# Testing for Deliberate Underpricing in the IPO Premarket: A Stochastic Frontier Approach

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***We reevaluate the IPO underpricing phenomenon using the stochastic frontier methodology. The advantage of the stochastic frontier is that it can be used to measure the level of deliberate underpricing in the premarket without using aftermarket information. This is accomplished through the estimation of a systematic one-sided error term that measures "inefficiency" or the difference between the maximum predicted offer price and the actual offer price. Data for the analysis are comprised of 1,035 IPOs of common stock issued by firm commitment between 1975 and 1984. IPOs appear to be deliberately underpriced in the premarket in both hot-market and nonhot-market periods. Moreover, the determinants of the maximum IPO price have different effects in the two time periods.***

One of the most widely investigated phenomena in the finance literature is the price performance of initial public offerings (IPOs) of common stock [see Ag-

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garwal and Rivoli (1990), Ibbotson (1975), Ibbotson, Sindelar, and Ritter (1988), and Ritter (1991), among others]. Although researchers have documented average underpricing (defined as the percent difference between the closing day bid price and the initial offer price) over the first few days of trading, little evidence exists as to whether this underpricing is deliberate, either because offer prices are discounted to reflect the fundamental risk of the firm [Ritter (1987)] or because of characteristics of the preoffering process [Benveniste and Spindt (1989) and Rock (1986)]. [On underpricing, see, for example, Allen and Faulhaber (1989), Baron (1982), Beatty and Ritter (1986), Benveniste and Spindt (1989), Rock (1986), Tinic (1988), and Welch (1989).] The conclusion of deliberate underpricing is problematic because researchers must use aftermarket data to infer the correct price relative to the premarket offer price. Similarly, certain studies of abnormal returns in the aftermarket employ the metric of the IPO price. IPOs need not be deliberately underpriced if the observed abnormally high initial returns are due to aftermarket characteristics such as fads [Aggarwal and Rivoli (1990) and Ritter (1991)] or underwriter price support [Hanley, Kumar and Seguin (1993) and Ruud (1993)]. A test of the alternatives requires, as a first step, the ability to estimate the degree of underpricing without relying on the aftermarket price.

Our purpose is to reexamine the IPO underpricing phenomenon. Unlike previous research, we measure underpricing using information available only in the premarket period. The stochastic frontier estimator [Aigner, Lovell, Schmidt (1977)] is the innovation that allows us to compare the actual price with the estimated "efficient" price. In effect, the stochastic frontier assumes that a maximum price exists, and that actual prices fall below the maximum for some systematic reason such as "economic inefficiency." This deviation from the maximum price can be measured by a one-sided error term. The degree of underpricing can be computed for each stock in question or for groups of stocks. Effectively, the "efficient" frontier is the equivalent of the full-information price frontier whose unbiased expectation is the efficient frontier, the maximum price that would prevail if all trading parties had complete information about the underlying value of the firm going public. The expectation is made explicit through a random two-sided disturbance term that completes the error structure. If no systematic underpricing exists, the one-sided error will not appear and the frontier will be equivalent to OLS estimation of prices [see Jondrow et al. (1982)].

The stochastic frontier estimator is well-suited for the IPO underpricing problem. Despite numerous applications, it has yet to be applied to the general finance literature or to this problem. In contrast to traditional approaches, the stochastic frontier allows investors, investment bankers, and financial officers of firms going public to estimate a maximum offer price prior to price setting by investment bankers and prior to the first day of trading. Financial officers can therefore evaluate the expected discount associated with an offer price proposed by underwriters. In turn, underwriters have an upper bound that can be incorporated in their decision making.

In this application, the frontier estimator is also used to compare the estimated price discount of a particular stock in the premarket with the initial aftermarket return of that stock. In doing so, insights about the hypotheses that predict premarket versus aftermarket pricing anomalies are gained. For example, suppose that the two sets of hypotheses are mutually exclusive, competing explanations of an observed pricing anomaly. Once an adjustment is made for deliberate underpricing, measured excess returns should largely disappear. On the other hand, if both phenomena exist independently, the correlation between the discount and the aftermarket return may be close to zero. The stocks that are discounted need not be the stocks that are then supported in the aftermarket. The evidence we present is indicative of the existence of both phenomena. Underpricing, at least as we measure it, explains a portion of the aftermarket returns at certain times (e.g., in hot-issue markets), but appears largely uncorrelated at other times.

This article is organized as follows. In Section 1 we review the existing research on the phenomenon of IPO pricing. Section 2 explains the concept of a full-information IPO price frontier and the associated estimator capturing systematic departures from the pricing frontier (deliberate underpricing). Section 3 contains a description of the data and model specifications. Section 4 provides empirical results of the stochastic frontier estimation and the initial returns regressions. Concluding remarks are found in Section 5.

