

Good IPOs drive in bad: Inelastic banking capacity and persistently large underpricing in hot IPO markets

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Abstract

In this paper, we consider the effect of labor market constraints on the Initial Public Offering (IPO) activity of investment banks. We posit that identifying IPO quality requires specialized screening labor that takes time to train. Positive shocks to economy's production frontier stimulate IPO demand. At this higher level of demand, screening labor costs must rise to clear the labor market. This results in underwriters optimally reducing screening quality, in the process encouraging firms with sub-marginal projects to also apply, further straining the screening labor market. In equilibrium, underpricing can be quite significant both because of lower quality screening and because of its role in lowering the quality of the applicant pool. Our model's predictions are consistent with empirical results such as positive correlation between IPO volume and underpricing, reduced information search per project during hot markets, and the persistence of high IPO volume in the face of increased underpricing.

1. Introduction

IPO issuers leave large sums of money on the table by selling under-priced shares, particularly during "hot markets". For example, during 1999-2000, average first day IPO returns were 65 percent compared to 15 percent for the rest of 1990s.¹ What is even more surprising is that current issuers' leaving substantial sums of money on the table

¹See Ritter (1984) and Loughran and Ritter (2002).

does not discourage new issuers from entering the market. In fact, Lowry and Schwert (2002) document that higher IPO underpricing precedes *rising* volume.

A natural explanation for higher underpricing during hot markets is that uncertainty may be higher. While this is more likely during periods of technological innovation, the question of why the uncertainty is not resolved through greater information collection remains. This question becomes even more salient in light of recent evidence which suggests less information collection during hot markets. For instance, Corwin and Schultz (2005) document that the size of underwriting syndicates is significantly smaller during 1997-2002, while Benveniste, Ljungqvist, Wilhelm and Yu (2003) document that higher initial returns result in a reduction of underwriters rank for subsequent issues. This evidence suggests that there may be rigidities intrinsic to the IPO process which make it difficult to reduce uncertainty through greater information collection.

In this paper, we develop a model of the IPO process that reconciles some of these apparent inconsistencies. We argue that the information generation process in IPOs is complex and depends on highly specialized labor that takes time to train. Sudden increases in the demand for IPOs result in higher wages and labor shortages. Investment bankers optimally respond by reducing the amount of labor demanded per IPO, resulting in lower amounts of information generation during periods when information is particularly valuable. This reduced quality of information generation provides a window of opportunity for entrepreneurs with sub-marginal projects to enter the IPO market, perpetuating a vicious circle of increased underpricing, increased volume, and declining quality.

Consistent with existing literature, we assume both underwriters and investors participate in the book-building process and underwriters share the proceeds of the issue through the gross spread. Thus, the underwriters objective is to maximize the offer price subject to a penalty that is positively related to the extent of overpricing. The gross spread underwriters earn might reflect the information they generate regarding issue quality or the bargaining power stemming from their long term relationship with the issuers.² With such an objective function, underpricing is negatively related to screening intensity. The intensity of screening depends on the endogenously determined wage rate in the labor market.

Unlike most existing work which concentrates on the pricing of IPOs, we focus on how pricing affects a firm's willingness to undertake an IPO. We assume a pool of firms armed with project opportunities, some good and some bad. Each firm knows its own project

²See Corwin and Schultz (2005) for an analysis of the information gathering role, and Sherman (2000) for an analysis of the long-term investment banker-issuer relationship.

quality, but to discover this quality, underwriters have to expend screening resources. The more screening labor they buy, the more able they are to separate good applicants from bad. Thus when screening quality is high, bad firms are less likely to apply. However, when a sudden increase in demand for IPOs pushes up the wage rate, underwriters optimally respond by reducing the amount of screening labor per project, thereby also increasing the incentive for firms with bad projects to enter the applicant pool. This not only reduces the quality of the applicant pool, but feeds back to further increase the demand for IPO screening and the wage rate. In equilibrium, the quality of the applicant pool and the accepted IPO pool are both worse. Underpricing is higher not only because of worse screening quality but also because of its role in making the applicant pool worse. Depending on the extent of the demand shock, the resulting underpricing can be large.

Interestingly, overheating can occur even if there is no increase in the number of potential projects in the pool, only an increase in the proportion of good projects, which could happen if the prospects of an industry improve or interest rates drop. The increase in good projects increases the demand for screening. For “larger” industries, this could result in higher labor costs lowering screening quality by enough to encourage some bad projects to enter the applicant pool, putting further pressure on screening supply. Thus, for each new good firm stimulated by improved industry prospects, more than one bad firm may attempt to obtain financing. Thus, we would observe a negative relation between the average quality of projects in the pool and the average quality of the projects actually financed in the IPO market. This is the exact opposite to the comparative static one would expect with exogenous screening costs, or for a shock to the prospects of a “small” industry whose increased demand for project evaluation is unlikely to strain the screening labor market.

A number of empirical implications result.

- In hot markets, underpricing can be significantly higher. Thus, volume and underpricing will be positively correlated.
- Information search per project can actually decrease during periods of high IPO demand.
- Equilibrium issue prices for IPOs and screening labor wages are simultaneously determined. Thus, any attempt to investigate one of these markets in isolation, in a single-equation framework, will lead to misleading results.
- IPO underpricing will be positively related to positive macroeconomic shocks and negatively related to small positive sector-specific shocks which are too small to

affect the investment banking labor market. Thus, we also expect regime shifting behavior with respect to the size and nature of market shocks.

- Because the rigidity in the labor market should decrease over time, the effects of labor market constraint should be strongest in earlier part of a “hot market,” right after the positive shock to the real economy. *Ceteris paribus*, underpricing should decrease over the life of a hot market, and both the applicant pool and the issued IPO pool should improve in quality.

To our knowledge, this paper is the first to relate labor market equilibrium to the equilibrium quality of service provided by investment banks. It is also the first to use rigidities in the labor market as an explanation for why underpricing may be higher during hot IPO markets. Our paper complements the asymmetric information models of Welch (1989) and Allen and Faulhaber (1989), where the asymmetry between the firm and the underwriters is resolved through the firm signaling its type rather than underwriters gathering information. Better quality issuers deliberately underprice to deter lower quality issuers from mimicking, and expect to make up their losses through future activities in the market³. Our paper is also related to Benveniste and Spindt (1989), Cornelli and Goldreich (2001), and Ljungqvist and Wilhelm (2002) in that investment banks play an active role in resolving the asymmetry in the market. In these papers, the asymmetry is between the bank and investors, and is resolved by banks offering investors truthful revelation contracts rather than by paying directly for information generation (screening). A paper closer in spirit to ours is Sherman and Titman (2002) which introduces costly information to the book building process, and derives implications for syndicate size. None of the above models, though, addresses the issue of whether underpricing changes with the supply of IPOs.

Loughran and Ritter (2002) attribute firm complacency to the suggestions of prospect theory developed by Kahneman and Tversky (1979). This theory asserts that people focus more on changes in their wealth rather than on wealth levels. Loughran and Ritter argue that issuing firms are less likely to bargain hard for further price increases when the offer price is already much higher than expected. While this is an attractive explanation, it leaves some questions unanswered. One in particular is why the substantial amount of money left on the table is not competed away through competition between underwriters. Thus, there needs to be some friction in the underwriting market which restrains competition in this environment. Our model provides a possible explanation for this friction.

³Michaely and Shaw (1994), though, provide evidence rejecting this form of ex-post settling up.

The rest of the paper is organized as follows. In section 2, we outline the basic structure of our model. In Section 3, we provide parametric assumptions under which we search for equilibria in our model. We establish some useful basic results in Section 4. In Section 5, we present detailed analysis of an equilibrium featuring IPO underpricing in a tight labor market. In Section 6, we describe some other equilibria of the model. Section 7 concludes the paper. The Appendix contains formal proofs of all results in the paper not contained in the text.

2. The Model

2.1. Overview

The main players in this model are entrepreneurs and underwriters. We model firms as projects owned by an entrepreneur, each of which have a terminal payoff of \tilde{X} . Projects can be of two types, Good (G) with a payoff of $\tilde{X} = 1$, or Bad (B) with a payoff of $\tilde{X} = 0$. For simplicity, the total number of projects (firms) in the economy is normalized to 1. At the beginning of the game, it is common knowledge that the fraction of G projects in the economy is ρ , and that the fraction of B projects is $1 - \rho$. Project quality is private information of the entrepreneurs. Underwriters can screen a project through the use of skilled labor. The quality of the appraisal depends on how much labor is employed.

The dynamic structure of the model is as follows. We assume a continuum of underwriters (investment banks). Each underwriter can underwrite one project. These underwriters privately make a decision to buy a quantity, η , of skilled labor. Skilled labor is purchased on a competitive labor market featuring an inelastic supply of labor fixed at \bar{q} . Because the total number of projects is normalized to 1, \bar{q} is best interpreted as per project supply of skilled screening labor. Hence an increase in project supply, holding labor fixed, is reflected through a fall in \bar{q} .

Firms wishing to raise equity in the IPO market apply to underwriters. Once a firm is matched with an underwriter, neither side has an exit option. Thus, the division of the proceeds from the underwriting process will be determined through a bilateral bargaining process. Following Hermalin and Katz (1991) for example, rather than model the extensive form bargaining game, we simply assume that the bargaining results in a split of the surplus from the underwriting between the firm and the underwriter, with a fraction β being captured by the firm and the remaining $1 - \beta$ by the underwriter.⁴

Before underwriting a new issue, underwriters use skilled labor to screen projects and set offer prices. The entrepreneur has an opportunity cost of w . For convenience, we

⁴See Hermalin and Katz (1991) for a discussion of the rationale for this reduced form approach.

assume that the opportunity cost for entrepreneurs of both B and G projects is the same. This assumption is not crucial for our results. What is required is that the net gain from undertaking the project is higher for G projects.

