NHH

INSTITUTT FOR FORETAKSØKONOMI

DEPARTMENT OF FINANCE AND MANAGEMENT SCIENCE

FOR 6 2010

ISSN: 1500-4066

AUGUST 2010

Discussion paper

Public information and IPO underpricing

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August 9, 2010

Abstract

We analyze the effect of public information on rational investors' incentives to reveal private information during the bookbuilding process and their demand for allocations in the IPO. Our model generates several new predictions. First, investors require more underpricing to truthfully reveal positive private information in bear markets than in bull markets (the incentive effect). Second, the fraction of positive private signals and of underpriced IPOs is increasing in market returns (the demand effect). Combined, these two effects can explain why IPO underpricing is positively related to pre-issue market returns, consistent with extant evidence. Using a sample of 5,000 U.S. IPOs from 1981-2008, we show that the empirical implications of the model are borne out in the data.

Keywords: public information, partial adjustment, underpricing, IPOs, bookbuilding

JEL Classification: G10, G32.

*We are grateful for comments by Espen Eckbo, Sturla Fjesme, Eva Liljeblom, Lucy White, Weidong Xu, and seminar participants at NHH, the LSBE/LSM joint finance workshop, the Swedish Network for European Studies in Economics and Business, and the University of Stavanger. All authors are at the Norwegian School of Economics and Business Administration (NHH), Helleveien 30, 5045 Bergen, Norway. Thorburn is also at the Center for Economic Policy Research and the European Corporate Governance Institute. Emails: einar.bakke@nhh.no; tore.leite@nhh.no; and karin.thorburn@nhh.no.

1 Introduction

Extant evidence shows that underpricing in initial public offerings (IPOs) is positively related to market-wide equity returns preceding the offering, suggesting that underwriters fail to fully adjust offer prices for publicly available information. As pointed out by Loughran and Ritter (2002) and Lowry and Schwert (2004) among others, partial adjustment to prior market returns is puzzling since it implies that underwriters reward investors for easily available public information.[1]

In this paper, we offer a rational explanation for partial adjustment to public information. Our model is based on the framework of Benveniste and Spindt (1989), where underwriters underprice IPOs to compensate investors for revealing private information during the subscription period. While their main prediction is that offer prices will adjust partially to investors' *private* information, this paper shows that it can also be rational with partial adjustment to *public* information. This is because publicly available information affects the incentives of investors to reveal their private information as well as their demand for allocations.

More specifically, the model shows that investors require higher compensation, i.e. more underpricing, to truthfully reveal favorable information when the public signal is negative. The intuition for this result starts with the underwriter's optimal rule for the allocation of shares in the IPO, which favors investors revealing positive private signals. In our model, as long as at least one investor reports a positive signal, investors reporting negative information will be left without any IPO allocation. Since public and private signals are conditionally correlated, the probability of being awarded underpriced shares after hiding good information is higher when public information is negative. The expected gains from lying about favorable private information are therefore higher in downmarkets than in upmarkets. As a result, negative market-wide information increases the need for the underwriter to underprice the issue in order to induce investors to truthfully reveal their positive information. We label this mechanism the incentive effect.

At the same time, public information also affects the distribution in investors' demand for allocations. We refer to this mechanism as the demand effect. To start with,

[1] See also Logue (1973), Hanley (1993), Bradley and Jordan (2002), Benveniste, Ljungqvist, Wilhelm, and Yu (2003), and Kutsuna, Smith, and Smith (2009). Using French IPOs, Derrien and Womack (2003) show that the offer price adjusts more fully to market returns in auctions than in the bookbuilding process. Da, Engelberg, and Gao (2009) and Liu, Sherman, and Zhang (2009) find that IPO underpricing increases with pre-IPO media coverage.

investors have little incentive to hide negative private information and don't require any underpricing to truthfully reveal a negative signal. When public information is positive, private information is likely to also be favorable, and hence the probability for underpricing of the shares in the offering is relatively high. Thus, through the demand effect, positive public information increases the probability that the IPO is underpriced.

The relative strength of the two effects determines how public information ultimately is related to underpricing. While the incentive effect produces a negative relation between public information and underpricing, the demand effect pulls in the opposite direction. Whenever the demand effect dominates the incentive effect, underpricing is positively related to public information and the offer price is only partially adjusted for market-wide returns. This is the case if the number of investors in the issue is sufficiently large.

We test the empirical implications of the model for a sample of 5,000 U.S. IPOs in the period 1981-2008. As a proxy for private information, we use the residual from a regression of the offer price revision at the end of the registration period on the S&P500 index, effectively purging any effect of market-wide returns from the price update. The predictions of the model are all borne out in the data. Importantly, for a given increase in private information, the first-day returns increase more in bear markets than in bull markets (the incentive effect). This effect is concentrated to issues where demand for the shares offered in the IPO is high. Moreover, the probability of positive private information and of positive initial returns is higher when public information is favorable (the demand effect).

Our evidence is consistent with the incentive mechanism implied by the information production argument of Benveniste and Spindt (1989). The ideal way to test this incentive mechanism is to relate actual allocations of shares to investors' indications of interest, but this requires proprietary data that is not easily available.[2] A more indirect test is to look for partial adjustment in the IPO price to private information obtained during the subscription period, as first done by Hanley (1993).[3] We refine this indirect test of information revelation by making the incentive mechanism contingent on pub-

[2]Cornelli and Goldreich (2001, 2003) and Jenkinson and Jones (2004) examine proprietary bid and allocation data from two separate U.K. investment banks. Bubna and Prabhala (2010) use similar data from Indian IPOs. While Cornelli and Goldreich as well as Bubna and Prabhala find support for the Benveniste and Spindt (1989) model, Jenkinson and Jones do not.

[3]Ljungqvist and Wilhelm (2002) estimate a structural model of IPO allocations and find greater institutional allocations to be associated with larger price revisions, consistent with information production.

lic information observed during the subscription period. As predicted by our model, it appears that the compensation investors require to reveal their private information is higher in downmarkets than in upmarkets. In other words, investors' private information seems to be more fully incorporated into the IPO price in upmarkets than in downmarkets.

Several papers have analyzed the partial adjustment of the IPO offer price to public information. Loughran and Ritter (2002) use prospect theory to explain the observed positive relation between market returns and underpricing. They argue that issuers care more for their newly discovered wealth than about leaving "money on the table", thus bargaining the price less aggressively when market-wide stock returns are high. Derrien (2005) proposes that investor sentiment correlated to market conditions drives demand and hence initial returns in hot market IPOs.

In Edelen and Kadlec (2005), a rational issuer sets the offer price by trading off the proceeds conditional on deal success against the likelihood that the IPO fails. If the conditional gains from an IPO are high, the issue will be priced relatively low to increase the probability of success. Assuming that the market value of the firm increases with that of its publicly traded competitors, the degree of underpricing will increase with industry-wide stock returns. In a Rock (1986) setting, Leite (2007) shows that positive public information reduces adverse selection and thus the winner's curse problem. At the same time, issuers price the issue more conservatively to increase the success probability, creating a positive correlation between market returns and the degree of underpricing. Finally, Sherman (2005) shows that partial adjustment will arise in the Benveniste and Spindt (1989) model if rational investors' opportunity costs are positively related to public information observed prior to the offering. In our model, information costs play no role and partial adjustment is related directly to information revelation.

The rest of the paper is organized as follows. Section 2 describes the model. The relation between public information and underpricing is discussed in Section 3. In Section 4, we report the result from our empirical tests of the model. Section 5 summarizes.

2 The model

We start with a firm that is about to offer its shares to outside investors through an IPO. The firm's value is good $G = 1$ with probability α and bad $B = 0$ with probability $1 - \alpha$. For simplicity, the number of shares to be floated is normalized to one, and investors are allocated fractions of this one 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 observing an independently identically distributed (i.i.d.) private signal $s_I = \{g_I, b_I\}$, where g_I represents positive information and b_I negative information about the firm. Let $n \in [0, N]$ denote the number of investors who observe positive private signals. Investors observe their private signals at zero cost.[4] The precision in the private signal s_I is similar across all investors and equals $\gamma = q(g_I|G) = q(b_I|B) > 1/2$, where $q(\cdot|\cdot)$ and $q(\cdot)$ denote conditional and unconditional probabilities throughout. The assumption that $\gamma > 1/2$ ensures that the signal is informative about the true value of the firm.

