Do IPO Underwriters Collude? *

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Abstract

We propose and implement, for the first time, a direct test of the hypothesis of implicit collusion in the U.S. underwriting market against the alternative of oligopolistic competition. We construct two models of an underwriting market – a market characterized by oligopolistic competition among IPO underwriters and a market in which banks collude in setting underwriter fees. The two models leads 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 of data on U.S. IPOs to test the predictions of the two models. Our empirical results are generally consistent with the implicit collusion hypothesis, and are inconsistent with the oligopolistic competition hypothesis.

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1 Introduction

The initial public offering (IPO) underwriting market in the U.S. is very profitable. IPO gross spreads, which cluster at 7%, seem high in absolute terms and are high relative to other countries (e.g., Chen and Ritter (2000), Hansen (2001), Torstila (2003), and Abrahamson, Jenkinson and Jones (2011)). In addition, returns on IPO stocks on the first day of trading (i.e. IPO underpricing) tend to be even higher (Ritter and Welch (2002), Ljungqvist and Wilhelm (2003), Loughran and Ritter (2004), and Liu and Ritter (2011). Underwriters are likely to be rewarded by investors for this money left on the table, in the form of "soft dollars", for example abnormally high trading commissions (e.g., Reuter (2006), Nimalendran, Ritter and Zhang (2006), and Goldstein, Irvine and Puckett (2011)).

There is an ongoing debate as to whether the high profitability of the U.S. IPO underwriting market in the U.S. is a result of implicit collusion among underwriters or, alternatively, a competitive outcome. In the latter scenario, high gross spreads may be a result of substantial entry costs into the IPO underwriting market due to the importance of underwriter prestige (e.g., Beatty and Ritter (1986), Carter and Manaster (1990), and Chemmanur and Fulghieri (1994)) and/or the importance of providing analyst coverage for newly public stocks (e.g., Dunbar (2000) and Krigman, Shaw and Womack (2001)), while high underpricing may be due to various kinds of information asymmetries (e.g., Baron (1982), Rock (1986), Allen and Faulhaber (1989), Welch (1989, 1992)), and Benveniste and Spindt (1992)).

On one side of the debate, Chen and Ritter (2000) argue that while factors such as rents to underwriter reputation, costs of post-IPO analyst coverage, price support, and underwriter syndication, may be consistent with high mean IPO fees, they do not explain the clustering of fees at the 7% level. Chen and Ritter (2000) conclude that the IPO underwriting market is likely to be characterized by "strategic price setting" (i.e. implicit collusion). They argue that collusion may be sustainable because underwriting business cannot be described as price competition, given that issuing firms care about underwriter characteristics in addition to IPO spreads charged by the underwriters (e.g., Krigman, Shaw and Womack (2001), Brau and Fawcett (2006), and Liu and Ritter (2011)). Similarly, Abrahamson, Jenkinson and Jones (2011) find no evidence that high gross spreads in the U.S. result from 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 attribute the high profitability of IPO underwriting in the U.S. to implicit collusion.

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 collusion allegation probe announcement, and that IPOs belonging to the 7% cluster exhibit low fees relative to similar IPOs that do not belong to the cluster. He interprets this and other evidence as inconsistent with the implicit collusion hypothesis.

The implicit collusion and oligopolistic competition hypotheses lead to many observationally equivalent empirical predictions. As a result, existing studies use indirect tests that rely on unspecified assumptions regarding expected equilibrium market structure (number of firms and costs of entry into the industry) under the collusive and competitive scenarios (e.g., Hansen (2001)) or reach conclusions in favor of one hypothesis (implicit collusion) that are based on a failure to reject it, as opposed to ability to reject an alternative (e.g., Abrahamson, Jenkinson and Jones (2011)).

In this paper we propose and implement, for the first time, a direct test of the hypothesis of implicit collusion in the U.S. underwriting market against the alternative of oligopolistic competition in that market without favoring ex-ante one hypothesis or the other. Our strategy consists of two steps. The first step is to construct two separate models of underwriting market. In the first model, characterized by oligopolistic competition, we assume that each investment bank sets its underwriting fees with the objective of maximizing its own expected profit from underwriting IPOs, while taking into account the optimal responses of other underwriters. In the second, collusive, model, we assume that underwriters cooperate in fee-setting, i.e. they choose underwriting fees that maximize their joint expected profit. In constructing these models we focus on the interaction among underwriters, similar to Liu and Ritter (2011), as opposed to interactions between underwriters and issuing firms (e.g., Loughran and Ritter (2002, 2004) and Ljungqvist and Wilhelm (2003)). Different from Liu and Ritter (2011), who assume that the underwriting market is characterized as local oligopolies, we are agnostic ex-ante regarding the structure of the market.

The second step is to employ data on U.S. IPOs in the period between 1975 and 2013 to test the predictions of the two models. We compute measures of direct and indirect compensation of investment banks for underwriting services, underwriters' market shares, and the state of the IPO market. We then examine the abilities of the two models to generate directional relations consistent with those observed in the data and determine which of the two models fits the data better.

Both models yield equilibrium relations between the market shares and absolute and proportional compensation of higher-quality and lower-quality underwriters on one hand and the state of the IPO market (i.e. demand for IPOs) on the other hand. These comparative statics following from the model of oligopolistic competition are in many cases different from those in the collusive model. These differences allow us to distinguish the two competing hypotheses empirically.

Our models feature heterogenous investment banks that provide underwriting services to heterogenous firms, whose value is enhanced by going public: higher-quality underwriters provide higher value-added to firms whose IPOs they underwrite. Banks set their underwriting fees with the objective of maximizing expected underwriting profits, while taking the resulting optimal strategies of rival underwriters into account. Firms choose whether to go public or stay private and, in case they decide to go public, which underwriter to use for their IPO, with the objective of maximizing the benefits of being public net of the costs of going public. Providing underwriting services entails increasing marginal costs. The resulting equilibrium outcome is that higher-quality underwriters charge higher fees, firms with relatively high valuations go public with higher-quality underwriters, medium-valued firms go public with lower-quality underwriters, while low-valued firms stay private as for them the relatively high costs of going public outweigh the benefits of public incorporation.