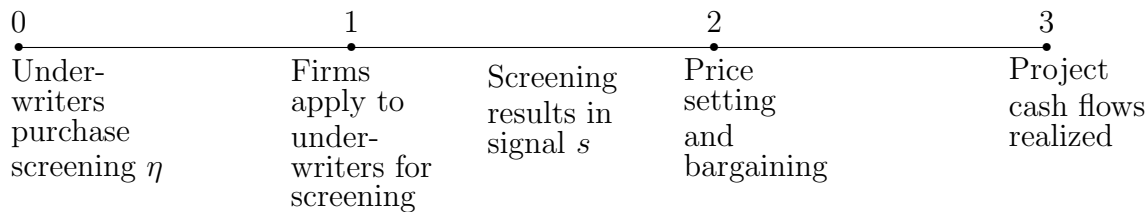
Underwriter screening is costly because underwriters pay in proportion to the quantity η of skilled labor employed. Screening produces a random signal \tilde{s} , which can take values of either H , L , or U . The conditional distribution of the signal based on true quality is given as follows:

x	$P(\tilde{s} = H \mid \tilde{X} = x)$	$P(\tilde{s} = L \mid \tilde{X} = x)$	$P(\tilde{s} = U \mid \tilde{X} = x)$
1	η	0	$1 - \eta$
0	0	η	$1 - \eta$

The assumed signaling structure implies that if an underwriter buys η quantity of labor, the underwriter receives a perfectly uninformative signal, U , with probability $1 - \eta$ and a perfectly informative signal, H or L with probability η . More general structures, which are tractable only through numerical analysis, yield similar results. In our set-up, η represents both the quantity of labor purchased by the underwriter and the quality of the signal received by the underwriter. We also assume that the signal produced by the underwriting process is publicly observable, or equivalently, that the underwriter cannot misreport the signal. In the equilibria we identify, under very mild restrictions discussed later, it is not in the interest of the underwriter to report a higher signal than the signal she observes. For this reason, this assumption of public observability is not strictly necessary for the validity of our results. However, assuming public revelation of the signal does rule out some equilibria and also allows us to dispense with the machinery required for developing an asymmetric information model. Although the realized signal is public information, the quality of labor used by the underwriter to produce the signal is private information. After observing the signal, the underwriter fixes an IPO price, and this price determines the proceeds from the issue.

After the IPO is priced, the cash flow from the project is realized. This cash flow determines the after-market price of the IPO. If price drops in the after-market, the underwriter bears a penalty proportional to the square of his realized profit from selling the issue to outside investors, $(1 - \beta)(X - p)$, i.e., we assume a penalty of the form $\gamma(1 - \beta) \max[p - x, 0]^2$. This penalty can be viewed as the reputational penalty to underwriters from price drops.

The following timeline illustrates the sequence of actions in this model.



See Table 1 for a summary description of all variables in our model.

3. Parametric assumptions and equilibrium

In order to focus on interesting sections of the parameter space, we impose the following parametric restrictions on the model.

Assumption 1 $2\gamma(1 - \rho)\rho > 1$.

Assumption 2 $\beta\rho > w$.

Assumption 3 $\rho > \bar{q}$.

Assumption 1 ensures that an uniformed underwriter has an incentive to underprice the IPO when all B entrepreneurs are trying to obtain financing. Assumption 2 ensures that the reservation payoff of entrepreneurs is low enough that unless the IPO is underpriced, all B entrepreneurs will want to issue when there is no screening. Assumption 3 ensures that the labor supply is insufficient to screen all good projects perfectly. Essentially these three assumptions exclude regions of the parameter space where (a) entrepreneurs with bad projects obtain financing without generating any underpricing or inducing any screening by the underwriter (b) entrepreneurs with bad projects “self-screen” by staying off the market even when fairly priced, and (c) there is a sufficient supply of screeners to perfectly screen all projects at a labor wage rate of zero. Analyzing these cases is not difficult but would be tedious and would produce few, if any, surprising results.

In our analysis, an equilibrium is a 4-tuple, consisting of an issue strategy for the entrepreneurs, a pricing strategy for underwriters, screening labor demand and a wage for screening labor. As we will verify later, in any Perfect Bayesian equilibrium, the equilibrium issue strategy will call for all entrepreneurs with G projects to issue. Thus, the analysis of the strategy choice of the entrepreneur can be reduced to considering the fraction of B entrepreneurs that issue. We call this fraction α . As we will also easily verify in the following analysis, it is optimal for the underwriter to set a price of 1 after a H signal and a price of zero after a L signal; thus the underwriter pricing strategy can

be reduced to fixing a price upon observing an uninformative signal. We call this price p_U . The underwriter's other decision is the quantity of skilled labor to purchase, η . In making this decision, the underwriter takes the labor wage as fixed.

4. Solving the Model

Solving our model requires deriving equilibrium conditions both in the IPO market and the screening labor market; in fact, the interactions between these markets is the focus of our analysis. To control modelling complexity we have adopted very simple specifications for both markets. Nevertheless, solving the model is complicated by the number of steps involved. Working backwards, the first step is to determine the underwriters optimal IPO policy, i.e., the quantity of skilled labor and the level of underpricing. The underwriter's solution is conditioned on her signal, H , L , or U , the expected quality of the firms choosing to perform IPOs, and the price of underwriting labor. The underwriter takes these parameters as given.

At the same time owner-entrepreneurs make a decision on whether to attempt an IPO. This decision is predicated on their private information regarding IPO quality, the pricing decision they expect from the issuer, and their conjecture regarding the quantity of underwriting labor. Fixing the price of underwriting labor we solve for a Bayesian Nash equilibrium in the underwriter owner-entrepreneur game satisfying standard equilibrium refinements. This yields the equilibrium fraction of firms that seek IPO financing, underpricing, and the demand for underwriting labor. By varying the price of skilled labor, a demand curve for labor is generated, which when intersected with labor supply curve generates the overall equilibrium for our model. Finally, we perform comparative statics to examine how in IPO/labor market equilibrium, shocks to the labor demand and/or quality of potential projects affect underpricing, and the quality of actually funded projects.

Before we analyze the various equilibria in this model, we will derive the optimal offer price, and the expected payoffs of entrepreneurs and underwriters, taking as constant the quality of screening, η , and the proportion of B projects that apply for screening, α .

4.1. Price setting and underwriter payoffs

Underwriters are risk neutral and thus maximize their expected payoff, which equals their fraction of issue proceeds less expected costs generated by ex post price drop. Thus the underwriter's payoff, excluding payments to skilled labor which are fixed at the time the pricing decision is made, as a function of the signal she receives and the price she

sets is given by

$$v(p, s, \eta) = (1 - \beta)p_s - (1 - \beta)\gamma E \left[(p_s - X)^+ \right]^2.$$

Under our assumed signal structure, with probability $1 - \eta$ the underwriter receives an uninformative signal. At the time the pricing decision is made, the underwriter's skilled labor purchase decision has already been fixed. Thus, the only remaining decision is the pricing of the issue. Moreover, because the signal is public information, sequential rationality on the part of the (risk neutral) investors implies that the issue price cannot exceed the expected value of the issue. If the U signal is from a G project, it will not be overpriced *ex post*. If it is from a B project, there will be overpricing *ex-post*, i.e., the after-market price will equal the issue's true value, 0. Thus the underpricing penalty will equal $\gamma(1 - \beta)(p - 0)^2$. Because the U signal is uninformative, probabilities conditional on U equal unconditional probabilities. Thus when the signal is uninformative the underwriter solves

$$\begin{aligned} \max_{p_U} (1 - \beta)p - (1 - \beta)\gamma p^2(1 - \pi) \\ \text{s.t. } p \leq \pi, \end{aligned} \quad (1)$$

where π represents the probability that that an entrepreneur attempting to obtain funds has a good project⁵.

Given the concavity of the objective function in p , problem (1) has a straightforward solution,

$$p_U^*(\pi) = \min \left[\frac{1}{2\gamma(1 - \pi)}, \pi \right]. \quad (2)$$

Within this pair of solutions, $p_U = \frac{1}{2\gamma(1 - \pi)}$ is the underpricing solution. Given assumption 1, we know that at $\pi = \rho$, the underpricing solution is optimal. This fact, the fact that $\frac{1}{2\gamma(1 - \pi)} \rightarrow \infty$ as $\pi \rightarrow 1$, and the convexity of $\frac{1}{2\gamma(1 - \pi)}$ together imply that there exists a unique π^{up} such that for $\rho \leq \pi < \pi^{\text{up}}$ underpricing is optimal and for $\pi > \pi^{\text{up}}$ pricing at expected value, π , is optimal. Solving explicitly for π^{up} (and using assumption 1) yields

$$\pi^{\text{up}} = \frac{1}{2} + \sqrt{\frac{1}{2} \left(\frac{1}{2} - \frac{1}{\gamma} \right)}, \quad (3)$$

⁵Thus, $\pi = \frac{\rho}{\rho + \alpha(1 - \rho)}$

and

$$p_U^*(\pi) = \begin{cases} \frac{1}{2\gamma(1-\pi)} & \text{if } \pi \in [\rho, \pi^{\text{up}}] \\ \pi & \text{if } \pi \in [\pi^{\text{up}}, 1]. \end{cases} \quad (4)$$

The expected payoff from the issue, excluding the cost of skilled labor is given by

$$V_U^* = (1 - \beta)[p_U^* - \gamma p_U^{*2}(1 - \pi)]. \quad (5)$$

With probability η , the underwriter receives a perfectly informative signal of the value of the entrepreneur's project. The probability of a perfectly informative signal being H equals the probability of a good project, π , and the probability of the perfectly informative signal being L equals the likelihood of a bad project, $1 - \pi$. In the case of a perfectly informative H signal the risk of *ex post* overpricing is zero and thus the underwriter will set a price equal to value of 1. In the case of the perfectly informative L signal, the highest price the market will pay is zero. Thus, when an underwriter receives the perfectly informative signal, her payoff, excluding the cost of screening labor, is

$$V_I^* = (1 - \beta)\pi. \quad (6)$$

Thus, the expected payoff to the underwriter given the purchase of η quantity of screening labor, at a wage rate θ is given by

$$V^*(\eta) = \eta V_I^* + (1 - \eta)V_U^* - \theta\eta. \quad (7)$$

4.2. The entrepreneur's payoffs

If the entrepreneur has a type G project, then for an informative signal, the issue price is 1, and for an uninformative signal, the issue price is p_U^* . Thus the expected payoff to an entrepreneur deciding to issue with a G project is

$$E_G(\eta) = \beta[\eta + (1 - \eta)p_U^*]. \quad (8)$$

With a B project, the payoff to the entrepreneur will equal zero when screening is informative, and p_U^* when it is not. Thus,

$$E_B(\eta) = \beta[(1 - \eta)p_U^*]. \quad (9)$$

4.3. Basic results

Proposition 1 *In any Perfect Bayesian equilibrium satisfying standard refinements, entrepreneurs with good projects issue with probability 1.*

Proof: Suppose the probability of issuance for G entrepreneurs is less than 1 but positive. In this case G entrepreneurs must be indifferent to issuing. The fact that the payoff from not issuing is independent of the project type, and the fact that the payoff from issuing is higher for a G project, show that the indifference of G entrepreneurs implies a lower payoff from issuing than not issuing for B projects. Thus, sequential rationality requires that B entrepreneurs not issue. However, Bayes rule then implies that in equilibrium $\pi = 1$. Thus by (4), $p_U^* = 1$, which implies that $E_G(\eta) = 1, \forall \eta$. This implies by assumption 2 that $E_G > w$, which in turn implies by sequential rationality that all G entrepreneurs issue with probability 1. This contradiction establishes our result. Next, turn to the case where entrepreneurs with good projects never issue. In this case because of the relative preference for issuing when the project is good, it must be the case that no entrepreneurs issue. In this case issuing is off the equilibrium path. However, a standard refinement, i.e., D1 refinement in Cho and Kreps (1987) requires that when one type has a greater preference for an off equilibrium action than another type over all possible responses by the uninformed party, all weight be placed on that type choosing the off equilibrium action. This restriction would for off equilibrium beliefs to place all weight on the G entrepreneurs issuing. Under this assumption, using exactly the same reasoning as we used above, we see that all entrepreneurs with G projects issue with probability 1. This contradiction establishes the result.

