# Partial Adjustment to Public Information and the Efficiency of the IPO Process

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**Abstract**

This paper studies the effect of public information on the pricing of IPOs. It shows that public information (inferred from market wide stock returns observed prior to the IPO) affects the pricing of IPOs by changing the incentives of investors to reveal private information to the underwriter during the subscription period, and by shifting the distribution in their demand for allocations. Consistent with empirical evidence, the model predicts a positive relation between market wide stock returns observed prior to the IPO date and the mean initial return, and a positive relation between the mean and the volatility of initial returns. In addition, it yields a number of new testable implications.

*Keywords:* Public information, partial adjustment, underpricing, IPOs, book-building

*JEL Classification*: G10, G32.

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## 1 Introduction

Empirical evidence shows that initial returns in IPOs are positively related to market wide stock returns observed prior to the offering date, which suggests that underwriters do not fully adjust offer prices to publicly available information.[1] As noted by Loughran and Ritter (2002), Lowry and Schwert (2004), and others, partial adjustment to information inferred from changes in market wide stock prices prior to the offering is puzzling since it indicates that underwriters compensate investors for easily available public information.

The present paper offers an explanation for this evidence based on the information revelation argument of Benveniste and Spindt (1989), where IPO underpricing is seen as compensation to informed investors for revealing private information to underwriters during the subscription period. While the main prediction of the information revelation argument is that IPO prices will only partially adjust to investors' *private* information, the present paper shows that the argument implies patterns in underpricing consistent with partial adjustment to *public* information as well.[2] Indeed, publicly available information is shown to both alter the incentives of investors to reveal private information (the incentive effect) and shifting the distribution in their demand for allocations (the demand effect). These two effects counteract and ensure that underpricing in general will not be independent of public information observed prior to the IPO.

In particular, positive (negative) public information has the effect of decreasing (increasing) the incentives of investors to shade their bids, which decreases (increases) the need for underpricing. At the same time, positive (negative) public information increases (decreases) the probability that investors' demand for allocations will be sufficient to generate underpricing in the first place, which contributes to increase (decrease) the level of underpricing. In other words, while the first effect (the incentive effect) pulls towards a negative relation between publicly available information and underpricing, the second effect (the demand effect) pulls in the opposite direction towards a positive relation. The model thus predicts "partial adjustment" to public information whenever the demand effect outweighs the incentive effect, which is shown to obtain whenever the number of investors in the issue is sufficiently large.

The direct implication of the incentive effect is that the average initial return among underpriced IPOs is less in issues preceded by positive market returns compared to issues preceded by negative market returns. Similarly, the direct implication of the demand

[1] See Logue (1973), Hanley (1993), Loughran and Ritter (2002), Bradley and Jordan (2002), and Lowry and Schwert (2004).

[2] See Hanley (1993) for evidence that IPO prices only partially adjust to private information.

effect is that the fraction of underpriced IPOs is higher in issues preceded by positive market returns compared to issues preceded by negative market returns.

The model also predicts a positive relation between the mean and the standard deviation of initial returns (despite universal risk neutrality). This implication is consistent with empirical evidence by Lowry, Officer, and Schwert (2008), who find a strong positive correlation between the mean and the volatility of initial returns. The model implies in addition that the volatility of initial returns will be higher in issues preceded by positive market returns compared to issues preceded by negative market returns.

The paper is related to Edelen and Kadlec (2005), where partial adjustment to public information obtains in a (symmetric information) bargaining game between the investors and the underwriter. In the present model, investors are privately informed and the bookbuilding process represents an information revelation mechanism. Leite (2007) demonstrates that the empirical evidence of partial adjustment to public information is consistent with the Rock (1986) argument, showing that public information affects the winner's curse problem and in turn the issuer's pricing decision. Sherman (2005) shows that partial adjustment will arise in the Benveniste and Spindt (1989) model if investors' information costs are interpreted as (part) an opportunity cost, and these costs are positively related to public information observed prior to the offering. In the present model, information costs have no role and partial adjustment is related directly to information revelation rather than to the investors' information costs. Finally, Loughran and Ritter (2002) use prospect theory to develop a behavior-based explanation of the observed positive relation between market wide stock returns and underpricing.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 presents and discusses the results. Section 4 concludes.

