ISSN 1936-5349

HARVARD

JOHN M. OLIN CENTER FOR LAW, ECONOMICS, AND BUSINESS

AN ASYMMETRIC PAYOFF-BASED EXPLANATION OF IPO "UNDERPRICING"

Atanu Saha and Allen Ferrell

Discussion Paper No. 587

6/2007

Harvard Law School
Cambridge, MA 02138

An Asymmetric Payoff-Based Explanation of IPO 'Underpricing'

Atanu Saha* and Allen Ferrell**

Abstract

The widely studied phenomenon of underpricing of new issues of common stock can be explained by underwriters' payoff asymmetry. Under uncertain investors' demand for a new issue, the underwriter's downside risk if he overestimates demand can be significantly larger than the upside potential when he underestimates demand. To protect himself from the large downside risk of overestimating demand, the underwriter rationally chooses a lower offer price than he would have in the absence of demand uncertainty.

JEL Classification: D82, G24, G32, K22

*Managing Director, AlixPartners LLP, 9 W 57th Street, Suite 3420, New York, NY 10019; ph: 212 297 6322; email: asaha@alixpartners.com

**Greenfield Professor of Law; Harvard Law School, Cambridge, MA 02138, ph: 617 495 8961; email: fferrell@law.harvard.edu. Research support from Gun Park and Alex Rinaudo and comments from Arthur Havenner, Louis Kaplow, Mark Ramseyer and Kathy Spier on an earlier version of the paper are gratefully acknowledged. Allen Ferrell is grateful to the John M. Olin Center in Law, Economics and Business at Harvard Law School for financial support.

An Asymmetric Payoff-Based Explanation of IPO 'Underpricing'

1. *Introduction*

Many studies have documented that unseasoned new issues of common stock are often substantially "underpriced." In defining underpricing, virtually all papers in the extant literature have compared the offer price to the first day closing price after the initial public offering (see, e.g., Ibbotson (1975), Ibbotson and Ritter (1995); Malkiel et al (2002)). In this paper, we present a model which can account for "underpricing" based on underwriter's uncertainty about the level of investors' demand for a contemplated offering of stock. In the presence of demand uncertainty, under a broad range of circumstances, an underwriter's downside risk of overestimating investors' true demand for a stock is substantially greater than the risk of underestimating demand. This new explanation for underpricing complements the standard theoretical explanations for 'underpricing' based on informational asymmetry, signaling and liability exposure. Moreover, this explanation has implications for several large securities class action suits based on IPO underpricing.

In recent years, IPO underpricing has been the center of several high profile securities litigation matters. In particular, various investors starting in 2001 filed class action lawsuits against 55 underwriters, 310 issuers and hundreds of executives of the issuing firms arguing, among other things, that the issuing firms' stock were underpriced as a result of a fraudulent scheme by underwriters to drive up the price of the stock in the immediate aftermath of the IPOs. The claimants argued that underwriters, through a variety of compensation arrangements and side-agreements, as well as the investors chosen by the underwriters to receive shares in underpriced issuances benefited from the immediate run-up in the stock price in the secondary market.

On October 13, 2004 Judge Scheindlin of the United States District Court for the Southern District of New York granted class certification in six of these securities class actions based, in part, on the IPO underpricing claim. The damages claimed by plaintiffs in these class actions ran into the billions. After Judge Scheindlin's decision, 298 issuers as well as a number of underwriters and issuing firm executives settled the class action claims for a guaranteed recovery for plaintiffs of one billion dollars. Those not settling, however, appealed the class certification. The Second Circuit ultimately concluded that class certification was not appropriate because with respect to the issues of reliance and knowledge of the scheme the plaintiffs did not satisfy the predominance requirement for class action (see In Re: Initial Public Offerings Securities Litigation, Docket Number 05-3349-CV (December 5, 2006)).

Much of the IPO underpricing litigation has turned on why the IPO shares were underpriced. Plaintiffs posit a deliberate fraudulent scheme as the explanation. Other possible explanations for underpricing can be found in the extant finance literature. In this paper we add to this literature by providing a new explanation for underpricing.

The Prior Literature

We briefly summarize in this section three of the most prominent explanations for underpricing from the vast literature on this subject: informational asymmetry, signaling and liability exposure.

Many researchers have focused on informational asymmetry between issuers, underwriters, and investors in explaining IPO underpricing. For example, Baron (1982) demonstrated that underpricing can result from information asymmetry where the underwriter is better informed about the capital markets than is the issuer and the issuer cannot observe the effort expended by the underwriter. Beneveniste and Spindt (1989) argue that the basic difficulty facing an underwriter in gathering information to price an issue is that investors have no incentive to reveal positive information before the stock is sold. As a result, underpricing is used by underwriters as a means to compensate investors in exchange for revealing positive information about the stock. Several papers have found some empirical support for informational asymmetry as at least a partial explanation for underpricing (see, e.g., Beatty and Ritter (1986); Hanley (1993)).

Several papers argue that underpricing can be the result of signaling (see, e.g., Allen and Faulhaber (1989); Grinblatt and Hwant (1989); and Welch (1989)). In these models, firms underprice as a signal of high-quality enabling these firms to raise more funds in the future on more advantageous terms. The empirical evidence for signaling explanations of underpricing is, at best, mixed (see Spiess and Pettway (1997)).

Finally, several authors claim that underpricing reduces liability exposure under the securities acts as firms with underpriced stock have less exposure to liability (see e.g., Ibbotson (1975); Tinic (1988)). Lowry and Shu (2002) provide some empirical support suggesting that underpricing can reduce liability exposure and that firms with higher liability exposure underprice more.