Given Proposition 1, the strategy choice of entrepreneurs can be summarized simply by the probability a B entrepreneur attempts to issue. We will represent this probability by α . Next we show that, in equilibrium, underwriters always choose an interior level of screening labor demand, strictly between the maximum and minimum levels.

Proposition 2 *In any Perfect Bayesian equilibrium satisfying standard refinements, the quantity of skilled labor purchased by the underwriter is strictly between 0 and 1.*

Proof: First note that since aggregate demand for screening labor equals $\eta^*[\rho + (1 - \rho)\alpha]$, given assumption 3, at $\eta^* = 1$ aggregate demand exceeds supply and thus is inconsistent with the equilibrium supply conditions. Now consider, $\eta^* = 0$. If $\eta^* = 0$, then screening labor demand is less than supply and thus, the price of screening labor equals 0. In this case, the only way for $\eta = 0$ to be optimal is if the equilibrium $\pi = 1$. But if $\pi = 1$, then $p_U^* = 1$ and by assumption 2, $E_B > w$. But this implies that all B

entrepreneurs will prefer to issue. In that case, $\pi = 1$ is not consistent with Bayes rule. This contradiction establishes the result.

Since the underwriter is choosing an interior level of labor demand and because the labor demand is linear in η , we must have $V^{*'}(\eta) = 0$ in any equilibrium. We see from inspection of equation (7) that this first-order condition is equivalent to the condition

$$V_I^* - \theta = V_U^*. \quad (10)$$

Using these results allows us to present the equilibrium conditions for the model in a very succinct form. First note that Bayes rule implies that there is a one-one mapping between $\alpha \in [0, 1]$ to $\pi \in [\rho, 1]$ the equilibrium probability that an issuing firm is a G -type. Thus, we can use π as the state variable representing the issuance strategy of B entrepreneurs instead of α . Next, note that screening labor demand, given by $\eta(\rho + \alpha(1 - \rho))$, by Bayes rule, is equal to $\eta\rho/\pi$.

5. Equilibrium with underpricing

In this section, we present the analysis of an equilibrium featuring a tight labor market, and underpricing of IPOs. The labor market equilibrium condition equating demand with inelastic supply determines the labor wage θ , and screening is only partially effective in that not all B projects are kept off the IPO market. In such an equilibrium, B entrepreneurs must be indifferent between issuing and not issuing. We define equilibrium as a triple (π, η, θ) satisfying the equilibrium conditions of sequential rationality, market clearing and underpricing as follows.

$$\begin{aligned} \beta(1 - \eta)p_U^*(\pi) &= w, \\ \eta\rho &= \pi\bar{q}, \\ V_I^*(\pi) - \theta &= V_U^*(\pi), \\ \text{and } \pi &\in [\rho, \pi^{\text{up}}]. \end{aligned} \quad (11)$$

We call all such equilibria satisfying the above conditions *partially effective screening equilibria with underpricing*.

5.1. Analysis

In this equilibrium, $p_U^* = \frac{1}{2\gamma(1-\pi)}$. Using equation (11), we can write

$$\eta^* = 1 - \frac{2\gamma w(1 - \pi^*)}{\beta}. \quad (12)$$

Substituting from (12) into (11), we have

$$\begin{aligned} \rho \left[1 - \frac{2\gamma w(1 - \pi^*)}{\beta} \right] &= \pi^* \bar{q}, \\ \Rightarrow \pi^* &= \frac{\rho(2\gamma w - \beta)}{(2\gamma w\rho - \beta\bar{q})}. \end{aligned} \quad (13)$$

Using (11), we can write

$$\begin{aligned} \theta^* &= V_I^*(\pi^*) - V_U^*(\pi^*), \\ \text{which reduces to } \theta^* &= (1 - \beta) \left[\pi^* - \frac{1}{4\gamma(1 - \pi^*)} \right]. \end{aligned} \quad (14)$$

Using the solution for π^* from (13), it is straightforward to prove that the range of labor supply within which there exist *partially effective screening equilibria with underpricing* is as follows.

$$\begin{aligned} \max \left[0, 1 - \frac{2\gamma w(1 - \rho)}{\beta} \right] < \bar{q} < \bar{q}_1^{\text{up}}, \quad (15) \\ \text{where } \bar{q}_1^{\text{up}} \text{ solves } \pi^* &= \pi^{\text{up}}. \end{aligned}$$

See appendix for details.

5.2. Project quality, underpricing and the labor market

We next examine key comparative statics. In particular, we wish to examine the effect of varying \bar{q} , the supply of labor, and ρ , the initial proportion of G projects in the population, on the equilibrium values of average IPO quality and expected underpricing. Recall that \bar{q} should properly be interpreted as the per project labor supply. Thus, a market featuring a low value of \bar{q} corresponds to what the empirical IPO literature calls a “hot” market. In other words we wish to contrast expected underpricing in “hot” and “cold” markets through an examination of the comparative statics with respect to \bar{q} . Also of interest is the quality of the average IPO during hot versus cold markets. Finally, we also wish to examine how changes in the ex-ante distribution of projects quality affect

expected underpricing and average IPO quality. For instance, does an increase in the ex-ante proportion of G projects in the economy translate to a higher average quality IPO? The following results summarize the answers to these questions.

Before we proceed to examine these comparative statics, we clearly define average IPO quality and expected underpricing in terms of the parameters of the model.

Definition 1

$$\text{Average IPO quality, } AQ = \pi. \tag{16}$$

Since the total number of projects in our model is normalized to unity, π , the probability that an entrepreneur attempting to obtain funds has a good project, is also a measure of average IPO quality.

Definition 2

$$\text{Expected underpricing, } EU = (1 - \eta) \left[\pi - \frac{1}{2\gamma(1 - \pi)} \right]. \tag{17}$$

This definition of expected underpricing follows from the fact that underpricing occurs only when the underwriter receives an uninformative signal.

The following proposition summarizes the effect of changing labor supply on average IPO quality and expected underpricing.

Proposition 3 *In any partially effective screening equilibrium with underpricing, average IPO quality increases with labor supply, and expected underpricing might increase or decrease with labor supply. However, when a majority of projects in the economy are expected to be G projects ex-ante, and the overpricing penalty is high enough, expected underpricing decreases with labor supply.*

Proof: See appendix.

As labor supply increases, underwriters decrease underpricing, since screening gets better on average. This dissuades B projects from coming on the IPO market, and hence average IPO quality, π^* increases in labor supply.

With respect to expected underpricing, things are not so straightforward. To be sure, $1 - \eta$ decreases in \bar{q} , which is to say that the *probability* of underpricing an issue goes down as labor supply increases. However, the *amount* of underpricing is not invariant to changes in labor supply. The expected value of a U project, as well as the issue price of a U project, both increase with labor supply. However whether this results in an increase or a decrease in underpricing (the difference between the expected value and the issue

price) depends on the net effect. For a given decrease in labor supply, if the expected value decreases more than the decrease in issue price, then the net effect is for expected underpricing to increase with labor supply. On the other hand if the decrease in expected value is less than that in issue price, the opposite is true. When labor supply is at the higher end of its feasible range, underpricing serves to keep almost all the B projects off the IPO market. Thus, issue price responds sharply to changes in labor supply. However, at the lower end of the feasible range, in spite of underpricing, screening is close to ineffective, and issue price is less responsive to changes in labor supply. At this end of the range, therefore, expected underpricing may sometimes be positively related to labor supply, although this relationship has to eventually reverse as we increase \bar{q} . A sufficient condition for expected underpricing to decrease with labor supply is that the ex-ante proportion of G projects in the economy is more than one half. This condition ensures that, as labor supply decreases, the issue price falls faster than the project's expected value, thereby increasing expected underpricing.

The following proposition examines the effect of changing the ex-ante distribution of projects in the economy on average IPO quality and expected underpricing in equilibrium.

Proposition 4 *In any partially effective screening equilibrium with underpricing, average IPO quality decreases with the quality of the pool of available projects, ρ , while expected underpricing might increase or decrease with the quality of the applicant pool. However, when a majority of projects in the economy are expected to be G projects ex-ante, and the overpricing penalty is high enough, expected underpricing increases with the ρ , the proportion of G projects in the economy.*

Proof: See appendix.

In this equilibrium, average project quality *decreases* in the ex-ante quality of projects. This is because a marginal increase in the ex-ante number of G projects increases the demand for screening so much that it enables more than the equivalent number of B projects to enter the IPO market.

The relationship between expected underpricing and ρ is ambiguous. In the partially screening equilibrium, the probability of underpricing unambiguously increases with ρ . Average project quality and issue price both decrease with the proportion of G projects, and the net effect of these quantities is unclear in general. However, if the ex-ante proportion of G projects is already large, the marginal G project puts so much pressure on the screeners that the net effect is for the underwriter to actually underprice more.

5.3. Numerical Analysis

In this subsection, we use a simple numerical example to illustrate the key features of our model. The exogenous parameters chosen are as follows: $\rho = 0.52, \beta = 0.90, \gamma = 3.2, w = 0.20$. For this set of parameters, the partially effective screening equilibrium with underpricing exists for \bar{q} in the range between 0.317 and 0.467. Figure 1 plots π versus \bar{q} for this equilibrium. Given the value of $\gamma = 3.2$, we can calculate π^{up} as 0.806. It will be noted that the average IPO quality in figure 1 is always below this value. As the labor market gets progressively tighter, underwriters are reluctant to hire expensive labor. Instead, they underprice issues by a greater amount because of increased uncertainty in the signal, and the deterioration in quality of the applicant pool, due to an increase in the fraction of B projects that enter the IPO market as a result of poor screening. The increase in the fraction of B projects entering the IPO market as the labor market tightens can also be seen from figure 2. Consistent with proposition 3, figure 3 shows that for sufficiently high values of ρ and γ , expected underpricing decreases in the labor supply \bar{q} .

Figure 4 plots average project quality against ex-ante project quality ρ . We observe the interesting result (stated in proposition 4) that average project quality *decreases* in the ex-ante quality of projects. Following from this result, figure 5 shows that expected underpricing actually increases with ex-ante project quality ρ .