## 1. The Theory of IPO Underpricing

Theoretical explanations for the observed positive abnormal returns of IPOs have, in general, focused on the asymmetry of information between the various agents involved with the IPO, namely, the issuer, the investment banker, and the group(s) of outside investors.[1] Baron (1982) assumes that investment bankers are better informed than the issuers. Thus, underpricing of IPOs is a mechanism for compensating investment bankers for the use of their reputation and expertise to signal the quality of the issuing firms. The payoff to investment bankers

[1] For reviews of the theoretical literature, see Dobson (1990) and Hanley and Ritter (1992).

is in the form of rents that may be captured from loyal buy-side clients. Benveniste and Spindt (1989) hypothesize that underpricing is used by investment bankers to compensate investors for revealing information during the preselling period to facilitate the pricing of the issue. According to Shiller (1990) and Welch (1992), underpricing of IPOs occurs for the purpose of initiating a cascade of buying activity. Allen and Faulhaber (1989), Grinblatt and Hwang (1989), and Welch (1989) provide signaling explanations in which investment bankers may seek to underprice IPOs to "leave a good taste" with investors. Tinic (1988) maintains that underpricing in IPOs occurs because of the risks of potential lawsuits that might otherwise arise. A common feature of these articles is the argument that underpricing of IPOs by the issuer and/or the investment banker(s) is deliberately undertaken.

Alternative hypotheses as to the cause of the "observed" underpricing (the percent difference between the closing day bid price in the aftermarket and the initial offer price) can be found in work by Aggarwal and Rivoli (1990), Hanley, Kumar, and Seguin (1993), Ruud (1993), and Shiller (1990). Aggarwal and Rivoli (1990) and Shiller (1990) contend that the observed short-run positive abnormal returns may be due to the existence of fads or speculative bubbles in the IPO market. They note that the characteristics of IPOs and the issuance process can easily lead to overvaluation by investors in the early trading period.[2] The speculative bubble/fads hypothesis implies that the initial positive average abnormal returns should be followed by negative average abnormal returns as the bubble bursts at a later date. Aggarwal and Rivoli (1990) and Ritter (1991), among others, investigate the aftermarket efficiency of IPOs. Focusing on the long-run performance of IPOs, the studies show that typically there are no positive abnormal returns for investors purchasing in the aftermarket. Moreover, if one examines the abnormal returns over the long run (1 to 3 years), the evidence suggests that IPOs consistently underperform the market. As Ritter (1991, p. 24) notes, the long-run performance of IPOs, suggests that "the offering price is not too low, but that the first aftermarket price is too high."

Ruud (1993) argues that the positive initial day returns are due to underwriter price support. The Securities and Exchange Commission allows investment bankers to intervene in the IPO aftermarket to stabilize prices. The effect of this price stabilization is to significantly reduce the number of negative initial returns that would be observed in the IPO aftermarket. That is, the intervention of the investment

[2] Camerer (1989) also points out that fads are more likely to be present in IPO markets because of the inherent difficulty in valuing these offerings and because of the high level of uncertainty that characterizes these issues.

bankers in the IPO aftermarket effectively censors the initial returns at some nonpositive value. The censoring of the negative tail of the distribution of initial return produces positive mean initial returns even if IPOs are priced at their intrinsic value. Results provided support for the hypothesis that IPOs are subject to underwriter price support in the aftermarket.

Thus, the evidence provided by Aggarwal and Rivoli (1990), Hanley, Kumar, and Sequin (1993), Ritter (1991), and Ruud (1993) is consistent with the view that IPOs are priced at their intrinsic value and it is the aftermarket inefficiencies caused by underwriter price support, fads, and/or speculative bubbles that lead to the abnormal price appreciation. This evidence calls into question the explanatory power of hypotheses which argue that the positive abnormal return is the result of deliberate underpricing by the issuer and/or investment banker. The unresolved nature of this issue is characterized by Ritter (1991, p. 24): "If issuers and their investment bankers set the offering price in a manner that reflects the firm's underlying fundamental value, however, it is even more of a mystery why some offerings have extremely high initial returns."

Using the stochastic frontier methodology, we seek to evaluate whether IPO underpricing is systematic in nature. OLS regressions of actual offer prices can only determine the effect of the issuer's fundamental characteristics on the setting of the actual offer price. This would understate the true or potential offer price if effects of adverse selection or information gathering cannot be measured. In contrast, the stochastic frontier methodology allows us to incorporate additional factors to determine the potential offer price that is not captured by fundamental characteristics of the firm. Note that these factors can be anything that influences the setting of the offer price, such as adverse selection, information gathering costs, or the cost of premarketing the issue.

## 2. Methodology

### 2.1 The stochastic frontier

A point on the stochastic frontier represents the maximum price that would prevail for a given IPO if all parties in the trade had full information. The difference between any given offer price and the maximum price under full information would be the result of random error alone. There would be no systematic underpricing and the frontier price can be computed by using ordinary least squares to estimate the expected price given observable variables.

If, however, there is deliberate underpricing (a systematic negative bias), the offer price will fall below the maximum potential by an amount or fraction represented by the one-sided error. In this case, there is both a stochastic error and a systematic one-sided error. Under stochastic frontier maximum likelihood estimation, any systematic error, if it exists, will appear in the form of skewness in the residuals and can be computed for each IPO separately. The average deviation from the full-information price can also be computed for each class of securities.