The Asymmetric Payoff-Based Explanation

Our study builds on the prior literature by providing a new explanation for underpricing which complements the traditional explanations for underpricing, in particular the informational asymmetry and signaling theories. We begin with the premise that underwriters face uncertainty about investors' true yet undisclosed demand for the issue. We demonstrate, without assuming asymmetric information, that underpricing is a natural consequence of an asymmetric payoff: the underwriter's downside risk of overestimating investors' true demand for the stock is significantly higher than the upside potential of underestimating it. In this context, it is important to note that we do not define 'underpricing' as the difference between the offer price and the first day closing price. Instead, we view it as the difference between the underwriter's chosen offer price and the higher price the underwriter would have set in the absence of uncertainty about the investors' level of demand for the new issue.

In the next section, we first analyze the situation in which underwriters have complete information (i.e., absence of demand uncertainty) concerning investors' true demand for an issue. We then demonstrate that the underwriter's optimal price and expected profits under demand uncertainty are lower than those under certainty. We undertake numeric simulations to quantify the extent of underpricing and verify the robustness of our results when a key assumption of the model is relaxed. Finally, we briefly compare our model predictions to the empirical findings in the existing literature.

2. The Model

The IPO pricing process can be temporally divided into two periods. In the first period, the underwriter is uncertain about the true level of institutional investors' demand for the issue and sets the offer price based on the ex-ante expectation about the parameters of the distribution of investors' preferences. The second period can be viewed as the commencement of trading, when the institutional demand is fully revealed. The market clearing price (i.e., first day closing price) is determined by the supply of the IPO issue and the combined demand of the institutional and retail investors. It is assumed that the retail investors' demand is monotonically related to the level of the institutional investors' demand.[1] Thus, in the remainder of the paper we will focus on the demand of the institutional investor. Additionally, we model the underwriter's choice of the offer price and not the first day closing price, because, as we show below, the underwriter's payoff is unaffected by the latter.

We will set out the model in the framework of a "firm-commitment" IPO. In contrast to a "best-effort" agreement, typically, in a firm-commitment arrangement, the underwriter "buys" a set number of shares (denoted by Q^*) at a fixed price (denoted by p^*) from the issuer and then offers the new issue to investors at an offer price that it determines to be optimal. If p denotes the offer price and demand for the issue at that price is denoted by $D(p,\cdot)$, then the underwriter's net pay-off from underwriting the issue is: $p \cdot D(p,\cdot) - p^*Q^* = p \cdot D(p,\cdot) - k$, where $k = p^*Q^*$ can be viewed as a fixed cost in the underwriter's profit function. Since k plays no role in the determination of the offer price that maximizes underwriter's pay-off or expected pay-off we will ignore k in setting out the underwriter's optimization problems.

We make the following assumption for the model framework:

A1. There are N investors. Each investor's decision to buy the issue can be viewed as a binary random variable X_i, where $X_i = 1$ if the i^{th} investor demands the new issue and $X_i = 0$, otherwise. Thus, the proportion of all N investors who buy is a random variable, $W = \sum_{i=1}^{N} X_i / N$.

A2. The numbers of investors, N, is very large. As a result, using the Central-limit theorem,[2] the distribution of W can be approximated by a normal cumulative distribution function (CDF) with a mean, denoted by m and a standard deviation, σ, such that $P[W \geq w] = 1 - \Phi(w, m, \sigma)$, where $P[\ ]$ denotes probability and $\Phi(\cdot)$ the normal CDF. Thus, the variable W can also be viewed as the average investor's 'reservation price' for the new issue.

A3. The underwriter is uncertain about the demand parameter, m, when it chooses the offer price, p, to maximize expected payoff. In the second period when

[1] See Ljungqvist (2006) for a model of IPO pricing of 'hot' issues where the retail investors are modeled as sentiment investors, with demands materially different from that of institutional investors.
[2] See Mood, Graybill and Boes, (1974), p. 234.

demand is revealed, two states of demand are possible, a high state wherein: $m^H = (1+\theta)\cdot m$; and a low state wherein: $m^L = (1-\theta)\cdot m$, with $0 \le \theta < 1$.

A4. The two states of demand are equally likely.

A5. The underwriter is risk neutral.

A6. The underwriter's marginal cost, *c,* is fixed and is assumed to be zero (all results extent to the case where $c > 0$).

A7. The underwriter's payoff and expected payoff functions are strictly concave in the offer price, *p.*

A8. The values of m and σ, are such that $P[W \le 0] \cong 0$. That is, the probability of the average investor's reservation price for the new issue being less than or equal to zero is infinitesimally small.

2.1 The Certainty Benchmark

We first set out the underwriter's choice problem under certainty. Since $P[W \ge p]$ denotes the proportion of all *N* investors who would demand the issue at price, *p*, the underwriter's market demand is given by $D(p,m) = N \cdot P[W \ge p] = N \cdot (1 - \Phi(p,m))$. This formulation of the firm's demand is grounded in consumer theory. On the one hand, it has been used widely in modeling rational behavior in a heterogeneous population of consumers and on the other in deriving the market demand faced by oligopolistic firms (see, for example, Prescott (1976); Anderson et al. (1992); Eaton and Lipsey (1989), p. 732; Talluri and Ryzin (2005)). Additionally, as Talluri and Ryzin (2005) point out: "[t]he normal (or Gaussian) distribution is frequently used as a model of demand." (p. 639). Importantly, $D(p,m) = N \cdot (1 - \Phi(p,m))$ satisfies all the regularity conditions[3] for a well-defined demand function under assumption A8.

Let the value of the mean of the CDF under certainty be denoted by $\bar{m} = (m^H + m^L)/2$. The underwriter's choice problem under certainty is:

[3] Let the domain of the demand function be $\Omega_p = [0, \infty)$; the regularity conditions are: (a) $D(\cdot)$ is continuously differentiable on Ω_p; (b) $D(\cdot)$ is strictly decreasing in *p*; (c) $D(\cdot)$ is bounded from above and below: $0 \le D(\cdot) < \infty$ for all *p* in Ω_p; (d) $D(\cdot)$ tends to zero at sufficiently high prices: $\inf_{p \in \Omega_p} D(\cdot) = 0$; (e) the revenue function, $p \cdot D(\cdot)$ is finite for all *p* in Ω_p and has a finite and strictly interior value of *p* that maximizes it. (Talluri and Ryzin (2005) , p. 312).

$$\underset{p}{Max}\, \pi = p \cdot D\left(p, \bar{m}\right).$$

Let the optimal offer price be denoted by p^o and the associated demand and pay-off be $D^o = D\left(p^o, \bar{m}\right)$ and $\pi^o = \pi\left(p^o\right)$. In the rest of the paper, we will characterize these interchangeably as the certainty-level or the benchmark level of price, demand and payoff.