The main comparative statics of the two models are as follows. First, in the collusive setting, in which the 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. The reason is that when underwriters coordinate their pricing strategies, they prefer to channel more IPOs to higher-quality underwriters, which can justify charging higher fees, in cold IPO markets. In hot markets, both higher-quality and lower-quality underwriters get IPO business because of increasing marginal costs of providing underwriting services and the resulting limit on the number of IPOs that the higher-quality banks are willing to underwrite. In the competitive setting, in which each bank maximizes its own expected profit, the relation between underwriters' market shares and the state of the IPO market depends on the degree of heterogeneity among underwriters.

When underwriter qualities are similar, the relation is expected to be negative, as in the collusive setting. The reason is different, however. In the case of similar-quality underwriters, the competition resembles Bertrand competition in nearly homogenous goods. With increasing marginal costs of underwriting, the higher-quality bank captures most of cold markets, in which the marginal costs are relatively flat, but a lower share of hot markets, in which the 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. The reason is that the lower-quality underwriters are forced to set very low fees in cold markets in order to get any business and end up underwriting relatively many (low-valued) IPOs. The ability to set low underwriting fees diminishes in hot IPO markets due to increasing marginal costs of underwriting, leading to higher market shares of higher-quality banks in hot markets.

Second, in the competitive scenario, the ratio of equilibrium dollar compensation received charged by higher-quality underwriters to those of 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 are forced to set fees that are significantly lower than those of higher-quality underwriters to get some share of the underwriting business, while this relative difference declines as the state of the IPO market improves.

The relation between the ratio of fees charged by the higher-quality banks to those charged by the lower-quality banks and the state of the market is expected to be hump-shaped in the collusive scenario. The reason is that in cold markets, the banks that coordinate their pricing strategies prefer to channel most of the IPOs to the higher-quality banks, as argued above, leading them to set high fees of the lower-quality banks relative to those of higher-quality ones to channel most IPOs to the latter. This incentive gradually weakens as the state of the IPO market improves because of increasing marginal costs of underwriting. However, as the state of the underwriting market improves further, the banks effectively become local monopolists, which leads to a negative relation between the state of the market and the ratio of fees charged by the higher-quality banks to those of the lower-quality banks. The reasons are similar to those in the competitive scenario: in hot IPO markets the fees are determined mostly by the banks' value-added as opposed to strategic pricing.

Third, in the competitive scenario, mean equilibrium proportional underwriter compensation (i.e. compensation relative to IPO proceeds) is predicted to increase in the state of the IPO market for both the higher-quality and lower-quality underwriters. The reason is that 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, increasing the ability of underwriters to charge higher (direct and indirect) fees. In the collusive setting, the relation between higher-quality banks' mean proportional fees and the state of the market is predicted to be positive for a reason similar to that in the competitive case, while the relation is U-shaped for lower-quality underwriters. The reason for the decreasing part of the relation is that in cold IPO markets, the banks are collectively better off channelling most IPOs to the higher-quality banks. This is achieved by setting relatively high fees by the lower-quality banks in cold markets, leading overall to the U-shaped relation between the lower-quality underwriters proportional fees and the state of the IPO market.

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

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

Third, consistent with the prediction of the collusive model, we find that the share of IPOs underwritten by higher-quality banks is generally negatively related to proxies for the state of the IPO market. Inconsistent with the predictions of the competitive model, this relation is significantly negative especially when underwriters are relatively heterogenous.

To summarize, the contribution of our paper is threefold. First, we propose a novel test that allows us to separate the hypothesis of implicit collusion in the U.S. underwriting market from the alternative of oligopolistic competition, based on matching the directional predictions derived from two separate models – one in which underwriters collude in fee-setting and the other one in which they compete – to the relations observed in the data. Second, the results of estimating the models' predictions empirically contribute to the debate regarding the structure of the U.S. IPO underwriting market, providing support for the implicit collusion hypothesis. Our third contribution is theoretical – ours is one of the first papers to model interaction among heterogenous underwriters and to derive competitive and collusive equilibria in a simple industrial organization setting.

The paper proceeds 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 provide empirical tests of the two models' predictions. Section 4 concludes. Appendix A provides all the proofs of the 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 that features multiple banks and multiple firms that may use their underwriting services. Then we solve in closed form a simplified version of the model featuring two restrictive assumptions. First, we assume that there are two heterogenous underwriters. Second, we assume a fixed underwriting fee structure. We provide two solutions to the model, corresponding to two distinct scenarios. The first one is the competitive scenario, in which each underwriter sets its fee with the objective of maximizing its 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 the demand for other bank's underwriting services. The solution of the model under these two scenarios allows us to derive comparative statics of underwriters' equilibrium market shares and absolute and proportional fees with respect to the state of the IPO market and the degree of heterogeneity among underwriters for the competitive and collusive cases. We summarize these comparative statics by listing empirical predictions that follow from the two models at the end of this section.

The assumptions of the simplified model are restrictive. First, in reality there are multiple underwriters. Thus, in Appendix B we make sure that increasing the number of underwriters does not affect the qualitative conclusions of the competitive and collusive models. 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 analyzing the case of three underwriters. In particular, 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 we focus on three scenarios 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 in because it is possible that larger (higher-quality) underwriters collude among themselves but compete with smaller (lower-quality) underwriters.[1] It is important to examine the "full collusion" scenario because it is hard to identify empirically the set of colluding banks. We verify in Appendix B that even if $M \leq K$ largest banks collude, the comparative statics of underwriting fees and market shares within a subset of $L < M$ largest banks are similar to those obtained in a model in which only L banks collude. by solving numerically the model that features three underwriters. In addition, it is possible that some banks engage in tacit collusion, while others do not – a case that is impossible to analyze in a model that features only two banks. The model with three underwriters allows us to examine the case in which two underwriters collude while the third does not.

Second, underwriting fees 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 shows clearly 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 and show that the

[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 a large firm size asymmetry.

