alpha_2)+3\alpha_2(\alpha_1-\alpha_2)}. \tag{29}$$

The expression in (29) is positive for $\alpha_1 > 2\alpha_2$ and it is negative for $\alpha_1 < 2\alpha_2$. ■

Proof of Proposition 6 Differentiating $\frac{N^*_{1_{Coll}}}{N^*_{1_{Coll}}+N^*_{2_{Coll}}}$ with respect to N leads to

$$\frac{\partial\left(\frac{N^*_{1_{Coll}}}{N^*_{1_{Coll}}+N^*_{2_{Coll}}}\right)}{\partial N} = -\frac{c(\alpha_1-\alpha_2)\alpha_2^2}{Nc(\alpha_1+\alpha_2)+\alpha_2(\alpha_1-\alpha_2)} < 0. \blacksquare$$

B Multiple banks

In this section we relax the assumption of two underwriters. Assume that there are K banks sorted by their quality. Assume also that banks that belong to the set $\mathbb{C}$ collude, while others do not. Extending the model to the case of multiple underwriters results in the following optimization problems of the K banks:

$$\mathbb{E}\pi_j = \max_{\lambda_j} \left(\lambda_j \left(N \left(\overline{V_j} - \underline{V_j} \right) \right) - c \left(N \left(\overline{V_j} - \underline{V_j} \right) \right)^2 \right) \; \forall \; B_j \notin \mathbb{C}, \tag{30}$$

$$\mathbb{E}\pi_{joint} = \max_{\lambda_j,\, j\in\mathbb{C}} \left(\sum_{j\in\mathbb{C}} \left(\lambda_j \left(N \left(\overline{V_j} - \underline{V_j} \right) \right) - c \left(N \left(\overline{V_j} - \underline{V_j} \right) \right)^2 \right) \right), \tag{31}$$

$$\underline{V_1} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2} \text{ and } \overline{V_1} = 1, \tag{32}$$

$$\underline{V_j} = \frac{\lambda_j - \lambda_{j+1}}{\alpha_j - \alpha_{j+1}} \text{ and } \overline{V_j} = \frac{\lambda_{j-1} - \lambda_j}{\alpha_{j-1} - \alpha_j} \; \forall \; 1 < j < K, \tag{33}$$

$$\underline{V_K} = \frac{\lambda_K}{\alpha_K - \mu} \text{ and } \overline{V_K} = \frac{\lambda_{K-1} - \lambda_K}{\alpha_{K-1} - \alpha_K}. \tag{34}$$

Equation (30) describes the problem of a bank that is not part of a set of colluding banks ($\mathbb{C}$), while (31) describes the maximization problem of colluding banks, whose goal is to maximize their joint profit.

As mentioned in Section 2, in this Appendix we examine the case of three underwriters. In particular, we focus on three scenarios:

1) all three underwriters compete ("competition");

2) two highest-quality underwriters collude and they compete with the third underwriter ("partial collusion");

3) all three underwriters collude ("full collusion").

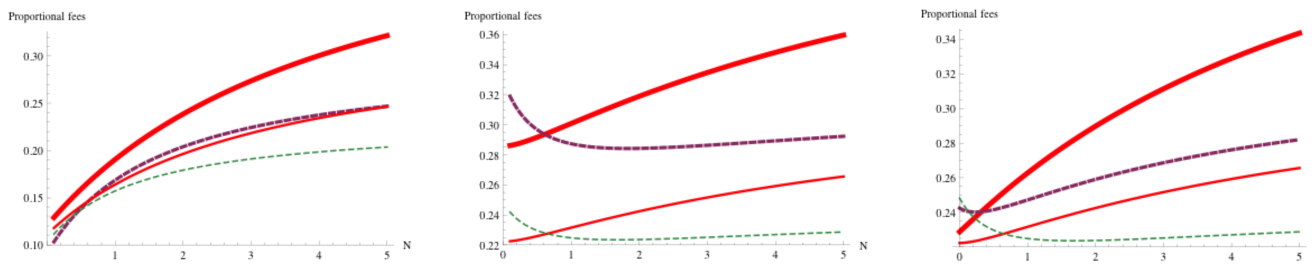
Figures 1 – 3 present comparative statics of market shares, absolute fees, and average proportional fees of the two higher-quality banks, B_1 and B_2, for the three scenarios described above. In Figures 1 – 3, thick lines correspond to the case of three underwriters. Thin lines, corresponding to the case of two underwriters as described in Section 2, are presented for comparison purposes.

Figure 1 presents weighted average proportional fees of the top two banks. The parameter values used in Figure 1 are: $\alpha_1 = 0.5$, $\alpha_2 = 0.3$, $\alpha_3 = 0.1$, $c = 0.1$. Solid lines depict the average proportional fee of B_1, while the dashed lines correspond to the average proportional fee of B_2.

Figure 1 demonstrates that the relations between the highest-quality bank's average proportional fee on one hand and the state of the IPO market on the other hand stay positive in the competitive scenario and in (fully and partially) collusive scenarios. On the other hand, the relation between the fee of the second bank exhibits a positive relation with the state of the IPO market in the competitive

Figure 1: Banks' proportional fees: The case of three banks

Figure 1A: Competitive case Figure 1B: Partially collusive case Figure 5C: Fully collusive case

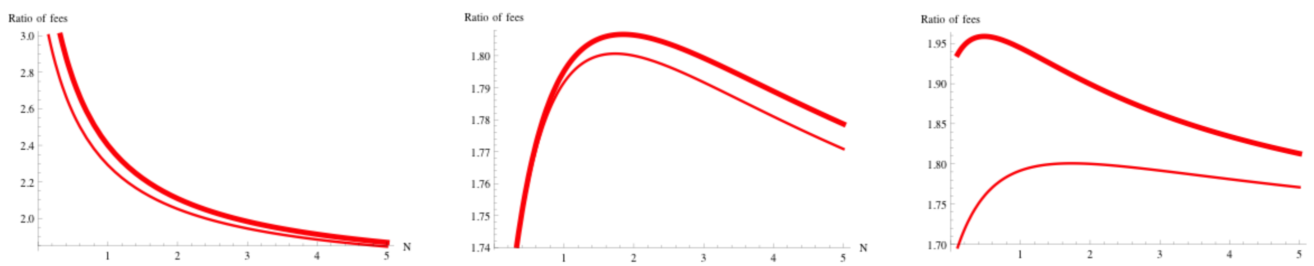


scenario and a U-shaped relation in the fully and partially collusive scenarios, consistent with the baseline results for two underwriters.