2.2 The Choice Problem Under Uncertainty

The underwriter's expected pay-off maximization problem is:

$$\underset{p}{Max}\, E\left[\tilde{\pi}\right] = p \cdot E\left[D\left(p, \tilde{m}\right)\right] = p \cdot \left\{D\left(p, m^H\right) + D\left(p, m^L\right)\right\}/2$$

Let the optimal choice be denoted by $\hat{p}$ and the associated expected demand $\hat{D} = E\left[D\left(\hat{p}, \tilde{m}\right)\right]$ and the expected profit be $\hat{\pi} = E\left[\tilde{\pi}\left(\hat{p}\right)\right]$.

2.3 The Key Results

We now present the key results of the paper. The proofs of these propositions are presented in the Appendix.

Proposition 1: $\dfrac{\partial \hat{p}}{\partial \theta} < 0$*, the underwriter's optimal price under uncertainty decreases with higher uncertainty regarding the level of investor's demand.*

Proposition 2: $\hat{p} < p^o$*, the underwriter's optimal price under uncertainty is lower than that under certainty. As a result,* $\dfrac{\partial \left|\hat{p} - p^o\right|}{\partial \theta} > 0$.

Proposition 3: $\hat{\pi} = E\left[\tilde{\pi}\left(\hat{p}\right)\right] < \pi\left(p^o\right)$*, the expected pay-off under uncertainty is less than that under certainty.*

Proposition 4: $\dfrac{\partial \hat{\pi}}{\partial \theta} < 0$*, the expected pay-off decreases with higher uncertainty.*

The economic intuition for these results is as follows: Although in the two states of demand the mean of the CDF, *m*, deviates symmetrically from its average value of $\bar{m}$ (by θ%), the impact of this deviation on the underwriter's demand and, as a result his pay-off, is *asymmetric*. That is, the percentage decline in payoffs (relative to the certainty benchmark) when the underwriter overestimates the average investors' demand level is larger than the payoff increase if the underwriter were to underestimate it.

This payoff asymmetry stems from the asymmetric effect of θ on demand. The demand function is concave in p in the relevant region (i.e., for all p less than the mean of the distribution). Thus a θ percent change in the mean (which can be conceptualized by keeping the mean the same and moving the price θ percent in both directions) has a larger negative effect (in absolute value) on demand for a downward change than the positive demand effect of an upward change. This asymmetric impact on demand translates to an asymmetric effect on the underwriter's payoff under the two states of demand. It is readily verified that, for any level of p^o, $\frac{\left|\pi^L - \pi^o\right|}{\pi^o} > \frac{\pi^H - \pi^o}{\pi^o}$, where $\pi^i = p^o \cdot D\left(p^o, m^i\right)$, $i = H, L$. Indeed, even for relatively small values of θ the difference between the downside risk and the upside potential can be substantial. For example, a θ of 30% yields, $\frac{\pi^L - \pi^o}{\pi^o}$= -77%, but $\frac{\pi^H - \pi^o}{\pi^o}$= 11%--a seven-fold difference!

It is important to note that the payoff asymmetry exists because the underwriter cannot ex post change the offer price when demand is revealed. If the underwriter were able to change the offer price in period 2 then the payoff asymmetry would disappear. For example, for the low state, the revised optimal price would be p^L yielding a payoff of π^L, which would be θ% lower than the certainty payoff of π^o; similarly, in the high-state, the realized payoff would be θ% higher than expected.

Also note that, while in the high-state the institutional investor's demand is $\Delta^H = \frac{D^H - D^o}{D^o}$% higher than the certainty-level, the market clearing price of the issue need not be only Δ^H% higher than the offer price. The market clearing price is determined by the equality of market demand and supply of the new issue after it commences trading; and market demand, as noted earlier, is the combined demand of the institutional and retail investors. Thus, the difference between the first day closing price and the offer price, for example, can be significantly higher than Δ^H%. However, as noted earlier, the first day closing price does not impact the underwriter's payoff.

2.4 *Numeric Analyses*

There are three objectives of the numerical analyses: first, we explore whether the key assumptions and the results of our paper hold under various values of θ; second we quantify the difference between the certainty level price, p^o, and the optimal price under uncertainty, $\hat{p}$; in doing so we also examine the difference between the certainty payoff, $\pi^o = \pi\left(p^o\right)$, and the expected payoff under uncertainty, $E\left[\tilde{\pi}\left(\hat{p}\right)\right]$; and finally, we explore whether the results of the paper hold when the assumption regarding the exogeneity of the two states of demand is relaxed. For all analyses that follows, we have set the mean of the willingness-to-pay distribution, denoted by $\bar{m} = \left(m^H + m^L\right)/2$, to the value of one and the standard deviation, σ, to $\bar{m}/4 = 1/4$.

In undertaking the numerical analyses we find that a critical assumption of the paper (Assumption A7) regarding the concavity of the expected payoff function, $E\left[\tilde{\pi}\right]$, does not hold for all values of θ. The fact that $E\left[\tilde{\pi}\right]$ ceases to be strictly concave for values of θ beyond a particular level becomes evident from Panel A through C in Figure 1.

In Panel A of this figure, we depict the payoff function (under certainty) and the expected payoff function under uncertainty when θ is 0.2, which implies that the mean of the willingness-to-pay distribution under the high and low states of demand deviates from the benchmark level by 20%. As to be expected from Proposition 2, we see that the expected pay-off function (dark line) reaches a maximum at a price ($\hat{p}$ = 0.66) that is lower than the price (p^o = 0.77) at which the pay-off function under certainty (gray line) reaches its maximum. Figure 1 also shows that when θ is 0.2, the expected pay-off function is strictly concave, and thus there is a single, unique maximum.

