Partial Adjustment to Public Information in the Pricing of IPOs*

Einar Bakke
University of Gothenburg and Centre for Finance

Tore E. Leite
Norwegian School of Economics

Karin S. Thorburn†
Norwegian School of Economics, CEPR and ECGI

January 2016

Abstract

Extant literature shows that IPO first-day returns are correlated with market returns preceding the issue. We propose a new explanation for this puzzling predictability by adding a public signal to Benveniste and Spindt (1989)'s information-based framework. A novel result of our model is that the compensation required by investors to truthfully reveal their information decreases with the public signal. This "incentive effect" receives strong empirical support in a sample of 6,300 IPOs in 1983-2012. The positive relation between initial returns and pre-issue market returns disappears for top-tier underwriters, where the order book is most informative, effectively resolving the predictability puzzle.

Keywords: IPO, underpricing, bookbuilding, public information, private information, partial adjustment

JEL Classification: G24, G32.

*We thank Sebastien Betermier, Espen Eckbo, Sturla Fjesme, Paolo Fulghieri, David Goldreich, Eva Liljeblom, Sebastian Muller, Kjell Nyborg, Ann Sherman, Tommy Stamland, Per Strömberg, Lucy White, Weidong Xu, Per Östberg, seminar participants at Aalto, BI Norwegian School of Business, Cass, K.U. Leuven/Louvain School of Management Joint Finance Workshop, Norwegian School of Economics, UC San Diego, University of Bergen, University of Stavanger, Oslo Business School, and University of Zurich, and participants at the American Finance Association, Australian Banking and Finance, European Finance Association, Northern Finance Association and Utah Winter Finance conferences for valuable comments. Bakke is grateful for financial support by Browaldh Stiftelsen and the Norwegian Research Council (Leiv Ericsson). This paper was written while he visited UC San Diego and BI Norwegian Business School.

†Corresponding author: karin.thorburn@nhh.no.

1 Introduction

Shares in initial public offerings (IPOs) are typically sold at a fixed price, which is set after marketing the issue to investors and recording their demand.[1] Despite the prior interaction with investors, the offer price typically generates a sizeable first-day return—the standard measure of underpricing. Over the period 1980-2014, the first-day return in U.S. IPOs averaged 18%, leaving substantial profits for investors participating in the offering.[2]

There is a number of alternative explanations for the underpricing in IPOs, ranging from asymmetric information to investor sentiment and conflicts of interests within integrated investment banks.[3] Benveniste and Spindt (1989) provide an information-based explanation for the underpricing. In their model, investors receive underpriced shares in return for truthfully revealing their demand during the book building preceding the offering, allowing the underwriter to set a price that maximizes the issuer's proceeds. Their argument receives strong empirical support beginning with Hanley (1993). She shows that the initial return is increasing in the revision of the offer price from the mid-point of the pricing range indicated in the prospectus, as if investors' information is not fully priced—an empirical regularity known as the "partial adjustment" phenomenon.

While it may be rational to compensate investors for *private* information that helps increase the precision of the offer price, there is substantial evidence that *public* information also affects IPO underpricing. As shown by Loughran and Ritter (2002) and Lowry and Schwert (2004), the higher the market return leading up to the offering, the greater is the underpricing.[4] This predictability of initial returns is puzzling since the public information is freely available to the underwriter and should be fully incorporated into the offer price. The extant literature has attacked this puzzle by assuming irrational behavior (Loughran and Ritter, 2002; Derrien, 2005) or an exogenous correlation between the state of the economy and the expected value of the issuer's shares to the investor (Edelen and Kadlec, 2005; Sherman, 2005; Leite, 2007).

Our contribution is twofold. First, we endogenously derive the correlation between the public signal and the IPO underpricing in a model that preserves the information-based intuition of the

[1] The auction method, most spectacularly used by Google in 2004, is an exception (Derrien and Womack, 2003; Lowry, Officer, and Schwert, 2010).

[2] Source: Jay Ritter at http://bear.warrington.ufl.edu/ritter/ipodata.htm

[3] See, e.g., Ljungqvist (2007) for a comprehensive survey of the empirical IPO underpricing literature.

[4] See also Logue (1973), Bradley and Jordan (2002), Benveniste, Ljungqvist, Wilhelm, and Yu (2003), Ince (2014) and Kutsuna, Smith, and Smith (2009).

Benveniste and Spindt (1989) framework. The key assumption is that the public and private signals are informative about the issuing firm's value, which in a rational Bayesian equilibrium generates a conditional correlation between the signals. Second, we perform large-sample tests of the model and find strong empirical support for its predictions.

In our model, the public information affects the equilibrium underpricing through two channels: investor demand for allocations and investor incentives to truthfully reveal their private information. We refer to the first channel as the *demand effect* of the public signal. Intuitively, since the public and private signals are conditionally correlated, the public information affects the distribution of investors' private signals and thus their demand for share allocations. Specifically, a positive (negative) public signal is associated with a higher (lower) likelihood of sufficient investor demand to generate underpricing.

The second channel through which the public signal affects underpricing is what we label the *incentive effect*: the conditional initial return necessary to induce investors to truthfully reveal their private signal. This channel is new to the literature and unique to our model. As in Benveniste and Spindt (1989), investors may misrepresent their information in an attempt to lower the offer price. However, the underwriter optimally allocates shares to investors reporting positive information and strategic false reporting may cut the investor's allocation. The likelihood that an untruthful investor receives shares in the issue depends on the public signal: it is lower (higher) for a positive (negative) signal, reducing (increasing) the incentives to report falsely. The public signal also affects the expected aftermarket value of the firm, where a positive (negative) signal reduces (increases) the marginal informational value of the private signal. Thus, to induce investors to truthfully reveal their signals, the underwriter must, *ceteris paribus*, underprice the issue less (more) when the public signal is positive (negative).

Through the demand effect and the incentive effect, the public signal has both a positive and a negative effect on the expected underpricing. The ultimate impact of the public signal depends on the relative magnitude of the two channels. In our setting, the informational value of each private signal is declining in the number of investors participating in the offering. Thus, when the number of investors is sufficiently large, the demand effect dominates the incentive effect and the expected underpricing is positively related to the public information, consistent with extant evidence.

We test our model in a sample of 6,300 U.S. IPOs in the period 1983 to 2012. To correct for any potential truncation of the initial returns caused by withdrawn offerings, we follow Edelen and Kadlec (2005) and use a two-step Heckman (1979) procedure. A unique and central implication of the model is that investors require higher conditional initial returns to truthfully report their private information in falling markets than in rising markets. We test this by regressing the initial IPO return on an interaction term between the private information and a dummy variable indicating that the return on the S&P500 index leading up to the issue is positive. To capture investor private information, we use the revision in the final offer price from the initial pricing range mid-point, orthogonalized to the S&P500 index to purge any effect of the market return on the offer price revision.

Cross-sectional regressions produce a negative and highly significant coefficient for the key interaction term. That is, the initial return associated with an offer price revision is lower when the market return is positive than when it is negative, as predicted by the model. This finding is new to the empirical literature and consistent with the incentive effect. The result are robust to the inclusion of standard control variables and the correction for self-selection, which in itself lacks statistical significance.

Like Benveniste and Spindt (1989), our model holds that investor bids are informative. Following Wang and Yung (2011), who show that the partial adjustment phenomenon is concentrated to top-tier underwriters, we split the sample according to underwriter rank. Importantly, the interaction term for the incentive effect is highly significant only in the subsample of top-tier underwriters, where the order book is held to be most informative.[5] Moreover, after controlling for the incentive effect, the correlation between the first-day return and the pre-issue market return disappears, hence resolving the puzzling predictability of initial returns.

For completeness, we also show that the implications of the demand effect hold in the data. As expected, the likelihood that the initial return is positive increases with the stock market return during the book building. The rest of the paper is organized as follows. Section 2 sets up the model. The relation between public information and the expected underpricing is discussed in Section 3. In Section 4, we describe the sample and report the results from our empirical tests. Section 5 concludes. All proofs are found in Appendix A.

[5]See, e.g., Ljungqvist (2007) and Jenkinson and Jones (2004).

2 The model

We start with a firm that is about to offer its shares to outside investors through an IPO. The true value of the firm is high G with probability α and low B with probability $1-\alpha$, where $G > B$. To simplify the exposition, and with no loss of insight, we let $G = 1$ and $B = 0$. We also normalize the number of shares to be floated to one and let investors be allocated fractions of this share. All agents are risk neutral and the risk-free interest rate is zero.

There are $N \geq 2$ investors participating in the offering. Each investor $i = 1, \ldots, N$ observes at a zero cost a private signal $s_i = \{g_i, b_i\}$, where g_i represents positive and b_i negative information about the firm. We may think of these investors as the underwriter's regular pool of investors and the signal s_i as their unique knowledge about the firm as well as information about their own demand and liquidity.[6] Let $n \in [0, N]$ denote the number of investors who observe positive private signals. The precision in the private signal s_i is the same across all investors and equals $\gamma = q(g_i|G) = q(b_i|B)$, where $q(\cdot|\cdot)$ and $q(\cdot)$ denote conditional and unconditional probabilities throughout. We let $\gamma > 1/2$ to make the signal informative about the true value of the firm, so that $q(G|g_i) > q(G) > q(G|b_i)$.

Moreover, all investors observe a common public signal $s = \{g, b\}$, where g represents positive and b negative information. The precision in the public signal is given by $\mu = q(g|G) = q(b|B)$, where $\mu > 1/2$ and so it is informative. We can think of the public signal as market-wide information, such as changes in aggregate demand or the business cycle, which affects the value of the firm. In the empirical analysis below, we use the stock market return during the book-building process as a proxy for the public signal.

We further assume that the signals, or more precisely the error terms, are uncorrelated conditional on the true value of the firm, so that $q(g_i, g|G) = q(g_i|G)q(g|G)$ and $q(g_i, g|B) = q(g_i|B)q(g|B)$.[7] By Bayes' rule, these assumptions yield the following result:

[6] Alternatively, one could assume that investors' private signals are costly and that the underwriter is able to distinguish informed from uninformed investors, and will allow only informed investors to participate in the book-building process. If now the underwriter is unable to commit to compensate investors for their informational costs, then the number N of investors in the offering will be determined endogenously from their incentive constraint and the pricing of the issue will be the same as under our zero-cost assumption.

[7] Using the normal distribution as a reference point, our informational assumptions are akin to having the true value of the firm V be normally distributed with some mean $\bar{V}$ and variance σ_V^2 and letting each investor i observe a signal $s_i = V + \epsilon_i$, where ϵ_i has a zero mean, $cov(\epsilon_i, \epsilon_j) = 0$ for $i \neq j$, and $cov(s_i, s_j) = \sigma_V^2 > 0$. Similarly, for a public signal $s = V + \epsilon_p$, it will be the case that $cov(\epsilon_i, \epsilon_p) = 0$, and $cov(s_i, s) = \sigma_V^2$.

Lemma 1 *The probability that an investor's private signal s_i is positive (negative) is higher if the public signal s is positive (negative) than if it is negative (positive); in other words, $q(g_i|g) > q(g_i|b)$ and $q(b_i|b) > q(b_i|g)$.*

Lemma 1 implies that the distribution of investors' private signals will depend on the realization of the public signal. The positive conditional correlation follows directly from the assumption that the signals are informative about the true value of the firm.[8]

Let $v(n, s)$ denote the market value of the firm after it is publicly listed. The aftermarket value is assumed to fully reflect all available information at the time of the offering. That is, $v(n, s)$ is the expected value of the firm conditional on the n positive private signals observed by investors and the public signal s, and hence $\partial v/\partial n > 0$. Because the aftermarket value of the firm increases with the number of positive private signals, n is also a measure of the demand for shares in the issue, and where a higher n corresponds to higher demand. We refer to the case where $n = N$ and all investors observe positive private signals as the high-demand state. The other extreme case, where $n = 0$ and all investors observe negative private signals, is labelled the low-demand state.