Figure 2 presents the relation between the ratio of the top two banks' absolute (dollar) fees under the three scenarios. Parameter values are identical to those in Figure 1.

Figure 2: Ratio of highest-quality bank's to medium-quality bank's absolute fees: The case of three banks

Figure 2A: Competitive case Figure 2B: Partially collusive case Figure 2C: Fully collusive case



It follows from Figure 2 that, similar to the two-bank case, the relation between the ratio of the two largest banks' absolute fees and the state of the IPO market is negative when these two banks compete and it exhibits a hump-shaped relation with N when the two banks collude, regardless of whether they collude with the third bank or compete with it.

Figure 3 presents the market share results. The market share of the highest-quality underwriter (B_1) is computed relative to the subset of the two highest-quality underwriters that we consider to be more likely to potentially collude (i.e. B_1 and B_2). The parameter values in Figure 3 are: $\alpha_1 = 0.5$, $\alpha_3 = 0.1$, $c = 0.1$. Similar to the case of two underwriters, we examine the case in which the quality of the second underwriter is similar to that of the first underwriter ($\alpha_2 = 0.4$) and the case in which

α_2 is substantially lower than α_1 ($\alpha_2 = 0.2$).[9]

Figure 3: Market share of highest-quality bank: The case of three banks

Figure 3A: Competitive case, small $\alpha_1 - \alpha_2$

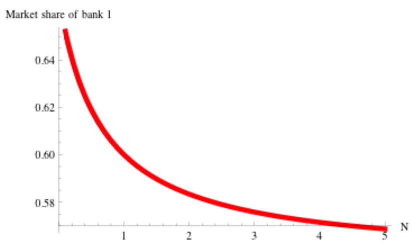


Figure 3B: Partially collusive case, small $\alpha_1 - \alpha_2$

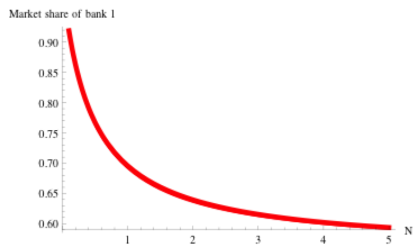


Figure 3C: Fully collusive case, small $\alpha_1 - \alpha_2$

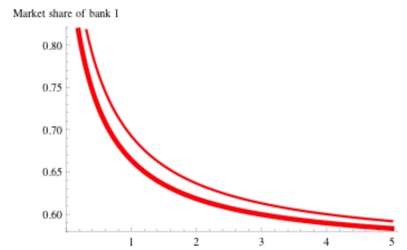


Figure 3D: Competitive case, large $\alpha_1 - \alpha_2$

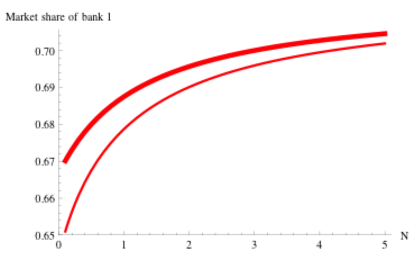


Figure 3E: Partially collusive case, large $\alpha_1 - \alpha_2$

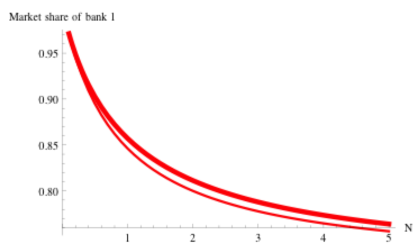
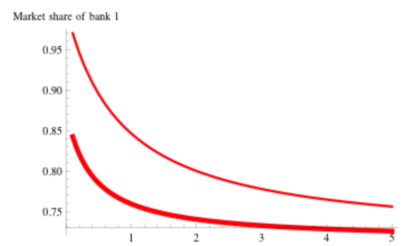


Figure 3F: Fully collusive case, large $\alpha_1 - \alpha_2$



It follows from comparing the competitive case in Figures 3A and 3D with the partially and fully collusive cases in Figures 3B, 3C, 3E, and 3F that when the difference between α_1 and α_2 is relatively small, the relation between the market share of the highest-quality underwriter and the state of the IPO market is negative in the competitive scenario and also in the partially collusive and fully collusive scenarios. In the case in which there is a large enough difference between α_1 and α_2, the relation between the market share of the highest-quality bank and the state of the IPO market is positive in the competitive scenario and is negative when the top two banks collude, regardless of whether they compete or collude with the third bank.

Overall, the numerical analysis in this section demonstrates that the comparative statics in our baseline model are robust to an inclusion of an additional, third, underwriter and, in general, are unlikely to be driven by the assumption of two underwriters.

[9]The shape of the relations described in Figures 1 – 3 generally holds for various sets of parameter values that satisfy $\alpha_1 > \alpha_2 > \alpha_3$.

C Optimal variable underwriting fees

In this Appendix we solve numerically a model in which we allow each of the two underwriters to choose not only its fixed fee, but also its variable fee, i.e. we now assume the following structure for bank j's fee: $F_{i,j} = \lambda_j + \mu_j V_i$.

For a given combination of λ_1, λ_2, μ_1, and μ_2 we compute using fine grid (of size $G = 0.01$) the optimal strategy of each firm whose value belongs to an interval $[0, 1]$:

$$\begin{aligned}
\text{remain private if } V_i(1+\alpha_1) - \lambda_1 - \mu_1 V_i &\leq 0 \text{ and } V_i(1+\alpha_2) - \lambda_2 - \mu_2 V_i \leq 0, \\
\text{IPO underwritten by } B_1 \text{ if } V_i(1+\alpha_1) - \lambda_1 - \mu_1 V_i &\geq \max\{V_i(1+\alpha_2) - \lambda_2 - \mu_2 V_i, 0\}, \\
\text{IPO underwritten by } B_2 \text{ if } V_i(1+\alpha_2) - \lambda_2 - \mu_2 V_i &\geq \max\{V_i(1+\alpha_1) - \lambda_1 - \mu_1 V_i, 0\},
\end{aligned}$$

and the resulting expected profits of each of the two banks, given by

$$\mathbb{E}\pi_j = \lambda_j GN \sum_{\mathbb{I}(i,j)=1} 1 + \mu_j GN \sum_{\mathbb{I}(i,j)=1} V_i - c\left(GN \sum_{\mathbb{I}(i,j)=1} 1\right)^2, \tag{35}$$

where $\mathbb{I}(i, j) = 1$ if an IPO of firm i is underwritten by bank j.

