Valuation of IPOs Using a Stochastic Frontier Approach: A Revisit*

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Abstract

We examine the determinants of market value and underpricing for 1221 IPOs using a stochastic frontier model applied to the previously unexamined 1999-2010 period. We find that the book value of assets, the percentage of shares retained by the original owners of the firm, the commission rate and the reputational rankings of the underwriters are the most important determinants of firm value and underpricing. We estimate that the mean ex-ante underpricing is 39.7% which, while seemingly high, is consistent with unusually large first day returns in our sample period and our focus on emerging growth IPOs. However, we do not find a positive relation between our model-based measure of ex-ante underpricing and first day aftermarket returns at the firm level.

JEL Classifications: G24, G32, C49

Keywords: IPO Underpricing; Market Value; Stochastic Frontier Model

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1. Introduction

There is a voluminous literature studying the initial underpricing and subsequent performance of initial public offerings (IPOs). Issues related to this phenomenon that have received particular attention include the valuation of IPOs and how various factors affect the price performance of IPOs. The reasons IPOs have received extensive examination are straightforward. First, firms that want to finance through the stock market need guidance in setting a reasonable price for their IPO. Second, investors (including both individual and institutional investors) must make purchase decisions based on the available information with respect to the issuing firms and/or the whole market. Finally, analysts need theoretical support to write recommendation reports.

Numerous empirical regularities have been documented relative to IPOs. Virtually all comprehensive studies, beginning with Ibbotson (1975), have shown that IPOs appear underpriced in the sense that they experience large run-ups in price on average on the first day or first month of trading. Lowry, Officer and Schwert (2010) and others have shown that the variance of the first-month price run-up in the cross section of IPOs is extremely large. Both the volume and the underpricing of IPOs have been shown to vary over time (see, for example, Ibbotson and Jaffe 1975, Ibbotson, Sindelar and Ritter 1988), and the magnitude of the first public trading day price run-up is positively related to pre-issue price increases as measured by the difference between the final offering price and the midpoint of the anticipated issue price range in the preliminary prospectus filed with the Securities and Exchange Commission (Hanley 1993, Loughran and Ritter 2002, Lowry and Schwert 2004). Finally, numerous studies show that the long-run performance of IPOs is unappealing in general and is inversely related to the short

run price run-up or to various measures of fair value, particularly during "hot market" periods; see for example Ritter (1991), Ritter and Welch (2002), Purnanandam and Swaminathan (2004).

Many different explanations of the observed IPO empirical regularities have been proposed in the literature. As Hunt-McCool, Koh and Francis (1996) discuss, the key question as it pertains to our study is whether the observed short-run price run-up is due to deliberate underpricing of IPOs. One possible reason for deliberate underpricing is that it indirectly compensates the underwriter for the large risks associated with a fixed-price offering when the issuing firm is inherently difficult to value (see, for example, Rock 1986, Benveniste and Spindt 1989, Lowry, Officer and Schwert 2010). Other explanations focusing on deliberate underpricing include lack of concern about underpricing by issuing firms due to prospect theory (Loughran and Ritter 2002), due to selling only a small part of the firm at the IPO (Habib and Ljungqvist 2001) or due to deficiencies in corporate governance and/or managerial compensation structure in the issuing firm (Chahine and Goergen 2013, 2014). However, alternate explanations of the first-day price run-up that focus on behavioral issues and do not involve deliberate underpricing have received increasing attention in the literature. Aggarwal and Rivoli (1990) and Shiller (1990) argue that the first day price run-up may be caused by fads or speculative bubbles in the IPO market. Ritter (1991), who documents that IPOs consistently underperform the market in the long run, notes that it may be that the first aftermarket price is too high rather than the issuing price being too low. More recent studies that provide evidence consistent with this conjecture include Cornelli, Goldreich and Ljungqvist (2006) who note that in the European data high grey market prices (which proxy for over optimism by small, retail investors) can explain both the initial price run-up and the long-term underperformance, and Da, Engleberg and Gao (2011), who show that a high Google Search

Volume Index specific to an issuing firm (a proxy for small investor attention) strongly contributes to short-term price run-ups and long-term underperformance in the firm's IPO.

As noted above, the short-term aftermarket performance of an IPO is not necessarily a correct measure of (deliberate) underpricing. In order to properly examine underpricing one needs to compare the offering prices with the intrinsic values of the shares of the issuing firms. Kim and Ritter (1999) summarize that there are three valuation methods that could be used: the discounted cash flow approach, the asset-based approach, and the comparable firms approach. The discounted cash flow approach is the best way to determine the value of a firm since it fully considers the firm's earning potential and growth opportunities; however, it is hard to estimate the future cash flows, determine an appropriate discount rate and value growth options in practice. The asset-based approach proxies a firm's value by estimating the underlying value of the issuing firm's assets. However, this approach is not applicable in most IPOs unless there is a significant proportion of the assets which can be liquidated quickly at well-determined market prices. Consequently, the comparable firms approach, which is usually implemented by capitalizing the earnings per share of the issuing firm at the average price-to-earnings (P/E) ratio of publicly-traded comparable firms, is the most widely used since accounting information for these firms is generally available. However, Kim and Ritter (1999) show that the comparable firms approach can result in large valuation errors because P/E and other ratios relating accounting numbers and market-determined prices often display great variation among firms in the same industry. Thus, we note that while each of these possible methods for determining the intrinsic values of IPOs has positive features, their limitations are substantial. In addition, these methods share a point in common: all of them usually employ aftermarket information in some fashion to evaluate the IPOs. As demonstrated by our previous discussion regarding the use of stock return data for the issuing firm,

it is difficult to determine if the underpricing of new issues is deliberate or if the underpricing is due to aftermarket characteristics such as fads or underwriter price support. Thus, in this study, we employ an alternative method, the stochastic frontier approach, to evaluate IPOs by using information only from the premarket period.[1]