With $v(n, s)$ as a conditional expectation, the marginal impact of each investor's private signal on the firm's aftermarket value is decreasing in the number N of investors in the offering. This way of modeling the impact of the private signals is consistent with standard micro-structure models, where investors' private information is reflected in the stock price through the trading process.[9] However, it contrasts with the Benveniste and Spindt (1989) setup, where the firm's aftermarket value is additive in investors' private signals so that each private signal "has an equal (absolute) marginal impact on the stock's value" (p. 347) irrespective of N.

The book-building process is run by an underwriter, whose services are free of charge. The underwriter declares a pricing and allocation rule that maximizes the proceeds to the issuer. After observing the public and private signals, investors report their signal by placing a "high" or "low" bid. In equilibrium, all investors truthfully report their signals. Thus, when the underwriter sets the offer price at the end of the book-building process, he correctly anticipates the firm's value $v(n, s)$ in the aftermarket.

[8]That is, $q(g_i|G) > 1/2$, $q(g|G) > 1/2$, $q(b_i|B) > 1/2$, and $q(b|B) > 1/2$.

[9]See, e.g., Kyle (1985). In Chen and Wilhelm (2008) a similar effect in the IPO aftermarket leads early stage investors to bid aggressively since they expect their information to become less important as additional informed investors enter the market.

Let $p(n, s)$ denote the offer price if n investors report a positive private signal and given the public signal s. Moreover, let $z(g_i, n)$ and $z(b_i, n)$ denote the fraction of the issue allocated to an investor who submits a high and a low bid, respectively. Since all private signals have the same precision, investors with identical bids receive equal allocations.

We follow Benveniste and Spindt (1989) and assume that the issuer is committed to price the firm at or below its aftermarket value, so that $p(n, s) \leq v(n, s)$. Unlike them, however, we place no restrictions on the number of shares that can be allocated to one investor.[10] As shown in Proposition 1 below, it is optimal to allocate the whole issue to investors submitting high bids as long as there is at least one high bid. As a consequence, an investor placing a low bid will receive an allocation if and only if the remaining $N - 1$ investors also bid low.[11]

Let us next consider investors' incentives to truthfully reveal their private signals. Trivially, an investor with negative information has little upside from reporting falsely. By placing a high bid, she risks being awarded shares at a price exceeding the aftermarket value implied by her private signal. Thus, she is better off truthfully bidding low and possibly—if all bids are low—receive shares at a price correctly reflecting her signal.

Instead, we need to worry about the incentives of investors with positive private signals. These investors may benefit from falsely reporting a negative signal in order to lower the issue price. The potential cost of such a strategy is, however, that at least one other investor may place a high bid, leaving the untruthful investor without any shares in the issuing firm.

For an investor i with a positive private signal, the expected payoff from bidding high is

$$U(s) = \sum_{n=1}^{N} q(n|s) z(g_i, n)[v(n, s) - p(n, s)], \tag{1}$$

where $q(n|s)$ is the probability that n investors receive positive private signals conditional on the public signal s and $v(n, s) - p(n, s)$ is the underpricing of the offering. With an allocation of $z(g_i, n)$, the expected payoff to investor i is her fraction of the underpricing, probability-weighted across different n.

[10] In Appendix B, we derive a more general model with allocation restrictions, which generates the same predictions.

[11] As Benveniste and Spindt (1989), we assume that the IPO is completed in the low-demand state. We do, however, adjust for the effect of withdrawn issues in the empirical analysis below.

The expected payoff to the same investor from falsely placing a low bid is

$$\hat{U}(s) = \sum_{n=1}^{N} q(n|s) z(b_i, n)[v(n,s) - p(n-1,s)]. \tag{2}$$

For a given n and s, the offer price is now lower, $p(n-1,s) < p(n,s)$, as is the probability of receiving an allocation in the IPO, $z(b_i,n) < z(g_i,n)$. By falsely placing a low bid, the investor earns a higher initial return conditional on an allocation, but at the same time risks ending up without any shares in the issuing firm.

The payoff $\hat{U}(s)$ is the minimum rent for an investor with a positive private signal and hence represents this investor's reservation value. To induce the investor to truthfully report her signal, the expected payoff $U(s)$ from bidding high must equal or exceed the expected profits $\hat{U}(s)$ from falsely bidding low. The issue must thus be priced and allocated to satisfy the truth-telling (incentive) constraint $U(s) \geq \hat{U}(s)$.

The expected proceeds $E\Pi$ from the IPO are given by

$$E\Pi = \sum_{n=0}^{N} q(n|s) p(n,s). \tag{3}$$

Formally, the objective of the underwriter is to maximize $E\Pi$ with respect to allocations $z(s_i,n)$ and prices $p(n,s)$ subject to the incentive constraint $U(s) \geq \hat{U}(s)$ and the pricing constraint $p(n,s) \leq v(n,s)$. Since issuance costs are exclusively determined by investors' informational rents $\hat{U}$, maximizing $E\Pi$ is equivalent to minimizing $\hat{U}$. The underwriter will further price and allocate the issue such that investors' truth-telling constraint is satisfied as an equality, $U(s) = \hat{U}(s)$.

Proposition 1 *The issuer maximizes expected proceeds $E\Pi$ by pricing the issue so that*

$$p(N,s) = v(N,s) - \frac{q(1|s)}{q(N|s)}[v(1,s) - v(0,s)], \tag{4}$$

and

$$p(n,s) = v(n,s) \text{ for } n = 0, \ldots, N-1 \tag{5}$$

while allocating it according to

$$z(b_i) = 0 \text{ and } z(g_i) = \frac{1}{n} \text{ for } n = 1, \ldots, N \tag{6}$$

and

$$z(b_i, n) = \frac{1}{N} \text{ for } n = 0. \tag{7}$$

Proposition 1 shows that the issue is underpriced in the high-demand state, where all N investors obtain positive private signals and, in equilibrium, truthfully submit high bids. Since the aftermarket value $v(n, s)$ is increasing in n, it follows that $v(1, s) > v(0, s)$ and $p(N, s) < v(N, s)$, so the issue is underpriced (Eq. (4)). In contrast, there is no underpricing when $n < N$ and investor demand is low (Eq. (5)). Moreover, the issue is optimally allocated by awarding $1/n$ shares to each of the n investors placing high bids (Eq. (6)), with the exception of the low-demand state, where all N investors bid low and each receive a fraction $1/N$ of the issue (Eq. (7)).

The underwriter underprices the issue in the high-demand state by partially adjusting the offer price to the private information uncovered during the book building, hence leaving a profit for the investors that are awarded shares. As the firm starts trading at its aftermarket price, the initial return is given by

$$r(N, s) = \frac{v(N, s)}{p(N, s)} - 1. \tag{8}$$

Since the probability of the high-demand state is $q(N|s)$, the expected initial return is

$$Er(s) = q(N|s)r(N, s). \tag{9}$$

The analysis so far has established that IPOs are expected to be underpriced in order to induce investors to truthfully report their private information, similar to Benveniste and Spindt (1989). In the next section, we go beyond this standard argument and examine the relation between the public information and underpricing.

3 Public information and underpricing

As shown in Eq. (9), the expected initial return $Er(s)$ is the product of the conditional initial return and the probability that the issue is underpriced. A key contribution of this paper is the insight that the public signal affects the expected initial return through both $r(N, s)$ and $q(N|s)$, as discussed next.

Proposition 2 (The incentive effect) *The initial return in the high-demand state is negatively related to the public signal s, so that $r(N, g) < r(N, b)$.*

Proposition 2 shows that the conditional initial return is negatively related to the public signal. To understand this result, which we label the incentive effect, note that the public signal affects investors' incentives in three ways. First, because the private and public signals are conditionally correlated, it follows that $q(1|g) < q(1|b)$. That is, the probability that an investor receives underpriced shares after falsely submitting a low bid is lower for a positive public signal, reducing the expected payoff from false reporting.

Second, the marginal impact of a positive private signal on the firm's aftermarket value is negatively related to the public signal, $\partial v(n, g)/\partial n < \partial v(n, b)/\partial n$. The payoff to an investor receiving underpriced IPO shares after reporting falsely is therefore lower for a positive public signal, reducing the investor's incentives to falsely place a low bid.

Third, the conditional correlation implies that $q(N, g) > q(N, b)$ and the likelihood that an investor receives underpriced shares after truthfully bidding high, $q(N, s)/N$, is higher for a positive public signal. Thus, the expected payoff from truthful reporting is higher for a positive public signal, and the underwriter can increase the IPO price without jeopardizing investors' incentives to bid high.

The incentive effect holds that the public signal has a negative impact on the expected initial return through investors' incentives to truthfully reveal their information. However, as shown in Eq. (9), the expected initial return is also affected by the public signal through the probability $q(N|s)$ that there is sufficient demand for the issue to be underpriced.

Proposition 3 (The demand effect) *The probability of the high-demand state, where the IPO is underpriced, is positively related to the public signal, i.e., $q(N|g) > q(N|b)$.*

As stated in Proposition 3, the likelihood of the high-demand state, where the issue is underpriced, is higher for a positive public signal. This channel, which we label the demand effect, follows trivially from the conditional correlation between the private and public signals.

Through the two channels in our model, the public information have both a positive and a negative impact on the expected underpricing. We next show that the demand effect will dominate as long as a large number of investors participate in the IPO.

Proposition 4 *When the number N of investors in the issue is sufficiently large, the demand effect strictly dominates the incentive effect and the expected initial return is positively related to the public signal.*

The intuition of Proposition 4 relies on the declining impact of an investor's private signal on the firm's aftermarket value as the number of investors in the issue increases. Specifically, as N increases, the investor's potential payoff from falsely bidding low, $v(1, s) - v(0, s)$, drops. This decline in informational rents reduces the amount of underpricing required to induce truthful revelation. Thus, an increase in N decreases the relative importance of the incentive effect. Once the number of investors in the issue is sufficiently large, the demand effect strictly dominates and the public signal is positively related to the expected underpricing, consistent with extant evidence.

In sum, our model provides a rational explanation for the empirical observation that the initial return in IPOs increases with the market return during the book-building process. We derive this prediction in a Bayesian equilibrium from the assumption that the private and public signals are informative about the underlying value of the issuing firm.

The model identifies two channels through which public information affects the expected IPO underpricing. The first channel is through investors' incentives to report truthfully, which influence the conditional initial return (the incentive effect). The second channel is through the likelihood that the issue is in high demand and the underwriter optimally underprices the issue (the demand effect). When the number of investors in the issue is large, the demand effect dominates the incentive effect and the expected initial return is positively related to the public signal.

4 Empirical tests of the model

In our model, the public signal has both a positive and a negative effect on the expected underpricing. Prior studies, which show that the initial return increases with the pre-issue market return, document the combined effect of the two channels. In this paper, we design an empirical testing strategy that allows us to examine each channel separately.

The incentive effect holds that the public signal affects the expected underpricing through investors' incentives to report truthfully. It the context of the literature, it implies that the underpricing associated with a given offer price revision is greater in falling markets than in rising markets. This empirical prediction is new to the literature and unique to our model. The demand effect, on the other hand, channels the impact of the public signal through the probability that the issue is underpriced. It implies that the likelihood of the underwriter underpricing the IPO increases with the pre-issue market return.

In the cross-sectional analysis below, we first establish that the positive relation between the initial return and the pre-issue market return found in other studies holds for our sample. We then test each of the two channels in our model and show that the predictability of the initial return to the market return disappears for top-tier underwriters once we control for the incentive effect. Before presenting the cross-sectional analysis, however, we'll first introduce the sample, provide a brief univariate analysis, and analyze the probability of completing the IPO.

4.1 Sample selection, description and key variables

We start by selecting all 13,462 U.S. IPOs in the period 1970 to 2012 from the Global New Issues database in Thompson Financial's SDC. To identify book-built IPOs, we restrict the sample to the 8,825 cases with a spread between the high and low filing price. SDC does not report a filing range prior to 1981, so this restriction effectively eliminates all offerings in the 1970s.