For given λ_1 and μ_1 we search for B_2's best response (i.e. a combination of λ_2 and μ_2 that results in the highest value of (35), λ_2' and μ_2'). We then search for λ_1' and μ_1', which are B_1's best response to λ_2' and μ_2', and we repeat this procedure until convergence. We use the resulting equilibrium λ_1^*, λ_2^*, μ_1^*, and μ_2^* in the competitive and collusive scenarios to compute banks' equilibrium market shares and underwriting fees.

Figures 4 – 6 depict comparative statics of market shares, average absolute fees, and average proportional fees. Thick lines correspond to the numerical solution of the model with variable underwriting fees discussed in this Appendix, while thin lines correspond to values obtained within an analytical solution of the model with fixed underwriting fees in Section 2. The parameter values for α_1, α_2, and c are identical to the corresponding values in Figures 1 – 3.

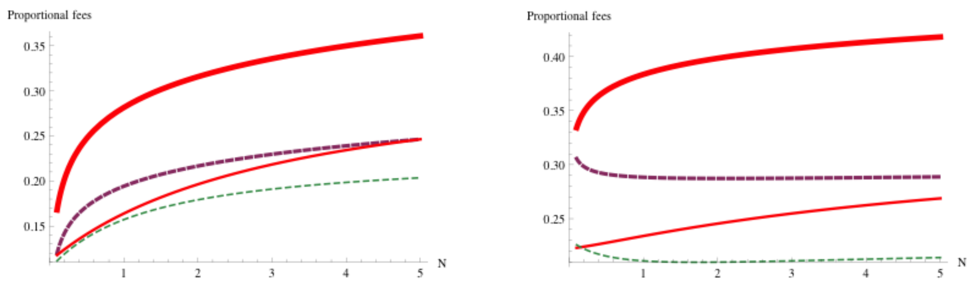
Figure 4 presents the two banks' weighted average proportional fees in the competitive and collusive scenarios. The definition of the weighted average proportional fee in the general case of variable underwriting fees has to be modified as follows:

Definition 2 *The weighted average proportional fee of bank j, $\overline{RF_j}$, equals* $\dfrac{\lambda_j^*\left(N\left(\overline{V_j} - \underline{V_j}\right)\right) + \mu_j^* N \int_{V=\underline{V_j}}^{\overline{V_j}} V dV}{N \int_{V=\underline{V_j}}^{\overline{V_j}} V dV}$.

Similar to the base-case model in Section 2.2, the two banks' average absolute fees are increasing in the state of the IPO market under the competitive scenario. The higher-quality bank's average absolute fee is increasing in N in the collusive scenario, whereas the lower-quality bank's average absolute fee exhibits a U-shaped relation with N.

Figure 4: Banks' proportional fees: The case of optimal variable fees

Figure 4A: Competitive case   Figure 4B: Collusive case



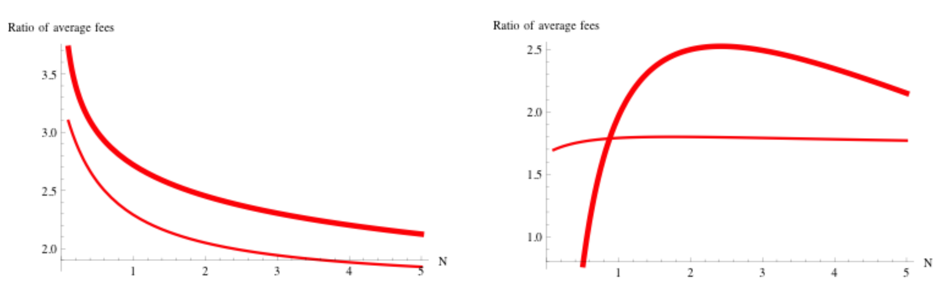
Unlike in the base-case model in Section 2.2, in which the fees paid to a given underwriter are identical for all firms, underwriting fees are now increasing in IPO size. Thus, in order to relate the ratio of the two banks' fees to the state of the IPO market, we first need to define an average fee charged by a bank:

Definition 3 *Bank j's weighted average absolute fee,* $\overline{F_j}$*, equals* $\dfrac{\lambda_j^* N\left(\overline{V_j}-\underline{V_j}\right)+\mu_j^* N\int_{V=\underline{V_j}}^{\overline{V_j}} V\,dV}{N\left(\overline{V_j}-\underline{V_j}\right)}$.

Figure 5 depicts the relation between the ratio of the two banks' weighted average absolute (dollar) fees and the state of the IPO market:

Figure 5: Ratio of higher-quality bank's to lower-quality bank's absolute fees: The case of optimal variable fees

Figure 5A: Competitive case   Figure 5B: Collusive case



Similar to the base-case model in Section 2, the ratio of the two banks' weighted average total fees is decreasing in the state of the IPO market in the competitive scenario and it exhibits a hump-shaped relation with the state of the market in the collusive case.

Figure 6 presents B_1's market share as a function of the state of the IPO market in the competitive and collusive scenarios.

Figure 6: Market share of higher-quality bank: The case of optimal variable fees

Figure 6A: Competitive case, small $\alpha_1 - \alpha_2$

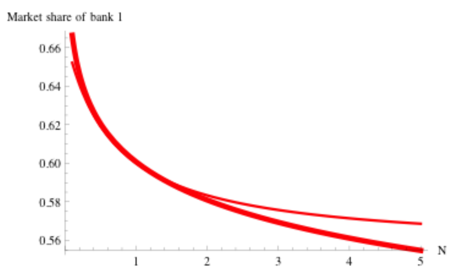


Figure 6B: Collusive case, small $\alpha_1 - \alpha_2$

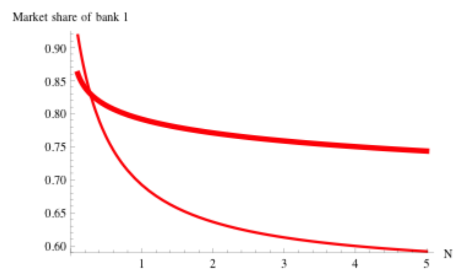


Figure 6C: Competitive case, large $\alpha_1 - \alpha_2$

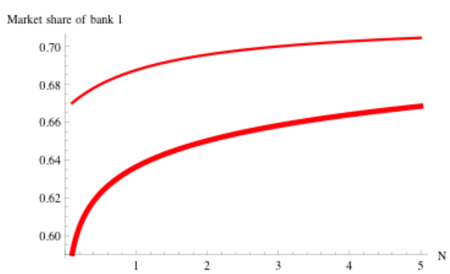
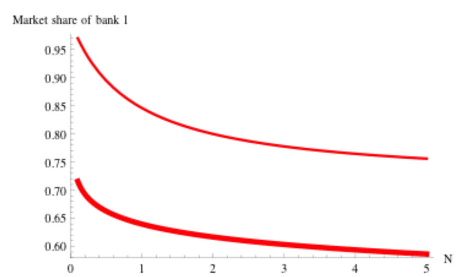


Figure 6D: Collusive case, large $\alpha_1 - \alpha_2$



As evident from Figure 6, the relations between banks' market shares and the state of the IPO market in the competitive and collusive scenarios are qualitatively similar to those in the zero-variable-fees model in Section 2.2.