Hunt-McCool et al. (1996) and Koop and Li (2001) also employ the stochastic frontier model to evaluate IPOs and examine the underpricing in IPOs. In particular, one of the most significant advantages of this model is that the estimation and measurement can be conducted with premarket information alone. Hunt-McCool et al. (1996) mix the pricing factors from firm specific characteristics and the factors resulting in underpricing to estimate firms' frontiers and compute the gap between real value and the frontier. They conclude that most abnormalities in aftermarket returns cannot be explained by the factors leading to premarket underpricing. The underpricing in IPOs is sensitive to issuing period (hot and non-hot periods). However, with the mixture of the firm-specific pricing factors and underpricing factors, it is hard to figure out the exact relationship between deliberate underpricing and underpricing factors. To avoid this shortcoming, Koop and Li (2001) categorize firm-specific pricing factors and underpricing factors in order to estimate the magnitude of underpricing in IPOs and determine how underpricing factors associate with underpricing simultaneously. But the data they employ contain both IPO and Seasoned Equity Offering (SEO) firms. The reason they mix IPO and SEO data is that they believe SEO firms are expected to be efficiently priced such that they can be used as a more relevant benchmark. However, they do not provide evidence to support that SEO firms are evaluated without bias, and there is no theoretical justification for comparing IPO firms and SEO firms directly given that

[1] Following Hunt-McCool et al (1996), we do examine the firm-level relations between underpricing measured using the frontier approach and subsequent first day aftermarket returns, but the underpricing estimates themselves are estimated solely using pre-market data.

IPOs are much more difficult to value and therefore pose much greater risks for underwriters. Hence, we will only employ IPO firms in this study and extend the sample period to recent years. In addition to possible defects in their data, another weakness of the model employed by Koop and Li (2001) is the narrow focus on asymmetric information as the underlying reason for the underpricing of IPOs, while ignoring non-rational and agency conflict explanations which have played major roles in more recent studies (see, for example, Ritter and Welch, 2002, Loughran and Ritter, 2004, Filatotchev and Bishop, 2002, Lee and Wahal, 2004, Cornelli at al. 2006, Da et al. 2011, Chahine and Goergen 2013, 2014).

Following Koop and Li (2001) we use the market value (MV) of a firm as the dependent variable and develop a stochastic market value frontier (similar to the stochastic production frontier) of a firm. This stochastic market value frontier defines the maximum market value attainable by a firm for a given set of observable firm characteristics. However, at the time of initial public offering (IPO) the actual market capitalization is below its market value frontier. This shortfall in the actual market value of a firm from its maximum possible attainable value is due to the underpricing of the IPO. In our market value frontier, the conditional mean of the inefficiency term could be viewed as the average loss in market value of a firm. Following Jondrow et al. (1982), we compute the conditional mean of the one-side error term of the stochastic frontier model as the point estimate of the firm-specific underpricing. Thus, the magnitude of underpricing can be explicitly computed using only firm-specific premarket characteristics instead of aftermarket information and/or comparable information. Next, the determinants of underpricing are also investigated here as is done in Koop and Li (2001), and we add an additional variable (venture capital involvement) that was not considered in their model. Finally, unlike Koop and Li (2001),

we investigate the relations between firm level underpricing estimated by our model and the subsequent first day aftermarket returns.

This study estimates the magnitudes of the underpricing of IPOs of 1,221 firms during the period 1999-2010. To our knowledge, this sample period lies entirely outside those used in previous studies that have employed any variation of the stochastic frontier approach in the context of examining IPOs: the sample period in Hunt-McCool et al (1996) was 1975-1984, and Koop and Li's (2001) sample ran from 1985-1998. Moreover, as explained in greater detail below, the IPO database we use in this study contains only de-novo (i.e. brand new) firms going public for the first time; it excludes spinoffs from, and reorganizations of, established publicly-traded firms. In this respect our sample may significantly differ from those used in previous studies.

The rest of the paper is organized as follows. The methodology is explained in detail in section 2. Sections 3 and 4 are devoted to the specific model and the data. Our findings are presented in section 5 and section 6 concludes the study.

2. Methodology

Similar to a production frontier, the market value frontier describes the relationship between firm characteristics and the maximum attainable market value. The word "frontier," emphasizes the idea of maximality. Let Q be the market value of a firm, P the offer price of the IPO and NS the total number of outstanding shares after the offering; then $Q = P \times NS$. Since NS is fixed at the time of offering, MV depends on P. If the IPO is underpriced, Q will not attain its frontier and will fall short of its maximum. Let Q_i^* be the maximum attainable market value of the i^{th} firm at the time of IPO if all characteristics of the firm are accurately and/or efficiently accounted for in the offer price. The maximum market value, Q_i^* is defined as the predicted market value frontier and is expressed as

$$Q_i^* = f(X_i, \beta) ex\, p(v_i), \tag{1}$$

where X_i's are the firm's characteristics, β is a parameter vector and v_i is a random disturbance term independently distributed as $N(0, \sigma_v^2)$. It is stochastic in sense that it captures the random shocks in the market beyond the underwriter's control.

If an IPO is underpriced, Q_i^* will not be attained. Let Q_i be the actual market value at the time of IPO. Then the underpricing of the i^{th} firm IPO is defined as the ratio of the actual and maximum market value and could be represented by the exponential factor, $exp(-u_i)$, i.e.

$$\frac{Q_i}{Q_i^*} = exp(-u_i), \tag{2}$$

so that the actual Q_i could be expressed as a function of frontier maximum value,

$$Q_i = Q_i^* exp(-u_i), \tag{3}$$

where, u_i are assumed to be independently distributed as truncations above zero of $N(\mu, \sigma_u^2)$. Following Aigner, Lovel and Schmidt (1977) and Meesuen and Van den Broeck (1977), the frontier function to be estimated is expressed as

$$\begin{aligned} Q_i &= f(X_i, \beta)\, exp(v_i - u_i) \\ &= f(X_i, \beta)\, exp(\varepsilon_i) \\ \text{or} \quad lnQ_i &= lnf(X_i, \beta) + \varepsilon_i, \ i = 1, \dots, n, \end{aligned} \tag{4}$$

where ε_i the disturbance term is composed of two terms, i.e. $\varepsilon_i = v_i - u_i$, $u_i \geq 0$, and $v_i$and u_i are independent of each other, i.e., $cov(u_i, v_i) = 0$ with $v_i \sim N(0, \sigma_v^2)$, $u_i \sim N^+(\mu_i, \sigma_u^2)$. Since $u_i \geq 0$, the value of each firm, lnQ_i, is bounded by the maximum benchmark value denoted by lnQ_i, i.e.

$$lnQ_i = lnQ_i^* - u_i \quad u_i \geq 0. \tag{5}$$

Koop and Li (2001) also used u_i to capture the shortfall in a firm's actual value but they estimated the stochastic frontier by using the Bayesian method[2].