In addition, all investors observe a common public signal $s = \{g, b\}$, where $s = g$ represents positive information and $s = b$ negative information. We can think of the public signal as market-wide information—such as changes in aggregate demand or the business cycle—that affects the value of the firm. The precision in the public signal is given by $f = q(g|G) = q(b|B)$, where $f > 1/2$. The public and the private signals are both informative and therefore positively conditionally correlated. That is, if the public signal is positive, then the probability of also obtaining a positive private signal is relatively high, and vice versa: $q(g_I|g) > q(b_I|g)$ and $q(g_I|b) < q(b_I|b)$.

Let $v(n, s)$ denote the (true) aftermarket value of the firm, i.e. the 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, the function $v(n, s)$ is the expected value of the firm conditional on the n positive private signals observed by investors and the public signal s. The specification of $v(n, s)$ as a conditional expectation implies that the marginal impact of each investor's private signal on the firm's aftermarket value is decreasing in the number of investors in the offering (N). This is in contrast to Benveniste and Spindt (1989), who assume that the aftermarket value is additive in investors' private signals and hence that each private signal "has an equal (absolute) marginal impact on the stock's value" (p. 347).

Because the aftermarket value of the firm increases in the number n of positive private signals, n is also a measure of the demand for shares in the issue, and where a higher

[4]We treat the number of investors N as exogenous. As an alternative, one could assume a positive information cost and let N be determined endogenously, with N being negatively related to the cost of information. Our assumption of zero information cost yields no loss of insight in the information revelation mechanism. See Sherman and Titman (2002) for an analysis of the effect of costly private information and participation limits in a Benveniste and Spindt (1989) setup.

value of n corresponds to higher demand. Indeed, the case for which $n = N$, and hence all investors observe positive private signals, is referred to as the high-demand state. In contrast, the case for which $n = 0$ and all investors observe negative private signals, is called the low-demand state.

The bookbuilding process is conducted as follows. Investors observe their private signals along with the public signal. Bids are submitted to the underwriter effectively by reporting the private signal. Each investor submits a high or low bid, which is to say that she reports either a positive or negative signal. In equilibrium, an investor who observes a positive private signal reports this truthfully by bidding high. Similarly, an investor with a negative signal truthfully reports this by submitting a low bid.

The firm pays no fees for the services of the underwriter. Before investors submit their bids, the underwriter states his pricing and allocation policy. He then responds to investors' bids according to this pre-committed policy. In equilibrium, the underwriter receives all the relevant information from investors about the firm. Thus, when determining the offer price, he correctly anticipates the firm's aftermarket value $v(n, s)$.[5]

Let $p(n, s)$ denote the IPO price if n investors report positive private signals ($s_I = g_I$) and given the public signal s. Let $z(g, n)$ denote the fraction of the issue allocated to an investor who submits a high bid, and $z(b, n)$ denote the fraction awarded to an investor submitting a low bid. Since all private signals have the same precision, investors with identical bids receive equal allocations. In other words, the issue is allocated pro-rata among investors who submit identical bids. We assume, as do Benveniste and Spindt (1989), 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 Benveniste and Spindt (1989), however, we place no restrictions on the number of shares that can be allocated to one investor. This implies that an entire issue may be allocated to one investor. As discussed below, as long as at least one investor observes a positive private signal, it is optimal to allocate the issue exclusively to investors with favorable information.

Let us now consider investors' incentives to truthfully reveal their private signals. Trivially, an investor with negative information has little incentive to misrepresent her signal. If she lies and submits a high bid, she is awarded a fraction of the issue at a price exceeding the after-market firm value implied by her private signal. Thus, she is better off truthfully submitting a low bid, and possibly be allocated a share of the IPO at a

[5] Since in our model the number of shares is one, the offer price is equal to the proceeds in the IPO.

price correctly reflecting her negative signal.

Instead, we need to worry about the incentives of investors with positive private signals. These investors may benefit from misrepresenting their private information, pretending to posses a negative signal in order to lower the issue price. The potential drawback of such a strategy is, however, that other investors may submit high bids, leaving the untruthful investor without any allocation in the offering.

For an investor i with a positive private signal, the expected payoff U from submitting a high bid that truthfully reveals her signal is

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

where $q(n|g_I, s)$ is the probability that a total of n investors receive positive private signals conditional on investor i observing the private signal $s_I = g_I$ and the public signal s. Recall that $z(g, n)$ is the fraction of the issue allocated to investor i for a given n if she submits a high bid. The expected payoff to investor i is thus her fraction of the IPO initial returns, probability-weighted across different n.

The expected payoff $\hat{U}$ to the same investor from misrepresenting her information by submitting a low bid equals

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

For a given n and s, the offer price is now lower, $p(n-1, s) < p(n, s)$, and the probability of receiving an allocation in the IPO is now $z(b, n) < z(g, n)$. That is, by submitting a low bid, the investor would get a higher return for a given allocation, but at the same time risks getting a smaller (or no) fraction of the shares in the issue.

The payoff $\hat{U}$ is the minimum rent for an investor with a positive private signal and $\hat{U}$ hence represents the reservation value to such an investor.[6] To induce this investor to truthfully reveal her signal, the expected payoff U from bidding high must be equal to or exceed the expected profits $\hat{U}$ from submitting a low bid. The issue must thus be priced and allocated to satisfy the truth-telling (incentive) constraint $U \geq \hat{U}$.

[6] As discussed above, investors with negative private information earn zero informational rents in equilibrium.

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 (firm) is to maximize $E\pi$ with respect to allocations $z(s, n)$ and prices $p(s, n)$ subject to the incentive constraint $U \geq \hat{U}$. Since issuance costs are determined exclusively 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 the investor's truth-telling constraint is satisfied as an equality, $U = \hat{U}$.

The absence of allocation restrictions allows the underwriter to allocate shares only to investors who submit high bids (i.e. report positive private information), regardless of the number of investors submitting high bids. In equilibrium, this allocation rule sets $z(b, n) = 0$ for all $n > 0$. That is, investors reporting a negative signal get a zero allocation as long as at least one investor reports a positive signal. This in turn minimizes the expected gains $\hat{U}$ from hiding a positive signal and thus maximizes the IPO proceeds $E\pi$. In the event that all investors obtain negative signals ($n = 0$), and in equilibrium submit low bids, the issue is allocated pro-rata among the N investors. In other words, the issue is never withdrawn in the low-demand state.[7]

The given allocation rule implies that an investor who submits a low bid receives no shares unless the remaining $N - 1$ investors also submit low bids, in which case each investor is allocated a fraction $1/N$ of the issue. The underwriter further reduces $\hat{U}$ (and hence increases $E\pi$) by not underpricing the issue in the low-demand state; i.e., by setting $p(0, s) = v(0, s)$. The expected payoff to an investor with a positive private signal from submitting a low bid is now

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

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

The expected payoff to an investor with a positive private signal from truthfully

[7] Busaba (2006) shows that it may be optimal to commit to withdraw the issue with a positive probability if demand is low. Busaba, Benveniste, and Guo (2001) find empirically that such a threat reduces underpricing. In our setting, however, it is never optimal to withdraw the issue.

revealing his signal by submitting a high bid is

$$U = \sum_{n=1}^{N} q(n|g_I, s)\frac{1}{n}[v(n, s) - p(n, s)]. \tag{5}$$

The set of prices $p(n, s);\ n = 1, \ldots, N$ that satisfies the investor's incentive constraint $U = \hat{U}$ is indeterminate, since there are N prices to be determined from only one constraint. For tractability and without loss of generality, let the issue be fairly priced (no underpricing), so that $p(n, s) = v(n, s)$ for each $n = 1, \ldots, N - 1$. Now the offer price in the high-demand state, $p(N, s)$, is uniquely determined from $U = \hat{U}$. With $\hat{U} > 0$, it follows that $U > 0$, which requires that $p(N, s) < v(N, s)$. That is, the issue is underpriced in the high-demand state where all investors observe positive private signals.[8]

Since the issue price is set to the firm's aftermarket value $v(n, s)$ in all states where $n < N$, the payoff in these states are zero ($U = 0|n < N$). The expected payoff to an investor with a positive signal of submitting a high bid therefore collapses to the expected payoff in the high-demand state where $n = N$:

$$U = q(N|g_I, s)\frac{1}{N}[v(N, s) - p(N, s)]. \tag{6}$$

The offer price $p(N, s)$ in the high-demand state is determined from the investor's incentive constraint $U = \hat{U}$, which gives

$$p(N, s) = v(N, s) - \frac{q(1|g_I, s)}{q(N|g_I, s)}[v(1, s) - v(0, s)]. \tag{7}$$

Since $v(1, s) > v(0, s)$, the issue is at all times underpriced in the high-demand state, i.e., $p(N, s) < v(N, s)$. With fair pricing in the remaining demand states, the issue is underpriced in expectation.