We require the IPO firms to have a filing midpoint of at least \$5 per share, be matched with CRSP and be listed on NYSE, AMEX or Nasdaq. All unit offerings, real estate investment trusts, financial institutions, American Depository Receipts, and closed-end funds are eliminated. We further restrict the sample to firms with a founding year in the Field-Ritter founding data set and a lead underwriter rank in the Ritter underwriter ranking data set, and require the completed

IPOs to trade by the 42nd trading day after the public listing.[12] These selection criteria produce a final sample of 6,301 IPOs filed between 1983 and 2012, of which 5,369 are completed and 932 are withdrawn.

Table 1 reports the number of cases, initial returns and pre-issue market returns by year. The initial return is defined as $IR1 = p_1/p_0 - 1$, where p_1 is the firm's closing price on the first day of trading and p_0 is the final offer price, winsorized at 200%. In the empirical analysis below, we use $IR1$ as a proxy for the underpricing in the IPO.[13] The market return ($Public$) is the return on the S&P500 index over the 42 trading days preceding the IPO issue date. We select this window to match the typical registration period in our sample. As shown in column (1), a majority of the sample firms (58%) file to go public in the 1990s, while 25% file in the 2000s and 17% file in the 1980s.

The next four columns of Table 1 present statistics for the 5,369 completed IPOs. As reported in column (3), the average initial return is 19.7%, with a peak of 67% and 53% in 1999 and 2000, respectively. Moreover, the average market return preceding the issue is 2.5% (column (4)) and it is positive for 72% of the IPOs (column (5)). Notice that even in the hot issue year of 1999, one-quarter of the completed IPOs were preceded by negative market returns. The last four columns of Table 1 present statistics for the 932 withdrawn IPOs. As shown in column (7), 15% of the IPOs in our sample are withdrawn. Not surprisingly, the withdrawn IPOs are preceded by a lower market return of on average 0.9% (column (8)). Yet, the pre-issue market return is positive for as many as 60% of the withdrawn IPOs (column (9)).

A test of our model requires a measure for the private information uncovered by the underwriter through the book-building process. We follow Hanley (1993) and rely on the revision in the final offer price: $Revision = p_0/p_{mid} - 1$, where p_{mid} is the midpoint of the initial filing range in the prospectus. Some of the price revision may, however, follow from market-wide information reaching the underwriter during the registration period. We therefore purge any effect of the stock market return from the offer price revision. Specifically, $Private$ is the residual ϵ from the regression $Revision = \alpha + \beta * Public + \epsilon$. Thus, we consider all information in the price revision beyond that

[12]The founding year and lead underwriter rank is from Jay Ritter's web page at the University of Florida.

[13]In unreported regressions, where we use the first-month return as a proxy for the underpricing, the inferences are qualitatively unchanged.

attributable to the stock market to be private.[14]

Price revisions are, however, discrete and done in tick size increments. Thus, even if there is no private information in the update and *Revision* is correctly adjusted for the market return, it is unlikely that ϵ equals exactly zero. With an average mid-range price in our sample of \$14, a tick size roughly corresponds to 1%.[15] We therefore set *Private* to zero for 243 cases where $|\epsilon| < 1\%$ of the mid-range price.

Wang and Yung (2011) find evidence of more frequent filing of price revisions by reputable investment banks and conclude that the partial adjustment phenomenon is attributable to the top-tier underwriters. As discussed in Ljungqvist (2007), this is consistent with the difference in results found by Cornelli and Goldreich (2003) and Jenkinson and Jones (2004). The former examine the order book of a top-tier underwriter and show that more informative bids—limit-order bids, bids received early, and revised bids—receive greater allocations. Jenkinson and Jones (2004), however, find no such evidence for the order book of a lower-tier underwriter and suggest that there are important differences in the informativeness of the order book between top-tier and lower-tier underwriters.

Since our framework requires informative investor bids, we follow Carter and Manaster (1990) and split our sample into IPOs where the highest-ranked lead underwriter is a top-tier underwriter (rank=9) versus a lower-tier underwriter (rank<9). Half of the completed IPOs in our sample are sold by top-tier underwriters, while the other half use lower-tier underwriters. Given systematic differences in the informativeness of the order book, the incentive effect should be strongest for the subsample of IPOs sold by top-tier underwriters.

The offer price revisions in our data are consistent with top-tier underwriters receiving informative bids and lower-tier underwriters failing to do so. First, the average price revision is positive for top-tier underwriters and negative for lower-tier underwriters, suggesting that top-tier underwriters receive more valuable information through the book building process. Second, when conditioning on a positive price revision, the offer price adjustment is substantially larger for the top-tier underwriters, consistent with a greater informational content. Third, the fraction of issues priced above (below) the initial filing range is significantly higher for top-tier (lower-tier) underwriters, as if their

[14]Although the price revision has been shown to vary with certain offer characteristics, these are known when the initial filing range is set and do not represent new information in our setting.

[15]Stocks trade on NYSE, AMEX and NASDAQ in price increments of \$1/8 or \$1/16 for most of our sample period.

book building generates more (less) valuable information.

4.2 Univariate analysis

We first examine the relation between the first-day return and the pre-issue market return in the univariate. Table 2 shows the average initial return ($IR1$) for the 5,369 completed IPOs, split by falling ($Public_{NEG}$) and rising ($Public_{POS}$) stock markets, where the subscripts NEG and POS indicate that the variable $Public$ is ≤ 0 and > 0, respectively.

In our model, the underwriter underprices the offering only in the high-demand state, i.e., when a large number of investors receive a positive private signal. To capture investor demand, the table further separates the issues into positive ($Private_{POS}$) and negative ($Private_{NEG}$) offer price revisions, adjusted for any influence of the market return as explained above. The first three columns present the full sample of completed IPOs, while columns (4)-(6) and (7)-(9) show the two subsamples of top-tier and lower-tier underwriters, respectively. Variable definitions and data sources are listed in Table 3.

Panel A addresses the incentive effect. Starting with the full sample, the average initial return is substantially higher when investor demand is high rather than low. For example, in column (1), $IR1$ is 41% for $Private_{POS}$ and only 4% for $Private_{NEG}$, consistent with underwriters rewarding investors for their private information. Moreover, comparing columns (1) and (3), the average initial return is lower in falling markets than in rising markets (18% vs. 20%, with $p<0.05$ for the difference). This positive correlation between initial returns and market returns is the predictability puzzle that our model sets out to explain.

The incentive effect, however, implies a negative relation between the conditional initial return and market return for issues in high demand. As shown in Panel A, the difference in mean initial return has the opposite sign for $Private_{POS}$, where average $IR1$ is significantly *higher* in falling than rising markets (41% vs. 35%, $p<0.05$), consistent with the incentive effect.

Panel B of Table 2 deals with the demand effect, which predicts that the likelihood that an issue is underpriced increases with the market return. As reported in table, the fraction of IPOs with positive initial return ($IR1 > 0$) is significantly lower in falling stock markets irrespective of investor demand. For example, 76% of all IPOs are underpriced in falling markets vs. 81% in rising markets, with $p<0.001$ for the difference, as implied by the demand effect.

We next turn to the subsamples based on underwriter quality. As shown in Panel A, the initial return is positively associated with underwriter rank. For example, when the market return is positive, the first-day return averages 25% for IPOs sold by top-tier underwriters (column (6)) and 16% for lower-tier underwriters (column (9)).

Focusing on the top-tier underwriters (columns (4) to (6)), the difference in average initial return across falling and rising markets is a significant -11% ($p<0.01$) for issues in high demand, consistent with the incentive effect. Panel B further shows that the fraction of IPOs with positive initial return is statistically undistinguishable across falling and rising market for these issues, as if the demand effect is weak. Combined, these two observations suggest that the conditional initial return—the incentive channel—drives the difference in average $IR1$ for high-demand issues sold by top-tier underwriters. This is consistent with our conjecture that the incentive effect should be stronger when the order book is relatively informative.

For lower-tier underwriters, however, our model predicts the incentive effect to be weak and the demand effect to dominate. The evidence in columns (7) to (9) of Table 2 supports this conjecture. First, for issues in high demand sold by lower-tier underwriters, the average initial return in Panel A is significantly *lower* in falling markets (22% vs. 27% in rising markets, $p<0.05$), as if the incentive effect is weak. Second, from Panel B, the probability that these IPOs have a positive initial return is also significantly lower in falling than rising markets (88% vs. 93%, $p<0.05$), as implied by the demand effect. Thus, for issues in high demand sold by lower-tier underwriters, it appears that the likelihood that the issue is underpriced—the demand channel—drives the initial return difference across market conditions.

Finally, Panel C of Table 2 shows the number of observations across the different subsamples and illustrates the conditional correlation between the private and public signals in our model. For the full sample, the fraction of IPOs with high demand ($Private_{POS}$) is significantly higher in rising than falling markets (49% vs. 39%). Conversely, the fraction of IPOs with low demand ($Private_{NEG}$) is significantly lower in rising markets (51% vs. 61% for $Public_{NEG}$). This pattern, which supports Lemma 1, holds across all underwriter types.

Overall, the univariate statistics in Table 2 are consistent with the empirical implications of our model. First, while the average initial return and the market return are positively associated in the sample at large, they are negatively related in the subsample where the incentive effect is expected to be strong (issues in high demand sold by top-tier underwriters). Second, the fraction of IPOs with a positive initial return is lower when the stock market is falling, as implied by the demand effect. Third, the likelihood that the final offer price is adjusted upwards—tantamount to high investor demand—is higher when markets are rising, consistent with a conditional correlation between the private and public signals.

4.3 Withdrawal of the IPO

To empirically test our model, we regress the initial return on the pre-issue market return in various specifications capturing the implications of the incentive and demand effects. Note first that issuers may choose to withdraw the IPO when the market return is low (Busaba, Benveniste, and Guo, 2001; Benveniste, Ljungqvist, Wilhelm, and Yu, 2003). The decision to withdraw the IPO leads to a truncation of the sample of initial returns and the coefficients from an ordinary least squares (OLS) regression may be biased. To correct for this truncation in the observed underpricing, we follow Edelen and Kadlec (2005) and use a two-step Heckman (1979) procedure.

This subsection describes the first step of the Heckman prodedure, in which the probability of completion (versus withdrawal) is estimated. Table 4 reports the coefficient estimates from probit regressions, where column (1) uses the full sample of 6,301 IPOs and columns (2) and (3) present the results for the two subsamples defined by underwriter rank.

The explanatory variables are issue and market characteristics that previously have been shown to affect the withdrawal decision. The first two variables are the pre-issue stock-market return in rising and falling markets: $Public*Public_{POS}$ and $Public*Public_{NEG}$, respectively. Moreover, *Underwriter Count* is the number of underwriters in the offering, *Amount Filed* is log of the dollar value of the issue, and *Underwriter Rank* is the Carter and Manaster (1990) rank of the top underwriter.

The next three variables describe the current state of the IPO markets, measured across all IPOs over the 42 trading days preceding the issue: *Spillover Revision* is the average offer price revision (*Revision*) ortogonalized to *Public*; *Spillover IR1* is the average initial return ($IR1$) ortogonalized to *Public* and *Spillover Revision*; and *Spillover Withdrawn* is the number of withdrawn IPOs during the same period.[16] All variables are defined in Table 3.

[16] We use the residuals from the regressions $Revision = \alpha + \beta * Public + \epsilon$ and $IR1 = \alpha + \beta_1 * Public + \beta_2 *$

Starting with column (1), the regression results are consistent with prior studies. The likelihood that the offering is successful decreases with issue size and increases with the number and rank of underwriters marketing the IPO. The probability of completing the issue also depends on the current state of the IPO markets, where the number of withdrawn IPOs and the first-day return of recent IPOs both have a negative effect on the completion rate. Controlling for the performance of recent IPOs, the completion likelihood is further decreasing in the pre-issue stock market return, *Public*, and it is more sensitive to the market return in falling than rising markets.