In the stochastic production frontier literature, u_i measures the technical inefficiency, and Jondrow et al. (1982) suggest using the mean or mode of the conditional distribution of u_i given ε_i as a point estimate of u_i. Since the production function is generally defined as the logarithm of production, Battese and Coelli (1988) proposed that, for the i^{th} firm, the technical efficiency should be estimated by $E[exp(-u_i|\varepsilon_i)]$. Following Battese and Coelli (1993, 1995), we assume that the u_i is obtained by the truncation at zero of the normal distribution with mean δZ_i and variance σ_u^2. Z_i denotes a set of g variables considered to be the determinants of underpricing in IPOs and δ is a $(1\times g)$ vector of coefficients to be estimated. Thus, the indicator of the underpricing is specified as

$$u_i = \delta Z_i + w_i \tag{6}$$

where w_i is a truncated normal random variable with zero mean and variance σ_u^2. The frontier model given in eq. (3) is jointly estimated with eq. (6). Thus, the u_i is distributed as $N^+(\delta Z_i, \sigma_u^2)$. Following Battese and Coelli (1993, 1995), the underpricing in IPOs is computed by

$$UdPr_i = 1 - E[exp(-u_i|\varepsilon_i)] = 1 - \left\{\frac{1-\Phi(r_i+\sigma_*)}{1-\Phi(r_i)}\right\} exp\left(-\mu_{*i} + \frac{1}{2}\sigma_*^2\right) \tag{7}$$

where $r_i = \frac{-\mu_{*i}}{\sigma_*}$, $\mu_{*i} = \frac{-\sigma_u^2\varepsilon_i + \delta Z_i\sigma_v^2}{\sigma_u^2+\sigma_v^2}$ and $\sigma_*^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_u^2+\sigma_v^2}$.

[2] It is beyond the scope of this paper to debate whether estimation of the frontier model is better using the classical method or the Bayesian method. A quick google search will reveal during the last ten years how many researchers have used the classical method versus the Bayesian method.

3. The Model:

To construct the benchmark of a firm's initial market value, i.e. the frontier, we employ a set of variables to specify the characteristics of a firm. Based on prior literature and our own intuition as discussed below, the following model is specified as the firms' frontier:

$$\begin{aligned} \ln Q_i = {} & \beta_0 + \beta_1 \ln(\text{Total Assets}_i) + \beta_2 \ln(\text{Total Debt}_i) + \beta_3 \ln(R\&D_i) + \beta_4 (\text{Comission Rate}_i) \\ & + \beta_5 \ln(\text{Age}_i) + \beta_6 (\text{Retention Ratio}_i) + \beta_7 (\text{Post IPO Insider Ownership}_i) \\ & + \sum_{k=8}^{14} \beta_k (\text{Industry Dummy}_{ki}) + \beta_{15} (\text{Year Dummy}) + v_i - u_i \end{aligned} \quad (8)$$

Following Koop and Li (2001), the market value of a firm, Q, is used as the dependent variable for the frontier model since the market value is obviously more comparable across firms than the stock price.[3] The market value of a firm is computed as the log of the product of the offer price and the total number of outstanding shares after the offering.

Many previous studies have (unsurprisingly) shown that there is a relation between historical accounting information and a firm's market value. It is straightforward that the expected relationship between the book value of a firm's assets, as reflected on its latest balance sheet prior to the offering, and a firm's market value is positive. It is similarly clear that other things held constant, the relation between a firm's level of debt and its market value is negative.[4]

Clearly, innovation and new technology serves as a resource for the growth of firms, and the capital used in production is not limited to physical capital. Habib and Ljungqvist (2005) and Depken, et al. (2006) documented that there is a positive relationship between "soft spending" and

[3] We are perplexed by the choice of Hunt-McCool et al (1996) to use the log of the offer price per share as the dependent variable in their model, especially because the independent variables they use to capture firm value (book value and sales) do not appear to be on a per-share basis.

[4] Following earlier studies, we initially included other accounting variables, i.e. sales and net income, as direct indicators of firm value in our model. However, because our sample consists entirely of emerging growth (de-novo) firms, we found that these variables had odd distributions. When included in our models their coefficients often had the wrong sign, were invariably statistically insignificant, and did not meaningfully affect efficiency estimates. For these reasons, we chose to exclude them from the models for which we report results in this paper.

firm value. In this study, "soft spending" is measured by the log of R&D (research and development expenses) in the fiscal year prior to the offering, and we expect "soft spending" to be positively related with firm value.

Valuation risk associated with an offering should, logically, negatively affect the offering price for an IPO and, by extension, the market value based on the offering price. Similar to Hunt-McCool et al (1996), we hypothesize that one indicator of valuation risk is the commission rate paid by the issuing firm to the underwriter(s). Hughes (1986) argues that underwriter compensation is related to the costs of investigating firm characteristics, implying that the commission rate will be higher for firms about which there is less public information that are, in turn, more difficult to value. Thus we expect a negative relation between commission rate and firm value.

The retention ratio in our model represents the percentage of the total shares in the company that will collectively be retained by the previous owners of the firm, i.e. it is formally defined as (1 – shares offered in IPO / total number of outstanding shares after the offering). Following Hunt-McCool et al (1996), we hypothesize that the retention ratio proxies for insider information possessed by owners of the privately-held firm: that previous owners with positive information will retain a larger percentage of the shares than those with negative information. Thus we expect a positive relation between the retention ratio and firm value.