6. Other Equilibria

Besides the partially screening equilibrium with underpricing, there are three other equilibria that we identify. Although our focus is on the previously derived equilibrium, we present a discussion of these other equilibria in the interest of completeness. First we define these other equilibria, extend the earlier numerical example to include these cases, and then present their analytics.

6.1. Definition

The first class of equilibria we consider in this section feature a complete failure of screening and all B entrepreneurs prefer to issue. This implies that the likelihood that an issuing entrepreneur has a G project is just the prior probability of a good project, i.e., $\pi = \rho$. We call these equilibria *screening failure equilibria*, which are ordered triples

(π, η, θ) satisfying the following conditions:

$$\begin{aligned}
\beta(1 - \eta)p_U^*(\pi) &\geq w, \\
\eta &= \bar{q}, \\
V_I^*(\pi) - \theta &= V_U^*(\pi), \\
\text{and } \pi &= \rho.
\end{aligned} \tag{18}$$

Next, we consider equilibria with $\theta = 0$. Inspection of equations (5) and (6) shows that (10) is satisfied with $\theta = 0$ if and only if $\pi = 1$. In this case, Bayes rule implies that no B type firms attempt to issue. Moreover, $\theta = 0$ is consistent with labor market equilibrium if and only if screening labor demand is less than supply, \bar{q} . Also, when $\pi = 1$, labor demand is $\eta\rho$. We call equilibria exhibiting these features *effective screening equilibria*. They are represented as (π, η, θ) triplets satisfying the following conditions:

$$\begin{aligned}
\beta(1 - \eta)\pi &< w, \\
\eta\rho &< \bar{q}, \\
\pi &= 1, \\
\text{and } \theta &= 0.
\end{aligned} \tag{19}$$

Finally, we consider a partially effective screening equilibrium featuring fair pricing. The labor market equilibrium condition equating demand with inelastic supply applies. Screening is only partially effective, and some B projects enter the IPO market. In equilibrium, B entrepreneurs must be indifferent between issuing and not issuing. Hence, this equilibrium is represented as a triple (π, η, θ) satisfying the equilibrium conditions of sequential rationality, market clearing and underpricing as follows.

$$\begin{aligned}
\beta(1 - \eta)p_U^*(\pi) &= w, \\
\eta\rho &= \pi\bar{q}, \\
V_I^*(\pi) - \theta &= V_U^*(\pi), \\
\text{and } \pi &\in [\pi^{\text{up}}, 1].
\end{aligned} \tag{20}$$

6.2. Numerical example

We now extend the analysis in section 5.3. to examine the big picture, where all equilibria exist. Recall that we chose exogenous parameters as follows: $\rho = 0.52, \beta = 0.90, \gamma = 3.2, w = 0.20$. First, observe that over this range of parameters, all the above

types of equilibria exist. When \bar{q} is between 0.317 and 0.467, we have the earlier partially effective screening equilibrium with underpricing. For $\bar{q} < 0.317$, we have an equilibrium where screening completely fails to keep B projects off the IPO market. When \bar{q} is in $(0.404, 0.52)$, there is an effective screening equilibrium. Finally, we have a partially effective screening equilibrium with fair pricing when q is in between 0.404 and 0.467. In other words, between \bar{q} of 0.404 and 0.467, we have multiple equilibria. Figure 6 shows these equilibria in a plot of π versus labor supply \bar{q} . As noted before, this set of parameters leads to $\pi^{\text{up}} = 0.806$. This underpricing threshold is shown as the dashed horizontal line in figure 6. Equilibria above this line feature fair pricing, while those below feature underpricing.

Figure 7 plots the equilibrium proportion of B projects, α , as a function of the fixed labor supply, \bar{q} , for all the above described equilibria. As can be seen from these figures, when labor supply is at the higher end of its feasible range, screening is very effective at keeping all B projects off the market. In this example, this happens for \bar{q} in the range $(0.404, 0.52)$. When labor supply is in the range $(0.404, 0.467)$, there is also a partially effective screening equilibrium without underpricing. This equilibrium has the unique feature that the proportion of B projects applying for an IPO is *increasing* in the supply of labor. To understand this, note that in equilibrium, all B projects are indifferent between applying or not. The fraction α of B projects that enters the IPO market serves to reduce per-project screening efficiency, which in turn increases the probability that B projects will be wrongly classified and the expected payoff of B projects so that they are exactly indifferent between applying or not. Consider an increase in the available supply of labor. To sustain this equilibrium, a greater fraction of B projects enters the IPO market and “soaks up” the excess labor, thereby obfuscating the screening labor enough to render B projects indifferent between applying and not.

As discussed previously, when labor supply is within the range $(0.317, 0.467)$, as the labor market gets progressively tighter, underwriters are reluctant to hire expensive labor. Instead, they underprice issues by a greater amount, fully aware that the average screening quality is lower, because of which the fraction of B projects that enters the IPO market progressively increases with such decreases in \bar{q} .

For a small enough labor supply (here, $\bar{q} < 0.317$), the screening mechanism of the underwriter is completely overwhelmed by all the B projects that apply for an IPO, and all B projects enter the IPO market along with all the G projects.

6.3. Analysis

6.3.1. Screening failure equilibrium

From (18), we have $\pi = \rho$, which implies that all such equilibria feature underpricing, which in turn implies that $p_U^* = \frac{1}{2\gamma(1-\rho)}$. Using (18), we can determine the bounds on \bar{q} for which such equilibria exist as

$$0 < \bar{q} < 1 - \frac{2\gamma w(1-\rho)}{\beta}. \quad (21)$$

All B projects enter the IPO market and the unit price of labor is determined as

$$\begin{aligned} \theta^* &= V_I^*(\rho) - V_U^*(\rho), \\ \text{which reduces to } \theta^* &= (1-\beta) \left[\rho - \frac{1}{4\gamma(1-\rho)} \right]. \end{aligned} \quad (22)$$

6.3.2. Effective screening equilibrium

In such equilibria, there will be just enough screening to prevent B projects from entering the IPO market. Using (19), we can solve for the minimal amount of screening which keeps B projects off the market. The solution is

$$\eta^* = 1 - \frac{w}{\beta}. \quad (23)$$

Clearly, $\pi = 1$ implies that there will not be any underpricing in this equilibrium. For this equilibrium, the labor market condition implies the following condition on labor supply, \bar{q} must be satisfied for effective screening equilibria to exist:

$$\bar{q} > \eta^* \rho = \left(\frac{\beta - w}{\beta} \right) \rho. \quad (24)$$

6.3.3. Partially effective screening with fair pricing

When pricing is fair, $p_U^* = \pi$. Then, using (20), we can derive

$$\eta^* = 1 - \frac{w}{\beta\pi^*}. \quad (25)$$

Substituting from (25) into (20), we can write

$$\begin{aligned} \left(1 - \frac{w}{\beta\pi^*} \right) \rho &= \pi^* \bar{q}, \\ \Rightarrow \pi^* \text{ solves } f(\pi) &\equiv -\beta\bar{q}\pi^2 + \beta\rho\pi - w\rho = 0. \end{aligned} \quad (26)$$

π^* is determined as the solution to the quadratic equation in (26). See the appendix for a proof that the smaller root of this equation can never be a equilibrium solution. Thus, we need only consider the larger root of the above equation in this case. Formally, the equilibrium π^* is given by

$$\pi^* = \frac{\rho}{2\bar{q}} + \frac{\sqrt{\beta^2\rho^2 - 4\beta\rho\bar{q}w}}{2\beta\bar{q}}. \quad (27)$$

To determine the bounds on \bar{q} for this equilibrium to exist, we note that the solution in (27) has to lie between ρ and 1, the feasible bounds on π . Also we use the fact that we are considering equilibria where pricing is fair. Using these facts, we can summarize the range of labor supply within which there exist *partially effective screening equilibria* featuring fair pricing as follows:

$$\frac{(\beta - w)\rho}{\beta} < \bar{q} < \min[\rho, \bar{q}_2^{\text{up}}], \quad (28)$$

where \bar{q}_2^{up} solves $\pi^* = \pi^{\text{up}}$.

See appendix for details.

Finally, using $V_I^*(\pi) - \theta = V_U^*(\pi)$, it is straightforward to derive the equilibrium price of labor as

$$\theta^* = \gamma(1 - \beta)\pi^{*2}(1 - \pi^*). \quad (29)$$

6.4. Comparative Statics

The following two propositions summarize the effect of changing labor supply on average IPO quality and expected underpricing.

Proposition 5 *Average IPO quality is constant at unity in any effective screening equilibrium, while it is always equal to the ex-ante proportion of G projects in any screening failure equilibrium. Further, average IPO quality decreases with labor supply in any partially effective equilibrium with fair pricing.*

Proof: See appendix.

Observe from Figures 6 and 7 that the nature of the relationship between π and \bar{q} is exactly opposite to that between α and \bar{q} . This follows from the definition of π . The dashed horizontal line in figure 6 is the value of π^{up} . At values of π above this threshold, equilibria feature fair pricing. Below this threshold, we observe underpricing.

When labor supply is almost sufficient to screen all G projects, screening is very effective, and average project quality is at its highest possible value. Roughly over the same

range of labor supply, there is also a partially effective screening equilibrium without underpricing. In this equilibrium average IPO quality is *decreasing* in the supply of labor. The reason is that in equilibrium, the marginal B project must be indifferent between applying or not. When B projects applying for screening overwhelm the screeners, increasing the expected payoff of B projects so more of them apply till the new marginal B project is exactly indifferent between applying or not. If labor supply increases, a greater fraction of B projects enters the IPO market and absorbs the excess labor, which reduces screening efficiency. This increase in the fraction of B projects is exactly enough to make all B projects indifferent between entering the IPO market and not. This reduces the quality of the average IPO.

Proposition 6 *Effective screening equilibria do not result in any underpricing. Expected underpricing decreases with labor supply in any screening failure equilibrium.*

Proof: See appendix.

The result that expected underpricing decreases with labor supply in a screening failure equilibrium is expected, given the structure of our model. In such equilibria, labor supply is so tight that all available labor is hired by underwriters. Also, since all B projects are on the market, the *amount* of underpricing is constant across all values of the labor supply. Therefore as we decrease the supply of labor, the *probability* of underpricing (i.e. of the underwriter obtaining an uninformed signal) increases, which in turn increases expected underpricing. This behavior can be observed in figure 8 over the relevant range.

The next set of propositions examines the effect of changing the ex-ante distribution of projects in the economy on average IPO quality and expected underpricing.