Turning to columns (2) and (3), most of the inferences hold across underwriters of different quality. The exception is the coefficient for $Public*Public_{POS}$, which is negative and significant for lower-tier underwriters only. That is, for top-tier underwriters, the completion likelihood is independent of the pre-issue market return when stock markets are rising.

We use the probit estimates from these first stage regressions to compute the Inverse Mill's ratio for each observation. The inclusion of the Inverse Mill's ratio in the second-step regressions helps correct for the self-selection in the truncated sample of initial returns.

4.4 Verifying Partial Adjustment to Public Information

Before examining the implications of our model, we first verify that the positive relation between the initial return and the pre-issue market return found by others also hold in the cross-section for our sample. Table 5 reports the coefficient estimates from OLS regressions for the initial return, $IR1$. The explanatory variables in column (1) are the two main variables of interest, *Public* and *Private*, as well as the Inverse Mill's ratio from Table 4.

Column (2) adds firm and issue characteristics such as firm age (*Age*), *Underwriter Rank*, *Amount Filed*, the percent of the offered shares newly issued by the firm (*Primary*), and dummy variables indicating that the firm is in the high-tech industry (*High Tech*), backed by a venture capital firm (VC) and listed on Nasdaq (*Nasdaq*). Column (3) further includes *Spillover* $IR1$ and *Spillover Revision*, both capturing the current state of the IPO markets. Finally, columns (4) and (5) split the sample by underwriter rank. All variables are defined in Table 3. Standard errors are clustered by Fama-French 49 industry.

As shown in Table 5, the coefficients for *Private* and *Public* are positive and statistically

Spillover Revision $+ \epsilon$.

significant (p<0.001) in all regression models. The former is consistent with underwriters leaving money on the table for investors submitting informed bids, as in Benveniste and Spindt (1989)'s information-based equilibrium. The latter is the puzzle of partial adjustment to public information that our model sets out to explain.

Note that the Inverse Mill's ratio is insignificant in columns (2)-(4), when the control variables are included. This suggests that the truncation caused by withdrawals does not bias the coefficient estimates in the regular OLS.[17] Moreover, several of the control variables are significant. The initial return is increasing in the average initial return and price revision of recent IPOs. Also, for the subsample of IPOs sold by top-ranked underwriters, the initial return decreases in firm age and tends to be higher for issuers backed by a venture capitalist.

4.5 Tests of the incentive effect

Having established the positive relation between underpricing and pre-issue market return in our sample, we next turn to tests of the incentive effect. A central prediction of our model is that, *ceteris paribus*, investors require less underpricing to truthfully report their information in rising markets than in falling markets. We test this prediction by regressing the initial return on our proxy for private information, separated by negative and positive market returns. Specifically, we run the following regression:

$$IR1 = \gamma + \beta_1 Public + \beta_2 Private + \beta_3 Private * Public_{POS} + e. \qquad (10)$$

The interaction variable $Private * Public_{POS}$ hence captures the difference in the impact of private information on the initial return in rising vs. falling markets. Our model predicts that $\beta_3 < 0$.

Table 6 reports the coefficient estimates from OLS regressions of Eq. (10) and has a similar structure as Table 5. Starting with the full sample (columns (1)-(3)), *Public* and *Private* again both generate positive and highly significant (p<0.001) coefficients in all regression specifications, consistent with partial adjustment. Turning to the interaction term $Private*Public_{POS}$, it enters with a significantly (p<0.05) negative coefficient in two of the three regression specifications. As

[17] The coefficient estimates are largely unchanged when we exclude the Inverse Mill's ratios from the regressions. Edelen and Kadlec (2005) also report an insignificant coefficient for the Inverse Mill's ratio and a significantly positive coefficient for the market return, indicating that the Heckman correction itself is insufficient to explain the partial adjustment to public information.

predicted by our model, the underpricing associated with a given price revision is smaller in rising markets than in falling markets.[18]

As discussed above, the incentive effect requires an informative order book. To the extent that high-quality underwriters receive more informative bids, the incentive effect should be strongest for these underwriters. Hence, to exploit potential differences in order book informativeness, columns (4) and (5) split the sample by underwriter rank.

Importantly, the interaction term $Private*Public_{POS}$ generates a negative and highly significant ($p<0.01$) coefficient for top-tier underwriters (column (4)). It is possible that top-tier underwriters tend to compensate investors less for their private information in positive markets than in negative markets, as implied by the incentive effect. Moreover, the coefficient for *Private* is higher for IPOs by top-tier than lower-tier underwriters (1.01 vs. 0.38, significantly different at the 1% level). It appears that investors on average receive higher compensation for their information in issues sold by top-tier underwriters, consistent with a more informative order book.

Note also that the coefficient for *Public* becomes insignificant when $Private*Public_{POS}$ is included in column (4). That is, for the subsample of top-tier underwriters, the positive relation between the initial return and the market return disappears after controlling for the incentive effect. Our model is thus able to successfully explain the puzzling partial adjustment to public information for the subsample of top-tier underwriters, where the order book is most informative.[19]

Column (5) of Table 6 shows the regression estimation for the subsample of lower-tier underwriters. Here, the initial return increases not only with *Public* and *Private*, but also with $Private*Public_{POS}$—something that our model is neither designed to nor able to explain. It is, however, consistent with Derrien (2005), who shows that both IPO prices and initial returns increased with investor demand during the internet bubble.

Another prediction of our model is that the incentive effect plays out only when investor demand is high and the issue is underpriced. To explore this dimension of the model, we re-estimate the regression models in Table 6 and add interaction terms with $Private_{POS}$, indicating that the final offer price is revised upwards. Given that $Private_{POS}$ captures high investor demand, we expect

[18]Sherman (2005) proposes that investors' opportunity cost of becoming informed increases with the market return. Her model thus predicts $\beta_3 > 0$, which is rejected by our evidence.

[19]Cornelli and Goldreich (2003) similarly show that the underwriter, in setting the issue price, relies on the reaction in investor bids to public information rather than the public information itself.

the incentive effect to be concentrated to issues with a positive price revision.

The coefficient estimates from these regressions are presented in Table 7. Starting with the full sample of IPOs (columns (1) to (3)), the coefficient for $Private{*}Private_{POS}$ is positive and highly significant ($p<0.001$), and of a much larger size than that of *Private* (0.85 vs. 0.14 in columns (2) and (3)). This is consistent with investors being compensated for their private information primarily when demand is high, as in our model. Moreover, $Private{*}Public_{POS}$ is insignificant, while $Private{*}Private_{POS}{*}Public_{POS}$ is negative and highly significant ($p<0.001$) in column (1), providing some evidence that the incentive effect largely plays out when demand is high.

We next turn to the subsample of top-tier underwriters (column (4)), where we expect the incentive effect to be strongest. First, the coefficient for *Private* is insignificant, while $Private{*}Private_{POS}$ is highly significant ($p<0.001$), as if partial adjustment to private information exists only when demand is high. Second, as in column (1), $Private{*}Private_{POS}{*}Public_{POS}$ is significantly negative ($p<0.001$), while $Private{*}Public_{POS}$ is insignificant, suggesting that the incentive effect exists only for high investor demand, as predicted by our model. Third, the coefficient for *Public* is now insignificant. For top-tier underwriters, our incentive effect—by channeling the effect of the market return through the offer price adjustment—captures what may have appeared like partial adjustment to public information.

For lower-tier underwriters (column (5) of Table 7), however, *Private* is positive ($p<0.05$) and $Private{*}Private_{POS}$ is insignificant, so investor demand does not influence the relation between the offer price revision and first-day return. Moreover, the coefficient for $Private{*}Private_{POS}{*}Public_{POS}$ now takes the opposite sign and is significantly positive ($p<0.05$). That is, consistent with Derrien (2005) and contrary to our incentive effect, first-day returns are more sensitive to an upward price revision in rising markets than in falling markets. As discussed above, the lack of evidence for our incentive effect among lower-tier underwriters may be explained by their less informative order books.

In sum, the implications of the incentive effect in our model are borne out in the data: the underpricing associated with an offer price revision tends to be lower when the market return is positive than when it is negative. This is consistent with underwriters adjusting the issue price more in response to investors' information in falling markets than in rising markets. Empirically, the effects are concentrated to IPOs sold by top-tier underwriters and with an upwards revision of the final offer price. These subsets capture investors placing informative bids and issues with high investor demand, both necessary conditions for the information-based argument by Benveniste and Spindt (1989) to hold. Importantly, when controlling for the incentive effect, the positive relation between the initial return and the market return disappears in the subsample of top-tier underwriters, effectively resolving the puzzle of partial adjustment to public information.

4.6 Tests of the demand effect

For completeness, we also perform tests of the demand effect, which predicts a positive correlation between the likelihood that the IPO is underpriced and the market return. Table 8 reports the coefficient estimates from probit regressions for the likelihood that the initial return is positive ($IR1_{POS}$). The regression model includes our standard control variables and standard errors are clustered by Fama-French 49 industry. Columns (1)-(4) use the full sample of completed IPOs, while columns (5) and (6) split the sample by underwriter rank.

Note first that, consistent with the demand effect, the likelihood that the issue is underpriced increases with *Public* and, in columns (2) and (4), with the dummy variable $Public_{POS}$ ($p<0.001$). Focusing on the last two columns, the coefficient for *Public* is greater for lower-tier underwriters than for top-tier underwriters (5.0 vs. 3.1, $p<0.001$ for the difference), suggesting that the demand effect is stronger for lower-tier underwriters.

The variable *Private* also produces a positive and significant coefficient ($p<0.001$) in all regression models. That is, the greater the investor demand, the more likely is the issue to be underpriced. This is consistent with our model, where the offer is underpriced only in the high-demand state.

Finally, several of the control variables generate significant coefficients. In the full sample of completed IPOs, the likelihood of a positive initial return increases with the mean initial return in recent IPOs (*Spillover* $IR1$) and it is higher for firms listing on Nasdaq. Moreover, the effect of the number of underwriters in the issue (*Underwriter Count*) varies with underwriter quality: it increases the probability that the issue is underpriced for top-tier underwriters and decreases this probability for lower-tier underwriters.

5 Conclusions

The empirical observation of an incomplete adjustment of the IPO offer price to the pre-issue market return has puzzled researchers. This paper proposes a simple mechanism that explains this positive relation between public information and IPO initial returns. By introducing an informative public signal to the Benveniste and Spindt (1989) information-based framework, we derive a rational Bayesian equilibrium, in which the public signal is conditionally correlated to investors' private signals.

In this equilibrium, public information is related to IPO underpricing through two different channels. The first channel—the demand effect—is via investor demand. Since the probability that investors receive positive private signals is higher when the public signal is positive, the likelihood of sufficient demand for the issue to be underpriced is also higher.

The second channel—the incentive effect—is through investors' incentives to truthfully reveal their information to the underwriter. In our model, a negative public signal increases the likelihood that a falsely reporting investor receives an allocation in the issue. With higher expected profits from false reporting, the minimum compensation to induce truthful revelation increases, and so does the conditional underpricing. Moreover, when the public signal is positive, the distribution of investors' private signals will shift to the right, and with it the firm's after-market value, reducing the marginal informational value of each private signal.

We test the predictions of the model for a sample of 6,301 U.S. book-built IPOs in the period 1983 to 2012. To empirically capture the public information, we use the return on the S&P500 index during the 42 trading days leading up to the issue. As a proxy for private information, we use the residual from a regression of the revision in the offer price from the filing range mid-point on the pre-issue stock market return. This purges any impact of the public market return on the price revision and attributes the remaining offer price adjustment to investors' private information.

In cross-sectional tests that are new to the literature, we use interaction variables to test the unique implications of the incentive effect. Most important, we show that the relation between the initial return and the offer price revision is greater in falling markets than in rising markets. This effect is concentrated to issues sold by top-tier investment banks, where the order book has been shown to be informative, and when investor demand is high. The finding is consistent with the incentive effect in our model and provides indirect support for the incentive mechanism proposed by Benveniste and Spindt (1989). Once we control for the incentive effect, the positive relation between the initial return and the pre-issue market return disappears. Thus, we are the first study to successfully and completely explain this puzzling relation for the top-tier underwriters.