Hunt-McCool et al (1996) used firm age in their model, and found it to have a weak positive relation with the offer price. Because this data is easy for us to obtain, we also include it in our model. However, we are not certain, a-priori, what the directional relation should be theoretically between firm age and total market value. On the one hand, an older firm that has survived for a long time might be less risky and easier to value, implying a positive relationship with firm value. Another interpretation, though, could be that a firm that has existed for a long time without going

public is (ceteris paribus) less exciting and has a lower upside than a younger firm, which would imply a negative relation between age and value.

In light of the importance of corporate goverance for post-IPO performance (Chahine and Goergen 2013, 2014), another variable that we believe could affect firm value is post-IPO insider ownership of shares, where insiders for this purpose are defined as officers and directors of the firm after it has gone public. We hypothesize that greater post-IPO insider ownership as a percentage of total shares outstanding after the IPO, as revealed in the prospectus, is associated with closer future alignment between management and outside stockholders and thus higher firm value at the time of the offering.[5]

Following both Hunt-McCool et al (1996) and Koop and Li (2001), we include industry controls in our model, whereby membership in certain industry groups may signal additional firm value. Consequently, we include the following industry dummy variables (which equal 1 if a firm is a member of the given industry based on primary SIC code and 0 otherwise): Chemicals, Oil and Gas (144 IPOs in our sample), Computer-related (412 IPOs), Electronics (112 IPOs), Health Care and Scientific (99 IPOs), Communications (72 IPOs), Retail (59 IPOs) and Financial (100 IPOs). A total of 216 IPOs did not belong to any of these industry groups. In addition, we include a year dummy in our model, which equals 1 if the IPO filing date was in 1999 or 2000 and 0 otherwise, in order to control for the possibility that investors valued stocks in general more highly during these two years that closely corresponed with the tech bubble in the U.S. stock market.

[5] We should note that while the retention ratio defined earlier appears to be very similar to post-IPO insider ownership, in actuality the former focuses on continued ownership by previous shareholders when the firm was private, while the latter focuses on future ownership by officers and directors after the firm goes public. These groups are not necessarily the same, as evidenced by the low correlation (less than 0.2) at the firm level between the two variables in our sample.

By using the shortfall from the frontier, i.e., the difference between the market value of a firm and its predicted optimal market value, the factors associated with the underpricing are determined. Our model for investigating determinants of the underpricing of IPOs is:

$$u_i = d_0 + d_1(Underwriter\ Rank_i) + d_2(NBER\ Up_i) + d_3(HOT_i) + d_4(Venture\ Capital_i) + w_i \qquad (9)$$

The economic intuition and predicted signs of determinants are discussed next. In early literature, researchers argue that mispricing is mainly due to the fundamental risk of issuing firms (Ibbostson, 1975) and the problem of information asymmetry (Benveniste and Wilhelm, 1990, Chemmaur, 1993, Welch, 1989 & 1992, and Habib and Ljungqvist, 2001), and predict that underpricing is positively related to uncertainty due to the degree of firms' fundamental risk and/or asymmetric information. Both Carter and Manaster (1990) and Carter, Dark, and Singh (1998) provide evidence that IPOs managed by more reputable underwriters are associated with less underpricing. Since Carter and Manaster (1990) argue that the prestige of underwriters selected by issuing firms can reveal their riskiness to the market, i.e., the higher the prestige of underwriters they choose, the lower the probability they will fail, and the less likely they are to be undervalued at the time of offering. In this study, the prestige of underwriters is represented by a ranking, scaled from 0 to 9. In particular, Carter and Manaster (1990) and Carter et al. (1998) proposed the particular methodology of ranking underwriters. Loughran and Ritter (2004) updated the rankings for 1992-2003 using their methodology and Jay R. Ritter maintains an updated post-2003 database of these rankings[6].

As for the remaining underpricing variables, following Koop and Li (2001) we include an NBER Up dummy variable which equals 1 if the issue date of the IPO is outside the range of dates in which the U.S. economy is classified as being in a recession by the National Bureau of

[6] http://bear.warrington.ufl.edu/ritter/ipodata.htm

Economic Research (NBER) and 0 if the issue date is during a recession. Chloe et al. (1993) argue that adverse selection issues are mitigated when more promising conditions for new investment exist; consequently we expect less underpricing when the economy is in an upswing and hence a negative coefficient on the NBER Up dummy. As suggested by Ritter (1984), a HOT index is also included to control for the hot market effect. Following Banerjee et al. (2011), the HOT index is computed as the ratio of the number of IPOs in a specific year over the total number of IPOs during the sample period. As argued by Ritter (1984), Ljungqvist et al. (2006) and Banerjee et al. (2011), the expected sign of the HOT index is positive – that is, we expect greater underpricing in hot issue periods. Finally, we include a Venture Capital dummy variable which equals 1 if our reading of the prosepctus indicates any backing by a known venture capital firm and 0 otherwise. A-priori, we expect venture capital investors to maximize their returns and hold out for a higher IPO offer price; consequently we expect less underpricing with venture capital involvement and a negative coefficient on the Venture Capital dummy.

4. Data

The primary IPO data over the 1999 to 2010 period is collected from the Firm Database of Emerging Growth Initial Public Offerings (IPOs) from 1990 through 2010 which are provided by Martin Kenney and Donald Patton, 2013. Emerging Growth in this database refers to the firms that are newly established or not based on older firms by being a spinoff or subsidiary operation. Particularly, the emerging growth status was established by checking the prospectus, particularly in the prospectus summary where the firm describes its activities, history, and business. There are 1369 Emerging Growth IPOs in the US from 1999 to 2010. Besides general company information, this dataset contains the basic issuing information for each IPO, such as shares offered, total shares outstanding after the offering, initial offer price and underwriter discount, such that the initial

market value of issuing firms, the age of issuing firms and underwriters compensation and commission rates can be computed accordingly. Other financial data of issuing firms, including total assets, total long-term debt and R&D expenditure in the fiscal year prior to the IPOs, is collected from the Compustat database. In addition, insider ownership before and after the offering and underwriter names are manually collected from firms' prospectuses, which are found on the SEC's EDGAR database. The rankings of underwriters are determined according to IPO Underwriter Reputation Rankings (1980-2014) collected from Jay R. Ritter's database.