Proposition 7 *Average IPO quality is constant at unity in any effective screening equilibrium, while it is linearly increasing in the proportion of G projects in any screening failure equilibrium. In any partially effective equilibrium without underpricing, average accepted project quality increases with the quality of the available pool of projects, ρ , whereas in any partially effective equilibrium with underpricing, average accepted project quality decreases with the quality of the pool of available projects, ρ .*

Proof: See appendix.

See Figure 9 for an illustration of the relationship between average IPO quality and the ex-ante proportion of G projects in the economy. In this example, the labor supply \bar{q} is fixed at 0.55. For ρ between 0.612 and 0.684, we have the partially effective screening equilibrium with underpricing described above, where average project quality decreases

in ex-ante project quality. When ρ is in the range $(0.55, 0.707)$, we have an effective screening equilibrium, where the average IPO quality is one, as there are no B projects that enter the IPO market. When ρ is in the range $(0.684, 0.806)$, we observe there is a screening failure equilibrium where all projects that apply get accepted for an IPO. Therefore, in this range, the average IPO quality is equal to the ex-ante project quality. Beyond $\rho = 0.806$, underpricing is no longer optimal, and hence there are no equilibria beyond this value of ex-ante project quality. When ρ is in between 0.612 and 0.707, there is a partially effective screening equilibrium with fair pricing. Here, keeping labor supply constant, increasing ex-ante project quality results in less pressure on screeners as there are less number of B projects that can apply, and hence average IPO quality increases with ρ .

Proposition 8 *Effective screening equilibria do not result in any underpricing. In all partially effective equilibria with underpricing and all screening failure equilibria, expected underpricing might increase or decrease with the quality of available projects, ρ .*

Proof: See appendix.

See Figure 10 for an illustration of this proposition. The interesting equilibria on this graph are the screening failure equilibrium and the partially effective screening equilibrium with underpricing. In the screening failure equilibrium (ρ between 0.684 and 0.806) underpricing happens to be decreasing in ρ , although this is not true in general. In the partially effective screening equilibrium, when ρ is in the range $(0.612, 0.684)$, expected project quality is decreasing, and expected underpricing is increasing in ex-ante project quality ρ .

7. Conclusion

In this paper we have developed a model of IPO underpricing that endogenizes the cost of screening labor to investment banks. The comparative statics produced by this model are both distinct and consistent with many of the stylized facts surrounding hot IPO markets: increased income for investment bankers, high levels of underpricing, a flood of marginal investment projects, and a reduction in underwriting standards. Two directions for extending this work seem promising. One direction is to try to extend the analysis of our specific investment banking problem to a dynamic setting. In such a setting, entrepreneurs with good projects could choose to either issue in hot markets or delay, hoping for less underpricing. Such endogenous timing might cool off hot markets by reducing the bunching of IPOs in the aggregate and thus better screening. It is worthwhile to note here that the incentive for good types to avoid bunching suggested

here is opposed to the conclusion of much of the asymmetric information literature (e.g., Admati and Pfleiderer (1988)) which shows that high quality types have an incentive to bunch their activities at a fixed point in time to minimize adverse selection costs. However, there are countervailing incentives to project delay. The better the entrepreneur's investment options, the larger her costs of delay. Thus, delaying this onset of projects could lower the market's evaluation of the quality of the entrepreneur's project. As long as perfect screening is not feasible in later periods, this reduction in perceived quality might discourage high quality firms from delaying projects to avoid the underpricing of hot IPO markets.

A dynamic setting would also provide investment banks with new incentives and opportunities. Notably, they would have incentives to smooth out the cost of skilled labor, and to increase the supply of labor in hot markets. Because labor contracts are difficult to enforce against workers (see Harris and Holmström (1982)), simply buying forward labor contracts might not be an effective means to stock supply for an anticipated hot market. However, overstaffing in cold market periods combined with building up firm-specific evaluation systems could provide firms with a somewhat captive supply of investment banking labor, and thus allow firms to capture more of the rents from hot markets, while at the same time improving screening in hot markets.

Another direction for extending this analysis is to apply equilibrium supply constraint conditions to other problems in economics which feature third-party screening. Our basic dynamic, under which supply shocks to the screening system leads institutions to rationally (at an individual level) economize on screening, which leads more bad types to enter the market, in turn makes screening even more costly, etc., could be modeled in many markets featuring screening. Consider the problem of a government trying to separate legitimate from illegitimate instances of a novel tax shelter. The more the tax shelter is adopted, the more difficult it will be for the fixed number of tax officers to evaluate the shelter, which means weaker screening and thus more illegitimate shelters being proposed, the increased number of shelters further weakening screening, etc. Or consider the problem of in a labor market context where the workers who are not screened will become future screeners. Here there is another feedback dimension — poor screening leads to poor screeners in the future, encouraging more substandard applicants to attempt to obtain positions. In short, we think that endogenizing the compensation of screeners both increases the explanatory power of screening models for the IPO market and has the potential to explain many other anomalous results in markets characterized by informational asymmetries as well.

Exogenous variables

Variable	Support	Description
\tilde{X}	$x \in \{0, 1\}$	Project cash flow
ρ	$0 \leq \rho \leq 1$	Proportion of good projects in economy
s	$s \in \{H, L, U\}$	Underwriter's screening signal
w	$w > 0$	Reservation wage of G and B projects
β	$0 \leq \beta \leq 1$	Fraction of IPO proceeds to firm net of commission
γ	$\gamma > 0$	Penalty to underwriter for overpricing
\bar{q}	$0 \leq \bar{q} \leq \rho$	Per-capita supply of screening labor

Endogenous variables

Variable	Support	Description
p_s	$p_s \in \{p_H, p_L\}$	Offer price of IPO (conditional on screening)
α	$0 \leq \alpha \leq 1$	Proportion of B projects in market
η	$0 \leq \eta \leq 1$	Optimal amount of underwriter screening
θ	$\theta \geq 0$	Unit price of screening labor

Table 1: Description of variables

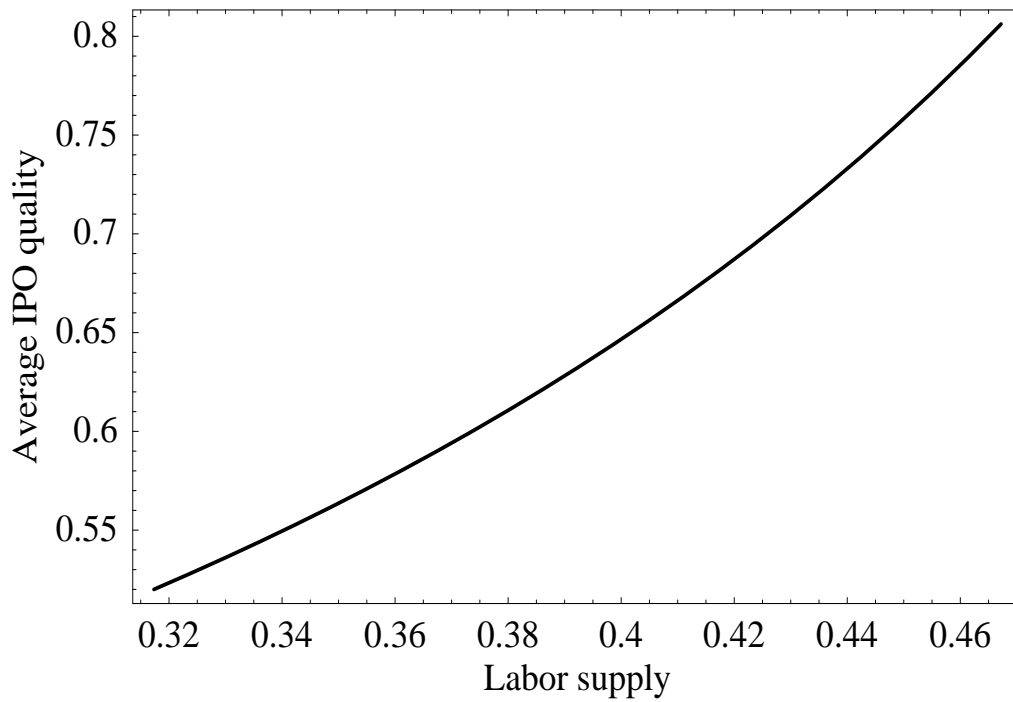


Figure 1: Partially effective screening: Average IPO quality, π vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

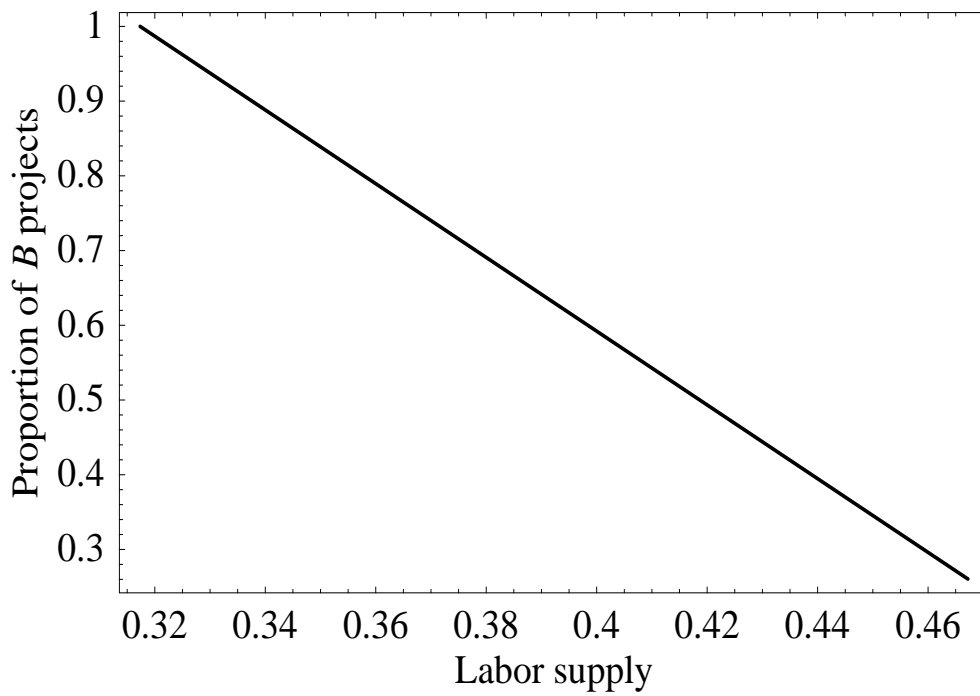


Figure 2: Partially effective screening: Proportion of B projects vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