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 equalling 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 pre-IPO 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. There are various advantages to being public 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 operating and investment decision making (e.g., Rothschild and Stiglitz (1971), Shah and Thakor (1988), and Chod and Lyandres (2011)).

The benefits of being public notwithstanding, there are also costs to going and being public. The two direct costs of going public is the compensation to be paid to IPO underwriter (i.e. IPO spread) and the money left on the table at the time of 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

[2] Similar to Chod and Lyandres (2011) and following a large body of industrial organization literature, we treat the total number of firms N 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.

bank receives in exchange for providing underwriting services as an underwriting fee (or IPO fee).[3] In what follows we will use the terms "underwriter" and "bank" interchangeably. If firm i decides to go public using underwriter j, its post-IPO value equals

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

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 from firm i for underwriting its IPO.

Consistent with empirical evidence (e.g., Altinkiliç and Hansen (2000)), we assume that the underwriter compensation consists of two components: a fixed fee, λ_j that is identical for all firms underwritten by bank j, and a variable component that increases in the size of the firm going public: $\mu_j V_i$. We assume that underwriters are potentially heterogenous 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)). We will say that underwriter j is 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 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 the empirical finding that proportional underwriting fee is decreasing in IPO size, while absolute fee is increasing in IPO size (e.g., Ritter (1987), Beatty and Welch (1996), and Torstila (2003)). Note that while this Lemma holds trivially in the case of fixed underwriting fees ($\mu_j = 0$), we show numerically in Appendix C that it continues to hold in the case of variable (IPO-size-dependent) fee structure.

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

[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)).

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 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)). 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 of total cost that is quadratic and marginal cost that 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 may remain private or it may perform an IPO underwritten by one of the 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 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 that relaxes the first assumption, while in Appendix C we relax the second assumption.

2.2 Two underwriters

In the case of two potentially heterogenous 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 (that 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 that could benefit the most from its IPO being underwritten by it 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 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 the higher fee that is charges, 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 of them get a positive share of the IPO 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 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 that is underwritten by a higher-quality bank commands higher proportional underwriting fee than an IPO that is underwritten by a lower-quality bank.

2.3 Equilibrium fees under competitive and collusive scenarios

2.3.1 Competitive case

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. Utilizing 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 is $N\left(\overline{V_j} - \underline{V_j}\right)$. Solving the system of two first-order conditions following from (5) results in equilibrium levels of each bank's fee 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 Collusive case

Assume now that the underwriting market is collusive in the sense that the two banks cooperate in setting 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 resulting 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 $N^*_{2_{Coll}}$:

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

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

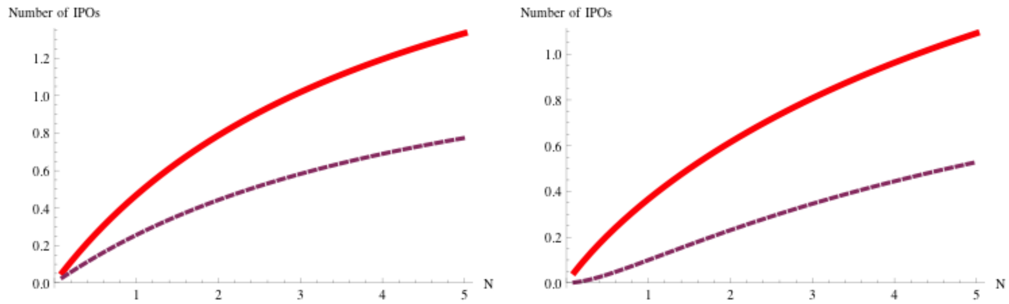
The first intuitive comparative statics result is that the number of IPOs underwritten by each bank, as well as the total number of underwritten IPOs is increasing in the number of firms considering going public, N, in both the competitive and collusive scenarios:

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.*

We illustrate the relation between the number of IPOs underwritten by each of the two banks and the number of firms considering going public in Figure 1. Figure 1A depicts the competitive scenario, while Figure 1B corresponds to the collusive scenario. The figures are constructed using the following parameter values: $\alpha_1 = 0.5$, $\alpha_2 = 0.3$, $c = 0.1$. In each figure the solid curve represents the number of IPOs underwritten by B_1, while the dashed curve represents the number of IPOs underwritten by B_2.

Figure 1: Number of IPOs as a function of the state of the IPO market

Figure 1A: Competitive case Figure 1B: Collusive case



The monotonic relation between the equilibrium number of IPOs and N in both the competitive and collusive settings is useful because it enables translating 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 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 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 proceed to 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* $\frac{\lambda^*_j\left(N\left(\overline{V_j}-\underline{V_j}\right)\right)+\mu^*_j N \int\limits_{V=\underline{V_j}}^{V_j} V dV}{N \int\limits_{V=V_j}^{\overline{V_j}} V dV}$

or, in the case of zero variable fees, $\frac{\lambda^*_j\left(\overline{V_j}-\underline{V_j}\right)}{\int\limits_{V=V_j}^{\overline{V_j}} V dV}$.

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.*

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, as the number of firms considering an IPO increases, the set of firms that the banks choose to underwrite becomes more and more selective. 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 by B_2 instead), 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, implying that the 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 more subtle, 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. The reason is if 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 that can charge a higher underwriting fee. Allocating IPOs to the lower-quality bank would have a substantial negative effect on the number of IPOs underwritten by the higher-quality bank, reducing the two banks' combined profit. It is only possible to channel most of the IPOs to the higher-quality bank by setting a high fee of the lower-quality bank, leading to a decreasing relation between the lower-quality bank's fee on one hand and the state of the IPO market on the other hand in relatively low states of the IPO market.