By contrast, under OLS, the systematic error component is incorporated into the intercept and is unidentifiable. The OLS intercept will lie below the frontier, and OLS would not predict the full-information price but rather the average of the actual set of initial offering prices.

This methodology provides a direct test of the existence of deliberate underpricing. If OLS estimation is equivalent to maximum likelihood (ML) estimation, no systematic underpricing exists in the premarket. This would suggest that researchers should devote their efforts to explaining abnormal returns as an aftermarket phenomenon.

## 2.2 The maximum likelihood estimator

The stochastic frontier model of ALS is estimated via ML methods. The frontier and distributional assumptions can be expressed as

$$\begin{aligned} P_i &= f(X_i;\beta) + e_i, \quad i = 1, 2, \ldots, n \qquad (1)\\ e_i &= v_i + u_i \\ v_i &\sim N(O, \sigma_v^2) \\ `u_i &\sim N[(\sqrt{2}/\sqrt{\pi}\sigma_u), \sigma_u^2] \\ u_i &= \min(`u_i, 0) \end{aligned}$$

where $P_i$ is the observed initial offer price at the time of offering; $X$ is a vector of characteristics; $\beta$ is a vector of coefficients of the IPO pricing frontier; $v$ denotes the symmetric error component; $u$ is the asymmetric component and is truncated at zero, since discounting takes the maximum value of 0 and, by assumption, is independent of $v$. The composite error term is $e$. The nonpositive error term $u_i$ is interpreted to mean that the actual price must lie on or below the true but unknown frontier, while the two-sided error $v_i$ suggests that observed prices may lie above or below the estimated frontier due to statistical noise.

Aigner, Lovell and Schmidt (1972) estimated the stochastic frontier model by using the distribution function of the sum of a symmetric normal random variable and a truncated random variable which had been derived by Weinstein (1964). The density function is

$$f(e_i) = (2/\sigma)f(e_i/\sigma)[1 - F(e_i\lambda\sigma^{-1})], \qquad (2)$$

where, $\sigma_2 = \sigma_u^2 + \sigma_v^2$; $\lambda = \sigma_u/\sigma_v$; $-\infty < e_i < +\infty$; and $f(e_i/\sigma)$ and $F(e_i\lambda\sigma^{-1})$ are the standard normal density and distribution functions, respectively.

If the $P$'s are independently distributed, and the nonstochastic part of $P_i$ is explained by a set of exogenous variables $X$, the log-likelihood function becomes

$$\ln L(P, \beta, \lambda, \sigma^2) = N \ln(\sqrt{2}/\sqrt{\pi}) + N \ln \sigma^{-1} + \sum_i \ln[1 - F(e_i\lambda\sigma^{-1})] - (1/2\sigma^2) \sum_i e_i^2, \qquad (3)$$

where $e_i = P_i - \beta' X_i$, $i = 1, \ldots, N$.

Aigner, Lovell, and Schmidt provide a means for obtaining the optimal values of $\sigma^2$, $\beta$, and $\lambda$. This approach, in contrast to the conventional OLS approach, enables one to identify the placement of the efficient IPO price frontier. In principle, OLS will provide a best linear unbiased and consistent estimate of the vector of slope coefficients so conventional hypothesis testing can be carried out. However, the OLS estimator of the intercept is biased and inconsistent, since the mean of the composite error is nonzero. The OLS estimator of slope coefficients may be less statistically efficient than the ML estimator that treats the composite error as asymmetric.

In this context, the estimate of $\lambda$ is of particular interest since it allows a comparison of ML to OLS estimates of the frontier. Specifically, $\lambda$, the skewness in the error component ($u_i$) relative to the symmetric random disturbance ($v_i$), measures gains in statistical efficiency of the frontier estimator over OLS.[3] The estimate of $\lambda$ has a straightforward interpretation for inferring deliberate IPO underpricing. If $\lambda$ goes to zero, deviations in actual prices from the frontier are due simply to statistical noise. This means that the symmetric error ($\sigma_v$) dominates the asymmetric error ($\sigma_u$) and maximum likelihood estimates are not significantly different from OLS estimates. On the other hand, if $\lambda$ is greater than zero, deviations from the frontier are characterized by some form of deliberate discounting in the premarket pricing of IPOs. In this case the half-normal error dominates the symmetric error term and ML estimates of the frontier will be quite different from OLS estimates. Thus, as $\lambda$ becomes large, deliberate discounting in the pricing of IPOs is indicated.

[3] See Hunt-McCool and Warren (1994) for a comparison of the deterministic and stochastic frontier estimators over OLS.