## 2 The Setup

A firm is to undertake an IPO. The true value of this firm is $G = 1$ with probability $\alpha$ and $B = 0$ with probability $1 - \alpha$. 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 in the offering, each observing a private signal $s_I = \{b_I, g_I\}$ about the value of the firm, where $b_I$ represents negative information and $g_I$ represents positive information. The precision in $s_I$ 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 value of the firm. A public signal $s = \{b, g\}$ is observed as well, where $s = g$ is positive information and $s = b$ is negative information. The precision in the public signal is given by $f = q(g|G) = q(g|B)$, where $f > 1/2$.

Let $v(n, s)$ denote the aftermarket value of the firm given that $n \leq N$ investors observe positive private signals and the public signal is $s$. The function $v(n, s)$ represents the expected value of the firm conditional on the public signal and the private signals observed by investors. This specification implies that the marginal impact of each investor's private signal on the aftermarket value of the firm is decreasing in the number of investors, and hence that the importance of each investor's private signal in the valuation of the firm is decreasing in the number of investors in the issue. This is in contrast to Benveniste and Spindt (1989), where each investor's private signal "has an equal (absolute) marginal impact on the stock's value."

The bookbuilding process is conducted as follows. Investors observe their private signals along with the public signal and submit their bids, each submitting either a high bid or a low bid. In equilibrium, an investor who obtains a positive private signal submits a high bid, while an investor who obtains a negative signal submits a low bid. In equilibrium, therefore, investors truthfully reveal their private signals through their bids. The underwriter states his pricing and allocation policy before investors submit their bids, and responds to investors' bids according to his pre-committed policy.

Let $p(n, s)$ denote the IPO price if $n$ investors submit high bids, given the public signal $s$. Let $z(g, n)$ $(z(b, n))$ denote the fraction of the issue allocated to an investor who submits a high (low) bid, when a total of $n$ investors submit high bids. Since the private signals of investors have equal precision, investors who submit equal bids receive equal allocations. In other words, the issue is allocated pro-rata among investors who submit identical bids. Following Benveniste and Spindt (1989), I assume that the issuer is committed not to price the issue above its aftermarket value, meaning that $p(n, s) \leq v(n, s)$. I place no restrictions on the number of shares that can be allocated to one investor, however, which implies that one investor may be allocated the entire issue.

The expected payoff to an investor who observes a positive private signal and submits a high bid equals

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

where $q(n|g_I, s)$ is the conditional probability that $n$ investors will obtain positive private signals, given the public signal $s$ in addition to one positive private signal. The expected payoff to the same investor of submitting a low bid (thereby shading his bid) equals

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

To induce the investor to submit a high bid the issue must be priced and allocated so that his truth-telling constraint

$$U \geq \hat{U} \tag{3}$$

is satisfied. This constraint will be satisfied with equality to minimize investors' rents.

The expected proceeds in the issue are equal to

$$E\pi = \sum_{n=0}^{N} q(n, s)p(n, s). \tag{4}$$

The underwriter prices and allocates the issue to maximize $E\pi$ subject to investors' incentive constraint (3). The absence of allocation restrictions allows the underwriter to allocate shares only to investors who submit high bids. Such an allocation rule minimizes $\hat{U}$ and hence maximizes $E\pi$. In the event that all investors obtain negative signals, and hence all investors, in equilibrium, submit low bids, the issue is allocated pro-rata among all $N$ investors. In other words, the issue is never withdrawn in the low-demand state.[3]

The given allocation rule implies that an investor who submits a low bid is allocated 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 the investor from submitting a low bid is now

$$\hat{U} = q(1|g_I, s)\frac{1}{N}[v(1, s) - v(0, s)], \tag{5}$$

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

The expected payoff to the investor from submitting a high bid and hence truthfully

[3] Busaba (2006) shows that it may be optimal to commit to withdraw the issue with a positive probability if low demand, and Busaba, Benveniste, and Guo (2001) find empirically that such a threath reduces underpricing. In the present setting, however, it can be shown that committing to withdraw the issue with a positive probability in the low demand state is not optimal.

revealing his signal equals

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

The set of prices $p(n, s); n = 1, \ldots N$ that satisfies the investor's incentive constraint $U = \hat{U}$ is indeterminate. To simplify the exposition, let $v(n, s) = p(n, s)$ for each $n = 1, \ldots, N - 1$. This implies that $p(N, s) < v(N, s)$, since $\hat{U} > 0$. In other words, the issue is underpriced only in the high-demand state where all investors observe positive private signals.