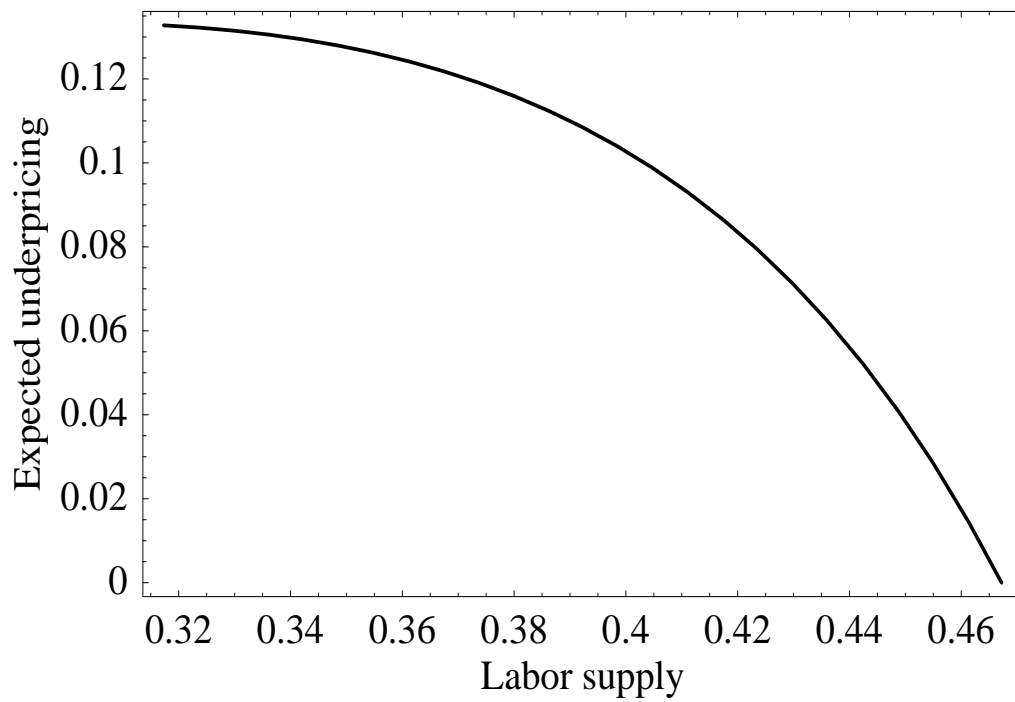


Figure 3: Partially effective screening: Expected underpricing vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

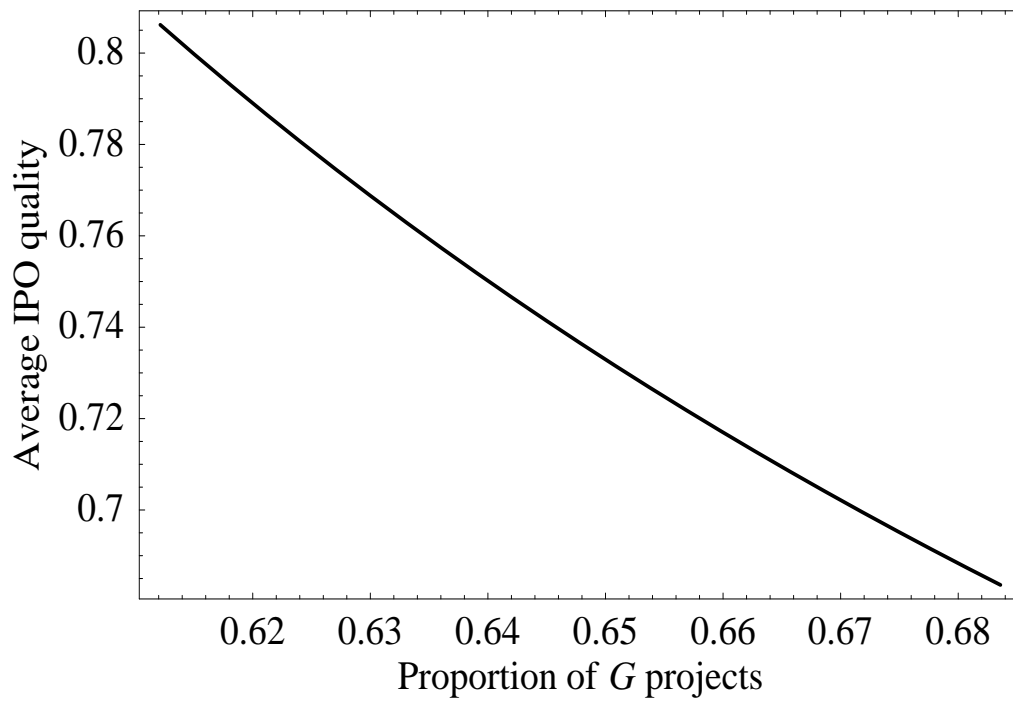


Figure 4: Partially effective screening: Average IPO quality, π vs. the ex-ante proportion of G projects, ρ ($\beta = 0.9, \bar{q} = 0.55, w = 0.20, \gamma = 3.2$)

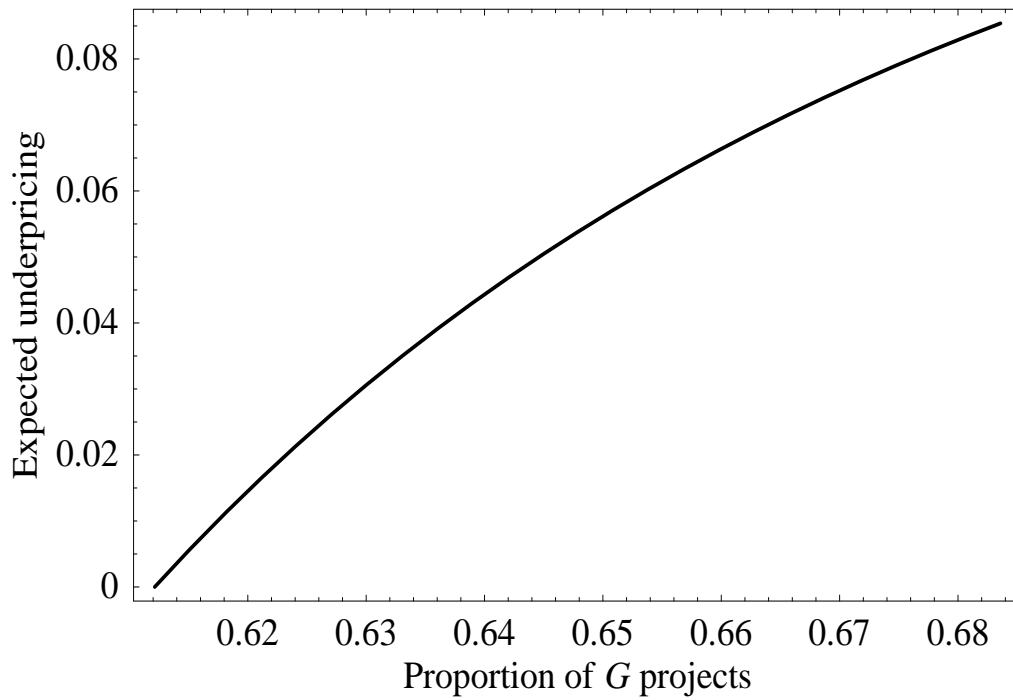


Figure 5: Partially effective screening: Expected underpricing vs. the ex-ante proportion of G projects, ρ ($\beta = 0.9, \bar{q} = 0.55, w = 0.20, \gamma = 3.2$)

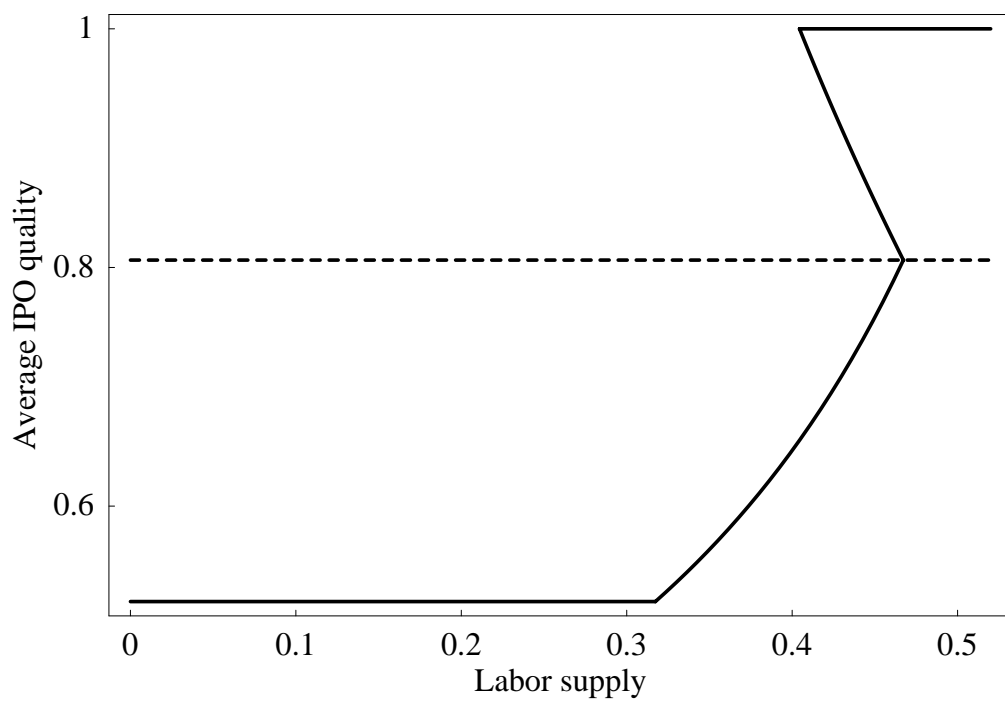


Figure 6: Average IPO quality, π vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

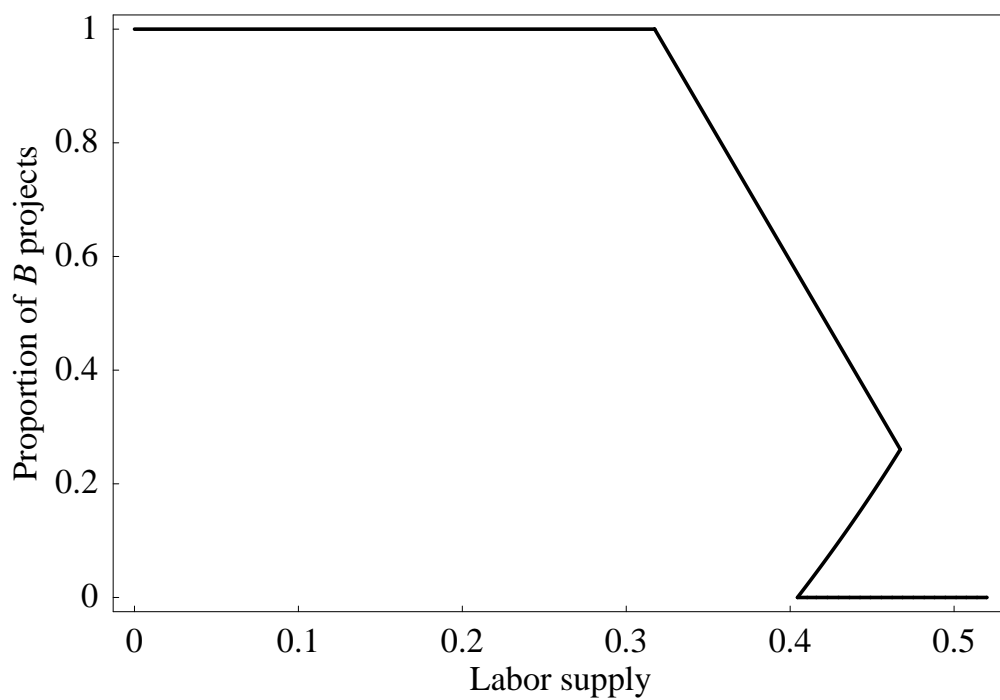


Figure 7: Proportion of B projects vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