However, Panel B of Figure 1 shows that is not the case when θ is 0.4. Our numerical analysis reveals that when θ is 0.4045 the expected pay-off function has twin maxima, one at a price of 0.57, which is less than p^o, and the other at 1.08, which is greater than p^o. In fact, for all values of $\theta > 0.4045$, the optimal price under uncertainty, $\hat{p}$, is always greater than that under certainty, p^o. For example, Panel C of Figure 1 shows that when θ is 0.6 the $E\left[\tilde{\pi}\right]$ function has two peaks, a local maximum at a price less than p^o and a global maximum at $\hat{p}$ = 1.24, which is clearly greater than p^o.

The relationship between θ and $\hat{p}$ is further illustrated in Figure 2. Since the optimal price under certainty is independent of θ, the flat gray line depicts p^o = 0.77. Consistent with the results in Propositions 1 and 2, we see $\hat{p}$ is less than p^o and the difference between the two prices increases with θ for all values of θ < 0.4045. However, when θ > 0.405, these results no longer hold since Assumption A7 is violated. At this critical value of θ, $\hat{p}$ jumps from being less than p^o to being greater. Beyond this value of θ = 0.4045, $\hat{p}$ increases monotonically with θ. In fact, the percent difference between $\hat{p}$ and p^o is virtually identical to the value of θ for all values of θ > 0.405. This percent difference is shown in Figure 3.

This figure also shows the percent difference between the pay-off under certainty and the expected pay-off under uncertainty for various values of θ. Unlike the relationship between $\hat{p}$ and p^o, however, the expected payoff under uncertainty remains less than the certainty pay-off for all values of θ, although the difference between the two diminishes beyond θ = 0.405.

To gain economic intuition into the observed non-monotonic relationship between $\hat{p}$ and p^o, assume for a moment that the underwriter knew that the high state of demand was far more likely than the low state; in that case, the underwriter would be better off choosing a high price (i.e., a price higher than p^o). For example, suppose we modify Assumption A4 and assume that the probability of a high-demand state is 90% and that of a low-demand state is 10%; furthermore assume that θ=0.3; under these assumptions, the numerical results show that the optimal price under uncertainty, $\hat{p}$, is 0.99, which is about 28% higher than p^o, the certainty price. In fact, we have verified numerically that if the probability of the high-state is 90% then $\hat{p} > p^o$ for all values of θ. The underwriter chooses a high $\hat{p}$ because at that price although the demand (and as a result the associated pay-off) in the low-state is virtually zero, its likelihood is also small. Hence the probability-weighted average of the pay-offs under the two states (i.e., the expected payoff) is maximized by a higher price.

A similar outcome occurs for large values of θ even when the two states of demand are equally likely. That is, for θ > 0.405, the underwriter's pay-off in the high-demand state at a high price (i.e., $\hat{p} > p^o$) much exceeds the pay-off in the low state at that same price. For example, when θ = 0.42, the optimal price, $\hat{p}$, is 1.10 and at that price D^H = 0.82; by contrast,

$D^L =$ 0.0002, implying that D^H is 4,100 times larger than D^L. In other words, even when the two states of demand are equally likely but the demand in the high-state is sufficiently large (when $\theta > 0.405$), it is rational for the underwriter to choose a high price that maximizes pay-off in the high-state and causes the demand in the low state to be virtually zero.

Endogenous Probability of the Two States

Throughout the paper we have assumed in the interest of analytical tractability that the probability of the two states of demand is exogenous and equal to half (see Assumption A4). Here, for the purposes of numeric analyses, we relax this assumption and explore whether the key results of the paper still hold. In particular, we assume that the likelihood of a high state of demand is inversely related to price.

Let us denote the probability of the high-demand state as: $\alpha(p)$ where it satisfies the following properties: (i) $0 \le \alpha(p) \le 1$; and (ii) $\alpha'(p) < 0$. The first property is an obvious consequence of $\alpha(p)$ being a probability; the second reflects the inverse relationship between price and the likelihood of a high demand state. The underwriter's optimal choice problem under uncertainty can now be rewritten as:

$$\underset{p}{Max}\, E[\tilde{\pi}] = p \cdot E\left[D(p,\tilde{m})\right] = p \cdot \left\{\alpha(p) D\left(p,m^H\right) + \left(1-\alpha(p)\right) D\left(p,m^L\right)\right\}.$$

In undertaking the numerical analysis, we have explored various functional forms for $\alpha(p)$ that satisfy the two properties listed above. Qualitatively the key results of the paper continue to hold for values of θ less than or equal to 0.41. For example, when we assume $\alpha(p) = \frac{1}{1+p}$, the numerical results are virtually identical to the ones presented in Figure 2 and Figure 3. If, however, we posit $\alpha(p) = e^{-p}$, then $\hat{p} < p^o$ holds for all values of $\theta < 0.52$ and the maximum percent difference between them reaches 37%, which is higher than the maximum difference of 27% (see Figure 3) derived under the assumption of exogenous probability of high-demand state. In sum, relaxing the exogenous probability assumption does not change any of the key results of the paper as long as θ is less than 0.41.

Is 'overpricing' likely to be prevalent?

Turning now to the practical implications of our results, the obvious question that arises is: how often do we expect θ to be equal to or higher than 41% (in which case our model predicts $\hat{p} > p^o$)? In this context, the dynamic information gathering process outlined in Benveniste and Spindt (1989) seems relevant. After providing a preliminary price range, underwriters typically undertake a process of information gathering, including a series of road-shows, to gauge the level of market interest for the new issue. In fact, the offer price is typically not set until the 11th hour just before the actual IPO, allowing the underwriter to make the most informed decision in setting the price. Consequently, we believe an error as high as $\pm 40\%$ in gauging the mean level of investors' demand is unlikely to be typical. Thus, we think that in most cases θ would less than 0.4045, allowing the assumptions and the key results of the paper to hold. However, the numerical results also provide insight into why in rare cases where the uncertainty regarding the demand for the new issue is large, or where the underwriter is virtually certain about the high-demand for the issue, the underwriter may choose to price the IPO at a relatively high price.