### 2.3 Specification of initial returns regressions

As in Ruud (1993), we interpret the existence of skewness in the measured returns to suggest excess returns. If aftermarket returns are randomly distributed around the full information offer price, the mean excess return will be zero and the distribution will be symmetric around this mean. In our sample, 460 of the 1,035 IPOs have a positive return, measured by comparing the first-day closing price with the premarket offer price. The mean return of the first-day closing prices for all 1,035 IPOs is around 10%, but is 19% for the 460 with positive returns. The measure of skewness is 5.79, suggesting that issues may be subject to excess returns. Of course, the measurement of excess returns remains dependent upon the premarket offer price. If excess returns are an artifact of measurement (resulting from the failure of the offer price to correctly indicate the economic value of the firm due to deliberate underpricing), they should disappear once adjustments are made for premarket underpricing. However, if they exist independent of underpricing, the correlation between the measured returns and measured underpricing may be close to zero. To test for the correlation between aftermarket returns and premarket underpricing, we first estimate the $P_i^*$'s, the predicted maximum prices for each of the IPOs. Using the modal formula proposed by Jondrow et al. (1982), the level of systematic underpricing for each IPO is computed. The formula is

$$\begin{aligned} u_i^* = M(u_i \mid e_i) &= -e_i(\sigma_u^2/\sigma^2) \quad \text{if } e_i \leq \text{Equation (4)} \\ &= 0 \quad\quad\quad\quad\quad\; \text{if } e_i > 0. \end{aligned}$$

The second stage involves a variant of the methodology proposed by Hunt and Warren (1987), where the percentage by which an issue is underpriced ($u_i^*/P_i^*$) is used as an independent variable in a regression in which the dependent variable is the initial-day return.[4]

$$\text{RETURN}_i = \alpha + \beta(u_i^*/P_i^*) + \epsilon_i, \tag{5}$$

where $\alpha$ $\beta$ and are parameters to be estimated and $\epsilon_i$ is the random error term. OLS is used to estimate this equation. The ratio of $u_i^*$ to the estimated frontier price $P_i^*$ is the issue-specific percent underpricing.

## 3. Data and Model Specifications

The data employed in this analysis were compiled by Jay R. Ritter. Our sample consists of 1,035 IPOs issued over the period 1975 to 1984

[4] Note that $M(u_i \mid e_i)$ is an observation-specific estimate of the asymmetric error. Given that the dependent variable ($LNOP$) in the first-stage regression is expressed in logarithmic terms, $u_i^*/P_i^* = 1 - \exp M(u_i \mid e_i)$.

with the requisite information. The criteria for choosing the sample are (1) the issue was underwritten by an investment banker via firm commitment, (2) the issue is comprised of only common stocks (unit offerings are excluded), (3) the issuer filed an S-1 or S-18 registration statement with the Securities and Exchange Commission, (4) the firm had at least 3 years of operating history before going public, and (5) the net proceeds from the issue are at least $1 million. Additional description of the data may be found in Ritter (1987, 1991). The proxies for the theoretical constructs are described below. The choice of these proxies is in part dictated by the underlying theory and from previous empirical research. Variable definitions are presented in the appendix, which includes variables related to the firm's value, risks, and general market trends.

Several authors, including Krinsky and Rotenberg (1989) and Ritter (1984), have shown a positive relationship between historical accounting information and firm value. We use LOGSALES as a proxy variable for the profitability of a firm. LOGBOOK is used as a measure of the level of firm operations.

Two variables are used to control for riskiness of the IPO: RISKS and LOGAGE. RISKS is the number of risk factors as indicated in the prospectus of the firm. Consistent with Beatty and Ritter (1986), we expect $P_i^*$ to be negatively related to RISKS. LOGAGE is a measure of the number of years since incorporation. Ritter (1987) suggests that the age of the firm may be a proxy for a reduction in ex ante uncertainty.

Hughes (1986) hypothesizes that underwriters' compensation is directly related to the costs of investigating firm characteristics. This implies that underwriters' compensation will be higher for firms about which there is less public information, for example, younger companies. This suggests a negative relationship between underwriters' commission (COM) and the initial firm value, and thus the potential offer price.

Tinic (1988) points out that small issues are typically offered by small start-up companies that are considered to be speculative issues. In contrast, larger issues are usually made by relatively seasoned large companies. Thus we would expect a positive relationship between issue size (LOGPROC) and potential offering price.

INSFR represents the percentage of the offering held by insiders. Downes and Heinkel (1982) and Grinblatt and Hwang (1989), among others, argue that the percent of ownership retained by insiders signals to investors private information possessed by insiders. This suggests that insiders with good information will, in general, retain a larger percentage of the company, while those possessing less favorable information will sell a larger percentage. Thus, ceteris paribus, the IPO offering price should be an increasing function of INS.

PERATIO is the average price earnings ratio of the S&P price/earnings ratio for the quarter in which the issue is offered to the public. PERATIO is used to adjust for general trends in the market that are likely to affect the behavior of investors and underwriters.

The dummy variables COMP through HEALTH control for six industry-specific effects associated with computer manufacturing (COMP), communications and electronic equipment (EQUIP), the oil and gas industry (OIL/GAS), data processing and computer services (SERVICE), manufacture of scientific instruments (INSTRUM), and the health sector (HEALTH). Firm value is not likely to be evenly distributed across industries (Ritter 1991).