The initial return associated with the high-demand state is given by

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

[8]The indeterminacy of prices comes from the absence of allocation restrictions, which allows the underwriter to optimally allocate shares only to investors who report positive information (except when all investors submit low bids). In the other extreme, requiring pro-rata allocations to all N investors, it will be strictly optimal to price the issue fairly in all states for which $n < N$ and to underprice the issue only in the high-demand state $n = N$.

Thus, the expected initial return equals

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

which measures the expected underpricing of the issue.

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

3 Public information and underpricing

As shown in Equation (9) above, the expected IPO initial return, $Er(s)$, is the product of the initial return in the high-demand state, $r(N,s)$, and the probability that this state occurs, $q(N|s)$. An key contribution of this paper is the insight that the public signal affects the expected initial return through both $r(N,s)$ and $q(N|s)$. This insight is summarized in our first proposition.

Proposition 1 *(i) The initial return in the high-demand state is negatively related to the public signal s, so that $r(N,g) < r(N,b)$. (ii) The probability of the high-demand state, and hence the probability that the IPO is underpriced, is positively related to the public signal, i.e., $q(N|g) > q(N|b)$.*

A formal proof of proposition 1 is in the Appendix. The public signal affects initial returns in the high-demand state through investors' incentives to truthfully reveal their positive signals. In particular, the likelihood of being allocated shares in the IPO for an investor concealing her positive private information is higher when the public signal is negative, $q(1|g_I,b) > q(1|g_I,g)$.[9] Accordingly, the expected gains from lying are negatively correlated to the public signal and so are investors' incentives to hide favorable information. As a result, the amount of underpricing required by investors to reveal their positive signals is lower when the public outlook is good. We call this mechanism the incentive effect. Contrary to extant evidence of partial adjustment to public information, the incentive effect suggests a negative relationship between public information and underpricing.

[9]Formally, it is required that $q(1|g_I,b)/q(N|g_I,b) > q(1|g_I,g)/q(N|g_I,g)$.

However, the public signal also impacts the probability $q(N|s)$ that there is sufficient demand—that the number of positive signals n is sufficiently high—for the issue to be underpriced. Specifically, positive public information increases the probability that investors obtain favorable private signals and hence submit high bids. We label this mechanism the demand effect. Obviously, a higher probability that investors have favorable private information increases the likelihood that the issue is underpriced in the first place. Thus, through the demand effect, the probability that an issue is underpriced is positively related to the public signal.

The incentive effect and the demand effect have opposite implications for the relationship between public information and underpricing. Proposition 1 therefore allows expected initial returns to be positively or negatively related to the public signal, depending on which of the two effects that dominates. The next proposition shows that as long as the number of investors in the issue is sufficiently large the demand effect will dominate.

Proposition 2 *Whenever the number of investors in the issue, N, is sufficiently large, the demand effect strictly dominates the incentive effect. In this case, initial returns are positively related to public information.*

See the Appendix for a formal proof. As the number of investors in the issue increases, the marginal impact of each investor's signal on the aftermarket value of the firm declines. This reduces the potential payoff, $v(1, s) - v(0, s)$, to the investor of hiding her positive private signal, lowering the amount of underpricing required to induce truthful revelation. In other words, an increase in the number of investors decreases the relative importance of the incentive effect. Once the demand effect strictly dominates, the public signal will be positively related to underpricing. Indeed, Proposition 2 predicts a positive relation between public information and initial returns—consistent with partial adjustment to public information—whenever the number of investors in the issue is sufficiently large.

The result that the incentive effect weakens with the number of investors N is critical to our model. It stems from our assumption that the aftermarket value of the firm represents the expected value of the firm conditional on investors' private signals and the public signal, which in turn ensures that the marginal impact on firm value of each investor's signal declines in N. This result exists in any standard micro structure model where investors' private information is reflected in the stock's price through the trading process.[10] It does not, however, arise in the Benveniste and Spindt (1989) setup where each investor's signal has constant marginal value.

Overall, our model provides a rational explanation for the empirical fact that offer prices adjust only partially to pre-issue market returns. We propose that this partial adjustment is the result of favorable private information and a following high demand for shares in the issue. We further identify a counteracting incentive effect, which produces a negative relationship between public information and underpricing. As long as investor demand in the IPO is sufficiently high, the demand effect will dominate, resulting in a positive correlation between initial returns and market returns.

Table 1 summarizes how the incentive and demand effects play out for different information sets. When private information is negative (low-demand state), there is little need for the underwriter to underprice the issue. In contrast, when investors have positive private information, their expected gains from lying are positive, and higher in bad times than in good times. As a result, conditional on a high-demand state, the level of underpricing will be higher when public information is negative rather than positive.[11] Table 1 further shows that, conditional on negative public information, the probability is higher that investors receive a negative (versus positive) private signal, and vice versa for positive public information. Since the model predicts underpricing only when private information is favorable, this implies that the probability of an issue being underpriced is higher when the public signal is positive. Comparing the relative underpricing and correlations across these different information sets will allow us to empirically test the model, which we turn to next.

4 Empirical tests of the model

4.1 Sample selection and description

We identify 8,498 U.S. IPOs in the period 1970-2008 from the Global New Issues databases in Thompson Financial's SDC. Since the model analyzes the bookbuilding process, we restrict the sample to 6,301 cases with a positive pricing range, i.e. with a

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

[11] In reality, a substantial fraction of IPOs are overpriced. See, e.g., Ruud (1993) and Lowry, Officer, and Schwert (2010).

positive spread between the high and low filing price. Because SDC does not report a filing range prior to 1981, this restriction effectively eliminates all IPOs in the 1970s.

We require firms to have a filing midpoint of at least $5 per share, to be listed in CRSP, and to be traded by the 40th trading day after the public listing on NYSE, AMEX or NASDAQ. All unit offerings, real estate investment trusts (REITs), American depository receipts (ADRs), and closed-end funds are eliminated. We further require the IPO firm to have a founding year in the Field-Ritter founding dataset and a lead underwriter rank in the Ritter underwriter ranking dataset. Both these databases are from Jay Ritter's webpage at the University of Florida. Our final dataset consists of 5,093 IPOs in 1981-2008, all of which have a complete set of control variables.

Table 2 reports the number of cases, and the average first-day return and market return by year. Two-thirds of the sample firms go public in the 1990s, one quarter in the 2000s and one tenth in the 1980s. Column 3 shows the first-day return $IR1 = p_1/p_0 - 1$, where p_1 is the firm's closing price on the first day of trading and p_0 is the final offer price. To curb extreme outliers, we winsorize $IR1$ at 200%. All stock price data is from CRSP. If there is no trade on a given day, we use the midpoint of the bid-ask spread. The average one-day return is 19% and varies substantially over time. The largest underpricing takes place in the years 1999 and 2000, with a mean first-day return of 63% and 54%, respectively. In contrast, the average $IR1$ never exceeds 6% in any one year during the 1984-1989 period. In the empirical analysis below, we use the first-day return ($IR1$) as a proxy for the underpricing of the offering.

The next three columns of Table 2 show the return on the S&P500 index over the 45 trading days preceding the IPO issue date ($SP500$), and the proportion of IPOs that take place in positive ($SP500 > 0$) and negative ($SP500 \leq 0$) market conditions, respectively. The average pre-issue market return is 2.7% and three-quarters of the sample IPOs are issues in bull markets. Interestingly, also in the years 1998-2000, at least one quarter of the issues (ranging from 21%-42% per year) take place in a downmarket. In the following, we use the S&P500 45-day return as a proxy for the public information that reaches investors during the bookbuilding period. We choose a 45-day window to match the number of trading days in the registration period for a typical IPO in our sample.

4.2 Univariate analysis

In the model, the expected underpricing depends on the relative size of the two counteracting effects of public information on investors' incentives and their demand for allocations. On the one hand, when public information is negative, underwriters must underprice the issue more in order to induce investors to reveal their positive private information (the incentive effect). On the other hand, since public and private signals are conditionally correlated, the demand for shares in the IPO—and thus the likelihood that the issue is underpriced—is lower when publicly available information is negative (the demand effect). These two effects imply several empirical patterns. First, for a given increase in private information, we should observe more underpricing in downmarkets than in upmarkets. Second, when public information is positive, investors are more likely to also have favorable private information and the proportion underpriced offerings should be higher. In the following, we test these predictions in several different ways. We start by examining the univariate differences in underpricing across various information sets.