2.5 Model Predictions Compared with the Empirical Findings in Extant Studies

Assuming exogenous probability for the states of demand, our numerical analyses show that for values of $0 \leq \theta < 0.41$ the underpricing percent ranges from zero to a maximum of 27%. The average level of underpricing is 9%. That is, on average we would expect underwriters to price new issues 9% higher if they had perfect information about the level of investors' demand.

Before we can compare these model results to the evidence in the empirical studies on underpricing a few observations are in order. As we noted earlier, most existing studies define underpricing as the difference between the price immediately after the IPO (typically first day closing price) and the offer price. However, it unclear whether the first day price or for that matter the price a first few weeks or a few months after the IPO is the right benchmark to compare in determining the extent of 'underpricing'. Studies have suggested (see e.g., Ljungqvist (2006)) that short-selling constraints and other inefficiencies in the market in the period shortly after the IPO prevent the market prices from moving down to their fundamental value. This hypothesis is supported by various empirical findings: for example, Malkiel et al. (2002) show that after the initial lock-up period (typically 180 days post-IPO), the prices of news issues show statistically significant negative abnormal returns. Furthermore, they show that the abnormal returns tend to negative through the 12-month period after the IPO. These findings are consistent with the evidence on long-run underperformance of IPOs (see e.g., Ljungqvist (2006) for a recent summary). Thus, it appears, if one were to define ‘underpricing’ as the difference between the fundamental value of the security and the offer price set by the underwriter, then using the first day closing price (as a measure of fundamental value) would greatly overstate the extent of ‘underpricing.’ One would likely get a much smaller average level of ‘underpricing’ if the offer prices were compared, for example, to the prices after the lock-up period for the new issues.

With this caveat in mind, we now turn to the empirical evidence in the existing literature. Loughran and Ritter (2002) report: “the average first-day return, measured from the offer price to the closing market price, is 14% for our sample firms” (p. 417). Their sample includes a total of 3025 IPOs in the period 1990 through 1998. Malkiel et al. (2002) report a slightly higher median first day return of 16.1%; however, their data period spans 1990 through 1999 and they report excess return, relative to the Nasdaq index, as opposed to raw returns. These figures are higher than the average 9% underpricing figure we find from the numerical analyses in our paper. However, in light of our argument that using first closing price in measuring ‘underpricing’ will tend to overstate the phenomenon, our model predictions seem consistent with the empirical evidence in the existing literature.

3. Conclusions

Prior research has focused on information asymmetry to explain ‘underpricing’ of IPOs. We provide a complementary explanation that is based on payoff asymmetry. We show that, under uncertain investors’ demand, the underwriter’s downside risk if he overestimates the demand for the new issue is significantly larger than the upside potential when he underestimates demand. To protect himself from the large downside risk, the underwriter chooses a lower offer price than he would have in the absence of demand uncertainty. Thus, we do not define ‘underpricing’ as the difference between the offer price and the first day closing price. Instead, consistent with our model, we characterize it as the difference between the underwriter’s chosen offer price and the higher price the underwriter would have set in the absence of uncertainty about the investors’ level of demand for the new issue.

However, this ‘underpricing’ is not found to be monotonically increasing with the level of uncertainty. Numerical analysis shows that one of the critical assumptions of the paper is violated when the level of uncertainty regarding investors’ demand becomes unusually large. In those cases, the underwriter’s pay-off maximizing price exceeds the one he would have charged in the absence of uncertainty.

References

Allen, F., and Faulhaber, G. 1989. Signaling by Underpricing in the IPO Market, Journal of Financial Economics, 32 (2), 303-324.

Anderson, de Palma, and Thisse, 1992, Discrete Choice Theory of Product Differentiation.

Baron, W. D. 1982. A Model of the Demand for Investment Banking Advising and Distribution Services for New Issues, The Journal of Finance, XXXVII (4), 955-976.

Beatty, R. and J. Ritter, 1986, Investment Banking, Reputation, and the Underpricing of Initial Public Offerings, Journal of Financial Economics 15, 213-232.

Benveniste, L.M. and Spindt, P.A. 1989, How Investment Bankers Determine the Offer Price and Allocation of New Issues, Journal of Financial Economics, 24, 343-361.

E. C. Prescott, 1976, Efficiency of the Natural Rate. Journal of Political Economy, 83: 1229-1236.

Eaton, B.C. and R.G. Lipsey, 1989, "Product Differentiation," in R. Schmalensee and R.D. Willig (eds.), Handbook of Industrial Organization, Vol. 1. Amsterdam: North-Holland, pp. 723-763.

Grinblatt, M. and Hwang, C.Y. 1989, Signaling and the Pricing of New Issues, Journal of Finance, 44, 393-420.

Hanley, K., 1993, The Underpricing of Initial Public Offerings and the Partial Adjustment Phenomenon, Journal of Financial Economics 34, 231-250.

Ibbotson, R.G., 1975, Price Performance of Common Stock New Issues, Journal of Financial Economics, 2, 235-272.

Ibbotson, R.G., and Ritter, J. 1995, Initial Public Offerings, Handbook of Operations Research and Management Science: Finance, North-Holland, Amsterdam.

Lougharn, T. and Ritter, J. , 2002, Why Don't Issuers Get Upset About Leaving Money on the Table in IPOs? The Review of Financial Studies, 15 (2), 413-443.

Ljungqvist, A., Nanda, V., and Singh, R. 2006, Hot Markets, Investor Sentiment, and IPO Pricing, Journal of Business, 79 (4).

Lowry, M. and S. Shu, 2002, Litigation Risk and IPO Underpricing, Journal of Financial Economics 65, 309-335.