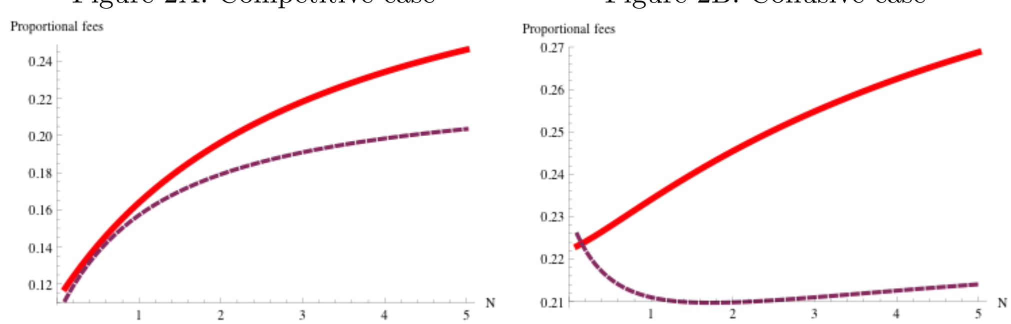
As N increases, the higher-quality bank becomes constrained by its increasing marginal cost of underwriting, making it optimal to allocate more IPOs to the lower-quality bank. Thus, when N is high, the incentives to set high fees for the lower-quality bank are weaker, making the first (positive) effect 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.

We illustrate the relation between the weighted average proportional fees charged by each of the two banks in Figure 2. Figure 2A corresponds to the competitive scenario, while Figure 2B represents the collusive case. The figures are constructed using the same parameter values as in Figure 1. In each figure the solid curve represents the average proportional fee of B_1, while the dashed curve represents the average proportional fee of B_2. Consistent with propositions 1 and 2, both underwriters' equilibrium proportional fees are increasing in the state of the IPO market in the competitive scenario, whereas the relation between the state of the market and the equilibrium fee of the lower-quality underwriter is U-shaped in the collusive scenario.

Figure 2: Banks' proportional fees as a function of the state of the IPO market

Figure 2A: Competitive case

Figure 2B: Collusive case



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, the marginal costs increase as well and each underwriter's situation starts resembling 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 be able to 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 it 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 that can extract higher fees. Thus, when N is low, the fee of the lower-quality bank is set relatively high in order not to 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.

We illustrate the relation between the ratio of the two banks' absolute fees in Figure 3. Figure 3A represents the competitive case, while Figure 3B corresponds to the collusive case. Parameter values are identical to those in Figures 1 and 2.

Figure 3: Ratio of higher-quality bank's absolute fee to that of lower-quality bank as a function of the state of the IPO market

Figure 3A: Competitive case

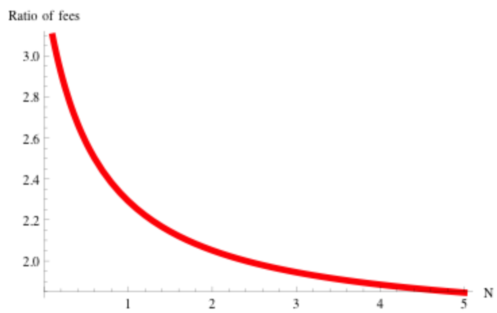
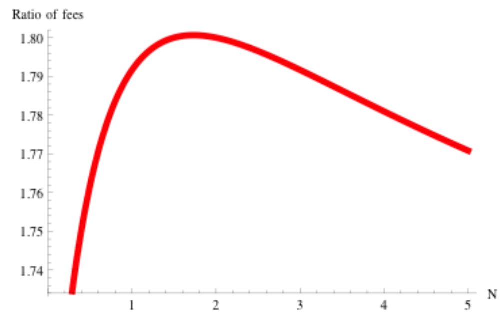


Figure 3B: Collusive case



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 the results in 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 homogenous 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 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 IPOs each bank underwrites is determined by that bank in isolation of 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 costs 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 starts driving the allocation of IPOs to the two banks, leading to an increased market share of 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.

We illustrate Propositions 5 and 6 in Figure 4, which depicts the relation between the share of IPOs underwritten by the higher-quality bank and the state of the IPO market. Figures 4A and 4C correspond to the competitive scenario, while Figures 4B and 4D correspond to the collusive scenario. All of the parameter values are as in Figures 1-3, except for α_2, which takes the value of 0.4 in Figures 4A and 4B and the value of 0.2 in Figures 2C and 2D. We use two values of α_2 in order to demonstrate the effect of the difference between the two banks' qualities on the relation between the higher-quality bank's market share and the state of the IPO market under the competitive scenario.

Figure 4: Market share of higher-quality bank as a function of the state of the IPO

market

Figure 4A: Competitive case, small $\alpha_1 - \alpha_2$

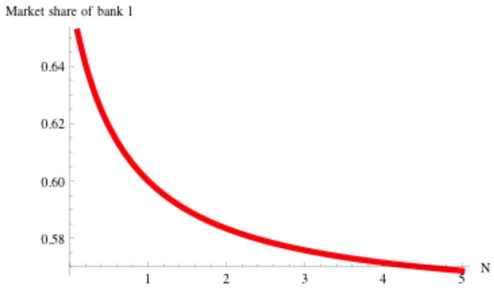


Figure 4B: Collusive case, small $\alpha_1 - \alpha_2$

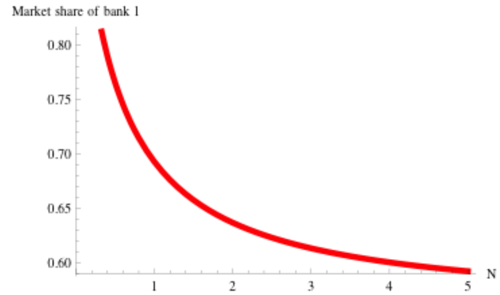


Figure 4C: Competitive case, large $\alpha_1 - \alpha_2$

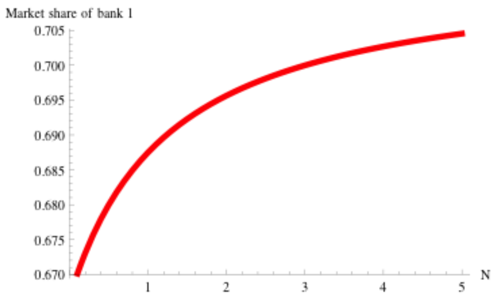
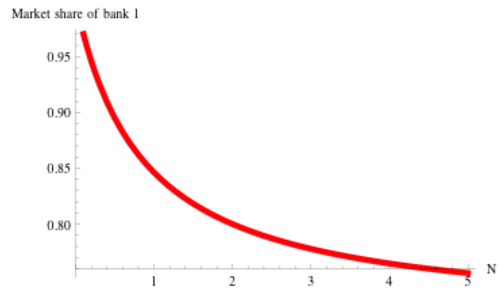