Testing the model requires a measure for private information. Since private information in itself is unobservable, we follow Hanley (1993) and turn to the outcome of the bookbuilding process. As discussed above, the objective of this process is to uncover investors' private information. Any revision in the final offer price from the indicated price in the initial filing range will—at least partly—reflect new information revealed by investors to the underwriter during the road show. We define the price update as $PU = p_0/p_{mid} - 1$, where p_{mid} is the filing range midpoint. Using PU as a proxy for private information assumes that all information reflected in the price update is private, also if it overlaps with concurrent public information.

Table 3 reports the average initial return (IR1) split by positive ($SP500 > 0$) and negative ($SP500 \leq 0$) public information, respectively. Variable definitions and data sources are shown in Table 4. In Panel A of table 3, the sample is further split by the sign of the price update (positive, zero, and negative). Interestingly, the univariate results for different information sets are consistent with the empirical patterns predicted by the model. When private information is bad ($PU < 0$), the level of underpricing is relatively small, with average initial returns of 5% in upmarkets and 4% in downmarkets. Consistent with Benveniste and Spindt (1989), the level of underpricing is much higher when private information is good ($PU > 0$). Unique to our model predictions, however, the average underpricing conditional on positive private information is particularly high when the issue takes place in a downmarket ($IR1 = 42\%$) compared to in an upmarket ($IR1 = 35\%$). Also, when public information is positive ($SP500 > 0$), a higher fraction of the issues involve positive rather than negative private information (48% vs. 40%), while the opposite holds when public markets are down (33% IPOs with a positive vs. 55% IPOs with a negative price update).

As pointed out above, the final revision of the offer price (PU) accounts for broadly available information that reaches the market during the registration period. To isolate information that is truly private, we compute a measure for investors' private information, $Private$, that purges the content of market-wide information from the offer price revision. Specifically, $Private$ is the residual from the regression $PU = \beta * SP500 + \epsilon$. In other words, $Private$ is any information in the price revision above and beyond what can easily be inferred from the public markets. It is the result of the extreme view that nothing but information in the price update that *cannot* be attributed to the public signal is considered to be private.[12]

For a total of 616 cases, the final offer price equals the mid-point of the offer range, so that $PU = 0$. It is difficult to know if the absence of a price revision is because any new information revealed during the bookbuilding process is marginal, or if the private information is perfectly offset by public information that reaches the market over the same time period. In any event, our estimation of $Private$ mechanically forces a negative correlation between $SP500$ and the private information variable for issues with no revision in the final offer price. In the empirical analysis below, we characterize these cases as bookbuilding processes that fail to generate any new private information, and thus set $Private$ to zero when $PU = 0$. For robustness, we also run all regressions (i) eliminating the 616 cases where $PU = 0$, (ii) using the original residual also when $PU = 0$, and (iii) using PU as a proxy for private information. While not reported in the paper, all results remain the same for any of these alternative proxies for private information.[13] Panel B of table 3 shows the average first-day return split by the sign of $Private$. Interestingly, this split generates initial return averages that closely map the

[12]Although the price revision has been shown to vary with other offer characteristics (e.g. stock exchange, total proceeds raised, underwriter rank, etc.), these characteristics are known already at the beginning of the bookbuilding process and therefore do not represent new information in our setting.

[13]The exception is the second definition, which mechanically forces a negative correlation between private and public information when $PU = 0$, and hence produces a negative sign on the coefficient for $SP500$ in the probit regressions reported in Table 7 below. All regression results are available from the authors on request.

ones reported for PU in Panel A.

As in Benveniste and Spindt (1989), our model predicts underpricing only when investor demand is high. We therefore create three dummy variables that indicate whether or not the final offer price is set outside the initial filing range. The high-demand state (HDS) represents IPOs where the offer price is on or above the upper bound of the filing range. Similarly, the low-demand state (LDS) indicates bookbuilding processes that yield an offer price on or below the lower bound of the filing range. Finally, the medium-demand state (MDS) indicates that the final offer price is within the initial filing range.

Panel C of Table 3 shows the average first-day returns across the three demand states. A similar pattern as for PU and $Private$ emerges. Again, the average first-day return is marginal (4%-5%) in the low-demand state, and higher in the high-demand state when the S&P500 return is negative (48%) vs. positive (38%). Also, most offerings (48%) are in LDS when markets are down, while most offerings (42%) are in HDS when markets are up. Overall, the predictions of the model seem to hold in the univariate across our different proxies for private information. We next test if the incentive and demand effects also hold in the cross-section.

4.3 Tests of the incentive effect

When the private signal is negative, investors have little incentive to hide their information. In contrast, in order to persuade investors to reveal positive private information, underwriters have to underprice the offering. A novel and central prediction of our model is that investors require more underpricing to reveal their private signal in downmarkets than in upmarkets. We test this prediction by regressing the initial return ($IR1$) on our proxy for private information ($Private$), split by different public information sets. The first regression specification is:

$$IR1 = \alpha + \beta_1 \; Private * SP500_{POS} + \beta_2 Private * SP500_{NEG} + \beta_3 SP500_{POS} + e. \quad (10)$$

$SP500_{POS}$ and $SP500_{NEG}$ are two mutually exclusive dummy variables. The variable $SP500_{POS}$ takes the value of one if the 45-day pre-issue market return is positive ($SP500 > 0$) and $SP500_{NEG} = 1$ if $SP500 \leq 0$. The interaction variables $Private * SP500_{POS}$ and $Private * SP500_{NEG}$ hence capture the effect of private information on underpricing when public information is positive and negative, respectively. Our model predicts that $\beta_1 < \beta_2$. We further include the dummy $SP500_{POS}$ separately to allow for the two interaction variables to have different intercepts.

The second regression specification is:

$$IR1 = \gamma + \delta_1 Private + \delta_2 Private * SP500_{POS} + \delta_3 SP500_{POS} + u. \tag{11}$$

This equation provides a direct test of whether the two coefficients β_1 and β_2 are different from each other. Specifically, the coefficient δ_2 for $Private * SP500_{POS}$ is such that $\delta_2 = \beta_1 - \beta_2$, and we predict $\delta_2 < 0$.[14]

The coefficient estimates from ordinary least squares (OLS) estimations of the initial return are shown in Table 5. The t-statistics reported in parenthesis use White (1980) heteroscedasticity-consistent standard errors. The first regression simply verifies that prior findings of partial adjustment to private and public information also hold in our sample. If the final offer price is fully adjusted to information revealed during the registration period, our information variables should be uncorrelated to the first-day return. As shown in column (1), however, the coefficient on $Private$ is positive and highly significant (p-value <0.001). That is, the final offer price is only partially adjusted for private information revealed during the bookbuilding process, consistent with the Benveniste and Spindt (1989) model. Moreover, by including both $SP500$ and $SP500_{POS}$, we follow Lowry and Schwert (2004) and allow for the partial adjustment to be asymmetric with respect to positive and negative public information. The coefficient for $SP500$ is positive and significant, consistent with the standard result of partial adjustment to public information. The coefficient for $SP500_{POS}$, however, is marginal and of a much smaller magnitude, suggesting that the effect of public information on initial returns largely is symmetric.

The next two regressions use the specifications presented in equations (10) and (11), respectively. As shown in columns (2) and (3), the coefficients for $Private * SP500_{POS}$ and $Private * SP500_{NEG}$ are $\beta_1 = 0.89$ and $\beta_2 = 1.08$, respectively, both highly significant from zero. Moreover, the difference between the two coefficients, δ_2, is negative with

[14]To see why, note that equation (11) can be rewritten as

$$IR1 = \gamma + \delta_1 Private * (SP500_{POS} + SP500_{NEG}) + \delta_2 Private * SP500_{POS} + \delta_3 SP500_{POS} + u, \text{ or}$$

$$IR1 = \gamma + (\delta_1 + \delta_2) Private * SP500_{POS} + \delta_1 Private * SP500_{NEG} + \delta_3 SP500_{POS} + u.$$

Compare this with equation (10) and it is obvious that $\delta_1 + \delta_2 = \beta_1$ and $\delta_1 = \beta_2$, such that $\delta_2 = \beta_1 - \beta_2$.

a p-value < 0.01. This result is consistent with the notion that investors require more underpricing in downmarkets than in upmarkets to reveal a given amount of private information, as predicted by the model.