Overall, the results in this Appendix illustrate that introducing variable underwriting fees does not affect the qualitative comparative statics derived in the baseline model.

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Table 1. Summary statistics

Panel A reports annual means for the sample of IPOs used in the empirical tests. The sample consists of 6,917 IPOs by U.S. firms during 1975-2013. The source of data is Thomson Financial's Security Data company and Jay Ritter. The sample excludes non-firm-commitment offerings, unit offerings, offerings by banks, closed-end funds, REITs, and ADRs, reverse LBOs, IPOs with offer price lower than $5, and offerings that are a part of a corporate spinoff. We also require the IPOs to have information on underwriting spread and total proceeds. Number IPOs is the number of IPOs in a given year. Value IPOs (in millions of dollars) is total annual IPO proceeds adjusted by Consumer Price Index (CPI) to 2010 dollars. Market return is the value-weighted annual market return. PNFI growth is the year-to-year growth in private nonresidential fixed investment. Mean spread refers to equally-weighted mean underwriter's fee divided by the size of the offering (offer proceeds), which, in turn, equals the product of shares issued and offer price. Mean underpricing refers to equally-weighted mean ratio of the share price at the end of the first trading day and the offer price, minus one. Mean underpricing (> 0) refers to equally-weighted mean underpricing, where negative underpricing is substituted by 0. Prop. VC is the proportion of IPOs backed by venture capital funds. Prop hi-tech is the proportion of IPOs in hi-tech industries. Prop. secondary is the equally-weighted mean proportion of secondary shares in IPOs. Prop. syndicated is the proportion of IPOs underwritten by multiple book runners.

Panel B presents descriptive statistics for the whole sample.

Panel C presents summary statistics of IPO underpricing for groups of underwriters classified by their reputation score (CM score), due to Carter and Manaster (1990) and Loughran and Ritter (2004). If an IPO has joint book runners (676 deals in our sample involve two to eleven joint book runners), we divide its proceeds evenly by the number of book runners and count this IPO multiple times in the analysis below.

Panel A. Summary statistics – by year

Year	Number IPOs	Value IPOs	Market return	PNFI growth	Mean spread	Mean underpricing	Mean under-pricing (> 0)	Prop. VC	Prop. hi-tech	Prop. secondary	Prop. syndicated
1975	12	1,105	37.36%	2.98%	7.15%	-0.21%	2.30%	0.000	0.000	0.529	0.000
1976	27	862	26.77%	11.43%	7.67%	1.62%	4.04%	0.370	0.370	0.372	0.000
1977	19	501	-2.98%	18.15%	8.34%	7.99%	8.89%	0.211	0.316	0.268	0.000
1978	22	724	8.54%	21.42%	7.79%	15.56%	16.79%	0.364	0.455	0.257	0.000
1979	45	1,045	24.41%	18.82%	8.16%	14.93%	16.34%	0.311	0.489	0.290	0.000
1980	68	2,438	33.24%	8.86%	8.05%	14.23%	15.61%	0.338	0.368	0.207	0.000
1981	177	5,097	-3.99%	16.24%	7.95%	6.35%	7.20%	0.305	0.418	0.208	0.000
1982	67	2,158	20.42%	2.56%	8.02%	11.21%	11.98%	0.313	0.597	0.245	0.000
1983	456	16,716	22.65%	-0.60%	8.04%	13.01%	14.22%	0.243	0.452	0.183	0.000
1984	199	3,506	3.16%	17.03%	8.45%	4.37%	5.85%	0.226	0.337	0.134	0.000
1985	187	5,980	31.41%	7.71%	8.09%	7.99%	8.67%	0.198	0.251	0.188	0.000
1986	349	17,668	15.56%	0.00%	7.69%	7.14%	8.09%	0.223	0.278	0.177	0.000
1987	254	16,303	1.83%	1.23%	7.70%	6.60%	7.31%	0.256	0.287	0.136	0.000
1988	90	4,268	17.56%	7.64%	7.61%	7.06%	7.68%	0.367	0.356	0.153	0.000
1989	100	4,792	28.43%	8.11%	7.52%	9.34%	9.63%	0.390	0.370	0.197	0.000
1990	102	5,322	-6.08%	3.25%	7.60%	11.75%	12.27%	0.422	0.343	0.154	0.000
1991	256	18,689	33.64%	-2.12%	7.27%	12.91%	13.28%	0.445	0.391	0.144	0.000
1992	342	24,278	9.06%	2.54%	7.36%	11.67%	12.29%	0.383	0.377	0.116	0.000
1993	402	22,519	11.59%	7.71%	7.39%	14.46%	14.92%	0.402	0.333	0.115	0.005
1994	342	14,450	-0.76%	8.71%	7.55%	10.38%	10.70%	0.364	0.356	0.113	0.006
1995	412	25,071	35.67%	10.75%	7.38%	22.78%	23.13%	0.444	0.515	0.138	0.000
1996	603	38,174	21.18%	8.42%	7.34%	17.64%	18.18%	0.421	0.476	0.085	0.000
1997	402	28,101	30.35%	10.15%	7.30%	14.58%	14.93%	0.330	0.404	0.090	0.005
1998	236	19,768	22.26%	9.02%	7.25%	22.16%	22.81%	0.317	0.458	0.088	0.033
1999	397	59,376	25.26%	8.68%	7.01%	73.26%	74.26%	0.644	0.803	0.038	0.049
2000	290	44,489	-11.05%	9.71%	6.99%	59.64%	61.06%	0.724	0.852	0.017	0.086
2001	60	17,764	-11.26%	-2.67%	6.86%	16.38%	17.25%	0.414	0.357	0.071	0.286
2002	49	8,808	-20.84%	-7.22%	6.95%	9.43%	11.17%	0.410	0.410	0.143	0.377
2003	52	8,600	33.14%	1.69%	6.98%	11.49%	12.67%	0.348	0.377	0.161	0.478
2004	141	22,143	13.00%	6.67%	6.79%	13.35%	13.99%	0.446	0.495	0.150	0.564
2005	127	24,030	7.32%	10.14%	6.68%	9.62%	10.67%	0.246	0.374	0.163	0.706
2006	127	23,049	16.21%	10.23%	6.73%	12.54%	13.47%	0.335	0.439	0.146	0.717
2007	125	25,894	7.31%	8.12%	6.72%	14.64%	16.10%	0.450	0.608	0.155	0.766
2008	17	18,408	-38.30%	1.06%	5.77%	14.87%	17.93%	0.351	0.270	0.256	0.865
2009	35	11,689	31.61%	-15.85%	6.37%	10.16%	10.97%	0.258	0.371	0.303	0.959
2010	80	27,606	17.89%	1.52%	6.48%	8.27%	9.07%	0.390	0.419	0.276	0.933
2011	69	21,360	-0.90%	9.15%	6.26%	13.85%	15.58%	0.513	0.538	0.248	0.949
2012	81	24,166	15.98%	8.85%	6.49%	19.38%	20.45%	0.527	0.506	0.186	0.963
2013	110	21,826	31.68%	3.81%	6.50%	25.01%	26.51%	0.515	0.533	0.072	0.973
Mean	178	16,378	13.80%	6.51%	7.40%	18.56%	19.36%	0.489	0.498	0.207	0.297