Figure 4D: Collusive case, large $\alpha_1 - \alpha_2$



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 side and the state of the IPO market on the other side depend crucially on whether the underwriters implicitly collude or compete. 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 test the collusion hypothesis against the alternative hypothesis of a competitive underwriting market, it is possible to validate empirically the main assumptions of the model. Lemma 1 and also 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 cost is expected to be decreasing in the market value of shares issued at the time of the IPO.*

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 cost 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 summarized in Propositions 1-6. These predictions, which allow potentially test the implicit collusion hypothesis against the alternative of competition among underwriters, are discussed in the next subsection.

2.5.2 Tests of the collusion and oligopolistic competition hypotheses

Propositions 1-2 result in empirical predictions regarding the effects of the state of the IPO market on 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 (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 relative underwriter compensation of higher-quality underwriters is expected to be increasing in the state of the IPO market.*

Propositions 3-4 lead to the empirical predictions regarding the effects of the state of the IPO market on the ratio of dollar compensation paid to higher-quality underwriters to that paid to 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 the average compensation paid to lower-quality underwriters is expected to be decreasing in the state of the IPO market.*

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

Propositions 5-6 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 are expected to be decreasing in the state of the IPO market if the heterogeneity in underwriters' qualities is relatively low and it is expected to be increasing in the state of the IPO market if the heterogeneity in underwriters' qualities is relatively high.*

Prediction 5b (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 on 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, closed-end funds, REITs, ADRs, unit offerings, 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 years 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 the 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 over $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. Early 1980s and the 1990s are the two hottest periods for IPOs. The forth column reports the mean annual value-weighed market return in each of the 39 year of our sample. Annual market returns range from -38% in 2002 to 37% in 1975, with an average of 13.8%.

The fifth column presents annual growth in private nonresidential fixed investment, 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 post-IPO day announcement returns (aka underpricing). Similar to past studies (e.g., Chen and Ritter (2000) and Hansen (2001)), the mean underwriting spread is 7.4%, and it has been on the declining trajectory over the last three decades. The 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., Loughran and Ritter (2004)), underpricing tends to be correlated with the hotness of IPO market: the correlation between mean annual underpricing and the number of IPOs in that year is 45%. The next columns 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 and/or biotech sector, 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 have to mean that they now collude more than previously in setting IPO fees. While underwriters do set the 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 7% exactly, 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 depends crucially on underwriter quality. Panel C of Table 1 presents statistics on the number and volume of IPOs underwritten by banks of various qualities, as proxied by the underwriter reputation score, first proposed by Carter and Manaster (1990) and extended by Loughran and Ritter (2004). The highest score of 9 is given to fifteen 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 the underwriter reputation score and the mean value of IPO proceeds, as follows from the last column in Panel C.

3.2 Empirical tests

3.2.1 Model validation

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

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

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 underwriter's compensation, following the evidence that suggests that institutional investors in IPOs indirectly reward underwriters for profits they make in the first day of aftermarket trading. For example, Reuter (2006) finds a positive relation between trading commissions paid by a mutual fund family to an underwriter and the former'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, Goldstein, Irvine and Puckett 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:

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

$Direct\&indirect\_comp_{i,j,t}$ 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 using other proportions of underpricing as a measure of indirect underwriter compensation, such as 10%.

$HQ_{i,t}$ is an indicator variable that equals one if underwriter i is of high quality in year t and equals 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:

$CM\_score_{i,t}$ 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 high-quality underwriter in that year.[4]

$Top\_ten_{i,t}$ 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 ten market shares.[5] The correlation between the two measures of underwriter quality is 59%.

$IPO\_size_{j,t}$ 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 final offer price. We use the logarithmic transformation of IPO size because this variable exhibits high skewness. According to Prediction 2, we expect that the coefficient on IPO size be negative, $\beta_2 < 0$.

We follow Hansen (2001), Torstila (2003), and Abrahamson, Jenkinson and Jones (2011) in defining the vector of control variables, $X_{i,t}$, in (19). They include 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, where high-tech sector follows the SIC-code-based definition 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

[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 top-five underwriters based on market share as high-quality ones.

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 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) 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 the 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 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 results of tests of Predictions 3-5, which are aimed at testing the two hypotheses.

3.2.2 Testing the collusion versus oligopolistic competition hypotheses

Testing Prediction 3

Prediction 3 of the model concerns the relation between 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 relatively low-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:

$\#IPOs_t$ is the annual number of IPOs underwritten 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.

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

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 Carter-Manaster (1990) score or on the share of 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 at 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, while in columns 9-12 we use VW_mktret_t. In columns 1, 2, 5, 6, 9, and 10, 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 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 twelve), while the coefficient on $Mkt\_state_t^2$ is positive and significant in all twelve specifications. However, the important finding 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 twelve specifications and are statistically significant at the 5% level in ten of them, suggesting a U-shaped relation between the state of the IPO market and compensation of lower-quality underwriters. The inflection points 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 $PNFI\_gr_t$), implying 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:

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

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 that this ratio exhibits. 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 are 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.

According to both the oligopolistic competition hypothesis and the implicit collusion hypothesis, we expect a positive coefficient on the state of the IPO market, $\beta_1 > 0$. According to the oligopolistic competition hypothesis, the coefficient on the quadratic term of the state of the IPO market is expected to be either insignificant or positive, $\beta_2 \geq 0$. According to collusion hypothesis, 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 is expected to be negative, $\beta_2 < 0$.

The results of estimating (21) are presented in Table 4. The table includes twelve 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 supportive of the collusion hypothesis and are 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 employing $PNFI\_gr_t$ as a measure of the state of the IPO market.