Malkiel, B.G., Garfinkle, N. and Bontas, C. 2002. Effect of Underpricing and Lock-Up Provisions in IPOs, The Journal of Portfolio Management. Spring (8274), 50-58.

Mood, Graybill, and Boes, 1974, Introduction to the Theory of Statistics, 3rd Edition.

Rock, K., 1986, Why New Issues are Underpriced, Journal of Financial Economics, 15, 187-212.

Spiess, D.K., and Pettway, R.H., 1997, The IPO and First Seasoned Equity Sale: Issue proceeds, Owner/managers' Wealth, and the Underpricing Signal, Journal of Banking and Finance, 21, 967-988

Talluri & Ryzin, 2005, The Theory and Practice of Revenue Management.

Tinic, S., 1988, Anatomy of Initial Public Offerings of Common Stock, Journal of Finance 43, 789-822.

Welch, I. 1989, Seasoned Offering, Imitation Costs, and the Underpricing of Initial Public Offerings, Journal of Finance, 44, 421-449.

Figure 1: The Payoff and Expected Payoff Functions for Various Levels of Theta

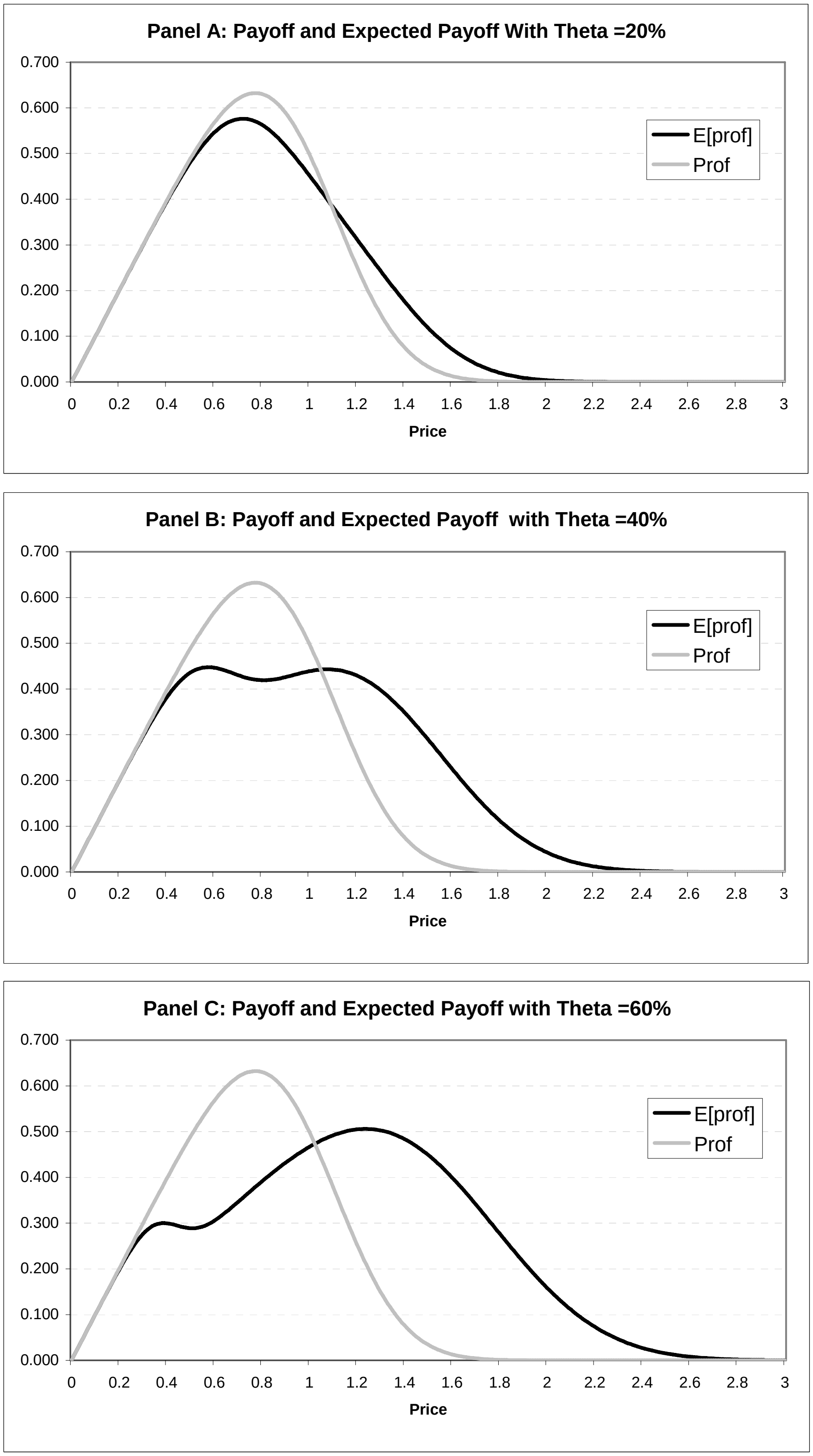


Figure 2: Optimal Offer Prices for Various Levels of Theta

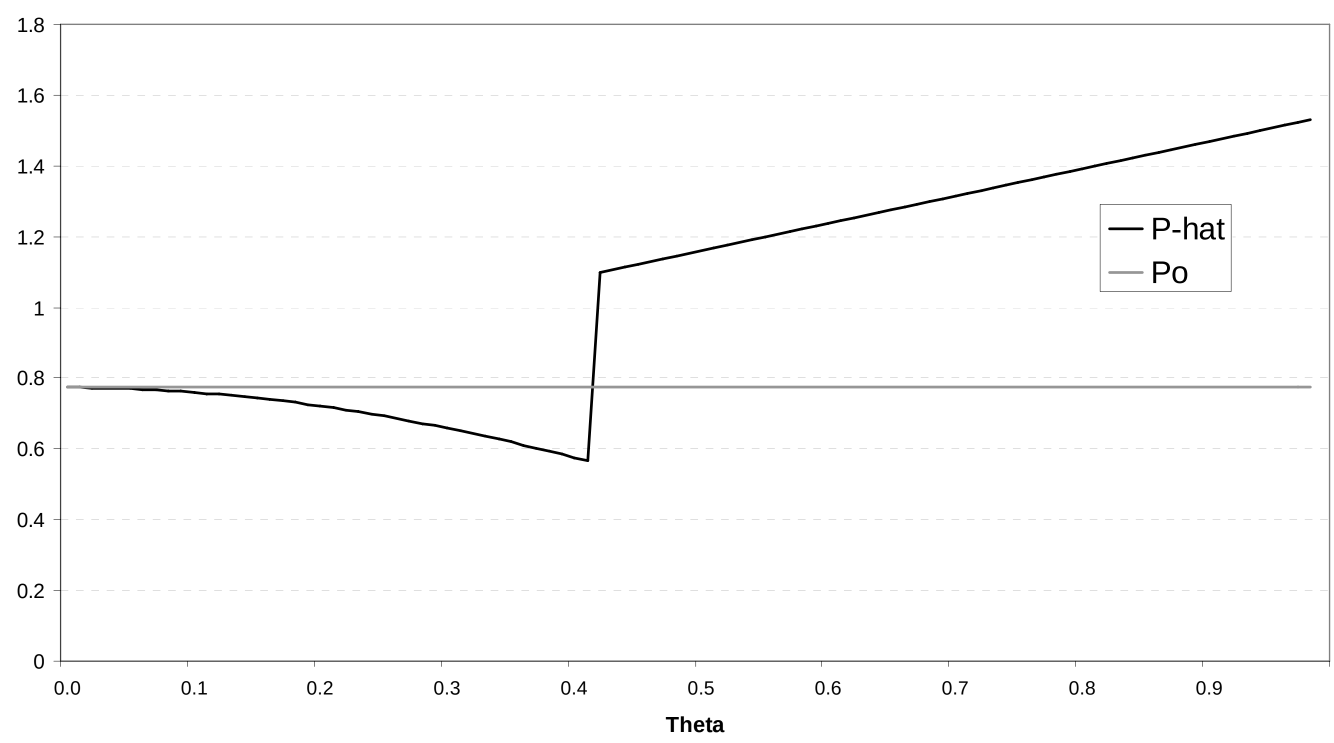
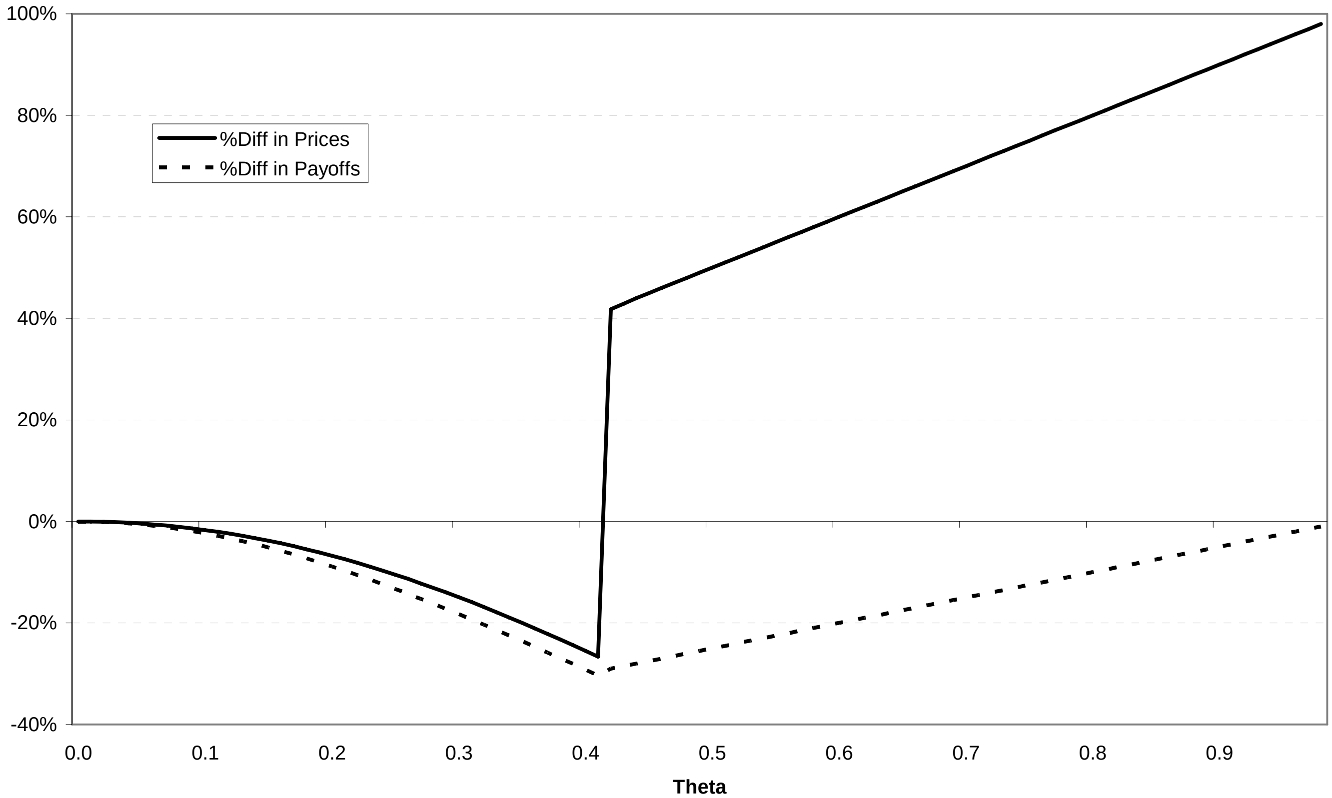


Figure 3: Percent Difference in Prices and Payoffs Under Certainty and Uncertainty



Proof of Propositions

Before proving the propositions we need to establish a preliminary result. The payoff asymmetry, i.e., $\frac{\left|\pi^L - \pi^o\right|}{\pi^o} > \frac{\pi^H - \pi^o}{\pi^o}$, holds only if $p^o < \bar{m}$. We show below that any optimal price under certainty is such that $p^o < \bar{m}$.