The last three columns of table 5 add other characteristics of the offering that have previously been shown to affect IPO initial returns. These control variables include the logarithm of the number of years since the firm was founded (Age), the logarithm of the total $ proceeds raised in the IPO ($Proceeds$), the logarithm of the total number of shares sold in the issue ($Shares$), and the average rank of the lead underwriter ($Rank$). Underwriters are ranked on a scale from 0 to 9, where a higher number imply higher underwriter quality. We further add dummy variables indicating that the firm is in a high-tech industry ($HighTech$), is listed on the New York Stock Exchange ($NYSE$) or NASDAQ ($NASDAQ$), and that the IPO takes place in the period 9/1998-8/2000 ($Bubble$), respectively.

Many of the control variables produce significant coefficients. The initial returns are decreasing in firm age and the $ proceeds raised in the IPO, and increasing in the number of shares offered and the average rank of the lead underwriter. Moreover, first-day returns tend to be higher for high-tech firms and offerings during the bubble period. Importantly, the empirical predictions of our model hold also when including control variables in the regressions. As reported in columns (5) and (6), the coefficients $\beta_1 = 0.79$ and $\beta_2 = 0.94$ are both still positive and highly significant. Also, $\beta_1 < \beta_2$, with the difference being significantly different from zero at the 5%-level.[15] In sum, the data supports the existence of our incentive effect.

One implication of the model is that underpricing is required only in the high-demand state—and not in the low-demand state—in order to induce investors to truthfully reveal their private information. As a further test of the incentive effect, we examine the impact of the interaction variables $Private * SP500_{POS}$ and $Private * SP00_{NEG}$ on $IR1$ separately for the different demand states: high, medium and low. The results from OLS regressions with the first-day underpricing as dependent variable are presented in table 6. As before, the t-statistics (in parenthesis) use White (1980) heteroscedasticity-consistent standard errors. All regressions include the full set of controls discussed above. While not shown in the table for expositional purposes, all the control variables receive coefficients of similar magnitude and significance as in Table 5.

[15]The regressions produce a two-sided t-test of the difference, while the model in fact only requires a one-sided t-test of the difference, effectively doubling the significance of the test.

The first column of Table 6 shows how the first-day return varies across different demand states and with private information. The initial returns tend to be lowest in the low-demand state, with a coefficient for LDS of -0.05 and highest in the high-demand state, with a coefficient for HDS of 0.05, both significant at the 0.1%-level (relative to the medium-demand state). Moreover, the change in the first-day return for a given change in private information is highest in the high-demand state (the coefficient for $Private * HDS$ is 1.06 and highly significant); intermediate in the medium-demand state (the coefficient for $Private * MDS$ is 0.44 with a p-value< 0.001); and insignificant from zero in the low-demand state. As shown in column (2), these three coefficients are significantly different from each other ($p < 0.001$). This suggests that the compensation investors require for truthfully disclosing their private information is highest in the high-demand state and close to zero in the low-demand state, as predicted by the model.

The remaining two columns of Table 6 examine the coefficient for $Private$ conditional on positive and negative public information, respectively, and across the low- and high-demand states. From columns (3) and (4), the coefficient for $Private * HDS$ is significantly smaller in upmarkets than in downmarkets (0.99 vs. 1.32, and different at the 1%-level), while the coefficient for $Private * LDS$ is close to zero and insignificantly different across the two public information sets (i.e., the two coefficients for $Private * LDS * SP500_{POS}$ and $Private * LDS * SP500_{NEG}$ are not significantly different).[16] To sum up, the regression results suggest that the underpricing compensating investors for private information is largely associated with the high-demand state.

Overall, the regression results support the existence of the incentive effect as predicted by the model. Investors' incentives to reveal their private information—and therefore the required level of underpricing—depends on nature of the public information. Specifically, investors require less compensation to disclose favorable private signals when market-wide prospects are optimistic than when the public outlook is poor. Having empirically established the existence of the incentive effect in the data, we now turn to tests of the effects of private and public information on investors' demand for shares.

[16]Cornelli, Goldreich, and Ljungqvist (2006) find that grey-market trading by individual investors on a forward (when-issued) basis is informative for the aftermarket price only when demand is high (versus low).

4.4 Tests of the demand effect

In general, investors' demand for IPO allocations depends on their private information: the better the private signal, the higher demand for shares in the IPO. In our model, the demand effect stems from the positive conditional correlation between public and private information, based on the assumption that public and private signals both are informative. Given positive public information, it is likely that the private signal also is favorable. This is the first implication of the demand effect that we test. Moreover, given the higher likelihood that investors have positive private signals, their demand and thus the proportion underpriced IPOs should be higher when public information is positive rather than negative. This is the second implication of the demand effect that we test.

Table 7 shows the coefficient estimates from probit regressions for the probability that the private information revealed during the bookbuilding process is positive versus negative ($Private_{POS}$). As discussed above, the model predicts that public and private information are positively correlated. This prediction is borne out in the data. As shown in columns (1) and (2), the coefficient is positive and highly significant ($p<0.001$) both for the continuous variable $SP500$ and the dummy variable $SP500_{POS}$. Thus, although $Private$ by construction is orthogonal to $SP500$ with respect to the final revision of the offer price (PU), $Private$ is still positively correlated to the public information ($SP500$), as predicted by the model. When including both market return variables at the same time in column (3), only the coefficient for $SP500_{POS}$ is significant, suggesting that it is the direction of the public information more than its magnitude that matters for the sign of the private signal.

The effect of public information on the likelihood of positive private information seems robust. In particular, the addition of control variables do no affect the sign or significance of the coefficients for $SP500$ or $SP500_{POS}$, as shown in columns (4)-(6). The probability for positive private information is decreasing in firm age, the number of shares offered, and the lead underwriter rank, and increasing in the size of the proceeds raised in the offering. Moreover, high-tech firms and IPOs during the bubble years tend to be associated with the revelation of positive private information.

In Table 8, we report the coefficients from probit regressions estimating the probability that the IPO is in a high-demand state and a low-demand state, respectively. Recall that, in the model, all investors must have positive private signals in order for the high-demand state to occur. Thus, the high-demand state can be viewed as a more coarse—and therefore more robust—proxy for issues with positive private information. Columns (1)-(4) reports the results from probit regressions where the high-demand state indicator (HDS) is the dependent variable. All coefficient estimates and significance levels are qualitatively the same as in the regressions for positive private information reported in Table 7 above. Specifically, the probability of pricing an issue above the filing range (HDS) is higher in upmarkets and increases with the size of the market return. As expected, the opposite results are obtained when a dummy for the low-demand state (LDS) is the dependent variable, as shown in columns (5)-(8). Here, the probability for an issue to be priced below its filing range is lower in upmarkets and decreases with the return on the market index during the registration period.

We next test the effect of public information on the likelihood that the first-day return is positive. Table 9 reports the coefficient estimates from probit regressions of the determinants of a positive (versus negative) first-day return ($IR1_{POS}$). Again, and as predicted by the model, the coefficients for $SP500$ and $SP500_{POS}$ are positive and significant at the 0.1%-level. The higher the pre-issue market return, the more likely is the initial return to be positive. Moreover, when including $SP500$ and $SP500_{POS}$ at the same time, reported in column (3), both variables produce positive and significant coefficients, suggesting that the effect is asymmetric across positive and negative market returns. In other words, the likelihood of a positive first-day return increases with the pre-issue market return, and in particular so when the market-wide return is positive.

While public information helps predict the occurrence of underpricing, the variable $Private$ also produces a positive and significant coefficient ($p<0.001$). That is, the more favorable the private information, the more likely is the offer to have a positive first-day return. This result is robust across all six regression specifications. Finally, columns (4)-(6) add our standard control variables. As shown in the table, the probability that the first-day return is positive decreases with the size of the offering ($Proceeds$) and is higher the more shares that are issued ($Shares$) and for firms listed on NASDAQ and NYSE (versus AMEX).

Overall, our tests support the existence of the incentive effect as well as the demand effect. Our model is interesting because it provides a rational explanation for partial adjustment of the offer price to public information. The novel mechanism is the incentive effect, which ties the sign of public information to investors' incentives to reveal their positive private signals. As predicted by the model, and played out in the data, investors receive more compensation for positive private information in downmarkets than in upmarkets. Moreover, the counteracting demand effect, implying a higher probability of positive private information and hence underpricing in bull markets than in bear markets, also receives strong support by the data. Combined, these two effects—and the way public information affects investors' incentives to disclose private information—can help explain the partial adjustment to public information that has been observed by many.

5 Summary

This paper presents a model that explains the relationship between public information and IPO initial returns. Building on the framework of Benveniste and Spindt (1989), where investors are compensated with underpriced shares for disclosing private information, we show that publicly available information is related to IPO underpricing through two different mechanisms.