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 to observe a negative relation within the subsample in which underwriters are relatively heterogenous and a positive relation within the subsample in which the underwriters are sufficiently homogenous. To test this hypothesis, we estimate the following regression:

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

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.[6]

$Hetero_t$ refers to the degree of heterogeneity in underwriter quality in year t. We measure this heterogeneity as the standard deviation of Carter-Manaster (1990) reputation scores 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 banks are those with top-ten market shares in the IPO underwriting market.

Insert Table 5 here

Under both the oligopolistic competition and 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 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 high underwriter heterogeneity indicator, β_1. We expect $\beta_1 < 0$ under the collusion hypothesis and $\beta_1 > 0$ under the oligopolistic competition hypothesis.

The results in Table 5 are more consistent with the collusion hypothesis than with the oligopolistic competition one. The estimate of β_2 is negative and significant in just one specification out of six, and is insignificant in the other specification. However, importantly, 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 sizeable. For example, a one standard deviation increase in $PNFI\_gr_t$ (7.2%) is associated with a $8 - 12$ percentage points drop in the market share of high-quality underwriters in years in which the

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

heterogeneity in underwriter quality is high. This result is in line with the prediction of the collusion hypothesis but is inconsistent with the competition hypothesis, which predicts positive β_1.

Tests using a Subsample of Largest Underwriters

As mentioned above, it is conceivable that larger (higher-quality) underwriters 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, banks. In what follows, we examine empirically the predictions of the two models while concentrating on a sample that consists of the largest ten 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 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 are 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.[7] High-quality underwriters in Table 6 are defined differently than in Tables 3–5. In particular, given that the vast majority of top-ten underwrites 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) 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-ten 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 fore. Importantly, the results for the lower-quality underwriters are consistent with the collusion hypothesis and are 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 lower-quality underwriters' compensation.

Panel B reports estimates of the regression in (21) for the top-ten 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

[7] The 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.

coefficients on the annual number of IPOs, proxying 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 top underwriters' compensation to that of lower-quality underwriters' compensation.

In Panel C, we report results of re-estimating (22) while concentrating on the subsample of top ten banks. Since we cannot measure underwriter heterogeneity within the subsample of top underwriters using the standard deviation of Carter-Manaster reputation score, we use the standard deviation of underwriters' IPO market shares as an alternative proxy for underwriter heterogeneity. The results in Panel C are consistent with the collusion hypothesis and are 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 heterogenous in their market shares and when they are relatively homogenous.

Overall, the results of tests reported in Tables 3-6 are generally consistent with the implicit collusion hypothesis in the U.S. IPO underwriting market, and are inconsistent with the hypothesis according to which underwrites engage in oligopolistic competition.

4 Conclusions

In this paper we attempt to shed light on an elusive question: Do IPO underwriters in the U.S, implicitly collude in setting underwriting fees? In order to try to answer this question, we construct two models of interaction among heterogenous IPO underwriters. In the first one, the 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, collusive, model, underwriters cooperate and set their fees in a way that maximizes their joint expected profit. These two models result in comparative statics of higher-quality and lower-quality underwriters' market shares, and absolute and proportional underwriting fees with respect to the state of the IPO market.

The two models generate different empirical predictions regarding the effects of the state of the IPO market on one hand on equilibrium market shares and compensation for underwriting services of banks of various qualities on the other hand. Our analysis is different from existing examinations of the structure of the underwriting market in that unlike existing studies that test implications of either a collusion or competition hypothesis in separation, we examine both hypotheses simultaneously. In other words, we provide a framework for a "horse race" between the two hypotheses. Our results illustrate 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.

The competitive and collusive models result in several contrasting empirical predictions. We exploit these differences in empirical implications and test the two models using data on U.S. IPOs from 1975 to 2013. Most of our evidence is consistent with the implicit collusion hypothesis, and it is mostly inconsistent with the oligopolistic competition hypothesis. 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)).

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 $N > \sqrt{\frac{\alpha_2(\alpha_1-\alpha_2)}{2c^2}}$. $\blacksquare$

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 $\alpha_1 < 2\alpha_2$. $\blacksquare$

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:

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

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

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

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

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

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 objective 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;

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

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

Figures 5-7 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 5-7, 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 5 presents weighted average proportional fees of the top two banks. The parameter values used in Figure 5 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 5: Banks' proportional fees: The case of three banks

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

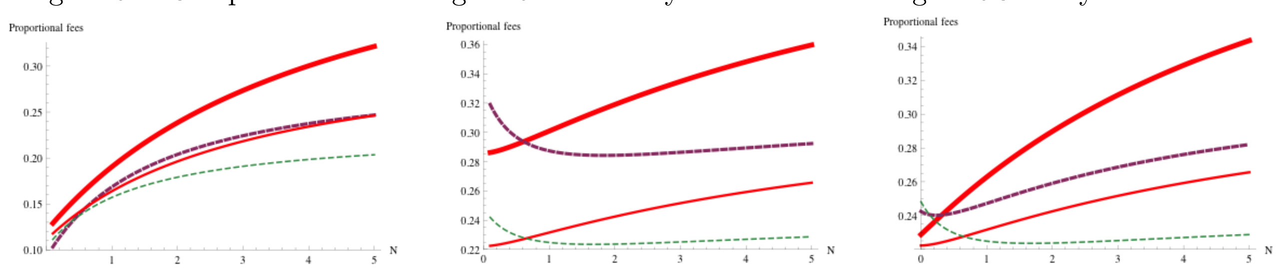


Figure 5 demonstrates that the relations between the highest-quality bank's average proportional fee on one hand and the state of the IPO market on the other hand stay positive in the competitive scenario and in (fully and partially) collusive scenarios. On the other hand, the relation between the fee of the second bank exhibits a positive relation with the state of the IPO market in the competitive scenario and a U-shaped relation in the fully and partially collusive scenarios, consistent with the baseline results for two underwriters.

Figure 6 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 5.