The expected payoff to the investor of submitting a high bid now equals

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

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

$$p(N, s) = v(N, s) - \frac{q(1|g_I, s)}{q(N|g_I, s)}[v(1, s) - v(0, s)]. \tag{8}$$

Since $v(1, s) > v(0, s)$, the issue is clearly underpriced in the high-demand state (i.e., $p(N, s) < v(N, s)$), and hence the issue is underpriced in expectation, since $p(n, s) = v(n, s)$ in the remaining demand states.

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

$$r(N, s) = \frac{v(N, s)}{p(N, s)} - 1, \tag{9}$$

and hence the expected initial return equals

$$Er(s) = q(N|s)r(N, s). \tag{10}$$

The empirical evidence suggesting partial adjustment to public information implies that underpricing is higher when the public signal is positive than when it is negative, or that $Er(g) > Er(b)$. The information revelation argument of Benveniste and Spindt (1989) predicts that IPO prices will only partially adjust to *private* information revealed by investors during the subscription period but is silent on the role of *public* information. In the next section, I examine the relation between public information and underpricing under the information revelation argument.

## 3 Public Information and Underpricing

The expected initial return, $Er(s)$, consists of the initial return associated with the high-demand state, $r(N, s)$, and its corresponding conditional probability $q(N|s)$. The following proposition considers how the initial return $r(N, s)$ and the conditional probability $q(N|s)$ are affected by the public signal.

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

Positive public information reduces the incentives of investors to understate their information (the incentive effect), and hence positive information reduces the amount of underpricing needed to induce investors to reveal private information. At the same time, positive public information increases the probability that investors obtain positive private signals and hence increases the probability that an investor will submit a high bid (the demand effect), which increases the probability that the issue will be underpriced in the first place. The expected initial return may therefore be positively or negatively related to the public signal depending on which of these two effects dominate.

**Proposition 2** *The demand effect will strictly dominate the incentive effect to give a positive relation between public information and underpricing, provided that the number of investors in the issue is sufficiently large.*

An increase in the number of investors decreases the marginal impact of each investors' private signal on firm value. This reduces the potential payoff to investors of shading their bids and hence reduces the need for underpricing. An increase in the number of investors, therefore, decreases the importance of the incentive effect relative to the demand effect and hence makes a positive relation between the public signal and underpricing more likely. Indeed, the proposition implies that the demand effect will strictly dominate the incentive effect to give a positive relation between the public signal and underpricing (and hence partial adjustment to public information) whenever the number of investors in the issue is sufficiently large.

The result that the strength of the incentive effect relative to the demand effect decreases in the number of investors obtains because the marginal effect of each investor's signal on firm value is decreasing in the number of investors. This effect will arise in any standard micro structure model where investors' private information is reflected in the stock's market price through the trading process (such as Kyle (1985)).[4] It does not arise in the standard Benveniste and Spindt (1989) setup because of an explicit assumption that the marginal effect of each investor's signal on the market value of the firm is constant and hence unrelated to the number of investors in the issue.

Empirically, the demand effect implies that the fraction of IPOs that are underpriced will be higher among IPOs that are preceded by positive market wide stock returns compared to IPOs that are preceded by negative market wide stock returns.[5] Similarly, the incentive effect implies that the mean initial return among IPOs that are underpriced will be less (or equal) in IPOs preceded by positive market returns compared to IPOs preceded by negative market returns. These are the main (and novel) testable predictions of the model.

The evidence that initial returns are positively related to public information is widely interpreted to reflect an inefficiency in the IPO pricing process. For example, Lowry and Schwert (2002) find the economic significance of partial adjustment to be small and conclude that the IPO process is "almost efficient." More recently, Ince (2008) argues that the literature understates this inefficiency by not properly taking into account the effect of withdrawn offerings and potentially mis-specifying firm specific public information as private. In the present model, the equilibrium offer price fully incorporates all relevant public information. Nonetheless, the model predicts a positive relation between public information and underpricing, which suggests that a zero relation between public information and underpricing represents a rather arbitrary benchmark by which to measure the efficiency of the IPO process.