We also find empirical support for the demand effect: the likelihood that the issue is underpriced increases in the public market return. While this result is not surprising, it helps complete our empirical examination of the model.

Our model requires an informative order book and therefore works particularly well for top-tier underwriters. In contrast, for lower-tier underwriters, where investor bids have been shown to be less informative, the positive association between the initial return and the market return maintains. Moreover, for these underwriters, the effect of the offer price revision on the initial return is larger when the pre-issue market return is positive, counter to our incentive effect. The new-found puzzle of low-quality underwriters allowing investors to capture a greater fraction of the upside in rising markets cannot be explained by our information-based model. Since such explanation is likely to rely on investor optimism or some other non-information based mechanism, we leave this puzzle for future research.

A Appendix

Proof of Lemma 1.

It follows by Bayes' rule that

$$q(g_i|g) = \frac{q(g_i, g)}{q(g),} \tag{11}$$

where

$$\begin{aligned} q(g_i, g) &= q(g_i, g|G)q(G) + q(g_i, g|B)q(B) \\ &= q(g_i|G)q(g|G)q(G) + q(g_i|B)q(g|B)q(B) \\ &= \gamma\mu\alpha + (1-\gamma)(1-\mu)(1-\alpha). \end{aligned} \tag{12}$$

Similarly,

$$q(g) = q(g|G)q(G) + q(g|B)q(B) = \mu\alpha + (1-\mu)(1-\alpha) \tag{13}$$

and hence

$$q(g_i|g) = \frac{\gamma\mu\alpha + (1-\gamma)(1-\mu)(1-\alpha)}{\mu\alpha + (1-\mu)(1-\alpha).} \tag{14}$$

It is then immediate that

$$q(g_i|b) = \frac{\gamma(1-\mu)\alpha + (1-\gamma)\mu(1-\alpha)}{(1-\mu)\alpha + \mu(1-\alpha)} \tag{15}$$

and also that

$$q(g_i|g) - q(g_i|b) = \frac{\alpha(1-\alpha)(2\mu-1)(2\gamma-1)}{[\mu\alpha + (1-\mu)(1-\alpha)][(1-\mu)\alpha + \mu(1-\alpha)]} > 0 \tag{16}$$

since $\mu > 1/2$ and $\gamma > 1/2$. It can similarly be shown that $q(b_i|b) > q(b_i|g)$ if $\mu > 1/2$ and $\gamma > 1/2$. ■

Proof of Proposition 1.

To minimize the expected payoff $\hat{U}(s)$ from falsely bidding low, investors submitting low bids get zero shares: $z(b_i, n) = 0$ for $n > 0$. For $n = 0$, each investor gets $1/N$ shares. $\hat{U}$ is further reduced by not underpricing the issue when $n = 0$, so that $p(0, s) = v(0, s)$.

The expected payoff to an investor with a positive private signal from bidding low is now

$$\hat{U}(s) = q(1|s)\frac{1}{N}[v(1, s) - v(0, s)], \tag{17}$$

which is strictly positive since $v(1, s) > v(0, s)$.

The expected payoff to an investor from truthfully bidding high is

$$U(s) = \sum_{n=1}^{N} q(n|s)\frac{1}{n}[v(n, s) - p(n, s)]. \tag{18}$$

Since there are $N - 1$ prices to be determined from one constraint, the set of prices $p(n, s)$; $n = 1, \ldots, N$ that satisfies the investor's incentive constraint $U(s) = \hat{U}(s)$ is indeterminate. With no loss of insight, we let $p(n,s) = v(n,s)$ for each $n = 1, \ldots, N-1$.[20] The offer price in the high-demand state, $p(N,s)$, is now uniquely determined from $U(s) = \hat{U}(s)$, where

$$U(s) = q(N|s)\frac{1}{N}[v(N,s) - p(N,s)], \tag{19}$$

which gives

$$p(N,s) = v(N,s) - \frac{q(1|s)}{q(N|s)}[v(1,s) - v(0,s)]. \tag{20}$$

Since $v(1,s) > v(0,s)$, it follows that $p(N,s) < v(N,s)$ and the issue is underpriced for $n = N$. ■

For the proofs of propositions 2-4, we use the following probabilistic assumptions and Bayes' rule:

$$\begin{aligned}
V &= \{G = 1, B = 0\} \\
s_i &= \{g_i, b_i\} \\
s &= \{g, b\} \\
q(g_i \mid G) = q(b_i \mid B) = \gamma &> q(b_i \mid G) = q(g_i \mid B) = (1-\gamma) && (21) \\
q(g \mid G) = q(b \mid B) = \mu &> q(b \mid G) = q(g \mid B) = (1-\mu) && (22) \\
q(G) = \alpha & \quad\; q(B) = (1-\alpha) \\
q(s) &= q(s|G)q(G) + q(s|B)q(B) \\
q(G \mid g) = \pi &= \frac{\mu\alpha}{\mu\alpha + (1-\mu)(1-\alpha)} \\
q(B \mid g) = \bar{\pi} &= (1-\pi) \\
q(B \mid b) = \beta &= \frac{\mu(1-\alpha)}{\mu(1-\alpha) + (1-\mu)\alpha} \\
q(G \mid b) = \bar{\beta} &= (1-\beta)
\end{aligned}$$

Assumptions (21) and (22) imply that the signals (s_i, s) are informative, and hence

$$\begin{aligned}
q(G|g) &> q(G) \\
\frac{\mu\alpha}{\mu\alpha + (1-\mu)(1-\alpha)} &> \alpha \\
\mu &> \mu\alpha + (1-\mu)(1-\alpha) \\
(2\mu - 1) &> (2\mu - 1)\alpha \\
q(g|G) = \mu &> 1/2,
\end{aligned}$$

which holds for all $\alpha \in (0,1)$.

Moreover, the probability of n positive private signals is given by

$$\begin{aligned}
q(n \mid G) &\sim Binomial[N, \gamma] \\
q(n \mid B) &\sim Binomial[N, (1-\gamma)] \\
q(n \mid s) &= q(n \mid G)q(G \mid s) + q(n \mid B)q(B \mid s).
\end{aligned}$$

[20]See Appendix B for a more general version of the model, where the issue is allocated to at least $\bar{n}$ investors and the n for which the issue is underpriced is determined endogenously.

Finally the expected aftermarket value $v(n,s)$ is given by

$$v(n,s) = G \times q(G \mid n,s) \quad = \quad 1 \times \frac{q(n \mid G)}{q(n \mid s)} q(G \mid s).$$

Proof of Proposition 2.

The initial return associated with the high-demand state equals

$$r(N,s) = \frac{v(N,s)}{p(N,s)} - 1; s \in \{b,g\}, \tag{23}$$

where

$$p(N,s) = v(N,s) - \frac{q(1 \mid s)}{q(N \mid s)} \left[v(1,s) - v(0,s) \right]. \tag{24}$$

We want to show that $r(N,g) < r(N,b)$, or that

$$\frac{v(N,g)}{p(N,g)} < \frac{v(N,b)}{p(N,b)}, \tag{25}$$

which is equivalent to

$$\frac{q(N \mid g)v(N,g)}{q(N \mid b)v(N,b)} > \frac{q(1 \mid g)}{q(1 \mid b)} \frac{[v(1,g) - v(0,g)]}{[v(1,b) - v(0,b)]}. \tag{26}$$

This inequality may be written as

$$\frac{q(G \mid g)}{q(G \mid b)} > \frac{q(1 \mid g)}{q(1 \mid b)} \frac{\left[\frac{q(1|G)}{q(1|g)} - \frac{q(0|G)}{q(0|g)} \right] q(G \mid g)}{\left[\frac{q(1|G)}{q(1|b)} - \frac{q(0|G)}{q(0|b)} \right] q(G \mid b)}, \tag{27}$$

which again can be expressed as

$$1 > \frac{q(0 \mid b)}{q(0 \mid g)} \frac{q(1 \mid G)q(0 \mid g) - q(0 \mid G)q(1 \mid g)}{q(1 \mid G)q(0 \mid b) - q(0 \mid G)q(1 \mid b)}. \tag{28}$$

Substituting $Z_s = \frac{1}{N} \frac{q(1|s)}{q(0|s)}$, the inequality in (28) simplifies to

$$1 > \frac{q(1 \mid G) - q(0 \mid G)NZ_g}{q(1 \mid G) - q(0 \mid G)NZ_b} = \frac{\gamma - (1-\gamma)Z_g}{\gamma - (1-\gamma)Z_b}. \tag{29}$$

Inequality (29) holds if $Z_g > Z_b$, and we therefore must have that

$$\begin{aligned}
Z_g = \frac{1}{N} \frac{q(1 \mid g)}{q(0 \mid g)} &> \frac{1}{N} \frac{q(1 \mid b)}{q(0 \mid b)} = Z_b \\
\frac{q(1 \mid G)q(G \mid g) + q(1 \mid B)q(B \mid g)}{q(0 \mid G)q(G \mid g) + q(0 \mid B)q(B \mid g)} &> \frac{q(1 \mid G)q(G \mid b) + q(1 \mid B)q(B \mid b)}{q(0 \mid G)q(G \mid b) + q(0 \mid B)q(B \mid b)} \\
\frac{\gamma(1-\gamma)^{N-1}\pi + \gamma^{N-1}(1-\gamma)\bar{\pi}}{(1-\gamma)^N \pi + \gamma^N \bar{\pi}} &> \frac{\gamma(1-\gamma)^{N-1}\bar{\beta} + \gamma^{N-1}(1-\gamma)\beta}{(1-\gamma)^N \bar{\beta} + \gamma^N \beta}
\end{aligned} \tag{30}$$

Dividing by γ^N and substituting $\Gamma = \frac{1-\gamma}{\gamma}$, we get

$$\begin{aligned}
\frac{\Gamma^{N-1}\pi+\Gamma\bar{\pi}}{\Gamma^{N}\pi+\bar{\pi}} &> \frac{\Gamma^{N-1}\bar{\beta}+\Gamma\beta}{\Gamma^{N}\bar{\beta}+\beta} \\
\frac{\Gamma^{N}\pi+\Gamma^{2}\bar{\pi}}{\Gamma^{N}\pi+\bar{\pi}} &> \frac{\Gamma^{N}\bar{\beta}+\Gamma^{2}\beta}{\Gamma^{N}\bar{\beta}+\beta} \\
\frac{\Gamma^{N}\pi+\Gamma^{2}\bar{\pi}+\bar{\pi}-\bar{\pi}}{\Gamma^{N}\pi+\bar{\pi}} &> \frac{\Gamma^{N}\bar{\beta}+\Gamma^{2}\beta+\beta-\beta}{\Gamma^{N}\bar{\beta}+\beta} \\
1-\frac{(1-\Gamma^{2})\bar{\pi}}{\Gamma^{N}\pi+\bar{\pi}} &> 1-\frac{(1-\Gamma^{2})\beta}{\Gamma^{N}\bar{\beta}+\beta} \\
\frac{(1-\Gamma^{2})\beta}{\Gamma^{N}\bar{\beta}+\beta} &> \frac{(1-\Gamma^{2})\bar{\pi}}{\Gamma^{N}\pi+\bar{\pi}}.
\end{aligned}$$

Assuming $\Gamma < 1$, which implies $\gamma > 1/2$, we have

$$\begin{aligned}
\beta[\Gamma^{N}\pi+\bar{\pi}] &> \bar{\pi}[\Gamma^{N}\bar{\beta}+\beta] \\
\Gamma^{N}[\pi\beta-\bar{\pi}\bar{\beta}] &> 0. \qquad (31)
\end{aligned}$$

As long as $\Gamma^N > 0$, we have that

$$\begin{aligned}
\pi\beta &> \bar{\pi}\bar{\beta}=(1-\pi)(1-\beta) \\
\pi\beta &> 1-\pi-\beta+\pi\beta \\
\pi+\beta &> 1 \qquad (32) \\
\pi+\beta=\frac{q(g|G)q(G)}{q(g)}+\frac{q(b|B)q(B)}{q(b)} &> 1 \\
q(g|G)q(G)q(b)+q(b|B)q(B)q(g) &> q(g)q(b) \\
q(g|G)q(G)q(b)+q(b|B)q(B)q(g) &> [q(g|G)q(G)+q(g|B)q(B)]q(b) \\
q(b|B)q(B)q(g) &> q(g|B)q(B)q(b) \\
q(b|B)q(g) &> q(g|B)q(b) \\
\mu[\mu\alpha+(1-\mu)(1-\alpha)] &> (1-\mu)[\mu(1-\alpha)+(1-\mu)\alpha] \\
\mu^{2}\alpha &> (1-\mu)^{2}\alpha \\
\mu &> 1/2 \qquad (33)
\end{aligned}$$

Thus, for any $\gamma, \mu > 1/2$, $\alpha \in (0, 1)$ and $\Gamma^N > 0$ we have that $r(N, g) < r(N, b)$. ■

Proof of Proposition 3.