## 4. Empirical Results

### 4.1 Summary statistics

Table 1 contains the means and standard deviations of the independent variables. These summary statistics are provided for the full sample of IPOs and for two subsamples: IPOs issued in hot-issue periods and those issued at all other times. Hot markets are defined as those in which measured initial returns are relatively high and/or are periods of unusually large issues of IPOs. Ibbotson and Jaffee (1975) defined hot markets as periods in which the measured aftermarket returns exceeded the median aftermarket return. Subsequentlly, Ibbotson, Riter, and Sindelar (1988, 1994) expanded this definition to include periods of large numbers of IPO issues. In this analysis we employ the data collected by Ritter through 1982, as well as additional data from 1983 and 1984 collected using Ritter's criteria. Ritter (1984) plotted the initial returns to determine the periods in which outliers occurred, and our definition corresponds exactly to his for the period through 1982. Ibbotson, Sindelar, and Ritter (1988) identified the hot-market periods that occur between 1960 and 1987. Their identification of hot-market periods applies to data in our sample obtained after 1982. In our analysis, the hot-issue market period is defined to include IPOs that were issued from January 1980 through March 1981 and from January 1983 through December 1984. The nonhot-issue market period includes IPOs issued from January 1975 through December 1979 and from April 1981 through December 1982. Summary statistics for these subsamples are provided in the remaining columns of Table 1.

In the full sample, on average an 8% commission was charged, and insiders held a majority of shares. It appears that about 50% of all offers arise from the industries defined by the six variables, COMP through HEALTH.

When the sample is divided by time period, summary statistics are roughly equal in hot-issue periods and other times. The only obvious

**Table 1**
**Summary statistics**[a]

| | Full sample | Hot | Nonhot |
|---|---|---|---|
| LOGOP (log of offer price) | 2.177 | 2.175 | 2.180 |
| | (0.686) | (0.685) | (0.687) |
| RETURNS | 0.099 | 0.103 | 0.091 |
| | (0.235) | (0.261) | (0.169) |
| LOGBOOK (log of book value) | 7.778 | 7.775 | 7.785 |
| | (1.661) | (1.755) | (1.451) |
| LOGSALES (log of sales) | 16.025 | 16.064 | 15.945 |
| | (2.085) | (2.165) | (1.911) |
| RISKS (number of risks on prospectus) | 4.661 | 4.683 | 4.614 |
| | (5.981) | (5.847) | (6.261) |
| COM (commission rate) | 0.080 | 0.079 | 0.081 |
| | (0.013) | (0.014) | (0.012) |
| INSFR (insider fraction) | 0.701 | 0.698 | 0.708 |
| | (0.120) | (0.122) | (0.116) |
| LOGAGE (log of age of firm) | 1.937 | 1.918 | 1.977 |
| | (1.003) | (0.995) | (1.019) |
| LOGPROC (log of proceeds from issue) | 15.817 | 15.930 | 15.582 |
| | (0.996) | (1.003) | (0.940) |
| PERATIO (S&P P/E ratio) | 10.08 | 9.15 | 12.0 |
| | (1.95) | (1.48) | (1.28) |
| COMP (computer industry) | 0.1159 | 0.1146 | 0.1187 |
| | — | — | — |
| EQUIP (communications equipment industry) | 0.1101 | 0.1032 | 0.1246 |
| | — | — | — |
| OIL/GAS (oil/gas industry) | 0.059 | 0.037 | 0.104 |
| | — | — | — |
| SERVICE (Computers/data processing services) | 0.088 | 0.083 | 0.098 |
| | — | — | — |
| INSTRUM (medical, scientific instruments industry) | 0.083 | 0.079 | 0.092 |
| | — | — | — |
| HEALTH (health/drug industry) | 0.062 | 0.066 | 0.053 |
| | — | — | — |

[a]Values are means with standard deviations in parentheses.

differences are the industrial distribution, and perhaps, PERATIO. The oil and gas industry is relatively important in the nonhot-issue period, and the PERATIO is somewhat higher in the nonhot-issue period. Despite the similarities in endowments between hot- and nonhot-issue periods, the full sample is divided into market periods because additional testing revealed structural differences in the determinants of the IPO price.[5] These differences are discussed in the next section.

## 4.2 Estimates of the stochastic frontier

The results of estimation of the price frontier for the full sample and for the two subsamples conditioned on market period are provided in Table 2. In the full sample, almost all coefficients are statistically significant and hold the expected signs. LOGBOOK and LOGSALES are pos-

[5] We are grateful to an anonymous reviewer for pointing out discrepancies in our earlier draft that lead us to test for differences by market periods.