The implication that partial adjustment to public information is reconcilable with efficiency is consistent with empirical evidence from Benveniste, Fu, Seguin, and Yu (2008) on equity carve-out IPOs. While they document partial adjustment to public information in the form of market wide stock returns, they also find that market wide stock returns no longer predicts initial returns once the returns for the parent company during the subscription period is included in the regression. Furthermore, partitioning the subsidiary's initial return into a predictable and an unpredictable part, they find that it is the unpredictable part of the subsidiary's initial return that is related to the parent's "first-day" return rather than the predictable part. In other words, the parent's "first-day" return cannot be predicted, which is consistent with market efficiency and

[4] In Chen and Wilhelm (2008) a similar effect in the context of secondary prices in the IPO aftermarket leads early stage investors to bid more aggressively as they expect their information to become less important when a new set of informed investors enters the market at a later stage.

[5] A substantial fraction of IPOs are overpriced; see Ruud (1993) and more recently Lowry, Officer, and Schwert (2008). To clean the data from biases caused by underwriters' support activities, they measure initial returns over a wider window than the common one-day return.

suggests that the predictable part of the subsidiary's initial return comes from frictions inherent in the IPO process rather than from pricing inefficiency.

Lowry, Officer, and Schwert (2008) find a strong positive correlation between the volatility and the mean of initial returns. To consider their evidence in the context of the present model, note that the standard deviation of the initial return equals

$$\sigma(s) = \sqrt{q(N,s)[(R(N,s)-1) - Er(s)]^2 + (1-q(N,s))[0 - Er(s)]^2}, \tag{11}$$

which can be simplified to

$$\sigma(s) = \sqrt{\frac{1-q(N,s)}{q(N,s)}} Er(s). \tag{12}$$

In other words, the model implies a positive relation between the expected initial return and the standard deviation of initial returns, which is consistent with the evidence by Lowry, Officer, and Schwert (2008) who find not only that IPOs associated with higher price updates have higher initial returns (consistent with the main prediction of the information revelation argument) but also have higher volatility of initial returns. While they explain this finding using Ritter's (1984) and Beatty and Ritter's (1986) ex-ante uncertainty argument (based on the Rock (1986) argument), the present paper shows that this evidence can be explained using the information revelation argument of Beneveniste and Spindt (1989) as well.

The next result extends the relation implied by equation (12) between the mean and the standard deviation of initial returns to provide a link between public information observed prior to the IPO and the standard deviation of initial returns.

**Proposition 3** *The standard deviation of the initial return is positively related to the public signal (i.e., $\sigma(g) > \sigma(b)$), provided that the number of investors in the issue is sufficiently large.*

In other words, the model implies that the volatility of initial returns will be higher in IPOs preceded by positive market returns compared to IPOs preceded by negative market returns. While closely related to the evidence by Lowry, Officer, and Schwert (2008), this prediction is yet to be tested.

# 4 Concluding Remarks

Empirical evidence shows that initial returns in IPOs are positively related to public information in the form of market wide stock returns observed in the time before the

IPO. The present paper shows that public information affects the pricing of IPOs by both altering the incentives of investors to reveal their private information in the book-building process (the incentive effect) and by changing the distribution in their demand for allocations (the demand effect). The paper shows further that IPO underpricing is positively related to public information whenever the demand effect outweighs the incentive effect, and that this is unambiguously the case if the number of investors in the issue is sufficiently high.

The direct empirical implication of the demand effect is that IPOs preceded by positive market returns will contain a higher proportion of underpriced offerings compared to IPOs preceded by negative market returns. The direct implication of the incentive effect is that the mean initial return among underpriced IPOs will be less than, or equal to, the corresponding conditional mean initial return for IPOs preceded by negative market returns. The model also predicts a positive relation between the mean and the volatility of initial returns, which is consistent with recent empirical evidence. In addition, it predicts that the volatility of initial returns will be higher in IPOs preceded by positive market returns compared to IPOs preceded by negative market returns.

The evidence that underpricing is positively related to market wide stock returns observed prior to the issue date is generally interpreted to represent an inefficiency in the IPO pricing process as it suggests that underwriters neglect to fully incorporate easily available public information into offer prices. The present model, however, predicts a positive relation between public information and IPO underpricing even if IPO prices always fully incorporate all available public information. In other words, the model suggests that the partial adjustment to public information observed in the data is partial only in appearance and hence that the zero relation between publicly available information and underpricing widely used as a benchmark for the efficiency of the IPO process is rather arbitrary.