By Bayes' rule it follows that

$$\begin{aligned}
q(N\mid g) &= q(N\mid G)q(G\mid g)+q(N\mid B)q(B\mid g) \qquad (34) \\
&= \gamma^{N}\pi+(1-\gamma)^{N}\bar{\pi} \\
q(N\mid b) &= q(N\mid G)q(G\mid b)+q(N\mid B)q(B\mid b) \qquad (35) \\
&= \gamma^{N}\bar{\beta}+(1-\gamma)^{N}\beta
\end{aligned}$$

Take the difference to prove the proposition.

$$\begin{aligned}
q(N \mid g) &> q(N \mid b) \\
\gamma^N \pi + (1-\gamma)^N \bar{\pi} &> \gamma^N \bar{\beta} + (1-\gamma)^N \beta \\
\pi + \left(\frac{1-\gamma}{\gamma}\right)^N \bar{\pi} &> \bar{\beta} + \left(\frac{1-\gamma}{\gamma}\right)^N \beta \\
(\pi - \bar{\beta}) + \Gamma^N (\bar{\pi} - \beta) &> 0 \\
(\pi + \beta - 1)(1 - \Gamma^N) &> 0 \qquad (36)
\end{aligned}$$

Using the same reasoning as from (32) to (33), it follows that $q(N \mid g) > q(N \mid b)$ holds for any $\mu > 1/2$, $\alpha \in (0,1)$ and $\Gamma^N < 1$ (which holds if $\gamma > 1/2$). ■

Proof of Proposition 4.

The proposition is proved by showing that

$$\lim_{N\to\infty} \frac{Er(g)}{Er(b)} = \lim_{N\to\infty} \frac{r(N,g)}{r(N,b)} \frac{q(N \mid g)}{q(N \mid b)} > 1. \qquad (37)$$

Assuming that the signals are informative ($\gamma, \beta > 1/2$), taking the limit of (31) and (36) implies

$$\begin{aligned}
\lim_{N\to\infty} \frac{r(N,g)}{r(N,b)} &= 1 \qquad (38) \\
\lim_{N\to\infty} \frac{q(N \mid g)}{q(N \mid b)} &> 1, \qquad (39)
\end{aligned}$$

which completes the proof. ■

B Appendix

In a more general version of the model, assume that the underwriter is constrained to allocate at most a fraction $\bar{m} < 1$ of the issue to one investor. A central implication of Benveniste and Spindt (1989) is that it is optimal to minimize (maximize) the fraction of shares allocated to investors reporting negative (positive) information. In the current setting, this implies that investors bidding low will be allocated shares only if $n < \bar{n} = 1/\bar{m}$. If $n\bar{m} \geq 1$, investors placing high bids will each receive $1/n$ of the issue. If instead $n\bar{m} < 1$, investors bidding high will each receive $1/\bar{n}$ of the issue, leaving $1 - n\bar{m}$ to investors that bid low, each receiving $\left(\frac{1}{N-n}\right)\left(1 - \frac{n}{\bar{n}}\right)$ of the issue.

The underwriter prices the issue after collecting investors' bids, committing to price the issue so that it is never overpriced *in expectation*. In particular, for the case $n \geq \bar{n}$, the issuer sets a price $p_H(s)$ in order to induce investors with positive signals to bid high. For the case $n < \bar{n}$, the underwriter sets a price $p_n(s) = v(n, s)$, which ensures that investors who bid low earn zero excess returns in equilibrium.[21] The pricing $p_H(s)$ for the case $n \geq \hat{n}$ may be interpreted as an upward revision of the offer price relative to the midpoint of the initial range, and similarly the pricing for the case $n < \hat{n}$ as a downward revision.

To find $p_H(s)$, consider first the expected payoff to an investor who falsely bids low:

$$\hat{U}(s) = \sum_{n=0}^{\bar{n}-1} \left(\frac{1}{N-n}\right)\left(1 - \frac{n}{\bar{n}}\right) q(n|s, g_i)(v(n+1, s) - v(n, s)), \tag{40}$$

where

$$q(n|g_i, g) = \binom{N-1}{n} \left(\frac{\gamma^{n+1}(1-\gamma)^{N-1-n}\mu\alpha + (1-\gamma)^{n+1}\gamma^{N-1-n}(1-\mu)(1-\alpha)}{\mu\gamma\alpha + (1-\mu)(1-\gamma)(1-\alpha)} \right) \tag{41}$$

$$q(n|g_i, b) = \binom{N-1}{n} \left(\frac{\gamma^{n+1}(1-\gamma)^{N-1-n}(1-\mu)\alpha + (1-\gamma)^{n+1}\gamma^{N-1-n}\mu(1-\alpha)}{(1-\mu)\gamma\alpha + \mu(1-\gamma)(1-\alpha)} \right) \tag{42}$$

$$v(n, g) = \frac{\gamma^n(1-\gamma)^{N-n}\mu\alpha}{\gamma^n(1-\gamma)^{N-n}\mu\alpha + (1-\gamma)^n\gamma^{N-n}(1-\mu)(1-\alpha)} \tag{43}$$

and

$$v(n+1, g) = \frac{\gamma^n(1-\gamma)^{N-n}\mu\alpha}{\gamma^n(1-\gamma)^{N-n}\mu\alpha + (1-\gamma)^n\gamma^{N-n}(1-\mu)(1-\alpha)}. \tag{44}$$

The expression for $\hat{U}(s)$ reflects the assumption that the underwriter sets a price that fully incorporates the information in investors' bids whenever $n < \hat{n}$.

Next, we establish the offer price $p_H(s)$ that is necessary to induce investors to truthfully bid high. The incentive constraint for such an investor is

$$\sum_{n=\bar{n}-1}^{N-1} \frac{1}{1+n} q(n|g_i, s)(v(n+1, s) - p_H(s)) \geq \hat{U}(s). \tag{45}$$

[21] An alternative pricing strategy is to offer a fixed price $p_L(s)$ that, in equilibrium, gives a zero expected return to investors with low bids. It can be shown, however, that this alternative pricing strategy will yield strictly higher incentives to falsely bid low, and hence it will yield higher underpricing and is not optimal. Importantly, the main results are unaffected by which of the two pricing strategies are employed.

Solving this constraint as an equality with respect to $p_H(s)$ gives

$$p_H(s) = \left(\sum_{n=\bar{n}-1}^{N-1} \frac{1}{1+n} q(n|g_i, s)\right)^{-1} \left(\sum_{n=\bar{n}-1}^{N-1} \frac{1}{1+n} q(n|g_i, s) v(n+1, s) - \hat{U}\right). \tag{46}$$

The expected aftermarket value of the firm conditional on an upward revision in the offer price ($n \geq \bar{n}$) is given by

$$v_H(s) = \left(\sum_{n=\bar{n}}^{N} q(n|s)\right)^{-1} \sum_{n=\bar{n}}^{N} q(n|s) v(n, s). \tag{47}$$

The issue is underpriced if $v_H(s) > p_H(s)$, which obtains whenever $\hat{U} > 0$.[22] The initial return associated with an upward revision in the offer price is then

$$r(s) = \frac{v_H(s)}{p_H(s)} - 1 \tag{48}$$

and the expected initial return is

$$Er(s) = \sum_{n=\bar{n}}^{N} q(n|s) r(s). \tag{49}$$

In other words, as in the simpler model in the paper, the expected initial return $Er(s)$ consists of the probability $\sum_{n=\bar{n}}^{N} q(n|s)$ of an upward revision in the offer price, and the initial return $r(s)$ conditional on this upward revision.

As before, partial adjustment to public information requires that

$$Er(g) > Er(b). \tag{50}$$

The incentive effect and the demand effect imply, respectively, that

$$\frac{r(g)}{r(b)} < 1 \tag{51}$$

and

$$\frac{\sum_{n=\bar{n}}^{N} q(n|g)}{\sum_{n=\bar{n}}^{N} q(n|b)} > 1. \tag{52}$$

It can be shown numerically that this more general version of the model behaves similarly to the simpler model solved analytically in the paper. In particular, the incentive effect and demand effect both hold (unequivocally), and the demand effect dominates the incentive effect whenever the number of investors is sufficiently large, ensuring partial adjustment to public information. Finally, the intuition as well as the empirical implications of the effects remain unaltered.

[22] This is seen by noting that $p_H(s)$ may be written as $p_H(s) = v_H(s) - \frac{\hat{U}(s)}{\sum_{n=\bar{n}-1}^{N-1} \frac{1}{1+n} q(n|s)}$ and hence $p_H(s) < v_H(s)$ if (and only if) $\hat{U}(s) > 0$.

References

Benveniste, Lawrence M., Alexander Ljungqvist, William J Wilhelm, and Xiaoyun Yu, 2003, Evidence of information spillovers in the production of investment banking services, *Journal of Finance* 58, 577–608.

Benveniste, Lawrence M., and Paul A. Spindt, 1989, How investment bankers determine the offer price and allocation of new issues, *Journal of Financial Economics* 24, 343–361.

Bradley, Daniel J., and Bradford D. Jordan, 2002, Partial adjustment to public information and IPO underpricing, *Journal of Financial and Quantitative Analysis* 37, 595–616.

Busaba, Walid Y., Lawrence M. Benveniste, and Re-Jin Guo, 2001, The option to withdraw IPOs during the premarket: empirical analysis, *Journal of Financial Economics* 60, 73–102.

Carter, Richard, and Steven Manaster, 1990, Initial public offerings and underwriter reputation, *Journal of Finance* 45, 1045–1067.

Chen, Zhaohui, and William J. Wilhelm, 2008, A theory of the transition to secondary market trading of IPOs, *Journal of Financial Economics*.

Cornelli, Francesca, and David Goldreich, 2003, Bookbuilding: How informative is the order book?, *Journal of Finance* 58, 1415–1444.

Derrien, François, 2005, IPO pricing in "hot" market conditions: Who leaves money on the table?, *Journal of Finance* 60, 487–521.

——— , and Kent L. Womack, 2003, Auctions vs. bookbuilding and the control of underpricing in hot IPO markets, *Review of Financial Studies* 16, 31–61.

Edelen, Roger M., and Gregory B. Kadlec, 2005, Issuer surplus and the partial adjustment of IPO prices to public information, *Journal of Financial Economics* 77, 347–373.

Hanley, Kathleen W., 1993, The underpricing of initial public offerings and the partial adjustment the underpricing of initial public offerings and the partial adjustment phenomenon, *Journal of Financial Economics* 34, 213–250.

Heckman, James J., 1979, Sample selection bias as a specification error, *Econometrica* 47, 153–161.

Ince, Özgür S., 2014, Why do IPO offer prices only partially adjust?, *Quarterly Journal of Finance* 4, 1450009.

Jenkinson, Tim, and Howard Jones, 2004, Bids and allocations in European IPO bookbuilding, *Journal of Finance* 59, 2309–2338.