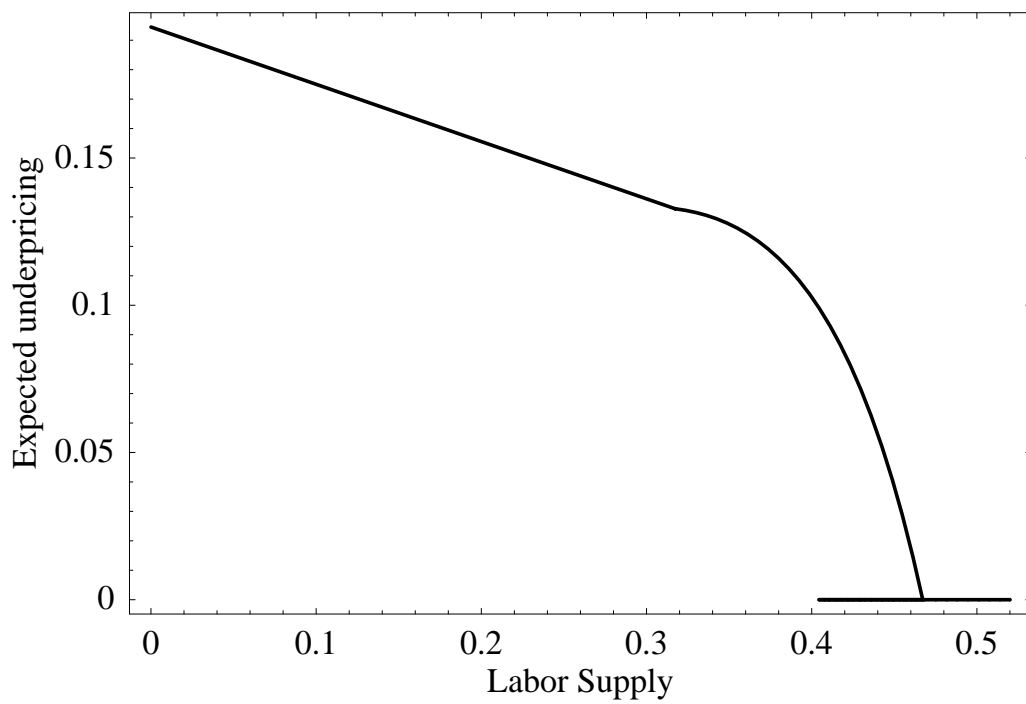


Figure 8: Expected underpricing vs. labor supply, \bar{q} ($\beta = 0.9, \rho = 0.52, w = 0.20, \gamma = 3.2$)

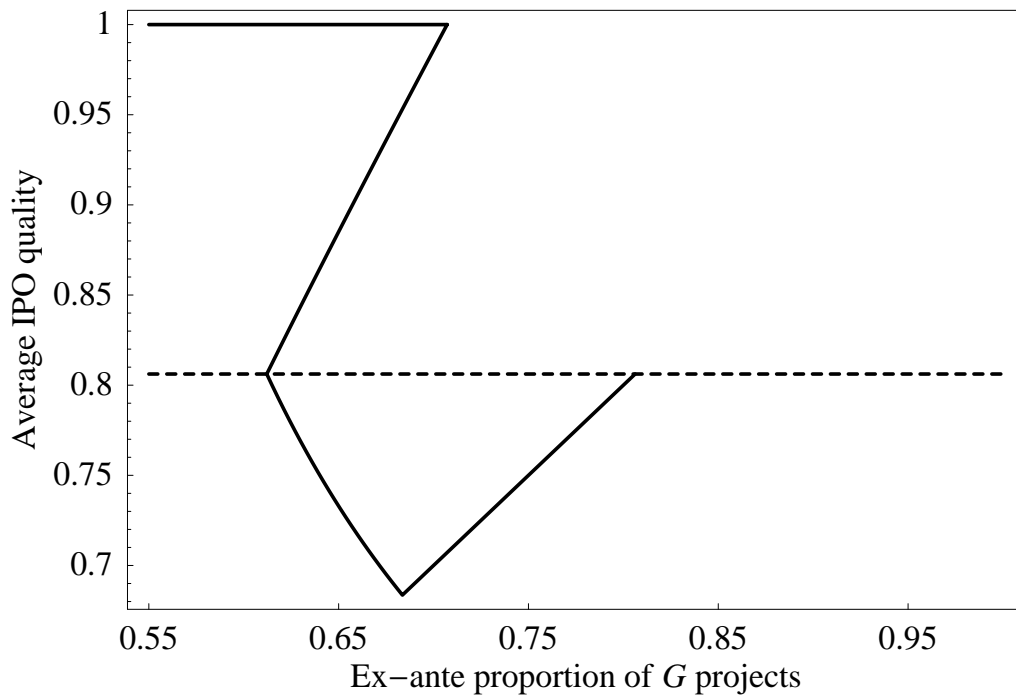


Figure 9: Average IPO quality, π vs. the ex-ante proportion of G projects, ρ ($\beta = 0.9, \bar{q} = 0.55, w = 0.20, \gamma = 3.2$)

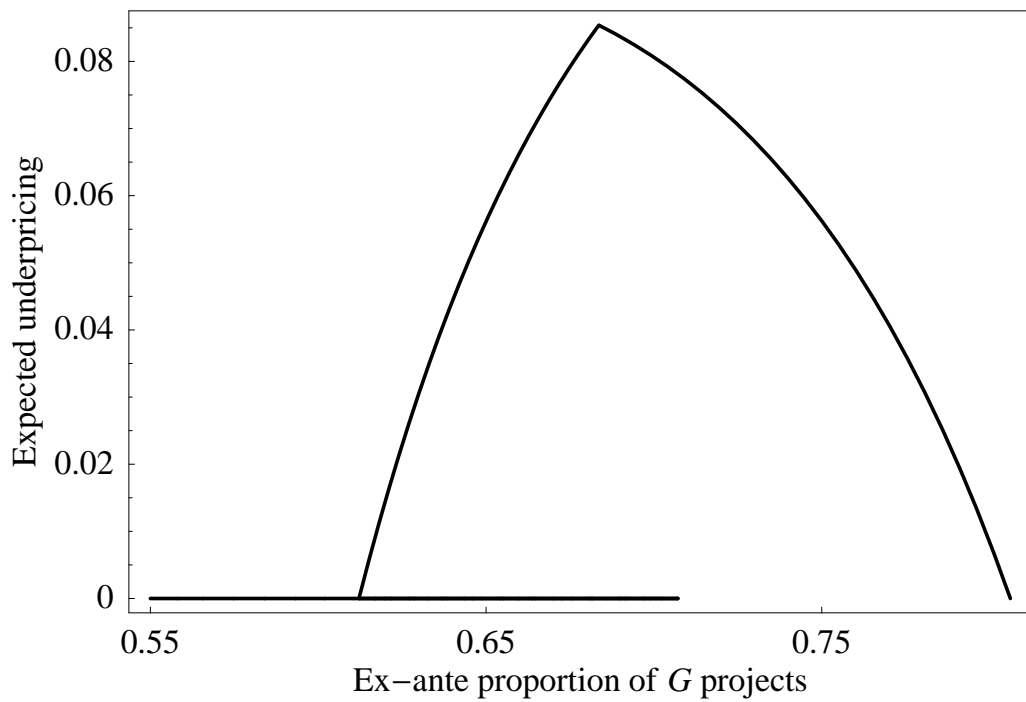


Figure 10: Expected underpricing vs. the ex-ante proportion of G projects, ρ ($\beta = 0.9, \bar{q} = 0.55, w = 0.20, \gamma = 3.2$)

Appendix

Probabilities

As is clear from the text of the paper, we need consider only equilibria where all G projects apply for an IPO and a proportion α of B projects apply. The priors of the underwriter in any such equilibrium are

$$\begin{aligned}\pi &= \frac{\rho}{\rho + (1 - \rho)\alpha}, \\ \text{and } 1 - \pi &= \frac{(1 - \rho)\alpha}{\rho + (1 - \rho)\alpha}.\end{aligned}\tag{A-1}$$

Using the priors and the signal structure, it is easy to derive the following posterior probabilities:

$$\begin{aligned}P(G | H) &= 1, \\ P(B | H) &= 0, \\ P(G | L) &= 0, \\ P(B | L) &= 1, \\ P(G | U) &= \pi, \\ \text{and } P(B | U) &= 1 - \pi.\end{aligned}\tag{A-2}$$

Rationale for Assumptions 1 and 2

For Assumption 1, we need that when all B projects enter the IPO market, if underwriters do not screen at all, then it is better to underprice projects screened as U . Therefore, we require that the price set for U projects under these conditions is the underpricing solution. In other words, we need:

$$\begin{aligned}\frac{1}{2\gamma(1 - \pi)} \Big|_{\pi=\rho} &< \pi|_{\pi=\rho}, \\ \Rightarrow 2\gamma(1 - \rho)\rho &> 1, \text{ which is Assumption 1}\end{aligned}$$

For Assumption 2, we need to ensure that if underwriters do not screen at all, i.e. choose $\eta = 0$, and if there is no underpricing, all B projects will always apply for

screening, i.e., we need that:

$$\begin{aligned} E_B(\eta = 0) &= \beta p_U^*|_{\alpha=1} > w, \\ \Rightarrow \beta \rho &> w, \text{ which is Assumption 2} \end{aligned}$$

Partially effective screening with underpricing

To determine the bounds on \bar{q} for which this equilibrium exists, we use the fact that π^* has to be between ρ and 1. Also, we need that for underpricing to prevail, $\pi < \pi^{\text{up}}$. In other words, we require

$$0 < \pi^* < \pi^{\text{up}} < 1. \quad (\text{A-3})$$

It can be easily verified that, in terms of bounds on \bar{q} , the above can be rewritten as:

$$\begin{aligned} \max \left[0, 1 - \frac{2\gamma w(1-\rho)}{\beta} \right] < \bar{q} < \bar{q}_1^{\text{up}}, \quad (\text{A-4}) \\ \text{where } \bar{q}_1^{\text{up}} \text{ solves } \pi_3^* = \pi^{\text{up}}. \end{aligned}$$

Comparative Statics: Proofs of Propositions 3 and 4

From equation (13) of the text, we have

$$\pi^* = \frac{\rho(2\gamma w - \beta)}{(2\gamma w \rho - \beta \bar{q})}. \quad (\text{A-5})$$

Differentiating with respect to \bar{q} , we have

$$\frac{\partial \pi^*}{\partial \bar{q}} = \frac{\beta \rho (2\gamma w - \beta)}{(2\gamma w \rho - \beta \bar{q})^2}. \quad (\text{A-6})$$

The equilibrium level of underwriter screening is obtained by substituting from equation (13) into (12) as follows:

$$\eta^* = \frac{(2\gamma w - \beta)\bar{q}}{(2\gamma w - \beta)\bar{q} + 2\gamma w(\rho - \bar{q})}. \quad (\text{A-7})$$

Therefore, for η^* to be less than one, we require that $(2\gamma w - \beta)$ be positive, which in turn implies that $\frac{\partial \pi^*}{\partial \bar{q}} > 0$.