**Table 2**
**Estimated frontier**[a]

| | Full sample | Hot | Nonhot |
|---|---|---|---|
| Constant | −1.003 | −1.307 | −0.608 |
| | (−3.57) | (−3.34) | (−1.12) |
| LOGBOOK (log of book value) | 0.015 | 0.010 | 0.023 |
| | (1.68) | (0.91) | (1.16) |
| LOGSALES (log of sales) | 0.235 | 0.019 | 0.042 |
| | (3.16) | (1.99) | (3.16) |
| RISKS (number of risks on prospectus) | −0.022 | −0.022 | −0.023 |
| | (−9.07) | (−6.94) | (−5.61) |
| COM (commission rate) | −11.37 | −9.392 | − 13.605 |
| | (−13.37) | (−9.07) | (−6.41) |
| INSFR (insider fraction) | 0.541 | 0.432 | 0.834 |
| | (6.11) | (3.80) | (5.39) |
| LOGAGE (log of age of firm) | 0.040 | 0.049 | 0.014 |
| | (3.42) | (3.34) | (0.70) |
| LOGPROC (log of proceeds from issue) | 0.222 | 0.244 | 0.201 |
| | (15.16) | (11.81) | (7.64) |
| PERATIO (S&P P/E ratio) | 0.009 | 0.003 | −0.024 |
| | (1.59) | (0.33) | (−1.67) |
| COMP (computer industry) | 0.0554 | 0.046 | 0.064 |
| | (1.54) | (0.98) | (1.09) |
| EQUIP (communication equipment industry) | −0.003 | 0.023 | −0.042 |
| | (−0.08) | (0.48) | (−0.75) |
| OIL/GAS (oil/gas industry) | −0.055 | −0.025 | −0.086 |
| | (−1.31) | (0.45) | (−1.36) |
| SERVICE (computers/data processing services) | 0.069 | 0.075 | 0.021 |
| | (1.71) | (0.050) | (0.32) |
| INSTRUM (medical, scientific instruments industry) | 0.078 | 0.036 | 0.134 |
| | (2.18) | (0.81) | (1.92) |
| HEALTH (health/drug industry) | 0.201 | 0.250 | 0.143 |
| | (4.88) | (5.29) | (1.73) |
| $\lambda$ | 2.672 | 2.92 | 1.992 |
| | (9.06) | (9.42) | (3.99) |
| $\sigma$ | 0.522 | 0.538 | 0.498 |
| | (33.54) | (28.97) | (13.64) |
| $n$ | 1035 | 698 | 337 |
| $L$ | −334.94 | −234.08 | −79.63 |

[a]Maximum likelihood estimates with $t$-statistics in parentheses.

itively correlated with the maximum potential offer price. The same is true of the insider fraction, age, and proceeds (INSFR, LOGAGE, and LOGPROC, respectively). Factors shifting the frontier down are related to risks and information costs (RISKS and COM). Three industries exhibit relatively high frontier prices: computer/data processing (SERVICE), scientific instruments (INSTRUM), and the health sector (HEALTH). The measure of the one-sided error $\lambda$ is also significant, suggesting that skewness in the residuals exists and that substantial gains in statistical efficiency of ML over OLS exists.

We investigate whether the regression coefficients are sensitive to the year in which the IPOs are offered, specifically between hot-issue periods and other times. Frequently, high initial returns are associated with a high volume of IPOs issued.

A log-likelihood ratio test is employed to determine whether a structural shift in IPO pricing occurs between hot- and nonhot-issue periods. This ratio is distributed $\chi^2$ with $K$ degrees of freedom, where $K$ is the number of restrictions. The computed test statistic is 41.62. Because we reject the null hypothesis that the coefficients are equal between hot- and nonhot-issue periods, the results provided from the full-sample estimation are no more than illustrative. The preferred structural models are estimated and results provided in columns 2 and 3 of Table 2. Column 2 contains the results from the hot-issue period. In column 3 the results estimated from the sample obtained in the nonhot period are found.

Generally, regression coefficients have the same signs in both subsamples and in the full sample estimation of the frontier. Significance levels differ slightly. The coefficients of LOGBOOK, LOGSALES, and SERVICE lose their statistical significance in both time periods.

Comparing across market periods, the magnitudes of the coefficients are roughly double in absolute terms in the nonhot period. Since the signs of coefficients are generally the same in each of the time periods, the influence of independent variables on prices is greater in the nonhot period. In other words, if endowments were identical between the two periods, the elasticity of the frontier price to a particular determinant would be larger in absolute terms in the nonhot issue period relative to the hot-issue period. Of interest also is the fact that the PERATIO effectively lowers the frontier, but only in the nonhot period.

Finally, the virtue of dividing the sample is apparent in the estimates of $\lambda$, which measures the relative influence of the asymmetric error to the symmetric error ($\lambda = \sigma_u/\sigma_v$). A nonzero and significant value of $\lambda$ can be used to infer the presence of deliberate underpricing in the IPO premarket. The potential gain in statistical efficiency from the stochastic frontier specification is impressive. The coefficients are positive and significant in both the hot- and nonhot issue periods. The magnitude is greater for the hot-market period than for either the full sample or the nonhot-issue period. Therefore, the IPO market appears to be characterized by deliberate underpricing in the premarket, and underpricing is potentially higher in the hot market.[6]

Recall that if a one-sided error exists, OLS slope coefficients will be unbiased, but the intercept will be biased downward, and the variances will be large vis-á-vis ML. This means that OLS prices will lie

[6] Given that $\lambda$ measures the relative influence of the asymmetric error to the symmetric error, omitted variables will have some impact on $\sigma_u$ and $\sigma_v$, and therefore $\lambda$. However, in other model specifications not reported, the coefficient on $\lambda$ remains relatively unchanged and statistically significant.

below the frontier and prediction of the full-information price will be biased downward. OLS predicts the average of the observed offer prices conditional on observed characteristics, and by definition assumes away the problem of deliberate discounting. OLS is therefore inappropriate in our application given the significance of the systematic error term.