Kutsuna, Kenji, Janet Kiholm Smith, and Richard L. Smith, 2009, Public information, IPO price formation, and long-run returns: Japanese evidence, *Journal of Finance* 64, 505–546.

Kyle, Albert S., 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315–1335.

Leite, Tore, 2007, Adverse selection, public information, and underpricing in IPOs, *Journal of Corporate Finance* 13, 813–828.

Ljungqvist, Alexander, 2007, IPO underpricing, in B. E. Eckbo, ed.: *Handbook of Corporate Finance: Empirical Corporate Finance*vol. 1 . chap. 7, pp. 375–422 (Elsevier/North-Holland, Handbooks in Finance Series).

Logue, Dennis E., 1973, On the pricing of unseasoned equity issues: 1965-1969, *Journal of Financial and Quantitative Analysis* 8, 91–103.

Loughran, Tim, and Jay R. Ritter, 2002, Why don't issuers get upset about leaving money on the table in IPOs?, *Review of Financial Studies* 15, 413–443.

Lowry, Michelle, Micah S. Officer, and G. William Schwert, 2010, The variability of IPO initial returns, *Journal of Finance* 65, 425–465.

Lowry, Michelle, and G. William Schwert, 2004, Is the IPO pricing process efficient?, *Journal of Financial Economics* 71, 3–26.

Sherman, Ann E., 2005, Global trends in IPO methods: Book building versus auctions with endogenous entry, *Journal of Financial Economics* 78, 615–649.

Wang, Wei, and Chris Yung, 2011, Ipo information aggregation and underwriter quality, *Review of Finance* 15, 301–325.

Table 1: **Sample Initial IPO Return and Pre-issue Market Return**

The table shows the average initial return and pre-issue market return by year for the sample of 6,301 U.S. IPOs filed in the period 1983 to 2012. The initial return is $IR1 = p_1/p_0 - 1$, where p_1 is the closing price on the first trading day and p_0 is the offer price, winsorized at 200%. *Public* is the return on the S&P500 index ($S\&P500$) over the 42 trading days leading up to the issue. N is the number of observations.

	Sample of all IPOs	Sample of completed IPOs				Sample of withdrawn IPOs			
			IR1	Public			% of	Public	
Year	N	N	Mean	Mean	% Positive	N	sample	Mean	% Positive
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1983	244	243	10.4	1.6	60.5	1	0.4	−3.2	0.0
1984	111	105	6.9	0.8	57.1	6	5.4	0.7	50.0
1985	110	102	5.7	4.0	82.4	8	7.3	5.4	87.5
1986	276	236	14.3	2.8	72.5	40	14.5	1.1	60.0
1987	187	165	12.9	6.1	86.1	22	11.8	2.8	90.9
1988	64	59	5.3	1.1	61.0	5	7.8	0.1	40.0
1989	80	66	7.7	3.2	69.7	14	17.5	3.6	78.6
1990	100	77	10.2	−0.2	55.8	23	23.0	2.2	73.9
1991	240	224	11.9	1.5	60.7	16	6.7	2.2	50.0
1992	354	304	10.5	2.0	65.8	50	14.1	0.9	66.0
1993	441	393	12.8	1.3	76.3	48	10.9	1.0	77.1
1994	369	317	8.9	−0.5	44.2	52	14.1	−0.1	50.0
1995	391	344	21.4	4.9	100.0	47	12.0	4.8	97.9
1996	585	536	16.9	3.9	85.6	49	8.4	4.4	83.7
1997	420	351	15.1	5.1	86.0	69	16.4	5.8	84.1
1998	292	214	25.5	4.9	79.9	78	26.7	1.3	52.6
1999	439	377	66.9	2.6	72.4	62	14.1	2.9	72.6
2000	392	311	52.9	0.1	49.5	81	20.7	−1.8	40.7
2001	135	58	16.3	0.2	48.3	77	57.0	−7.2	15.6
2002	63	49	10.9	−3.7	24.5	14	22.2	−4.5	21.4
2003	55	47	12.3	3.4	100.0	8	14.5	3.5	87.5
2004	143	129	12.5	2.3	68.2	14	9.8	−0.5	21.4
2005	154	134	12.1	1.5	67.9	20	13.0	1.7	80.0
2006	148	124	13.6	2.6	80.6	24	16.2	2.1	70.8
2007	156	132	14.9	1.6	67.4	24	15.4	1.2	54.2
2008	41	17	6.4	−3.2	29.4	24	58.5	−3.2	33.3
2009	43	35	11.3	5.0	97.1	8	18.6	6.5	75.0
2010	90	78	9.4	3.4	71.8	12	13.3	−1.2	41.7
2011	84	69	14.8	1.7	65.2	15	17.9	−0.4	33.3
2012	94	73	16.0	3.9	86.3	21	22.3	0.9	61.9
Total	6 301	5 369	19.7%	2.5%	72.0%	932	14.8%	0.9%	60.1%

Table 2: **Univariate Comparison of IPO Initial Returns Across Positive and Negative Market Returns**

The table shows the IPO initial returns ($IR1$) conditional on positive and negative pre-issue market returns. Panel A reports the average $IR1$ and Panel B reports the fraction of $IR1 > 0$, where $IR1 = p_1/p_0 - 1$, winsorized at 200%, and p_1 is the closing price on the first trading day and p_0 is the offer price. Panel C shows the number of observations for the different subsamples. Each panel splits the sample by a proxy for investor demand: $Private_{POS}$ and $Private_{NEG}$ denote issues where the revision of the final offer price, purged of any impact of *Public*, is positive and negative, respectively. The columns further split the sample by $Public_{NEG}$ and $Public_{POS}$, where *Public* is the return on the S&P500 index over the 42 trading days preceding the issue date, and the subscripts NEG and POS indicate that $Public \leq 0$ and $Public > 0$, respectively. Columns (4)-(9) further divide the sample by underwriter rank according to Carter and Manaster (1990), where *Top-tier* is rank=9 and *Lower-tier* is rank<9. All variables are defined in Table 3. The sample consists of 5,369 completed US IPOs filed between 1983 and 2012. *, **, *** and **** denotes significance at the 10%, 5%, 1%, and 0.1% level, respectively, using a t-test for the difference in mean (Panel A) and a standard proportionality test for the difference in the proportion (Panels B and C).

	Sample of all IPOs			Subsample of top-tier underwriters			Subsample of lower-tier underwriters		
	Public_{NEG}	(Diff.)	Public_{POS}	Public_{NEG}	(Diff.)	Public_{POS}	Public_{NEG}	(Diff.)	Public_{POS}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Average Initial Return $IR1$ in % (The Incentive Effect)									
Private_{POS}	40.8	-5.5^{**}	35.3	52.7	-10.8^{***}	41.8	21.9	4.9^{**}	26.8
Private_{NEG}	4.3	2.6^{***}	6.9	2.4	3.5^{****}	6.0	5.8	1.8	7.6
All IPOs	17.9	2.6^{**}	20.4	24.6	0.7	25.3	10.8	4.7^{****}	15.6
Panel B: Percent Positive Initial Returns, $IR1 > 0$ (The Demand Effect)									
Private_{POS}	90.8	2.8^{**}	93.7	92.6	1.5	94.0	88.1	5.1^{**}	93.2
Private_{NEG}	54.2	8.0^{****}	63.5	52.4	7.3^{**}	59.7	55.7	8.6^{**}	64.3
All IPOs	75.9	5.0^{****}	80.9	77.0	4.1^{***}	81.0	74.9	5.9^{****}	80.8
Panel C: Number of IPOs N (Conditional Correlation)									
Private_{POS}	502		1804	309		1023	193		781
% of all IPOs	38.6	10.0^{****}	48.6	46.5	8.1^{****}	54.7	30.4	12.1^{****}	42.5
Private_{NEG}	797		1906	355		848	442		1058
% of all IPOs	61.4		51.4	53.5		45.3	70.5		29.5
All IPOs	1503		3866	768		1939	735		1927

Table 3: **Variable Definitions**

The table shows names and definitions of, and sources for, the variables used in the analysis. Ken French and Jay Ritter refer to their respective data webpages. p_0 is the final offer price, and p_L and p_H are the lower and upper bound, respectively, of the initial filing range.

Name	Definition	Sources
A: Variables critical for testing the model		
Revision	Revision of the final offer price from the initial filing range midpoint (p_{mid}), defined as $Revision = p_0/p_{mid} - 1$.	SDC
IR1	Initial return $IR1 = p_1/p_0 - 1$, where p_1 is the firm's closing price on the first trading day, and winsorized at 200%. Proxy for underpricing.	SDC, CRSP
Public	Return on the S&P500 index over the 42 trading days preceding the issue. Proxy for public information during the book building period.	CRSP
Private	The residual from the regression $Revision = \alpha + \beta * Public + \epsilon$, set to zero when $\lvert\epsilon\rvert < 1\%$. Proxy for private information.	SDC, CRSP
$_{POS}$, $_{NEG}$	The subscripts $_{POS}$ and $_{NEG}$ indicate a dummy taking the value of one if the variable is positive and non-positive, respectively.	
Top-tier	Dummy indicating that at least one of the underwriters has a Carter and Manaster (1990) rank of 9.	SDC
Lower-tiers	Dummy indicating that all of the underwriters has a Carter and Manaster (1990) rank below 9.	SDC
B: Control variables		
Age	Log of firm age since the founding year.	Jay Ritter
Primary	Percentage of shares sold in IPO as primary share (new issue).	SDC
Amount Filed	Log of total $ amount filed in the IPO.	SDC
Spillover Revision	Price revision spillover. The average *Revision*, orthogonalized to *Public*, for all IPOs in the 42 trading days prior to listing.	SDC, CRSP
Spillover IR1	Initial return spillover. The average $IR1$, orthogonalized to *Spillover Revision* and *Public*, for all IPOs in the 42 trading days prior to listing.	SDC, CRSP
Spillover Withdrawn	The number of withdrawn IPOs in the 42 trading days prior to listing.	SDC
Underwriter Count	Log of the number of underwriters in the IPO.	SDC
High Tech	Indicator that the IPO firm is a high-technology firm.	SDC
VC	Indicator that the IPO firm is backed by a venture capital firm.	SDC
Nasdaq	Indicator that the IPO firm is listed on Nasdaq.	CRSP
C: Clustering Variables		
$FF49id$	Fama-French 49 industry indices definitions.	Ken French

Table 4: **Probability of Completing the IPO**

The table reports the coefficient estimates from a probit regression for the probability that a filed IPO is completed vs. withdrawn prior to the issue. Column (1) uses the full sample, while columns (2) and (3) split the sample by underwriter rank: *Top-tier* and *Lower-tiers* indicate that the highest-ranked underwriter has a Carter and Manaster (1990) rank=9 and rank<9, respectively. All variables are defined in Table 3. The z-scores (in parenthesis) use standard errors clustered by Fama-French 49 industry. *, **, *** and **** denote significance at the 10%, 5%, 1%, and 0.1% level, respectively. The sample consists of 6,301 book-built U.S. IPOs filed in the period 1983 to 2012.