Figure 6: Ratio of higher-quality bank's to medium-quality bank's absolute fees: The case of three banks

Figure 6A: Competitive case

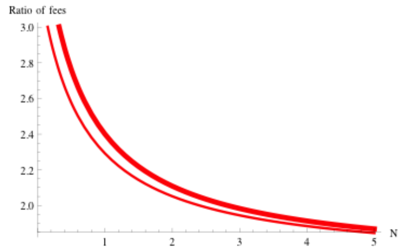


Figure 6B: Partially collusive case

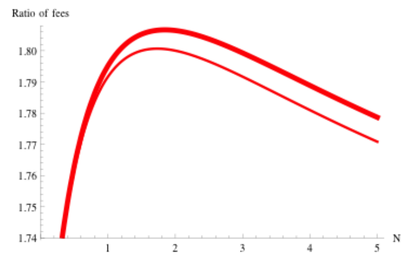
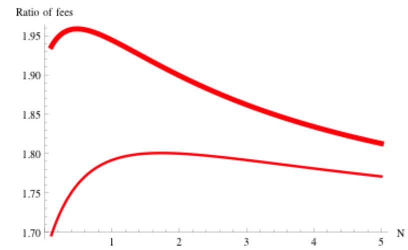


Figure 6C: Fully collusive case



It follows from Figure 6 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 the third bank.

Figure 7 presents the market share results. The market share of the highest-quality underwriter (B_1) depicted in Figure 5 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 7 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 ($\alpha_2 = 0.2$).[8]

[8] The shape of the relations described in Figures 5-7 generally holds for various sets of parameter values that satisfy $\alpha_1 > \alpha_2 > \alpha_3$.

Figure 7: Market share of higher-quality bank: The case of three banks

Figure 7A: Competitive case, small $\alpha_1 - \alpha_2$

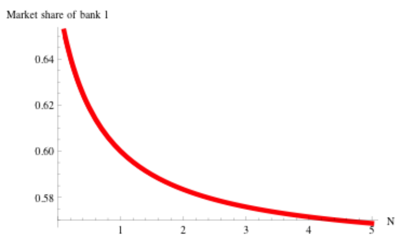


Figure 7B: Partially collusive case, small $\alpha_1 - \alpha_2$

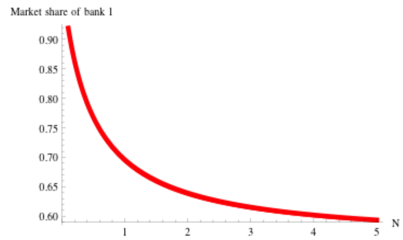


Figure 7C: Fully collusive case, small $\alpha_1 - \alpha_2$

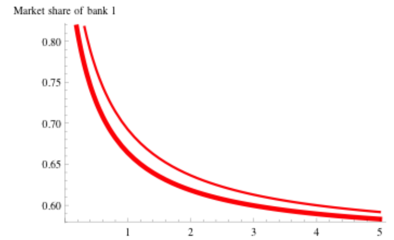


Figure 7D: Competitive case, large $\alpha_1 - \alpha_2$

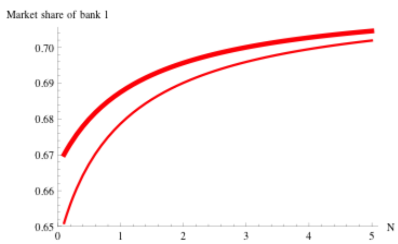


Figure 7E: Partially collusive case, large $\alpha_1 - \alpha_2$

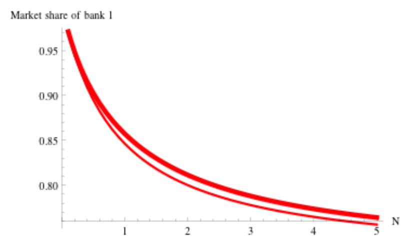
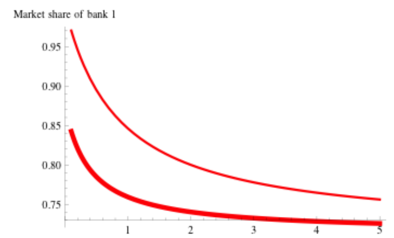


Figure 7F: Fully collusive case, large $\alpha_1 - \alpha_2$



It follows from comparing the competitive case in Figures 7A and 7D with the partially and fully collusive cases in Figures 7B, 7C, 7E, and 7F that 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 increasing in the competitive scenario and is decreasing when the top two banks collude, regardless of whether they compete or collude with the third bank. 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.

Overall, the numerical analysis in this section demonstrates that the comparative statics in our baseline model are unlikely to be driven by the assumption of two underwriters.

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 $[0, 1]$:

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

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

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

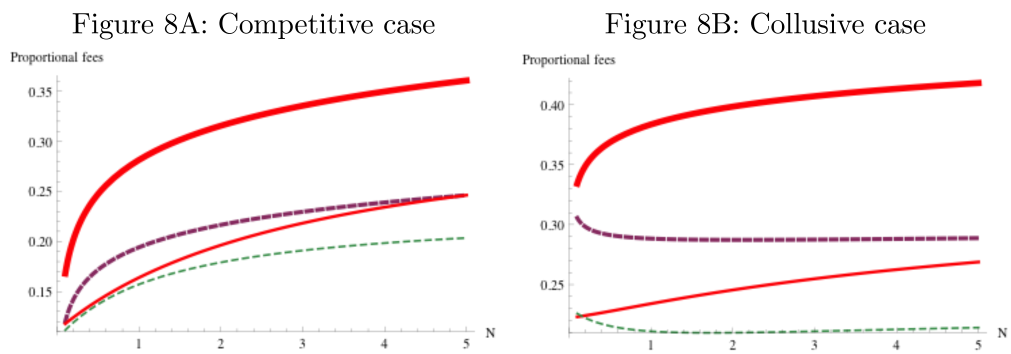
where $\mathbb{I}(i, j) = 1$ if an IPO of firm i is underwritten by bank j.

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 8-10 depict comparative statics of market shares, average absolute fees, and average proportional fees, similar to Figures 2-4. 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 from an analytical solution of the model with fixed underwriting fees in Section 2.