Panel B. Summary statistics – IPO characteristics

	Mean	St. Dev.	Min	Median	Max
Spread	7.40%	1.11%	0.75%	7.00%	17.00%
Underpricing	18.56%	39.36%	-50.00%	7.14%	697.50%
Underpricing (> 0)	19.36%	38.86%	0.00%	7.14%	697.50%
Prop. VC	0.395	0.489	0.000	0.000	1.000
Prop. hi-tech	0.456	0.498	0.000	0.000	1.000
Prop. secondary	0.131	0.207	0.000	0.000	1.000
Prop. mult. bookrunners	0.098	0.297	0.000	0.000	1.000

Panel C. Summary statistics – Book runners by reputation score

CM score	Num. underwriter/years	Num. IPOs	Total value IPOs	Mean value IPO
not rated	6	7	39	5.55
1	86	137	1,541	11.25
2	258	383	3,913	10.14
3	240	361	4,982	13.76
4	179	297	4,268	14.23
5	289	504	14,714	28.41
6	211	439	16,650	35.65
7	289	684	33,052	43.84
8	321	1738	134,070	68.72
9	325	2379	425,515	134.15

Table 2. Underwriter compensation, underwriter quality, and IPO size

This table presents the results of regressions in which the dependent variable is proportional underwriter compensation. We compute proportional underwriter compensation in two ways. In columns 1 and 3 we only include the direct component of compensation, i.e. the underwriting spread. In columns 2 and 4 we include both the underwriting spread and the indirect component, which we estimate to be 5% of IPO underpricing, following Goldstein, Irvine and Puckett (2011). In cases of negative underpricing, the indirect component of underwriter compensation is assumed zero. HQ (high quality) dummy is an indicator variable equalling one if an underwriter belongs to the group of top underwriters. This group contains underwriters with Carter-Manaster score 9 in columns 1 and 2, and those with one of the highest ten market shares of IPO underwriting, based on $ amount of IPOs underwritten in columns 3 and 4. IPO size is the natural logarithm of IPO proceeds net of underwriting spread. Other independent variables include Volatility (the volatility of daily returns in the 12 months following the offering), Secondary (the proportion of secondary shares sold by existing shareholders in the IPO), Hi-tech (dummy variable for high-tech or biotech issuer), VC (dummy variable for VC-backed IPOs), and Syndicate (dummy variable for IPOs with multiple book runners). The regressions are performed on the IPO-underwriter level. In cases in which there are multiple book runners, an IPO enters the sample multiple times. The regressions are estimated with year fixed effects. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient on one of the two main independent variables (HQ dummy and IPO size) at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on HQ dummy and on IPO size, which follow from Propositions 1 and 2 of the model in Section 2.

Measure of high quality banks		CM score = 9		Top 10 market share	
Measure of compensation		Direct	Direct & indirect	Direct	Direct & indirect
	Prediction				
HQ dummy	> 0	0.111***	0.387**	0.099**	0.501***
		(2.78)	(2.45)	(2.47)	(3.22)
IPO size	< 0	-0.803***	-0.732***	-0.799***	-0.748***
		(-30.21)	(-17.47)	(-30.31)	(-18.52)
Volatility		4.225	16.393	4.113	16.054
		(5.49)	(6.30)	(5.34)	(6.34)
Secondary		-0.308	-0.355	-0.314	-0.383
		(-4.23)	(-3.45)	(-4.30)	(-3.74)
Hi-tech		-0.020	0.196	-0.021	0.186
		(-0.80)	(3.98)	(-0.85)	(3.88)
VC		-0.260	-0.025	-0.258	-0.029
		(-8.04)	(-0.25)	(-7.96)	(-0.29)
Syndicate		0.330	0.446	0.338	0.484
		(5.72)	(4.36)	(5.82)	(4.76)
Intercept		10.292	9.988	10.304	10.100
		(88.03)	(31.95)	(86.42)	(34.49)
R squared		68.51%	28.10%	68.49%	28.46%
Number obs.		7,702	7,702	7,702	7,702
Number clusters		504	504	504	504

Table 3. Underwriter compensation, underwriter quality, and the state of the IPO market