	Sample of all IPOs (1)	Top-tier (2)	Lower-tiers (3)
$Public * Public_{POS}$	-2.141^{***}	-0.320	-3.466^{****}
	(-2.97)	(-0.36)	(-3.39)
$Public * Public_{NEG}$	10.244^{****}	8.534^{****}	11.900^{****}
	(11.80)	(7.38)	(8.77)
Underwriter Count	1.007^{****}	1.244^{****}	0.680^{****}
	(16.20)	(12.89)	(10.11)
Amount Filed	-0.503^{****}	-0.475^{****}	-0.535^{****}
	(-15.20)	(-10.23)	(-9.22)
Underwriter Rank	0.067^{****}		0.106^{****}
	(4.83)		(8.29)
Spillover IR1	-1.721^{****}	-1.679^{****}	-1.824^{****}
	(-14.98)	(-7.35)	(-7.37)
Spillover PU	-0.279	-0.344	-0.148
	(-0.72)	(-0.66)	(-0.28)
Spillover WD	-0.054^{****}	-0.057^{****}	-0.051^{****}
	(-10.27)	(-6.82)	(-7.72)
Constant	8.913^{****}	8.641^{****}	9.428^{****}
	(15.40)	(10.31)	(10.05)
Observations	6,301	3,071	3,230
of which completed	5,369	2,707	2,662
of which withdrawn	932	364	568
Pseudo R^2	0.225	0.288	0.191

Table 5: **Tests for Partial Adjustment to Public Information**

The table reports the coefficient estimates from OLS regressions for the initial return ($IR1$). *Public* is the return on the S&P500 index over the 42 trading days leading up to the issue. *Private* is the residual from the regression $Revision = \alpha + beta * Public + \epsilon$, where the dependent variable is the revision in the final offer price from the filing range midpoint. The Inverse Mill's ratio is from the probit regressions in table 4. All variables are defined in Table 3. The t-statistics (in parenthesis) use standard errors clustered by Fama-French 49 industry. *, **, *** and **** denotes significance at the 10%, 5%, 1%, and 0.1% level, respectively. The sample consist of 6,301 book-built U.S. IPOs between 1983-2012.

	Sample of all completed IPOs			Top-tier	Lower-tiers
	(1)	(2)	(3)	(4)	(5)
Public	0.385****	0.419****	0.422****	0.268**	0.675****
	(4.53)	(4.85)	(5.11)	(2.31)	(5.65)
Private	0.864****	0.806****	0.695****	0.870****	0.505****
	(9.30)	(11.88)	(14.57)	(15.51)	(13.71)
Age		−0.034****	−0.020****	−0.027****	−0.007
		(−3.75)	(−4.48)	(−5.17)	(−1.27)
High Tech		0.066****	0.020**	0.030*	0.009
		(4.57)	(2.07)	(1.69)	(0.81)
Underwriter Rank		0.013***	0.001		0.003
		(3.06)	(0.39)		(1.01)
Primary		0.002	0.009	0.023	−0.045
		(0.07)	(0.41)	(1.04)	(−0.71)
Amount Filed		0.001	−0.001	−0.001	−0.001
		(0.46)	(−0.58)	(−0.24)	(−0.56)
VC		0.040***	0.033***	0.061***	−0.002
		(3.17)	(2.82)	(3.32)	(−0.21)
NASDAQ		0.034***	0.021*	0.025*	−0.009
		(3.52)	(1.96)	(1.87)	(−0.57)
Spillover IR1			0.794****	0.778****	0.621****
			(9.39)	(9.48)	(5.09)
Spillover PU			0.624****	0.569****	0.613****
			(7.06)	(5.65)	(4.17)
Inverse Mill's Ratio	−0.056**	0.007	−0.012	−0.049	0.086***
	(−2.67)	(0.36)	(−0.56)	(−1.45)	(2.78)
Constant	0.199****	0.061	0.198****	0.189****	0.210**
	(8.63)	(1.06)	(5.28)	(3.99)	(2.61)
Observations	5369	5369	5369	2707	2662
Adjusted R^2	0.182	0.216	0.330	0.386	0.204

Table 6: **Tests for the Incentive Effect**

The table reports the coefficient estimates from OLS regressions for the initial return ($IR1$). *Public* is the return on the S&P500 index over the 42 trading days leading up to the issue. $Public_{POS}$ is a dummy variable taking the value of one if $Public > 0$. *Private* is the residual from the regression $Revision = \alpha + beta * Public + \epsilon$, where the dependent variable is the revision in the final offer price from the filing range midpoint. The Inverse Mill's ratio is from the probit regressions reported in table 4. All variables are defined in Table 3. The t-statistics (in parenthesis) use standard errors clustered by Fama-French 49 industry. *, **, *** and **** denotes significance at the 10%, 5%, 1%, and 0.1% level, respectively. The sample consist of 6,301 book-built U.S. IPOs between 1983-2012.

	Sample of all completed IPOs			Top-tier	Lower-tiers
	(1)	(2)	(3)	(4)	(5)
Public	0.613****	0.576****	0.417***	0.211	0.709***
	(3.79)	(3.88)	(3.08)	(1.11)	(3.30)
Private	0.981****	0.934****	0.704****	1.006****	0.376****
	(6.82)	(8.24)	(11.90)	(11.68)	(8.57)
$Private * Public_{POS}$	−0.152**	−0.168**	−0.012	−0.178***	0.168****
	(−2.09)	(−2.42)	(−0.41)	(−2.89)	(3.71)
$Public_{POS}$	−0.033**	−0.023*	0.001	0.012	0.001
	(−2.07)	(−1.80)	(0.06)	(0.60)	(0.04)
Age		−0.034****	−0.020****	−0.027****	−0.006
		(−3.73)	(−4.45)	(−5.11)	(−1.20)
High Tech		0.066****	0.020**	0.031*	0.007
		(4.60)	(2.07)	(1.70)	(0.69)
Underwriter Rank		0.013***	0.001		0.003
		(3.12)	(0.39)		(0.97)
Primary		0.002	0.009	0.025	−0.044
		(0.07)	(0.41)	(1.13)	(−0.70)
Amount Filed		0.001	−0.001	−0.001	−0.001
		(0.48)	(−0.59)	(−0.23)	(−0.47)
VC		0.040***	0.033***	0.062***	−0.002
		(3.20)	(2.83)	(3.38)	(−0.21)
NASDAQ		0.034***	0.021*	0.025*	−0.007
		(3.51)	(1.97)	(1.90)	(−0.45)
Spillover IR1			0.793****	0.773****	0.629****
			(9.39)	(9.47)	(5.02)
Spillover PU			0.623****	0.554****	0.619****
			(7.11)	(5.56)	(4.17)
Inverse Mill's Ratio	−0.059***	0.004	−0.011	−0.049	0.085***
	(−2.74)	(0.21)	(−0.57)	(−1.45)	(2.74)
Constant	0.218****	0.076	0.198****	0.179***	0.203**
	(8.09)	(1.31)	(4.70)	(3.46)	(2.53)
Observations	5369	5369	5369	2707	2662
Adjusted R^2	0.184	0.218	0.330	0.386	0.205

Table 7: **Tests for the Incentive Effect when Private Information is Positive**

The table reports the coefficient estimates from OLS regressions for the initial return ($IR1$). *Public* is the return on the S&P500 index over the 42 trading days leading up to the issue. $Public_{POS}$ is a dummy variable taking the value of one if $Public > 0$. *Private* is the residual from the regression $Revision = \alpha + beta * Public + \epsilon$, where the dependent variable is the revision in the final offer price from the filing range midpoint. *Top-tier* and *Lower-tiers* indicate that the highest-ranked underwriter has a Carter and Manaster (1990) rank=9 and rank<9, respectively. The Inverse Mill's ratio is from the probit regressions in Table 4. *Other Controls* are the control variables from column (3) of Table 5. All variables are defined in Table 3. The t-statistics (in parenthesis) use standard errors clustered by Fama-French 49 industry. *, **, *** and **** denotes significance at the 10%, 5%, 1%, and 0.1% level, respectively. The sample consist of 6,301 book-built U.S. IPOs between 1983-2012.

	Sample of all completed IPOs			Top-tier	Lower-tiers
	(1)	(2)	(3)	(4)	(5)
Public	0.559***	0.385**	0.385**	0.175	0.678***
	(3.22)	(2.62)	(2.62)	(0.89)	(3.10)
Private	0.114	0.144**	0.144**	−0.021	0.255**
	(1.62)	(2.08)	(2.08)	(−0.22)	(2.23)
$Private * Public_{POS}$	0.026	−0.005	−0.005	0.132	−0.104
	(0.33)	(−0.06)	(−0.06)	(1.53)	(−0.84)
$Private * Private_{POS}$	1.394****	0.846****	0.846****	1.344****	0.241
	(11.41)	(6.79)	(6.79)	(8.75)	(1.29)
$Private * Private_{POS} * Public_{POS}$	−0.470****	−0.115	−0.115	−0.551****	0.428**
	(−3.66)	(−1.03)	(−1.03)	(−3.59)	(2.21)
$Public_{POS}$	−0.012	−0.004	−0.004	0.038	−0.040
	(−0.68)	(−0.21)	(−0.21)	(1.33)	(−1.58)
$Private_{POS}$	0.072*	0.062*	0.062*	0.121***	0.010
	(1.82)	(1.71)	(1.71)	(2.79)	(0.31)
$Private_{POS} * Public_{POS}$	0.023	0.021	0.021	0.015	0.025
	(1.01)	(0.88)	(0.88)	(0.42)	(0.71)
Other controls	no	yes	yes	yes	yes
Inverse Mill's Ratio	−0.060***	−0.018	−0.018	−0.061*	0.079**
	(−2.91)	(−1.03)	(−1.03)	(−1.94)	(2.49)
Constant	0.090****	0.124***	0.124***	0.025	0.208***
	(5.49)	(2.90)	(2.90)	(0.56)	(2.70)
Observations	5369	5369	5369	2707	2662
Adjusted R^2	0.215	0.347	0.347	0.407	0.220

Table 8: **Tests for the Demand Effect**

The table reports the coefficient estimates from probit regressions for the likelihood that the initial return is positive ($IR1_{POS}$). *Public* is the return on the S&P500 index over the 42 trading days leading up to the issue. *Private* is the residual from the regression $Revision = \alpha + beta * Public + \epsilon$, where the dependent variable is the revision in the final offer price from the filing range midpoint. Columns (1) through (4) use the full sample, while columns (5) and (6) split the sample by underwriter rank: *Top-tier* and *Lower-tiers* indicate that the highest-ranked underwriter has a Carter and Manaster (1990) rank=9 and rank<9, respectively. All variables are defined in Table 3. The z-scores (in parenthesis) use standard errors clustered by Fama-French 49 industry. *, **, *** and **** denotes significance at the 10%, 5%, 1%, and 0.1% level, respectively. The sample consist of 5,369 book-built U.S. IPOs between 1983-2012.

	Sample of all completed IPOs				Top-tier	Lower-tier
	(1)	(2)	(3)	(4)	(5)	(6)
Public	3.853****		3.885****		3.129****	4.948****
	(7.77)		(7.99)		(3.78)	(8.95)
$Public_{POS}$		0.267****		0.278****		
		(4.52)		(4.87)		
Private	3.104****	3.060****	3.140****	3.104****	3.616****	2.718****
	(22.65)	(22.65)	(24.02)	(23.69)	(19.43)	(13.34)
Age			0.000	−0.002	−0.008	0.011
			(0.02)	(−0.10)	(−0.28)	(0.37)
Underwriter Count			0.013	0.020	0.100**	−0.091**
			(0.52)	(0.81)	(2.42)	(−2.49)
Spillover IR1			0.513***	0.523***	0.218	0.877**
			(2.80)	(3.07)	(0.98)	(2.51)
Spillover PU			−0.414*	−0.502**	−0.508*	−0.103
			(−1.75)	(−2.21)	(−1.67)	(−0.23)
High Tech			0.030	0.033	0.060	−0.001
			(0.53)	(0.58)	(0.81)	(−0.01)
Primary			−0.056	−0.043	−0.015	−0.169
			(−0.47)	(−0.37)	(−0.11)	(−0.82)
Amount Filed			−0.025*	−0.025*	−0.027*	−0.001
			(−1.94)	(−1.93)	(−1.78)	(−0.03)
VC			0.043	0.038	0.087	0.028
			(0.93)	(0.83)	(1.55)	(0.36)
NASDAQ			0.095**	0.098**	0.029	0.166***
			(2.20)	(2.24)	(0.48)	(2.74)
Constant	0.709****	0.606****	1.073****	0.942****	0.965***	0.774**
	(19.17)	(12.89)	(4.12)	(3.57)	(2.73)	(2.52)
Observations	5369	5369	5369	5369	2707	2662
Pseudo R^2	0.123	0.117	0.129	0.124	0.165	0.104