Figure 8 presents the two banks' weighted average proportional fees in the competitive and collusive scenarios. 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 8: Banks' proportional fees: The case of optimal variable fees



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 that 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 2 *Bank j's weighted average absolute fee, $\overline{F_j}$, equals* $\frac{\lambda_j^* N\left(\overline{V_j}-\underline{V_j}\right)+\mu_j^* N \int_{V=\underline{V_j}}^{\overline{V_j}} V dV}{N\left(\overline{V_j}-\underline{V_j}\right)}$.

Figure 9 depicts the relation between the ratio of the two banks' weighted average absolute (dollar) fees and the state of the IPO market:

Figure 9: Ratio of higher-quality bank's to medium-quality bank's absolute fees: The case of optimal variable fees

Figure 9A: Competitive case

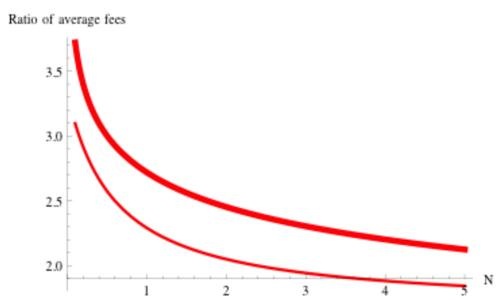
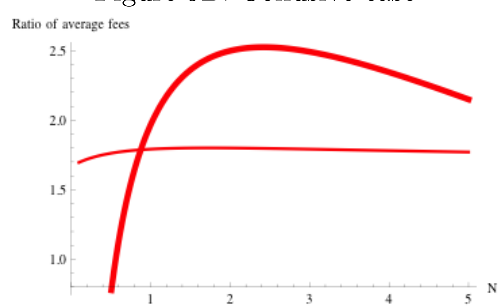


Figure 9B: Collusive case



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 10 presents B_1's market share as a function of the state of the IPO market in the competitive and collusive scenarios. Parameter values in Figure 10 are the same as in Figure 4.

Figure 10: Market share of higher-quality bank: The case of optimal variable fees

Figure 10A: Competitive case: small $\alpha_1 - \alpha_2$

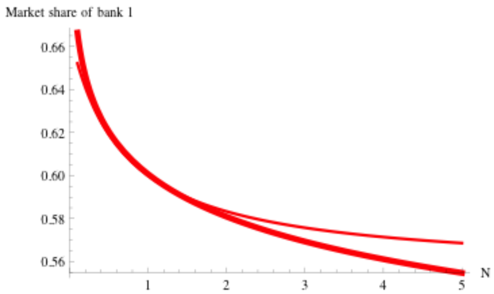


Figure 10B: Collusive case: small $\alpha_1 - \alpha_2$

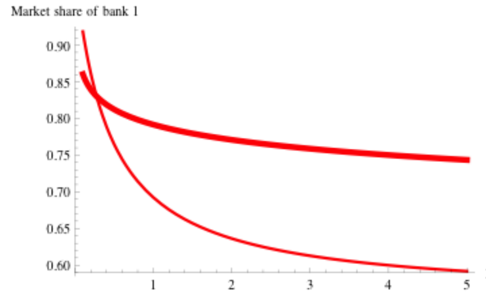


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Figure 10C: Competitive case: large $\alpha_1 - \alpha_2$

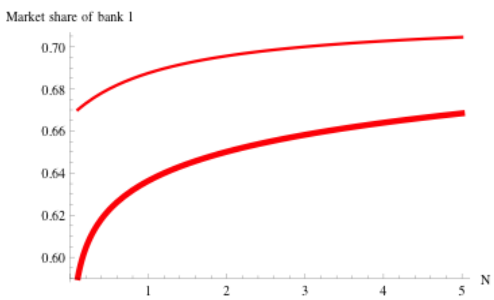
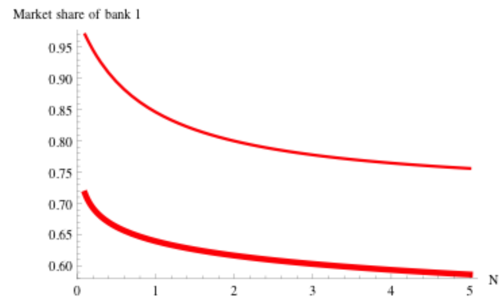


Figure 10D: Collusive case: large $\alpha_1 - \alpha_2$



As evident from Figure 10, 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, and offerings that are a part of a corporate spinoff. We also require the IPOs to have information of underwriting spread and total proceeds. Number IPOs is the number of IPOs in a given year. IPO proceeds (in millions of dollars) are 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%	7.4-%	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%	75.00%	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 groups 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 estimate 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	Prediction	Direct	Direct & indirect	Direct	Direct & indirect
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 groups 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 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.

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

Measure of IPO state	Predictions		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.	Comp.	Coll.	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	Predictions		Annual num. IPOs		PNFI growth		Market return	
Measure of IPO high quality banks	Comp.	Coll.	Score 9	Top 10	Score 9	Top 10	Score 9	Top 10
IPO state * High hetero	> 0	< 0	-0.003	-0.051***	-1.754***	-1.098***	-0.173	-0.458***
			(-0.11)	(-3.99)	(-3.08)	(-3.06)	(-0.53)	(-2.67)
IPO state * Low hetero	< 0	< 0	0.031	-0.042	-2.063***	-0.325	-0.158	0.029
			(0.48)	(-1.34)	(-3.59)	(-0.90)	(-0.59)	(0.21)
Intercept			0.564	0.869	0.694	0.836	0.596	0.817
			(8.32)	(26.56)	(15.59)	(29.79)	(11.54)	(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 groups 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			Top 3 market share		Top 5 market share	
Measure of competition			Direct	Direct and indirect	Direct	Direct and indirect
	Predictions Comp.	Coll.				
IPO state	≤ 0	> 0	0.195*** (6.77)	0.199*** (7.64)	0.141*** (6.11)	0.132*** (5.36)
IPO state^2	< 0	< 0	-0.032*** (-5.55)	-0.032*** (-6.19)	-0.023*** (-6.50)	-0.020*** (-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 Comp.	Predictions Coll.	Top 3 market share	Top 5 market share
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