First, and unique to our model, market-wide information affects the underpricing required for investors to reveal their positive private signal. When the public outlook is negative, the expected profits from hiding favorable private information is higher. Accordingly, investors require a higher compensation—in the form of more underpricing—to disclose good news when public information is bad. This is the incentive effect.

Second, because public and private signals are informative, they are also conditionally correlated. That is, the probability of receiving a good private signal given a positive market outlook is higher than if the market outlook is poor. Consequently, investors are more likely to have positive signals—which is necessary for the issue to be underpriced in the first place—in upmarkets than in downmarkets. As a result, the probability that an issue is underpriced is higher when public information is positive. This is the demand effect.

Whether underpricing ultimately is positively or negatively related to public information depends on which of the two effects dominates. If the number of investors in the offering is sufficiently large, the demand effect will dominate and initial IPO returns will be increasing in pre-issue market returns. Our model thus allows for the possibility of either under- or over adjustment to public information in the offer price.

We test the predictions of the model for a sample of 5,000 U.S. IPOs in 1981-2008. As a proxy for private information, we use the residual from an OLS regression of the final offer price revision on the pre-issue market returns. This purges any effect of market-wide information from the price revision, attributing the remaining change to investors' private signals.

In cross-sectional tests, we show that for a given change in private information, initial returns change more in downmarkets than in upmarkets. In other words, investors' private information is more completely incorporated into the IPO price when the pre-issue market-wide returns are positive rather than negative. This effect is particularly pronounced for issues that are priced above the filing range and largely absent in issues that are priced below the filing range. This is consistent with the incentive effect.

We also find a positive correlation between public and private information—despite the orthogonalization procedure described above—and between public information and the probability that the issue is priced above its initial filing range, as well as a positive correlation between market returns and the probability of a positive first-day return. This is all consistent with the demand affect.

Our model provides a rational explanation for partial adjustment in the offer price to public information, as observed by many others. One potential extension is to explore the mechanisms that determine the relative strengths of the demand and the incentive effects. Another extension is to develop the model's predictions with respect to the volatility of initial returns and examine how return volatility is affected by market conditions. Both extensions will help us better understand the larger mechanisms behind IPO pricing and allocations.

A Appendix

Proof of Proposition 1.

(i) The initial return associated with the high-demand state equals

$$r(N,s) = \frac{v(N,s)}{p(N,s)} - 1; s = \{b,g\}, \tag{12}$$

where

$$p(N,s) = v(N,s) - \frac{q(1,g_I,s)}{q(N,g_I,s)}\left[v(1,s) - v(0,s)\right]. \tag{13}$$

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

$$\frac{v(N,g)}{p(N,g)} \leq \frac{v(N,b)}{p(N,b)}, \tag{14}$$

which is equivalent to

$$\frac{q(N,g_I,g)v(N,g)}{q(N,g_I,b)v(N,b)} \geq \frac{q(1,g_I,g)}{q(1,g_I,b)}\frac{[v(1,g)-v(0,g)]}{[v(1,b)-v(0,b)]} \tag{15}$$

Using Bayes rule and rearranging, this inequality may be written

$$1 \geq \frac{\gamma - (1-\gamma)\Xi}{\gamma - (1-\gamma)\Theta}, \tag{16}$$

where

$$\Xi = \frac{(1-\gamma)^{N-1}\gamma f\alpha + \gamma^{N-1}(1-\gamma)(1-f)(1-\alpha)}{(1-\gamma)^N f\alpha + \gamma^N(1-f)(1-\alpha)} \tag{17}$$

and

$$\Theta = \frac{(1-\gamma)^{N-1}\gamma(1-f)\alpha + \gamma^{N-1}f(1-\alpha)}{(1-\gamma)^N(1-f)\alpha + \gamma^N f(1-\alpha)} \tag{18}$$

To prove the proposition, we need to show that $\Xi - \Theta \geq 0$. To see that this inequality is satisfied, note that $\Xi - \Theta$ can be rearranged so that

$$\Xi - \Theta = \frac{\alpha(1-\alpha)(2f-1)[(1-\gamma)^{N-1}\gamma^{N+1} - \gamma^{N-1}(1-\gamma)^N + \gamma^N(1-\gamma)^N]}{[(1-\gamma)^N f\alpha + \gamma^N(1-f)(1-\alpha)]\left[(1-\gamma)^N(1-f)\alpha + \gamma^N f(1-\alpha)\right]} \tag{19}$$

$$= \frac{\alpha(1-\alpha)(2f-1)(1-\gamma)^{N-1}\gamma^{N-1}(2\gamma-1)}{[(1-\gamma)^N f\alpha + \gamma^N(1-f)(1-\alpha)]\left[(1-\gamma)^N(1-f)\alpha + \gamma^N f(1-\alpha)\right]}, \tag{20}$$

which is strictly positive since $f, \gamma > 1/2$.

(ii) By Bayes' rule it follows that

$$q(N|g) = \frac{\gamma^N f\alpha + (1-\gamma^N)(1-f)(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \tag{21}$$

and

$$q(N|b) = \frac{\gamma^N (1-f)\alpha + (1-\gamma^N) f(1-\alpha)}{(1-f)\alpha + f(1-\alpha)} \tag{22}$$

The difference between the two may be written

$$q(N|g) - q(N|b) = \frac{\alpha(1-\alpha)(2f-1)[\gamma^N - (1-\gamma)^N]}{[1-\alpha(1-f)-(1-\alpha)f][\alpha(1-f)+f(1-\alpha)]}, \tag{23}$$

which is strictly greater than zero. ■

Proof of Proposition 2.

The proposition is proved by showing that

$$\lim_{N\to\infty} \frac{Er(g)}{Er(b)} > 1 \tag{24}$$

By Bayes' rule and straightforward algebra it follows that

$$\frac{Er(g)}{Er(b)} = \frac{(1-f)\alpha + f(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \times \frac{f\alpha + (\frac{1-\gamma}{\gamma})^N (1-f)(1-\alpha)}{(1-f)\alpha + (\frac{1-\gamma}{\gamma})^N f(1-\alpha)} \times A, \tag{25}$$

where

$$A = \frac{(1-f)\alpha\Big[\Big(\frac{1-\gamma}{\gamma}\Big)^N (1-f)\alpha + f(1-\alpha)\Big] - f(1-f)\alpha(1-\alpha)\frac{1}{\gamma}\Big(\frac{1-\gamma}{\gamma}\Big)^{N-1}(2\gamma-1)}{f\alpha\Big[\Big(\frac{1-\gamma}{\gamma}\Big)^N f\alpha + (1-f)(1-\alpha)\Big] - f(1-f)\alpha(1-\alpha)\frac{1}{\gamma}\Big(\frac{1-\gamma}{\gamma}\Big)^{N-1}(2\gamma-1)} \tag{26}$$

Recalling that $\gamma > 1/2$ and hence that $\frac{1-\gamma}{\gamma} < 1$ it follows that

$$\lim_{N\to\infty} \frac{Er(g)}{Er(b)} = \frac{(1-f)\alpha + f(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \times \frac{f}{1-f}. \tag{27}$$

It is now straightforward to show that the right hand side of (29) is strictly greater than one, which completes the proof. ■

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Table 1: **Mechanism, conditional probability and underpricing across different information sets**

The table shows the intuition for the mechanism generating underpricing (or no underpricing), the conditional probability for the private signal and the required underpricing across different information sets with respect to positive/negative public information and positive/negative private information, respectively.

Public information	**Private information**	**Demand state**	**Mechanism**	**Intuition of the mechanism**	**Under-pricing**
Positive	Positive	High	Incentive effect	Investors are less likely to be allocated shares in the IPO if positive private information is concealed $\Longrightarrow$ less compensation required for truthful revelation of the private signal	Yes (less)
			Demand effect	Probability of positive private signal is greater than if public information is negative	
	Negative	Low	Incentive effect	No incentive to hide negative private information	No
			Demand effect	Probability of negative private signal is smaller than if public information is negative	
Negative	Positive	High	Incentive effect	Investors are more likely to be allocated shares in the IPO if positive private information is concealed $\Longrightarrow$ more compensation required for truthful revelation of the private signal	Yes (more)
			Demand effect	Probability of positive private signal is smaller than if public information is positive	
	Negative	Low	Incentive effect	No incentive to hide negative private information	No
			Demand effect	Probability of negative private signal is greater than if public information is positive	

Table 2: **Sample return characteristics by year**

The table shows the annual distribution of the sample of 5,093 U.S. IPOs in 1981-2008, and the average first-day return and stock market return by year. The first-day 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%. The return on the S&P500 index ($SP500$) is measured over the 45 trading days preceding the issue. Market conditions report the proportion of IPOs that take place in a positive market ($SP500 > 0$) and negative market ($SP500 \leq 0$), respectively.