Similar to previous literature (e.g., Loughran and Ritter, 2004), the following criteria are imposed to obtain the final sample. First, the initial offer price should exceed $5, which leads to the exclusion of 2 firms from the database. Second, 5 firms are excluded since the underwriter ranking is zero or unavailable. Third, because of missing insider ownership information, 12 firms are excluded. Finally, accounting data should be available for the issuing firms in the year prior to the offering. In particular, accounting information for 129 firms was wholly or partially unavailable in the Compustat database. This lack of availability of either total assets, total debt or R&D expense in the fiscal year prior to the IPO further reduces the number of IPO firms in our study to 1221, around 10.8% attrition from the original sample size.

< INSERT TABLE 1 HERE >

Table 1 contains the descriptive statistics of the variables used in estimation. In our model, the dependent variable of the frontier model is the total market value of firms' common equity, Q, which is computed as the product of the initial offer price and a firm's total outstanding shares after the offering. As shown in Table 1, the market value of firms' common equity Q is right-skewed, and the mean and median are $502 million and $314 million respectively. Similar to Q, firms' other characteristics are also right-skewed. In particular, the median and 3rd quartile of

firms' total assets in the fiscal year prior to offering are, $36 million and $137 million, respectively, whereas the mean is $321 million. Clearly, the mean is driven by the largest firms.

Our proxy of "soft expenditure", research and development expense (R&D Expense) has a mean of around $6 million in the fiscal year prior to the offering, but nearly half of the sample firms have no expenditure on R&D. Total debt in the fiscal year prior to the initial public offering for the sample firms ranges from $0 million to $9,448 million. In particular, the mean and median of the total debt are $91 million and $2 million respectively. To a lesser extent, firm age is also right-skewed, with a mean and median of 12.8 years and 8 years, respectively. However, the remaining firm characteristic variables, i.e. the commission rate, retention ratio and post-IPO insider ownership, exhibit little evidence of skewness given that the means and medians of these variables are all close to each other.

The lower part of Table 1 reports the descriptive statistics of the determinants of the underpricing in IPOs. Specifically, underwriters' reputation is represented by a ranking which is on a 1 to 9 scale. In this study, if some sample firms have multiple underwriters or lead underwriters, their rank is determined by the rank of the book-runner or the highest-ranking joint book-runner. Accordingly, an average firm has an underwriter ranking of 8.25, i.e. a typical firm employs at least one underwriter ranking 8 or 9 at the offering. The mean of the Up Dummy indicates that 94.8% of IPOs took place when the U.S. economy was not in recession according to the NBER. Similarly, the mean for the Venture Capital Dummy indicates that 59.4% of the IPOs in our sample had some venture capital backing. Finally and not unexpectedly (given how the Hot Index is constructed), the descriptive statistics for this variable are consistent with the notion that a disproportionate number of IPOs in our sample occur in years in which the Hot Index is high. Further information on this relation is provided in Table 4.

5. Empirical Analysis

The frontier model specified in equations (8) and (9) is estimated by using the FRONTIER Version 4.1 software[7]. Table 2 reports the estimates for the whole sample consisting of 1,221 IPOs ranging from 1999 to 2010. Specifically, Panel A presents the estimates for the market value frontier given in equation (8); Panel B presents the estimates of coefficients corresponding to the determinants of underpricing given in equation (9) and Panel C presents diagnostic statistics for the model. In Panel C, the likelihood ratio statistic rejects the null hypothesis that $u = 0$[8], i.e., the one-sided error term is statistically different from zero. Hence, there exists underpricing in our sample firms during 1999-2010.

< INSERT TABLE 2 HERE >

From Panel A, we note that the coefficient estimate for the log of total assets is positive and highly significant, which is consistent with our expectation that a firm's market value is positively related to the book value of its assets. However, contrary to our expectations neither the log of total debt, nor the log of R&D expense is found to be significantly related to market value in our model. In accordance with expectations, there is a strong and highly statistically significant inverse relation between the commission rate paid to the underwriter(s) and market value. Because the commission rate may proxy for valuation risk, this finding is consistent with the idea that firms with greater valuation risk have lower offering prices, other things equal.

[7] The software was downloaded from Center for Efficiency and Productivity Analysis, i.e. http://www.uq.edu.au/economics/cepa/software.php.

[8] In this case, the LR test statistic has a mixed chi-square distribution with the number of degrees of freedom equal to the number of restrictions on the parameters used in the estimation of underpricing determinants. Hence, for the sample in this study, the number of degrees of freedom of the LR test is 6, since the restrictions are u=d_0=d_1=…=$d_4 = 0$.

Another variable that is found to strongly impact the market value of the firm is the retention ratio, essentially defined as the proportion of shares kept by the original owners of the firm immediately after the firm goes public. Indeed, based on the t-statistic, this is the single most important firm charactersitic in the entire model and indicates that the signal sent by former shareholders that they are willing to retain a larger proportion of the shares after the firm goes public exerts a strong positive influence on the offer price (and by extension, the market value based on the offer price). In contrast, the proportion of the shares (post-IPO) that will be held by officers and directors, based on information revealed in the prospectus, while as expected positively associated with market value, is not quite statistically significant. Panel A in Table 2 also reveals a negative association between firm age and market value, indicating that the longer the time that has elapsed between a firm's founding and its going public, the lower its market value. The only interpretation we can offer is that the negative signal offered by advanced age (the firm is unexciting and has less upside potential) outweighs the positive signal (the firm is stable and has lower risk). The coefficients on the industry dummies in Panel A indicate that membership in the communications industry was associated with significantly higher market value during our sample period, while financial firms and those in the chemical industry or the oil and gas industry had lower market values, ceteris paribus. Finally, the positive and significant coefficient on the year dummy indicates that investors were willing to pay higher prices for IPOs during the latter stages of the tech bubble that characterizes the first two years of our sample.