Further evidence of statistical efficiency gains of the stochastic frontier over OLS can be gleaned by comparing the *t*-ratios in Tables 2 and 3. Table 3 contains the results of OLS estimation of the model on the three samples. In fact, almost all variances are smaller under ML, and in only one case is there a sign and significance change. Under OLS as opposed to the frontier approach, PERATIO becomes a negative and significant determinant of the predicted price in both market periods. The strict interpretation of this change in significance of PERATIO is that general market trends affect the actual offer price rather than the expected full-information price in hot markets. Finally, the OLS intercepts should be smaller than ML estimates because the one-sided error component is shifted into the constant term under OLS. In fact, the intercepts are not significantly different in the specifications we report. Empirically, this is a distinct possibility due to random error.

The results obtained from the stochastic frontier methodology indicate that the average level of deliberate underpricing in the IPO premarket is 8.86% during the hot-issue period and 8.0% for the nonhot-issue period. They are computed as an average of the ratios of underpricing to the frontier price for all underpriced IPOs; and then, this ratio is reduced by the proportion of underpriced IPOs in the total issued. The observed average initial-day returns are 10.28% and 9.12%, respectively.

### 4.3 Estimates of initial returns regressions

Evidence of deliberate underpricing is not sufficient to eliminate the hypothesis that excess returns dominate the aftermarket, however. Both premarket and short-run aftermarket anomalies may occur under conditions of imperfect competition or information asymmetry. Until now we have been unable to test for one without assuming away the other. Thus, we would like to determine if our estimate of deliberate underpricing is directly related to the observed initial-day returns. A finding of a positive and significant relationship between the initial-day abnormal returns and the estimate of deliberate underpricing would support the hypothesis that the average initial-day return is overstated because of the inability to adjust for systematic underpricing. If the correlation between the two were nearly perfect, we could argue further that excess returns appear to be an artifact of measurement problems because the IPO price is the metric against

**Table 3**
**Estimated Frontier**[a]

| | All | Hot | Nonhot |
|---|---|---|---|
| Constant | 1.069 | −0.96 | −0.705 |
| | (−2.70) | (−1.96) | (−1.07) |
| LOGBOOK (log of book value) | 0.016 | 0.013 | 0.029 |
| | (1.74) | (1.22) | (1.40) |
| LOGSALES (log of sales) | 0.021 | 0.015 | 0.043 |
| | (2.49) | (1.55) | (2.80) |
| RISKS (number of risks on prospectus) | −0.029 | −0.028 | −0.028 |
| | (−10.72) | (−7.78) | (−6.73) |
| COM (commission rate) | −13.61 | −12.64 | −14.59 |
| | (−9.66) | (1.70) | (5.93) |
| INSFR (insider fraction) | 0.619 | 0.463 | 0.964 |
| | (6.19) | (3.81) | (5.67) |
| LOGAGE (log of age of firm) | 0.046 | 0.058 | 0.001 |
| | (3.56) | (3.63) | (0.31) |
| LOGPROC (log of proceeds from issue) | 0.215 | 0.227 | 0.198 |
| | (11.54) | (9.76) | (6.76) |
| PERATIO (S&P P/E ratio) | 0.005 | −0.194 | −0.034 |
| | (0.77) | (−1.87) | (−2.51) |
| COMP (computer industry) | 0.053 | 0.043 | 0.061 |
| | (1.41) | (0.93) | (1.02) |
| EQUIP (communication equipment industry) | 0.020 | 0.061 | −0.036 |
| | (0.54) | (1.28) | (−0.63) |
| OIL/GAS (oil/gas industry) | −0.091 | −0.096 | −0.106 |
| | (−1.78) | (−1.19) | (−1.70) |
| SERVICE (computer/data processing services) | 0.062 | 0.050 | 0.048 |
| | (1.51) | (0.97) | (0.75) |
| INSTRUM (medical, scientific instruments industry) | 0.073 | 0.0004 | 0.168 |
| | (1.74) | (0.0007) | (2.61) |
| HEALTH (health/drug industry) | 0.191 | 0.201 | 0.154 |
| | (3.97) | (3.44) | (1.89) |
| $n$ | 1035 | 698 | 337 |
| $R^2$ | 0.742 | 0.732 | 0.791 |

[a]Ordinary least-squares estimates with $t$-statistics in parentheses.

which aftermarket returns are evaluated.