Listing year	Sample size (N)	First-day return (IR1)	S&P500 return (SP500)	Market conditions: proportion positive	proportion negative
1981	4	3.9%	-1.5%	50.0%	50.0%
1982	1	4.7%	1.6%	100.0%	0.0 %
1983	14	11.1%	2.5%	71.4%	28.6%
1984	10	2.0%	1.9%	40.0%	60.0%
1985	46	5.4%	4.0%	78.3%	21.7%
1986	207	4.1%	2.6%	70.0%	30.0%
1987	194	5.6%	6.3%	88.7%	11.3%
1988	72	4.8%	2.0%	63.9%	36.1%
1989	58	5.7%	4.4%	72.4%	27.6%
1990	69	9.2%	0.3%	60.9%	39.1%
1991	226	10.9%	1.4%	58.4%	41.6%
1992	305	9.0%	2.1%	66.6%	33.4%
1993	417	11.6%	1.4%	82.5%	17.5%
1994	324	8.7%	-0.6%	45.1%	54.9%
1995	359	20.5%	5.1%	99.7%	0.3%
1996	571	15.9%	4.1%	82.1%	17.9%
1997	381	14.2%	5.3%	83.7%	16.3%
1998	256	20.8%	5.4%	78.9%	21.1%
1999	421	63.4%	2.5%	73.2%	26.8%
2000	323	53.8%	0.2%	57.9%	42.1%
2001	68	14.6%	0.2%	48.5%	51.5%
2002	49	8.0%	-3.8%	26.5%	73.5%
2003	53	12.7%	4.1%	92.5%	7.5%
2004	162	12.2%	1.7%	64.2%	35.8%
2005	162	11.7%	1.2%	65.4%	34.6%
2006	168	11.4%	2.5%	81.0%	19.0%
2007	157	13.3%	2.0%	66.2%	33.8%
2008	16	2.4%	-3.3%	50.0%	50.0%
Total	5,093	19.2%	2.7%	73.1%	26.9%

Table 3: **First-day returns split by positive and negative information**

The table shows the average first-day return, split by positive and negative public information ($SP500$), respectively. The first-day 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%. The table shows a further split by the sign of the final revision of the offer price (PU, Panel A), the price update residual ($Private$, Panel B), and the demand state ($HDS/MDS/LDS$, Panel C). All variables are defined in Table 4. The sample is 5,093 U.S. IPOs, 1981-2008.

Panel A: Price update (PU)

Public information:	Positive ($SP500 > 0$)			Negative ($SP500 \leq 0$)		
Price update:	Positive	Zero	Negative	Positive	Zero	Negative
First-day return (IR1)	34.7%	11.0%	4.6%	42.4%	12.1%	3.5%
Number of cases, N	1788	448	1485	455	168	749
Percent of cases	48%	12%	40%	33%	12%	55%

Panel B: Price update residual ($Private$)

Public information:	Positive ($SP500 > 0$)			Negative ($SP500 \leq 0$)		
Private information:	Positive	Zero	Negative	Positive	Zero	Negative
First-day return (IR1)	35.5%	11.0%	4.9%	41.5%	12.1%	3.5%
Number of cases, N	1724	448	1549	466	168	738
Percent of cases	46%	12%	42%	34%	12%	54%

Panel C: Demand state ($HDS/MDS/LDS$)

Public information:	Positive ($SP500 > 0$)			Negative ($SP500 \leq 0$)		
Demand state:	High	Medium	Low	High	Medium	Low
First-day return (IR1)	37.9%	9.4%	4.5%	47.5%	9.0%	3.5%
Number of cases, N	1577	880	1264	396	320	656
Percent of cases	42%	24%	34%	29%	23%	48%

Table 4: **Variable definitions**

The table shows names and definitions of, and sources for, the variables used in the analysis. Jay Ritter refers to his webpage at the University of Florida. p_0 is the final offer price.

Name	Definition	Sources
A: Variables critical for testing the model		
$IR1$	One-day initial return, defined as $IR1 = p_1/p_0 - 1$, where p_1 is the firm's closing price on the first trading day, winsorized at 200%. Proxy for underpricing.	SDC, CRSP
$SP500$	Return on the S&P500 index over the 45 trading days preceding the offer (the book building period). Proxy for public information.	CRSP
PU	Revision in the final offer price from the initial filing range midpoint (price update), defined as $PU = p_0/p_{mid} - 1$, where p_{mid} is the midpoint of the filing range.	SDC
$Private$	The residual (ϵ) from the regression of the price update on the S&P500 return: $PU = \beta * SP500 + \epsilon$, and set to zero when $PU = 0$. Proxy for private information.	SDC, CRSP
$_{POS}$, $_{NEG}$	The subscript $_{POS}$ and $_{NEG}$ indicate a dummy taking the value of one if the variable is positive and non-positive, respectively.	
HDS	Dummy indicating that the final offer price is above the initial filing range (high demand state), defined as $p_0 \geq p_H$, where p_H is the upper bound of the filing range.	SDC
LDS	Dummy indicating that the final offer price is below the initial filing range (low demand state), defined as $p_0 \leq p_L$, where p_L is the lower bound of the filing range.	SDC
MDS	Dummy indicating that the final offer price is within the initial filing range (medium demand state), defined as $p_L < p_0 < p_H$, where p_L and p_H are the lower and upper bound, respectively, of the filing range.	SDC
B: Control variables		
Age	Log of firm age since the founding year.	Jay Ritter
$Proceeds$	Log of total $ proceeds raised in the IPO.	SDC
$Shares$	Log of total number of shares sold in the IPO.	SDC
$Rank$	Average rank of the lead underwriter.	Jay Ritter
$HighTech$	Dummy indicating that the IPO is done by a high-technology firm.	SDC
$Bubble$	Dummy indicating that the IPO took place in the period 9/1998-8/2000.	SDC
$NASDAQ$	Dummy indicating that the firm lists on NASDAQ.	CRSP
$NYSE$	Dummy indicating that the firm lists on New York Stock Exchange.	CRSP

Table 5: **Tests of the incentive effect (I)**

Tests of the incentive effect using OLS regressions. The dependent variable is the first-day return ($IR1$). All variables are defined in Table 4. The t-statistics (in parenthesis) use White's (1980) heteroscedasticity-consistent standard errors. +, *, **, and *** denotes significance at the 10%, 5%, 1%, and 0.01% level, respectively. The sample is 5,093 U.S. IPOs in 1981-2008.

	(1)	(2)	(3)	(4)	(5)	(6)
$Private$	0.939***		1.082***	0.829***		0.943***
	(28.93)		(17.47)	(24.98)		(17.08)
$Private * SP500_{POS}$		0.890***	-0.192**		0.793***	-0.150*
		(23.98)	(-2.66)		(21.63)	(-2.42)
$Private * SP500_{NEG}$		1.082***			0.943***	
		(17.47)			(17.08)	
$SP500_{POS}$	-0.0236+	-0.0277*	-0.0277*	-0.0225*	-0.0256*	-0.0256*
	(-1.93)	(-2.15)	(-2.15)	(-2.04)	(-2.22)	(-2.22)
$SP500$	0.339**	0.351**	0.351**	0.404***	0.415***	0.415***
	(2.74)	(2.85)	(2.85)	(3.70)	(3.80)	(3.80)
Age				-0.0120***	-0.0119***	-0.0119***
				(-4.50)	(-4.47)	(-4.47)
$Proceeds$				-0.0529**	-0.0558***	-0.0558***
				(-3.24)	(-3.46)	(-3.46)
$Shares$				0.0525**	0.0559**	0.0559**
				(2.73)	(2.95)	(2.95)
$Rank$				0.00331*	0.00339**	0.00339**
				(2.57)	(2.63)	(2.63)
$HighTech$				0.0434***	0.0446***	0.0446***
				(6.56)	(6.70)	(6.70)
$Bubble$				0.324***	0.321***	0.321***
				(15.91)	(15.82)	(15.82)
$NASDAQ$				0.0239+	0.0230	0.0230
				(1.71)	(1.63)	(1.63)
$NYSE$				-0.00983	-0.0101	-0.0101
				(-0.62)	(-0.63)	(-0.63)
$Constant$	0.205***	0.209***	0.209***	0.261***	0.262***	0.262***
	(23.88)	(22.66)	(22.66)	(4.20)	(4.21)	(4.21)
Adjusted R^2	0.364	0.367	0.367	0.487	0.488	0.488

Table 6: **Tests of the incentive effect (II)**

Tests of the incentive effect using OLS regressions. The dependent variable is the first-day return ($IR1$). All variables are defined in Table 4. The control variables (not shown here) are the same as in table 5. The t-statistics (in parenthesis) use White's (1980) heteroscedasticity-consistent standard errors. +, *, **, and *** denotes significance at the 10%, 5%, 1%, and 0.01% level, respectively. The sample is 5,093 U.S. IPOs in 1981-2008.