This table presents the results of regressions in which the dependent variable is mean annual proportional underwriter compensation. We compute proportional underwriter compensation in two ways. In odd columns we only include the direct component of compensation, i.e. the underwriting spread. In even columns we include both the underwriting spread and the indirect component, which we estimate to be 5% of IPO underpricing, following Goldstein, Irvine and Puckett (2011). In cases of negative underpricing, the indirect component of underwriter compensation is assumed zero. The main dependent variables are the state of the IPO market (IPO state) interacted with high quality and low quality underwriter indicators (HQ and LQ respectively), and the state of the IPO market squared. We use three measures of the state of the IPO market. The first one, used in columns 1-4, is the annual number of IPOs, divided by 100. The second one, used in columns 5-8, is the annual growth in private nonresidential fixed investment. The third one, used in columns 9-12, is the value-weighted annual market return. HQ (high quality) dummy is an indicator variable equalling one if an underwriter belongs to the group of top underwriters. This group contains underwriters with Carter-Manaster score 9 in columns 1, 2, 5, 6, 9, and 10, and those with one of the highest ten market shares of IPO underwriting, based on $ amount of IPOs underwritten, in columns 3, 4, 7, 8, 11, and 12. IPO Size is the natural logarithm of IPO proceeds net of underwriting spread. Other independent variables include Volatility (mean volatility of daily returns in the 12 months following the offerings by a given underwriter in a given year), Secondary (mean proportion of secondary shares sold by existing shareholders in IPOs by a given underwriter in a given year), Hi-tech (proportion of high-tech or biotech issuers), VC (proportion of VC-backed IPOs), and Syndicate (proportion of IPOs with joint book runners). The regressions are performed at the underwriter-year level. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient on one of the three main independent variables (interaction of the state of IPO market with HQ dummy, interaction of the state of IPO market with LQ dummy, and the state of IPO market squared) at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state * HQ, IPO state * LQ, and IPO $state^2$, which follow from Proposition 3 of the model in Section 2.

Measure of IPO state	Predictions Comp.	Predictions Coll.	Annual number of IPOs				PNFI growth				Market return			
Measure of HQ banks			CM score = 9		Top 10 market share		CM score = 9		Top 10 market share		CM score = 9		Top 10 market share	
Measure of comp.			Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect
IPO state *HQ	≥ 0	≥ 0	-0.055	-0.033	-0.043	-0.004	-0.167	2.204**	-0.511	1.297*	0.003	0.370	0.040	0.429
			(-1.39)	(-0.40)	(-1.07)	(-0.05)	(-0.43)	(2.35)	(-1.31)	(1.83)	(0.02)	(0.93)	(0.23)	(1.47)
IPO state *LQ	≥ 0	< 0	-0.124***	-0.175**	-0.124***	-0.176**	-2.447***	-2.532***	-2.454***	-2.463***	-0.611***	-0.493	-0.722***	-0.652*
			(-2.98)	(-2.17)	(-2.98)	(-2.19)	(-5.54)	(-3.05)	(-5.61)	(-3.09)	(-2.84)	(-1.44)	(-2.96)	(-1.68)
IPO state^2	> 0	> 0	0.016**	0.037***	0.016**	0.036***	12.390***	13.014***	10.869***	9.759*	2.633***	4.300***	2.837***	4.593***
			(2.55)	(2.80)	(2.50)	(2.76)	(4.59)	(2.46)	(4.18)	(1.95)	(4.28)	(4.26)	(4.23)	(4.22)
IPO size			-0.955	-0.920	-0.961	-0.934	-0.944	-0.891	-0.944	-0.888	-0.958	-0.897	-0.962	-0.904
			(-32.00)	(-17.47)	(-33.21)	(-18.06)	(-32.29)	(-16.66)	(-32.31)	(-16.47)	(-30.19)	(-15.67)	(-30.42)	(-15.78)
Volatility			5.277	16.178	5.284	16.207	5.375	17.073	5.413	17.112	4.425	15.972	4.527	16.119
			(4.77)	(6.52)	(4.79)	(6.58)	(4.96)	(6.80)	(4.99)	(6.83)	(4.06)	(6.49)	(4.15)	(6.54)
Secondary			-0.809	-1.211	-0.823	-1.239	-0.807	-1.332	-0.845	-1.403	-0.757	-1.280	-0.788	-1.326
			(-7.04)	(-7.11)	(-7.22)	(-7.34)	(-6.99)	(-7.63)	(-7.24)	(-7.99)	(-6.85)	(-7.71)	(-6.95)	(-7.78)
Hi-tech			0.036	0.302	0.030	0.289	0.030	0.294	0.027	0.288	0.045	0.305	0.042	0.301
			(0.70)	(3.17)	(0.58)	(3.05)	(0.59)	(3.08)	(0.52)	(3.02)	(0.86)	(3.18)	(0.81)	(3.16)
VC			-0.423	-0.453	-0.427	-0.461	-0.417	-0.468	-0.418	-0.469	-0.420	-0.447	-0.422	-0.450
			(-7.65)	(-4.70)	(-7.70)	(-4.75)	(-7.59)	(-4.85)	(-7.57)	(-4.81)	(-7.59)	(-4.61)	(-7.62)	(-4.60)
Syndicate			0.439	0.528	0.446	0.546	0.456	0.400	0.465	0.414	0.503	0.458	0.511	0.470
			(5.48)	(3.94)	(5.77)	(4.18)	(5.91)	(3.07)	(6.11)	(3.21)	(6.62)	(3.53)	(6.75)	(3.63)
Intercept			11.064	11.046	11.085	11.096	10.912	10.905	10.924	10.920	10.899	10.793	10.917	10.819
			(82.87)	(43.43)	(83.64)	(43.59)	(87.83)	(45.34)	(87.39)	(44.63)	(85.44)	(45.36)	(84.65)	(45.22)
R squared			69.64%	41.14%	69.73%	41.38%	69.82%	40.96%	69.84%	40.93%	69.68%	41.07%	69.76%	41.16%
Num. obs.			2,204	2,204	2,204	2,204	2,204	2,204	2,204	2,204	2,204	2,204	2,204	2,204
Num. clusters			504	504	504	504	504	504	504	504	504	504	504	504

Table 4. Ratio of high-quality to low-quality underwriter compensation and the state of the IPO market