Results of the initial returns equation estimated by OLS are presented in Table 4. The dependent variable $\text{RETURN}_i$ is the first available aftermarket bid price of issue $i$. It is regressed against the ratio of $u_i^*$ to the frontier price, the percent by which issue $i$ was predicted to be underpriced. (Jandrow's modal formula provided previously is used to compute $u_i^*$.) Here, all aftermarket returns, even those that are negative, are included in the analysis. As in the estimates of the frontier, all observations including those with negative aftermarket returns are included so the analysis is not biased with a selected sample. Thus, both the dependent variable and independent variable contain a large number of zeros. The low $R^2$'s found in Table 4 are not too surprising under these circumstances. (The $R^2$'s remains low, however, when the subset of positive returns are modeled.) The coefficient of underpricing is significant in only one time period. We find no statistical relationship between measured underpricing and returns in the nonhot period. Thus, it appears that where aftermarket returns are

**Table 4**
**OLS estimates of IPO returns as a function of underpricing**[a]
**Coefficient and (t-statistic)**

| | Full sample | Hot | Nonhot |
|---|---|---|---|
| Constant | 0.08 | 0.07 | 0.09 |
| | (9.31) | (6.49) | (8.10) |
| $u * / P_i^*$ | 0.24 | 0.35 | 0.04 |
| | (5.07) | (5.76) | (0.06) |
| $R^2$ | 0.02 | 0.05 | 0.001 |
| $n$ | 1035 | 698 | 337 |

[a]Coefficient with $t$-statistic in parentheses.

relatively high, deliberate underpricing plays a role in the determination of the returns. This finding, coupled with structural differences in the IPO pricing equations across the two time periods, leads us to conclude that underpricing, as we have measured it, is capable of explaining away only a portion of the observed excess returns. It contributes to the magnitude of measured excess returns at times when extremely high aftermarket returns prevail.

## 5. Summary and Concluding Remarks

Our analysis has provided two tools for future study of premarket and aftermarket IPO pricing. First, we have provided a means of differentiating the measured premarket underpricing from aftermarket returns by applying the stochastic frontier estimator. Second, we have provided empirical evidence that shows that the measure of IPO underpricing is sensitive to the market period. Hence, hot markets have both higher abnormal returns (by definition) and more underpricing in the premarket.

What we have been unable to establish is that the measure of premarket underpricing can explain away most abnormalities in aftermarket returns. A host of literature suggests that other factors, including underwriter reputation, consumer confidence or fads, market power on the part of underwriters, and the like, are needed to complete the puzzle. Both premarket underpricing and aftermarket excess returns appear to coexist simultaneously. Both problems are short-run phenomena that may be based on the little available information about such firms as compared to publicly held firms; they may simply reflect the initial segment of a learning curve in which errors are large at first but are vitiated over time.

We can only speculate about the joint effects of underpricing, sensitivity to market periods, and relatively weak relationships between measured underpricing and excess returns. For example, if the distribution of underwriters varies at the two time periods, those that have greater market power may dominate during hot markets. This could lead to more underpricing and/or more abnormal returns via manipulation. It is also true that if a bandwagon effect exists in hot markets, only the expectations of underpricing and excess returns over all issues will be realized in fact. In other words, investors may know underpricing exists, but in terms of any one stock, they have no knowledge if excess returns will occur.

What is most important in terms of our contribution to the IPO literature is that a measure of deliberate underpricing is developed without any reliance on the aftermarket price or information that is available only in the aftermarket. The theoretical concept of a full information price frontier and an ML estimator to identify the full information price frontier are outlined according to the stochastic frontier methodology. We estimate the average level of deliberate underpricing at 8.9% and 8.0% for hot- and nonhot-issue periods, respectively.

Estimated frontiers seem especially suitable for IPOs, and in general for financial economic applications as well. This approach has very important practical applications for financial officers of firms who are selecting an underwriter and determining if the suggested IPO price is appropriate. The maximum full-information price is available for making this decision.

## Appendix: Variable Symbols and Definitions

### Dependent Variables:

#### First Stage:

| | |
|---|---|
| LOGOP | natural log of the offering price |

#### Second Stage:

| | |
|---|---|
| RETURNS | the IPO initial return, calculated using the offering price and the first available aftermarket bid price |

### Independent Variables:

| | |
|---|---|
| LOGBOOK | natural log of tangible book value of equity |
| LOGSALES | natural log of previous 12-month sales revenue before going public |
| RISKS | number of risks factors listed on prospectus |
| COM | commission rate for the issue |
| INSFR | fraction of outstanding shares held by insiders |
| LOGAGE | natural log of age of the firm |
| LOGPROC | natural log of net proceeds of issue |

| | |
|---|---|
| COMP | dummy variable for computer manufacturing, equals 1 if SIC = 357, otherwise 0 |
| EQUIP | dummy variable for communications and electronic equipment, equals 1 if SIC = 366 or 367, otherwise 0 |
| OIL/GAS | dummy variable for oil and gas, equals 1 if SIC = 131, 138, 291, or 679, otherwise 0 |
| SERVICE | dummy variable for computer and data processing services, equals 1 if SIC = 737, otherwise 0 |
| INSTRUM | dummy variable for optical, medical, and scientific instruments, equals 1 if SIC = 381–384, otherwise 0 |
| HEALTH | dummy variable for health care, HMOs, drugs, and genetic engineering, equals 1 if SIC = 805–809, or 282, otherwise 0 |
| PERATIO | price-earnings ratio of S&P 500, average for quarter in which IPO is traded |

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