	(1)	(2)	(3)	(4)
$Private$		0.443***		
		(4.36)		
$Private * HDS$	1.056***	0.612***		1.317***
	(14.59)	(5.04)		(11.59)
$Private * MDS$	0.443***		0.503***	0.503***
	(4.36)		(4.98)	(4.98)
$Private * LDS$	0.0543	-0.389***		0.0270
	(1.42)	(-3.76)		(0.52)
$Private * HDS * SP500_{POS}$			0.987***	-0.329**
			(13.04)	(-2.72)
$Private * HDS * SP500_{NEG}$			1.317***	
			(11.59)	
$Private * LDS * SP500_{POS}$			0.0867*	0.0597
			(2.05)	(1.09)
$Private * LDS * SP500_{NEG}$			0.0270	
			(0.52)	
HDS	0.0484***	0.0484***	0.0449***	0.0449***
	(3.84)	(3.84)	(3.67)	(3.67)
LDS	-0.0521***	-0.0521***	-0.0481***	-0.0481***
	(-6.22)	(-6.22)	(-5.75)	(-5.75)
$SP500_{POS}$	-0.0240*	-0.0240*	0.00298	0.00298
	(-2.26)	(-2.26)	(0.22)	(0.22)
$SP500$	0.314**	0.314**	0.337**	0.337**
	(2.89)	(2.89)	(3.12)	(3.12)
Control variables:	Yes	Yes	Yes	Yes
Adjusted R^2	0.525	0.525	0.529	0.529

Table 7: **Tests of the demand effect (I)**

Tests of the demand effect using probit regressions. The dependent variable is a dummy for positive private information ($Private_{POS}$). All variables are defined in Table 4. t-statistics are in parenthesis. +, *, **, and *** denotes significance at the 10%, 5%, 1%, and 0.01% level, respectively. The sample is 5,093 U.S. IPOs in 1981-2008.

	(1)	(2)	(3)	(4)	(5)	(6)
$SP500$	2.317^{***}		0.418	1.724^{***}		-0.372
	(6.11)		(0.79)	(4.03)		(-0.63)
$SP500_{POS}$		0.321^{***}	0.290^{***}		0.295^{***}	0.323^{***}
		(7.93)	(5.16)		(6.45)	(5.10)
Age				-0.0813^{***}	-0.0823^{***}	-0.0825^{***}
				(-4.13)	(-4.17)	(-4.18)
$Proceeds$				2.475^{***}	2.479^{***}	2.481^{***}
				(33.02)	(33.02)	(33.00)
$Shares$				-2.596^{***}	-2.603^{***}	-2.607^{***}
				(-29.91)	(-29.98)	(-29.95)
$Rank$				-0.0205^{**}	-0.0196^{*}	-0.0196^{*}
				(-2.66)	(-2.54)	(-2.53)
$HighTech$				0.393^{***}	0.395^{***}	0.395^{***}
				(8.81)	(8.83)	(8.84)
$Bubble$				0.401^{***}	0.406^{***}	0.406^{***}
				(6.47)	(6.53)	(6.53)
$NASDAQ$				0.268^{*}	0.260^{*}	0.257^{*}
				(2.12)	(2.05)	(2.02)
$NYSE$				-0.0964	-0.0910	-0.0922
				(-0.69)	(-0.64)	(-0.65)
$Constant$	-0.240^{***}	-0.413^{***}	-0.402^{***}	-4.709^{***}	-4.825^{***}	-4.817^{***}
	(-11.66)	(-11.84)	(-10.65)	(-11.01)	(-11.24)	(-11.22)
Pseudo R^2	0.005	0.009	0.009	0.234	0.238	0.238

Table 8: **Tests of the demand effect (II)**

Probit regressions testing for the demand effect. The dependent variable is a dummy for the high-demand state (HDS) in columns 1-4 and for the low-demand state (LDS) in columns 5-8. All variables are defined in Table 4. t-statistics are in parenthesis. +, *, **, and *** denotes significance at the 10%, 5%, 1%, and 0.01% level, respectively. The sample is 5,093 U.S. IPOs in 1981-2008.

Dependent variable:	HDS				LDS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$SP500$	3.630***		3.728***		-3.974***		-3.624***	
	(9.35)		(8.35)		(-10.15)		(-8.34)	
$SP500_{POS}$		0.365***		0.373***		-0.358***		-0.321***
		(8.83)		(7.85)		(-8.97)		(-7.28)
Age			-0.100***	-0.101***			0.0677***	0.0692***
			(-4.91)	(-4.95)			(3.46)	(3.54)
$Proceeds$			2.517***	2.525***			-2.368***	-2.372***
			(32.38)	(32.49)			(-32.40)	(-32.52)
$Shares$			-2.600***	-2.620***			2.618***	2.633***
			(-28.99)	(-29.24)			(30.30)	(30.54)
$Rank$			-0.0169*	-0.0159*			0.0294***	0.0285***
			(-2.13)	(-2.00)			(3.80)	(3.69)
$HighTech$			0.470***	0.472***			-0.230***	-0.230***
			(10.26)	(10.31)			(-5.15)	(-5.16)
$Bubble$			0.484***	0.487***			-0.320***	-0.322***
			(7.73)	(7.76)			(-4.91)	(-4.94)
$NASDAQ$			0.573***	0.550***			-0.307**	-0.276*
			(3.95)	(3.77)			(-2.75)	(-2.47)
$NYSE$			0.138	0.135			-0.0740	-0.0595
			(0.87)	(0.85)			(-0.58)	(-0.46)
$Constant$	-0.388***	-0.557***	-5.905***	-5.892***	-0.212***	-0.0548	1.841***	1.783***
	(-18.39)	(-15.56)	(-13.15)	(-13.11)	(-10.37)	(-1.62)	(4.39)	(4.27)
Pseudo R^2	0.013	0.012	0.260	0.259	0.016	0.012	0.219	0.216

Table 9: **Tests of the demand effect (III)**

Probit regressions testing for the demand effect. The dependent variable is a dummy for positive first-day returns ($IR1_{POS}$). All variables are defined in Table 4. t-statistics are in parenthesis. +, *, **, and *** denotes significance at the 10%, 5%, 1%, and 0.01% level, respectively. The sample is 5,093 U.S. IPOs in 1981-2008.

	(1)	(2)	(3)	(4)	(5)	(6)
$SP500$	3.186***		2.302***	3.439***		2.625***
	(7.31)		(3.74)	(7.76)		(4.21)
$SP500_{POS}$		0.293***	0.126*		0.304***	0.115^{+}
		(6.67)	(2.02)		(6.86)	(1.84)
$Private$	2.658***	2.652***	2.653***	2.902***	2.868***	2.896***
	(22.82)	(22.78)	(22.78)	(19.53)	(19.38)	(19.49)
Age				0.000403	-0.000504	0.000295
				(0.02)	(-0.03)	(0.02)
$Proceeds$				-0.259**	-0.231**	-0.258**
				(-3.20)	(-2.88)	(-3.19)
$Shares$				0.313***	0.272**	0.311***
				(3.36)	(2.94)	(3.33)
$Rank$				0.0112	0.0114	0.0115
				(1.44)	(1.47)	(1.47)
$HighTech$				0.0823^{+}	0.0863^{+}	0.0839^{+}
				(1.81)	(1.90)	(1.85)
$Bubble$				0.0460	0.0500	0.0454
				(0.66)	(0.72)	(0.65)
$NASDAQ$				0.403***	0.379***	0.397***
				(3.80)	(3.59)	(3.75)
$NYSE$				0.302*	0.293*	0.302*
				(2.45)	(2.38)	(2.45)
$Constant$	0.704***	0.573***	0.636***	0.0251	0.0501	-0.00576
	(29.42)	(15.21)	(15.40)	(0.06)	(0.12)	(-0.01)
Pseudo R^2	0.118	0.117	0.119	0.126	0.124	0.127