Panel B of Table 2 reveals that, as expected, the coefficient on underwriter rank is negative and highly significant, showing that higher underwriter reputation results in less underpricing in IPOs. Similarly in accordance with expectations, the negative coefficient on the Up Dummy indicates that IPOs that occur when the U.S. economy is not in recession are associated with less

underpricing. However, contrary to expectations, the positive and significant coefficient on the Hot Index indicates that underpricing appears to actually be greater (ceteris paribus) in hot new issue markets, and we find no statistically significant relation between venture capital backing and underpricing.

To shed further light on whether coefficient estimates are stable over time, we next divide our sample of 1,221 IPOs into three subsamples based on offer date, and estimate separate market value frontier models for each of the subsamples. The three subsamples we chose are the tech bubble period of 1999-2000, the post-tech bubble, pre-financial crisis period (January 2001 to June 2008) and the financial crisis period and its immediate aftermath (July 2008 to December 2010).

< INSERT TABLE 3 HERE >

The subperiod model results are reported in Table 3. As in Table 2, coefficient estimates on firm characteristics are reported in panel A, coefficients on underpricing determinants in panel B, and model diagnostics in panel C. For obvious reasons, the year dummy used previously is omitted in the subperiod models, and the Up Dummy must be omitted for the January 1999 – December 2000 subperiod because the U.S. economy was not in a recession at any point during these years. While the likelihood ratio tests for all three subperiods reject the null hypothesis, indicating that there is statistically significant underpricing in all of them, we nevertheless urge caution in interpreting the results from the final July 2008 – December 2010 subperiod given that there were only 63 IPOs during this period. In comparing the first two subperiods, the following differences stand out. First, while both total assets and the commission rate exert strong influences on firm value in both periods with the expected signs, in both cases the influence appears stronger in the January 2001 – June 2008 period, and post-IPO insider ownership is significant as well whereas in the previous tech bubble period it is not. In contrast, the negative influence of firm age

on market value appears to be largely confined to the 1999-2000 tech bubble period, and firms in the communication industry (which are most closely associated with the internet) enjoy a valuation bonus in 1999-2000 that largely vanishes in later periods. Finally, among the underpricing determinants, the hot index (counterintuitively) is significantly positive during 1999-2000 but not in later periods. Putting it all together, our interpretation of the subperiod results in Table 3 is that fundamental factors that theory says should matter in the valuation of IPOs – such as the book value of assets, valuation risk and corporate governance – exert a greater influence on the market value of firms going public in the January 2001 to June 2008 period than during the 1999-2000 tech bubble. We note, however, that some theoretically important characteristics and determinants such as the retention ratio and underwriter rank exert equally strong influences in both periods.

5.1 Underpricing Estimates

The underpricing of the i^{th} firm given in equation (7) is computed for all firms in our sample. Descriptive statistics for the underpricing estimates for the whole sample and for each year are reported in Table 4. The means are the simple averages.

< INSERT TABLE 4 HERE >

From Table 4, we note that our findings indicate the market values of firms are underpriced by a huge amount: the offer price falls 39.7% short of its optimal value on average, and the range of the underpricing is from 18.1% to 88.4% of the optimal value, indicating that even in the best cases there is subtantial underpricing based on ex-ante data. Further, we note that, on average, the IPOs in 1999 exhibited the most underpricing while IPOs in 2009 demonstrated the least underpricing, i.e. 47.7% and 25.8% of their optimal values respectively.

The mean underpricing that we find is much greater than has been reported in previous studies using the stochastic frontier approach; Hunt-McCool et al. (1996) report average

underpricing of about 8-9%, while Koop and Li (2001) report that IPO firms in their sample are 25-30% underpriced on average. We believe there are several factors that explain this large discrepancy in results. First, the sample periods of these studies are completely different (i.e. they do not overlap), and other measures of underpricing based on first day returns also show greater underpricing during our sample period. Ritter (2014) provides both the number of IPOs, and average underpricing based on first day aftermarket returns, in each year between 1980 and 2013. Using mean equally-weighted underpricing each year, and weighting each year by issue volume, we calculate average aftermarket underpricing of 12.8% over the 1985-1998 period (the sample period used by Koop and Li, 2001) versus 35.8% during our 1999-2010 sample period – most of this difference is driven by hugely elevated first-day returns, relative to historical norms, in 1999 and 2000, which is roughly consistent with our finding in Table 4 that underpricing is highest, on average, during those years. As noted previously, another reason we would expect to find greater underpricing in our study is that we focus exclusively on emerging growth, de-novo IPOs (which are likely to be more difficult to value and exhibit greater underpricing); the two earlier studies included spinoffs and reorganizations of existing firms. As we will explain in more detail in the next section, this difference in the composition of our sample can account for a further 5.5% difference in first-day aftermarket returns. Finally, there are subtle but possibly crucial methodological differences that may also contribute to our finding of greater underpricing. Hunt-McCool et al. (1996) use the offer price per share as the dependent variable, even though accounting-based independent variables in their model appear to be specified in an aggregated (rather than on a per share) basis; in our opinion, this choice may render their conclusions suspect. While Koop and Li (2001), similar to our study, do use Q (the product of the the offer price and the total number of shares outstanding after the IPO) as their dependent variable, one of their

independent variables is the total fees paid by the issuing firm to the underwriters. Because the total fees paid will be primarily determined by the size of the offering, which in turn is closely related to the dependent variable Q, we believe the primary direction of causation in Koop and Li's model runs from the market value Q to fees paid, raising substantial statistical bias issues.[9] We get around this problem by using the commission rate, in place of total fees, to proxy for the valuation risk of the firm, and thus believe that inferences from our model are more reliable.

5.2 Relations between Ex-Ante Underpricing and First Day Returns

Subsequent to our estimation of the efficient frontier model solely using ex-ante data, we obtained aftermarket stock price data for each IPO in our sample (we were unable to obtain this data for 2 firms). The aftermarket stock price data is from CRSP. We calculate a first day return as: (close price / offer price) -1. The first day return is a commonly used traditional measure of ex-post underpricing.