Using the expressions for η^* and π^* , we can write expected underpricing in this

equilibrium as

$$\begin{aligned} E_{up} &= (1 - \eta^*) \left[\pi^* - \frac{1}{2\gamma(1 - \pi^*)} \right] \\ &= \frac{2\gamma w \pi^* (1 - \pi^*) - w}{\beta}. \end{aligned} \quad (\text{A-8})$$

By the chain rule of differentiation, we can write

$$\frac{\partial E_{up}}{\partial \bar{q}} = \frac{\partial E_{up}}{\partial \pi^*} \frac{\partial \pi^*}{\partial \bar{q}}. \quad (\text{A-9})$$

From (A-8), we have

$$\begin{aligned} \frac{\partial E_{up}}{\partial \pi^*} &= \frac{2\gamma w(1 - 2\pi^*)}{\beta} \\ &= \frac{2\gamma w[2\beta\rho - \beta\bar{q} - 2\gamma w\rho]}{\beta(2\gamma w\rho - \beta\bar{q})}. \end{aligned} \quad (\text{A-10})$$

The above expression cannot be unambiguously signed in general, while from above we know that $\frac{\partial \pi^*}{\partial \bar{q}} > 0$. In other words, we cannot unambiguously determine the direction of the relationship between expected underpricing and \bar{q} .

However, when the expression $h(\bar{q}) \equiv 2\beta\rho - \beta\bar{q} - 2\gamma w\rho < 0$, we can conclude that expected underpricing decreases in \bar{q} . The expression $h(\bar{q})$ is decreasing in \bar{q} . Hence a sufficient condition for this expression to be negative over all values of \bar{q} relevant for this equilibrium is that it is negative at the lowest feasible value. From above, we know that the minimum \bar{q} required for this equilibrium to exist is

$$\bar{q}_{min} = \max \left[0, 1 - \frac{2\gamma w(1 - \rho)}{\beta} \right] \quad (\text{A-11})$$

Evaluating $h(\bar{q})$ at $\bar{q} = 1 - \frac{2\gamma w(1 - \rho)}{\beta}$, it is easy to see that a sufficient condition for $h(\bar{q})$ to be negative is that $\rho > 0.5$. Evaluating $h(\bar{q})$ at $\bar{q} = 0$, we see that $2\beta\rho - \beta\bar{q} - 2\gamma w\rho < 0$ requires $\gamma > \frac{\beta}{w}$.

It is also easy to verify that the derivative of π^* with respect to ρ is

$$\frac{\partial \pi^*}{\partial \rho} = \frac{\beta\bar{q}(\beta - 2\gamma w)}{(2\gamma w\rho - \beta\bar{q})^2} < 0. \quad (\text{A-12})$$

Once again using the chain rule, we have

$$\frac{\partial E_{up}}{\partial \rho} = \frac{\partial E_{up}}{\partial \pi^*} \frac{\partial \pi^*}{\partial \rho}. \quad (\text{A-13})$$

Once again, this expression cannot be unambiguously signed in general, but when γ is large and $\rho > 0.5$, expected underpricing is increasing in ex-ante project quality.

Partially effective screening with fair pricing

Proof that the smaller solution of (26) never applies

In this equilibrium, π^* is determined as the solution to the quadratic equation in (26):

$$f(\pi) \equiv -\beta \bar{q} \pi^2 + \beta \rho \pi - w \rho = 0. \quad (\text{A-14})$$

By the implicit function theorem, we have

$$\frac{\partial \pi^*}{\partial \bar{q}} = -\frac{\frac{\partial f}{\partial \bar{q}}}{\frac{\partial f}{\partial \pi}}. \quad (\text{A-15})$$

At the lower root, the above quadratic is increasing, which implies that $\frac{\partial f}{\partial \pi} > 0$. Also, $\frac{\partial f}{\partial \bar{q}} = -\beta \pi^2 < 0$. Therefore, we can conclude that $\frac{\partial \pi^*}{\partial \bar{q}} > 0$ at the lower root. Hence, the largest possible value for the lower root is at $\bar{q} = \rho$, which evaluates to

$$\frac{1}{2} - \frac{\sqrt{\beta^2 - 4\beta w}}{2\beta}. \quad (\text{A-16})$$

Thus, we have established that the value of the lower root is always less than 1/2. However, from (3), we have:

$$\pi^{\text{up}} = \frac{1}{2} + \sqrt{\frac{1}{2} \left(\frac{1}{2} - \frac{1}{\gamma} \right)}.$$

Together, these facts imply that fair pricing is never optimal at the lower root of the above quadratic equation. Hence, we consider only the larger root in the analysis of Equilibrium 2.

Bounds on equilibrium

To determine the bounds on \bar{q} for this equilibrium to exist, we note that π^* has to lie between ρ and 1, the feasible bounds on π . Also, we need that IPOs are fairly priced in

this equilibrium. Recall that this means that $\pi^* > \pi^{\text{up}}$. Hence, we can write

$$\rho < \pi^{\text{up}} < \pi_2^* < 1, \quad (\text{A-17})$$

where the first inequality follows directly from assumption 1.

Inspection of equation (27) reveals that π^* is monotonically decreasing in \bar{q} . Therefore, we can rewrite equation (A-17) as bounds on \bar{q} for this equilibrium to exist as:

$$\frac{(\beta - w)\rho}{\beta} < \bar{q} < \bar{q}_2^{\text{up}} < \frac{\beta\rho - w}{\beta\rho}, \quad (\text{A-18})$$

where \bar{q}_2^{up} solves $\pi^* = \pi^{\text{up}}$.

Two further details need attention. First, we require that the solution for π^* be real, which implies:

$$\begin{aligned} \beta^2\rho^2 - 4\beta\rho\bar{q}w &> 0, \\ \Rightarrow \bar{q} &< \frac{\beta\rho}{4w}. \end{aligned} \quad (\text{A-19})$$

However, the bound in (A-19) is always higher than the uppermost bound in (A-18), and is hence not binding. To see this notice that:

$$\begin{aligned} \frac{(\beta\rho - w)}{\beta\rho} &< \frac{\beta\rho}{4w}, \\ \Leftrightarrow (\beta\rho - 2w)^2 &> 0, \text{ which condition is always true.} \end{aligned}$$

Second, we need to ensure that \bar{q} is always less than its maximum possible value, ρ . Therefore, we can finally summarize the bounds on \bar{q} for this equilibrium to exist as:

$$\frac{(\beta - w)\rho}{\beta} < \bar{q} < \min[\rho, \bar{q}_2^{\text{up}}], \quad (\text{A-20})$$

where \bar{q}_2^{up} solves $\pi^* = \pi^{\text{up}}$.

Other equilibria: Proofs of propositions 5 through 8

Screening failure equilibrium

In this equilibrium, since we know that $\pi^* = \rho$, average IPO quality is invariant to changes in labor supply, \bar{q} , and is linearly increasing in the proportion of G projects, ρ .

Since we also know that $\eta^* = \bar{q}$, we can write expected underpricing as

$$E_{up} = (1 - \bar{q}) \left[\rho - \frac{1}{2\gamma(1 - \rho)} \right]. \quad (\text{A-21})$$

Inspection of the above equation reveals that, in this equilibrium, expected underpricing is decreasing in labor supply. Differentiating the above expression with respect to ρ , we have

$$\frac{\partial E_{up}}{\partial \rho} = (1 - \bar{q}) \left[1 - \frac{1}{2\gamma(1 - \rho)^2} \right]. \quad (\text{A-22})$$

As is obvious, this expression cannot be signed in general.

Fully effective screening

In this equilibrium, $\pi^* = 1$, which means average IPO quality is invariant to \bar{q} as well as ρ . Further, there is no underpricing in this equilibrium.

Partially effective screening with fair pricing

From (A-14) above, the average IPO quality, π^* is determined as the larger solution to the equation

$$f(\pi, \bar{q}) \equiv -\beta\bar{q}\pi^2 + \beta\rho\pi - w\rho = 0. \quad (\text{A-23})$$

By the implicit function theorem, we have

$$\frac{\partial \pi^*}{\partial \bar{q}} = -\frac{\frac{\partial f}{\partial \bar{q}}}{\frac{\partial f}{\partial \pi}}. \quad (\text{A-24})$$

At the larger root, the above quadratic is decreasing, which implies that $\frac{\partial f}{\partial \pi} < 0$. Also, $\frac{\partial f}{\partial \bar{q}} = -\beta\pi^2 < 0$. Together, this implies that

$$\frac{\partial \pi^*}{\partial \bar{q}} < 0. \quad (\text{A-25})$$

Viewing the above quadratic as a function of π and ρ , and again applying the implicit function theorem, we have

$$\frac{\partial \pi^*}{\partial \rho} = -\frac{\frac{\partial f}{\partial \rho}}{\frac{\partial f}{\partial \pi}}. \quad (\text{A-26})$$

Also, note that from equation (12), we have

$$\eta^* = 1 - \frac{w}{\beta\pi^*}. \quad (\text{A-27})$$

For η^* to be positive, we need $\frac{\partial f}{\partial \pi} = \beta\pi - w > 0$. Again using the fact that at the larger root of the quadratic, we must have $\frac{\partial f}{\partial \pi} < 0$, we have the result that

$$\frac{\partial \pi^*}{\partial \rho} > 0. \tag{A-28}$$

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