This table presents the results of regressions in which the dependent variable is the natural logarithm of the ratio of annual mean absolute (dollar) compensation of an underwriter that belongs to a high quality group to annual mean absolute (dollar) compensation of underwriters that do not belong to a high quality group. We compute absolute (dollar) underwriter compensation in two ways. In odd columns we only include the direct component of the compensation, i.e. the underwriting spread multiplied by issue proceeds. In even columns we include both the underwriting spread multiplied by issue proceeds and the indirect component, which we estimate to be 5% of IPO underpricing multiplied by issue proceeds. In cases of negative underpricing, the indirect component of underwriter compensation is assumed zero. The main dependent variables are the state of the IPO market (IPO state) and the state of the IPO market squared. We use three measures of the state of the IPO market. The first one, used in columns 1-4, is the annual number of IPOs, divided by 100. The second one, used in columns 5-8, is the annual growth in private nonresidential fixed investment. The third one, used in columns 9-12, is the value-weighted annual market return. The group of high quality underwriters contains underwriters with Carter-Manaster score 9 in columns 1, 2, 5, 6, 9, and 10, and those with the highest ten market shares of IPO underwriting, based on $ amount of IPOs underwritten, in columns 3, 4, 7, 8, 11, and 12. Diff variables refer to the difference between annual mean of the variable for a high quality underwriter and annual mean value of the variable within the group of low quality underwriters. IPO Size is the natural logarithm of IPO proceeds net of underwriting spread. Other independent variables include Volatility (mean volatility of daily returns in the 12 months following the offerings by a given underwriter in a given year), Secondary (mean proportion of secondary shares sold by existing shareholders in the IPO by a given underwriter in a given year), Hi-tech (proportion of high-tech or biotech issuers), VC (proportion of VC-backed IPOs), and Syndicate (proportion of IPOs with multiple book runners). The regressions are performed at the underwriter-year level for samples of high quality underwriters. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient on one of the two main independent variables (the state of IPO market and the state of IPO market squared) at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state and IPO state^2, which follow from Proposition 4 of the model in Section 2.

Measure of IPO state	Predictions Comp.	Predictions Coll.	Annual number of IPOs				PNFI growth				Market return			
Measure of HQ banks			CM score = 9		Top 10 market share		CM score = 9		Top 10 market share		CM score = 9		Top 10 market share	
Measure of comp.			Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect	Direct	Direct & indirect
IPO state	<= 0	> 0	0.042*	0.046*	0.112***	0.100***	0.295	0.345	0.085	0.077	0.213**	0.271***	0.177	0.125
			(1.70)	(1.72)	(5.69)	(5.17)	(1.30)	(1.53)	(0.50)	(0.44)	(2.38)	(3.70)	(1.48)	(1.07)
IPO state^2	< 0	< 0	-0.001	-0.002	-0.015***	-0.012***	-5.189***	-6.121***	-3.566***	-3.594***	-0.414	-0.455	-0.883**	-0.471
			(-0.21)	(-0.35)	(-5.15)	(-3.99)	(-3.38)	(-3.58)	(-3.57)	(-3.24)	(-1.03)	(-1.12)	(-2.03)	(-1.08)
Diff IPO size			0.903	0.895	0.794	0.805	0.914	0.908	0.784	0.795	0.901	0.892	0.803	0.808
			(32.96)	(33.41)	(14.86)	(16.83)	(33.95)	(34.53)	(14.22)	(16.18)	(34.09)	(33.93)	(15.95)	(17.63)
Diff volatility			-4.021	-3.495	-0.890	-0.915	-5.775	-5.273	-0.959	-1.128	-6.132	-5.752	0.006	-0.376
			(-2.00)	(-1.38)	(-0.66)	(-0.75)	(-3.52)	(-2.43)	(-0.86)	(-1.14)	(-3.74)	(-2.69)	(0.00)	(-0.33)
Diff secondary			-0.132	-0.132	0.068	-0.031	-0.190	-0.193	0.034	-0.063	-0.181	-0.183	-0.040	-0.125
			(-1.77)	(-1.56)	(0.63)	(-0.29)	(-2.61)	(-2.26)	(0.31)	(-0.57)	(-2.23)	(-1.92)	(-0.42)	(-1.28)
Diff hi-tech			0.047	0.056	-0.026	0.008	0.085	0.099	-0.039	-0.004	0.062	0.073	0.000	0.024
			(0.96)	(1.04)	(-0.61)	(0.18)	(1.56)	(1.60)	(-0.91)	(-0.09)	(1.24)	(1.33)	(0.01)	(0.55)
Diff VC			-0.033	0.000	0.004	0.035	-0.051	-0.020	0.023	0.057	-0.044	-0.012	-0.035	0.010
			(-0.80)	(0.00)	(0.08)	(0.78)	(-1.10)	(-0.41)	(0.43)	(1.11)	(-0.97)	(-0.26)	(-0.70)	(0.20)
Diff syndicate			-0.757	-0.787	-0.819	-0.734	-0.813	-0.839	-0.929	-0.846	-0.814	-0.838	-0.844	-0.779
			(-5.44)	(-5.47)	(-9.92)	(-9.02)	(-6.73)	(-6.75)	(-10.01)	(-9.34)	(-6.36)	(-6.16)	(-9.14)	(-8.21)
Intercept			-0.249	-0.239	-0.126	-0.113	-0.201	-0.192	0.044	0.050	-0.183	-0.176	0.023	0.021
			(-9.96)	(-8.75)	(-2.49)	(-2.48)	(-6.94)	(-6.23)	(0.73)	(0.93)	(-5.10)	(-4.54)	(0.41)	(0.41)
R squared			89.68%	87.10%	86.66%	86.48%	89.32%	86.86%	85.84%	85.69%	89.20%	86.74%	85.76%	85.41%
Num. obs.			323	323	378	378	323	323	378	378	323	323	378	378
Num. clusters			31	31	57	57	31	31	57	57	31	31	57	57

Table 5. High quality underwriters' market share and the state of the IPO market

This table presents the results of regressions in which the dependent variable is the market share of high quality underwriters, computed based on $ amounts of IPO proceeds. The group of high quality underwriters contains underwriters with Carter-Manaster score 9 in odd columns and those with the highest ten market shares of IPO underwriting, based on $ amount of IPOs underwritten, in even columns. The dependent variables are the state of IPO market (IPO state) interacted with indicator variables for high and low heterogeneity in underwriter qualities (high hetero and low hetero respectively). We use three measures of the state of the IPO market. The first one, used in columns 1-4, is the annual number of IPOs, divided by 100. The second one, used in columns 5-8, is the annual growth in private nonresidential fixed investment. The third one, used in columns 9-12, is the value-weighted annual market return. Our measure of underwriter quality heterogeneity is based on the annual standard deviation of underwriters' Carter-Manaster scores. Annual standard deviations above (below) time-series mean correspond to years with high (low) underwriter heterogeneity. The regressions are performed at the year level. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient estimate at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state * High hetero and IPO state * Low hetero, which follow from Proposition 5 of the model in Section 2.