< INSERT TABLE 5 HERE >

Descriptive statistics for the aftermarket first day returns for our entire sample and by year are provided in Table 5. We note that the mean first day return for all years is 41.3%, which is close to the 39.7% mean ex-ante underpricing generated by our stochastic frontier model. However, the distributions of estimated ex-ante underpricing and the ex-post returns are very different. We note that the standard deviation of the first day returns is considerably larger, both for the entire sample combined and for each individual year: there are numerous instances of negative first day returns, and also many instances of extremely high first day returns, particularly in 1999 and 2000. Another noteworthy aspect of the results arises from comparing our overall 41.3% mean first day return to the 35.8% mean first day return over the years 1999-2010

[9] It is noteworthy that the t-statistic on the fees coefficient reported by Koop and Li (2001, Table 5) appears to be around 75.

(weighting each year by issue volume) in Ritter's (2014) broader IPO database. Since the main difference in the composition of the samples is that we exclude spinoffs and reorganizations, the implication is that our focus on de-novo IPOs likely results in mean first day returns that are 5.5% higher.

We next examine the statistical relations at the firm level between the ex-post first day returns and the estimates of ex-ante underpricing provided by our model. If the traditional interpretation that the positive first day returns in IPOs are due to deliberate underpricing is correct, then we would expect a significant positive relation at the firm level between the model-based estimate of the underpricing and the first day return. Hunt-McCool et al. (1996, Table 4), for their 1975-1984 sample, do find a significant postive relation between ex-ante underpricing and first day return; however, they also report a very low R^2 from their regression, and when they segregate their sample into hot and nonhot issue periods they find that the significant positive relation exists only during the hot periods.

< INSERT TABLE 6 HERE >

We provide estimates of the following OLS regression models in Table 6:

$$FDRET_i = \beta_0 + \beta_1 UDPR_i + e_i \quad (10)$$

$$FDRET_i = \beta_0 + \beta_1 UDPR_i + \beta_2 HOT_i + \beta_3 (HOT_i \times UDPR_i) + e_i \quad (11)$$

Where $FDRET_i$ is the first day return for firm i, $UDPR_i$ is the ex-ante estimate of underpricing of firm i based on our stochastic frontier model and HOT_i is the value of the hot index during the year of the IPO's offer date. We estimate model 10 for our entire sample and for each of three subsamples depending on offer date: January 1999 – December 2000, January 2001 – June 2008 and July 2008 – December 2010. Model 11 is motivated by Hunt-McCool et al's (1996) finding

that the relation between first day returns and ex-ante undepricing differs based on the hotness of the market for new issues.

The model 10 results do show a positive coefficient on $UDPR_i$ for the full sample, but this relation is not statistically significant. Moreover, this result appears somewhat confounding because when we estimate model 10 for the three subsamples, the coefficient on $UDPR_i$ becomes negative and highly significant for the first two subsamples (IPOs issued Jan. 1999 – Dec. 2000 and Jan. 2001 – Jun. 2008), and remains negative (albeit insignificant) in the third. Taken together, the model 10 results indicate that a variable that is strongly asociated with both the first day returns and ex-ante underpricing – and varies by subperiod – is missing from the model. Therefore, in light of the previosuly mentioned findings of Hunt-McCool et al. (1996, Table 4), we also provide results for Model 11 for the full sample. Model 11 includes the hot index value related to the issue year of each IPO and an interaction effect between the hot index and the firm-level underpricing. These results show a marginally significant negative constant term, a positive but insignificant coefficient on $UDPR_i$, a hugely significant positive coefficient on HOT_i, and a hugely significant negative coefficient on $HOT_i \times UDPR_i$, the interaction effect. We interpret these results as follows: first day returns tend to be close to zero (or even negative on average) and there is no relation between first day return and ex-ante underpricing during the coolest periods (hot index close to zero). However, as the market for new issues heats up, average first day returns markedly increase, but they increase more for firms that show *less* ex-ante underpricing. In this respect our findings are the polar opposite of Hunt-McCool et al. (1996), because the negative coefficient on the interaction effect implies a negative relation between ex-ante underpricing and subsequent first day returns during hot new issue periods. We also note

that the regression results for model 11 are consistent with our finding in Table 2 that there is more ex-ante underpricing as the hot index increases.

6. Conclusion

Following two earlier studies but using a different, non-overlapping sample period, this study estimates the magnitude of the underpricing in IPOs for 1,221 firms during the 1999-2010 period by constructing a market value stochastic frontier model. In particular, the value of a firm's underpricing is estimated by the mean of the inefficiency term, the one-sided error term, conditional on the entire error. The advantage of using the stochastic frontier approach to measure underpricing, in place of the traditional approach of focusing on first day aftermarket returns, is twofold. First, it is not clear, based on the extant literature, to what degree the first day returns on IPOs reflect deliberate underpricing as opposed to market inefficiencies. Second, the frontier approach may provide evidence regarding the extent to which measures related to the theoretically important concept of valuation risk influence underpricing.

Our stochastic market value frontier model estimates, for both our entire sample and for subsamples based on offer date, indicate that the most important positive ex-ante determinants of a firm's market value are the book value of its assets and the retention ratio. The latter is simply the portion of shares retained by the original owners immediately after the IPO is completed; a higher retention ratio apparently sends a strong signal to the market that the existing owners of the privately-held firm are optimistic regarding the firm's future prospects. We find that the most important negative determinant of market value is the commission rate paid to the underwriters. This finding is intriguing because the commission rate likely proxies for valuation risk, implying that firms with greater valuation risk have lower market values. In addition to estimating the market value frontier, we also investigate the determinants of underpricing in IPOs. Confirming previous

studies, we show that the most important determinant is underwriter rank: the higher the underwriter rank, the lower the underpricing. Because firms with greater information asymmetry and greater valuation risk are likely to attract lower-ranked underwriters, these results are consistent with theoretical models hypothesizing that greater valuation risk is likely associated with greater deliberate underpricing.