# A Appendix

**Proof of Proposition 1.** (i) The initial return associated with the high-demand state equals

$$r(N,s) = \frac{v(N,s)}{p(N,s)} - 1; s = \{b,g\}, \tag{13}$$

where

$$p(N,s) = v(N,s) - \frac{q(1,g_I,s)}{q(N,g_I,s)} \left[v(1,s) - v(0,s)\right]. \tag{14}$$

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

$$\frac{v(N,g)}{p(N,g)} \leq \frac{v(N,b)}{p(N,b)}, \tag{15}$$

which is equivalent to

$$\frac{q(N,g_I,g)v(N,g)}{q(N,g_I,b)v(N,b)} \geq \frac{q(1,g_I,g)}{q(1,g_I,b)} \frac{[v(1,g)-v(0,g)]}{[v(1,b)-v(0,b)]} \tag{16}$$

Using Bayes rule and rearranging, this inequality may be written

$$1 \geq \frac{\gamma-(1-\gamma)\Xi}{\gamma-(1-\gamma)\Theta}, \tag{17}$$

where

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

and

$$\Theta = \frac{(1-\gamma)^{N-1}\gamma(1-f)\alpha + \gamma^{N-1}f(1-\alpha)}{(1-\gamma)^N(1-f)\alpha + \gamma^N f(1-\alpha)} \tag{19}$$

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

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

$$= \frac{\alpha(1-\alpha)(2f-1)(1-\gamma)^{N-1}\gamma^{N-1}(2\gamma-1)}{[(1-\gamma)^N f\alpha + \gamma^N(1-f)(1-\alpha)]\,[(1-\gamma)^N(1-f)\alpha + \gamma^N f(1-\alpha)]}, \tag{21}$$

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

(ii) By Bayes' rule it follows that

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

and

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

The difference between the two may be written

$$q(N|g) - q(N|b) = \frac{\alpha(1-\alpha)(2f-1)[\gamma^N - (1-\gamma)^N]}{[1-\alpha(1-f)-(1-\alpha)f][\alpha(1-f)+f(1-\alpha)]}, \tag{24}$$

which is strictly greater than zero. ■

**Proof of Proposition 2.** Partial adjustment to public information implies that underpricing is higher after a positive public signal than after a negative signal, or, in other words that,

$$\frac{Er(g)}{Er(b)} > 1 \tag{25}$$

The proposition is proved by showing that

$$\lim_{N\to\infty} \frac{Er(g)}{Er(b)} > 1 \tag{26}$$

By Bayes' rule and straightforward algebra it can be shown that

$$\frac{Er(g)}{Er(b)} = \frac{(1-f)\alpha + f(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \times \frac{f\alpha + (\frac{1-\gamma}{\gamma})^N (1-f)(1-\alpha)}{(1-f)\alpha + (\frac{1-\gamma}{\gamma})^N f(1-\alpha)} \times A, \tag{27}$$

where

$$A = \frac{(1-f)\alpha\Big[\Big(\frac{1-\gamma}{\gamma}\Big)^N (1-f)\alpha + f(1-\alpha)\Big] - f(1-f)\alpha(1-\alpha)\frac{1}{\gamma}\Big(\frac{1-\gamma}{\gamma}\Big)^{N-1}(2\gamma-1)}{f\alpha\Big[\Big(\frac{1-\gamma}{\gamma}\Big)^N f\alpha + (1-f)(1-\alpha)\Big] - f(1-f)\alpha(1-\alpha)\frac{1}{\gamma}\Big(\frac{1-\gamma}{\gamma}\Big)^{N-1}(2\gamma-1)} \tag{28}$$

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

$$\lim_{N\to\infty} \frac{Er(g)}{Er(b)} = \frac{(1-f)\alpha + f(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \times \frac{f}{1-f}. \tag{29}$$

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

**Proof of Proposition 3.** Using the same approach as in the proof of Proposition 2, it can be shown that

$$\lim_{N\to\infty} \frac{\sigma(g)}{\sigma(b)} = \sqrt{\frac{(1-f)\alpha + f(1-\alpha)}{f\alpha + (1-f)(1-\alpha)} \times \frac{f}{1-f}} \tag{30}$$

which is strictly greater than one. ■

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