Measure of IPO market state			Annual num. IPOs		PNFI growth		Market return	
Measure of IPO high quality banks			Score 9	Top 10	Score 9	Top 10	Score 9	Top 10
	Predictions Comp.	Predictions Coll.						
IPO state * High hetero	> 0	< 0	-0.003 (-0.11)	-0.051*** (-3.99)	-1.754*** (-3.08)	-1.098*** (-3.06)	-0.173 (-0.53)	-0.458*** (-2.67)
IPO state * Low hetero	< 0	< 0	0.031 (0.48)	-0.042 (-1.34)	-2.063*** (-3.59)	-0.325 (-0.90)	-0.158 (-0.59)	0.029 (0.21)
Intercept			0.564 (8.32)	0.869 (26.56)	0.694 (15.59)	0.836 (29.79)	0.596 (11.54)	0.817 (29.93)
R squared			1.06%	31.37%	32.86%	20.62%	1.38%	18.02%
Number observations			39	39	39	39	39	39

Table 6. Subsample of largest underwriters

In all three Panels of Table 6, the sample is restricted to underwriters with the highest ten market shares of IPO underwriting, based on $ amount of IPOs underwritten, or all underwriters in case there are fewer than ten underwriters in a given year.

Panel A presents the results of regressions in which the dependent variable is mean annual proportional underwriter compensation. We compute proportional underwriter compensation in two ways. In odd columns we only include the direct component of compensation, i.e. the underwriting spread. In even columns we include both the underwriting spread and the indirect component, which we estimate to be 5% of IPO underpricing. In cases of negative underpricing, the indirect component of underwriter compensation is assumed zero. The main dependent variables are the state of the IPO market (IPO state) interacted with high quality and low quality underwriter indicators (HQ and LQ respectively), and the state of the IPO market squared. We use the annual number of IPOs, divided by 100, as a measure of the state of the IPO market. HQ (high quality) dummy is an indicator variable equalling one if an underwriter belongs to the group of top underwriters. This group contains underwriters with one of the highest three (five) market shares of IPO underwriting, based on $ amount of IPOs underwritten, in columns 1-2 (3-4). We use the same set of control variables as in Table 3; their estimates are not reported. The regressions are performed at the underwriter-year level. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient estimate at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state * HQ, IPO state * LQ, and IPO state^2, which follow from Proposition 3 of the model in Section 2.

Panel B presents the results of regressions in which the dependent variable is the natural logarithm of the ratio of annual mean absolute (dollar) compensation of an underwriter that belongs to a high quality group to annual mean absolute (dollar) compensation of underwriters that do not belong to a high quality group. We compute absolute (dollar) underwriter compensation in two ways. In odd columns we only include the direct component of the compensation, i.e. the underwriting spread multiplied by issue proceeds. In even columns we include both the underwriting spread multiplied by issue proceeds and the indirect component, which we estimate to be 5% of IPO underpricing multiplied by issue proceeds. In cases of negative underpricing, the indirect component of underwriter compensation is assumed zero. The main dependent variables are the state of the IPO market (IPO state) and the state of the IPO market squared. We use the annual number of IPOs, divided by 100, as a measure of the state of the IPO market. The group of high quality underwriters underwriters with one of the highest three (five) market shares of IPO underwriting, based on $ amount of IPOs underwritten, in columns 1-2 (3-4). We use the same set of control variables as in Table 4; their estimates are not reported. The regressions are performed at the underwriter-year level for samples of high quality underwriters. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient estimate at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state and IPO state^2, which follow from Proposition 4 of the model in Section 2.

Panel C presents presents the results of regressions in which the dependent variable is the market share of high quality underwriters, computed based on $ amounts of IPO proceeds. The group of high quality underwriters underwriters with one of the highest three (five) market shares of IPO underwriting, based on $ amount of IPOs underwritten, in columns 1-2 (3-4). The dependent variables are the state of IPO market (IPO state) interacted with indicator variables for high and low heterogeneity in underwriter qualities (high hetero and low hetero respectively). We use the annual number of IPOs, divided by 100, as a measure of the state of the IPO market. Our measure of underwriter quality heterogeneity is based on the annual standard deviation of underwriters' $ market shares of IPOs underwritten. Annual standard deviation above (below) time-series mean correspond to years with high (low) underwriter heterogeneity. The regressions are performed at the year level. t-statistics are reported in parentheses. *, **, *** indicate significance of a coefficient estimate at the 10%, 5%, and 1% level, respectively. The prediction column presents the predicted sign on IPO state * High hetero and IPO state * Low hetero, which follow from Proposition 5 of the model in Section 2.

Panel A. Underwriter compensation, underwriter quality, and the state of the IPO market

Measure of HQ banks			Top 3 market share		Top 5 market share	
Measure of competition			Direct	Direct and indirect	Direct	Direct and indirect
	Predictions Comp.	Coll.				
IPO state ∗HQ	≥ 0	≥ 0	-0.072 (-1.33)	-0.010 (-0.10)	-0.076 (-1.45)	-0.062 (-0.77)
IPO state ∗LQ	≥ 0	< 0	-0.095* (-1.83)	-0.191** (-2.33)	-0.101* (-1.92)	-0.203*** (-2.57)
IPO state^2	> 0	> 0	0.012 (1.52)	0.031** (2.45)	0.012 (1.54)	0.031** (2.55)
R squared			72.40%	50.03%	72.48%	49.11%
Num. obs.			378	378	378	378
Num. clusters			60	60	60	60

Panel B. Ratio of high-quality to low-quality underwriter compensation and the state of the IPO market

Measure of HQ banks	Predictions		Top 3 market share		Top 5 market share	
Measure of competition			Direct	Direct and indirect	Direct	Direct and indirect
	Comp.	Coll.				
IPO state	≤ 0	> 0	0.195***	0.199***	0.141***	0.132***
			(6.77)	(7.64)	(6.11)	(5.36)
IPO state^2	< 0	< 0	-0.032***	-0.032***	-0.023***	-0.020***
			(-5.55)	(-6.19)	(-6.50)	(-5.57)
R squared			90.24%	88.89%	89.78%	88.25%
Num. obs.			117	117	195	195
Num. clusters			25	25	38	38

Panel C. High quality underwriters' market share and the state of the IPO market

Measure of HQ banks	Predictions		Top 3 market share	Top 5 market share
	Comp.	Coll.		
IPO state * High hetero	≥ 0	≥ 0	-0.048***	-0.125***
			(-3.90)	(-3.72)
IPO state * Low hetero	≥ 0	< 0	-0.054***	-0.155**
			(-4.74)	(-4.54)
R squared			34.38%	43.72%
Num. obs.			39	39