The underwriter's profit maximization problem's first order condition (foc), dividing through by N:

$$\frac{\partial \pi}{\partial p} = 1 - \Phi\left(p, \bar{m}\right) - p \cdot \phi\left(p, \bar{m}\right)$$

where $\phi\left(\cdot\right)$ is the normal pdf. Evaluating the foc at $\bar{m}$:

$$\left.\frac{\partial \pi}{\partial p}\right|_{p=\bar{m}} = 1 - \Phi\left(\bar{m}, \bar{m}\right) - \bar{m} \cdot \phi\left(\bar{m}, \bar{m}\right) = 1/2 - \bar{m} \cdot \phi\left(\bar{m}, \bar{m}\right)$$

$$= \frac{1}{2} - \frac{\bar{m}}{\sigma\sqrt{2Pi}}.$$

Now note $\frac{\bar{m}}{\sigma\sqrt{2Pi}} > \frac{1}{2}$ for all $\bar{m} > 1.2533 \cdot \sigma$. However, by Assumption A8, since we require $P[W \leq 0] \cong 0$ it must be that $\bar{m} > 1.2533 \cdot \sigma$. Thus, $\left.\frac{\partial \pi}{\partial p}\right|_{p=\bar{m}} < 0 \Rightarrow p^o < \bar{m}$, since by Assumption A7, $p \cdot D\left(p, m\right)$ is strictly concave in *p*.

Proof of Proposition 1

As noted above, since $P[W \leq 0] \cong 0$, we posit $W \sim \Phi\left(m, \sigma\right)$ with $\sigma = \frac{m}{4} \Rightarrow P\left[w \leq 0\right] < 10^{-4}$.

Let us now re-parameterize the underwriter's choice problem under uncertainty as follows:

$$\underset{p}{Max}\, E\left[\tilde{\pi}\right] = p \cdot E\left[D\left(p, \tilde{m}\right)\right] = p \cdot \left\{D\left(p, m^o\right) + D\left(p, m^o \cdot t\right)\right\}/2$$

where $m^H = m^o$; $m^L = m^o \cdot t$ and $0 < t \leq 1$. The demand uncertainty is characterized by $t < 1$. In this set up, when $t = 1$ the expected profit maximization problem collapses to the problem under certainty. Also, note when $t = 1$, $\bar{m} = \left(m^o + t \cdot m^o\right)/2 = m^o$.

Thus, in terms of the notations in the main body of the paper, $\theta = \frac{(1-t)}{(1+t)} \Rightarrow \frac{\partial \theta}{\partial t} < 0$.

Without any loss of generality let us rescale the distribution of *W* such that $m^o = 1$. Now note:

$$\frac{\partial \hat{p}}{\partial t} \doteq \frac{\partial^2 E\left[\tilde{\pi}\right]}{\partial t \partial p} = \frac{e^{-z}\hat{p}\sqrt{\frac{2}{Pi}}}{2 \cdot t^4} \cdot \left(t^2 + 8 \cdot \left(t - \hat{p}\right)\right)$$

where $\doteq$ denotes 'has the same sign as' and $z = \frac{8 \cdot \left(p - t\right)^2}{t^2}$. Thus, $\frac{\partial \hat{p}}{\partial t} > 0$ if $\left(t - \hat{p}\right) > 0$.

To demonstrate $\left(t - \hat{p}\right) > 0$ evaluate the expected profit maximization problem's foc at t:

$$\left.\frac{\partial E\left[\tilde{\pi}\right]}{\partial p}\right|_t = \left(2 - 4\sqrt{\frac{2}{Pi}}\left(1 + t \cdot e^{-8(t-1)^2}\right) - Erf\left[2\sqrt{2}\left(t-1\right)\right]\right)/4$$

It is readily verified that the above expression is negative for all $0 < t < 1$. By A7, since, $E\left[\tilde{\pi}\right]$ is strictly concave in *p*, $\left.\frac{\partial E\left[\tilde{\pi}\right]}{\partial p}\right|_t < 0 \Rightarrow \hat{p} < t$. Thus, $\frac{\partial \hat{p}}{\partial t} \doteq \left(t - \hat{p}\right) > 0 \Rightarrow \frac{\partial \hat{p}}{\partial \theta} < 0$, since $\frac{\partial \theta}{\partial t} < 0$. ∎

Proof of Proposition 2

By Proposition 1, since $\frac{\partial \hat{p}}{\partial t}$ > *0* for all $0 < t < 1$, and $\hat{p} = p^o$ when t = 1, it must be true that $\hat{p} < p^o$ for all values of $t < 1$; *i.e.*, $\hat{p}$ must approach p^o "from below" as $t \to 1$.

∎

Proof of Proposition 3

Recall: $$\hat{\pi} = E\left[\pi\left(\hat{p}\right)\right] = \hat{p} \cdot \left\{D\left(\hat{p}, m^o\right) + D\left(\hat{p}, m^o \cdot t\right)\right\} / 2 .$$

Differentiating with respect to t and applying envelope theorem:

$$\frac{\partial \hat{\pi}}{\partial t} \doteq \frac{\partial D(\cdot)}{\partial m} = \frac{2 \cdot p \cdot \sqrt{\frac{2}{Pi}} e^{-\frac{8(m-p)^2}{m^2}}}{m^2} > 0$$

Since $\frac{\partial \hat{\pi}}{\partial t} > 0$ and $\hat{\pi} = \pi^o$ when t =1, it must be true for all $t < 1$ that $\hat{\pi} < \pi^o$. ∎

Proof of Proposition 4

Follows from the result in Proposition 3, $\frac{\partial \hat{\pi}}{\partial t} > 0$, and $\frac{\partial \theta}{\partial t} < 0$. ∎