We observe that the offering price of a new issue of an average firm with an initial public offering in the U.S. between 1999 and 2010 falls 39.7% short from its optimal value. While this estimate of ex-ante underpricing greatly exceeds those from two previous studies using a methodology similar to ours, it is consistent with much greater first day aftermarket returns during our sample period and also with the composition of our sample, which (unlike in the case of the two earlier studies) excludes spinoffs and reorganizations of existing publicly-traded firms. We show, however, that while the mean of the model-based, ex-ante underpricing in our sample is close to the mean of the first day aftermarket returns (41.3% for the firms in our sample), there is not a statistically significant positive relation at the firm level between the ex-ante underpricing and the first day return. If anything, taking into account the interaction between the hotness of the market for new issues and the model-based underpricing estimates, we find a negative association at the firm level between underpricing and subsequent first day returns in hot markets. Our interpretation of these results is that while there likely is (as theory predicts) deliberate underpricing in IPOs, first day aftermarket returns at the firm level are not explained by this underpricing and are, instead, likely due to market inefficiencies.

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Table 1: Descriptive Statistics of IPO Characteristics

	Mean	St. Dev.	Minimum	Q1	Median	Q3	Maximum
Firm Characteristics							
Q ($ Millions)	502.130	752.220	13.200	192.607	313.769	549.554	11975.499
Total Assets ($ Millions)	321.269	2086.410	0.094	15.711	36.090	137.160	48765.349
Total Debt ($ Millions)	90.685	431.535	0.000	0.059	1.891	19.935	9447.682
R&D Expense ($ Millions)	6.203	14.039	0.000	0.000	2.212	7.840	339.337
Commission Rate	0.069	0.005	0.019	0.070	0.070	0.070	0.100
Retention Ratio	0.741	0.125	0.000	0.692	0.762	0.823	0.979
Age	12.799	17.277	1.000	5.000	8.000	13.000	158.000
Post-IPO Insider Ownership	0.437	0.209	0.000	0.292	0.445	0.592	1.000
Determinants of Underpricing							
Underwriter Rank	8.247	1.300	1.000	8.000	9.000	9.000	9.000
Up Dummy	0.948	0.221	0.000	1.000	1.000	1.000	1.000
HOT Index	0.157	0.095	0.007	0.091	0.097	0.281	0.281
Venture Capital Dummy	0.594	0.491	0.000	0.000	1.000	1.000	1.000

Notes: Q is the a-priori market value of the firm, defined as the offer price × total number of outstanding shares after the offering. Total Assets, total debt and r&d expense are for the last fiscal year prior to the offer date. The commission rate is computed as underwriter compensation / (offer price × shares offered in IPO). The retention ratio is defined as (1 – shares offered in IPO / total number of outstanding shares after the offering), and post-IPO insider ownership is defined as projected number of shares held by officers and directors after IPO is completed (as indicated in the prospectus) / total number of outstanding shares after the offering. The underwriter rank is determined according to IPO Underwriter Reputation Rankings (1980-2014) collected from Jay R. Ritter's database. The up dummy is defined as 1 if the U.S. economy is not in recession on the offer date and 0 otherwise. The HOT index is computed as the ratio of the number of IPOs in a specific year over the total number of IPOs during the sample period. The venture capital dummy equals 1 if our reading of the prosepctus indicates any backing by a known venture capital firm and 0 otherwise.

Table 2: Stochastic Market Value Frontier Model Estimates

	Coefficient	Standard Error	t-statistic
Panel A: Firm Characteristics			
Constant	11.1830	0.2982	37.4987***
ln(Total Assets)	0.2213	0.0150	14.7929***
ln(Total Debt)	0.0056	0.0048	1.1686
ln(R&D Expense)	-0.0004	0.0050	-0.0787
Commission Rate (%)	-32.2763	3.1813	-10.1455***
Retention Ratio (%)	2.5647	0.1462	17.5411***
ln(Age)	-0.0876	0.0223	-3.9373***
Post-IPO Insider Ownership (%)	0.1253	0.0794	1.5719
Chemicals, Oil and Gas	-0.1073	0.0626	-1.7128*
Computers	0.0487	0.0500	0.9735
Electronics	0.1032	0.0692	1.4927
Health and Scientific	-0.1029	0.0700	-1.4685
Communications	0.2163	0.0772	2.8017***
Retail	-0.0112	0.0814	-0.1380
Financial	-0.1430	0.0738	-1.9361*
Year Dummy (= 1 if 1999 or 2000)	0.2324	0.0920	2.5270**
Panel B: Determinants of Underpricing			
Constant	2.2013	0.1664	13.2328***
Underwriter Rank	-0.2059	0.0145	-14.2338***
Up Dummy	-0.1509	0.0742	-2.0347**
Hot Index	1.1077	0.4811	2.3023**
Venture Capital Dummy	0.0101	0.0376	0.2684
Panel C: Diagnostics			
LR Test of u = 0 (χ_2)			203.4733***
Sigma-squared	0.2917	0.0118	24.8157***
Gamma	0.0065	0.4053	0.0161
# of Firms	1221		

Note: *, ** and ***, respectively, denote statistical significance at the 10%, 5% and 1% levels.

Table 3: Stochastic Market Value Frontier Model Estimates, by Subsample

	Jan. 1999 - Dec. 2000 IPOs			Jan. 2001 - Jun. 2008 IPOs			Jul. 2008 - Dec. 2010 IPOs		
	Coefficient	Standard Error	t-statistic	Coefficient	Standard Error	t-statistic	Coefficient	Standard Error	t-statistic
Panel A: Firm Characteristics									
Constant	10.3810	0.4447	23.3453***	10.8127	0.4898	22.0778***	11.9634	1.8330	6.5268***
ln(Total Assets)	0.1556	0.0210	7.4236***	0.2999	0.0236	12.6940***	0.3431	0.0395	8.6890***
ln(Total Debt)	0.0071	0.0071	1.0001	-0.0063	0.0067	-0.9360	-0.0175	0.0100	-1.7422*
ln(R&D Expense)	0.0029	0.0074	0.3926	-0.0053	0.0074	-0.7067	0.0221	0.0185	1.1933
Commission Rate	-17.4545	4.7748	-3.6556***	-37.2661	4.3726	-8.5226***	-62.7462	0.9910	-63.3174***
Retention Ratio (%)	3.2042	0.2462	13.0155***	2.1769	0.1962	11.0928***	2.7556	0.3158	8.7257***
ln(Age)	-0.1841	0.0387	-4.7560***	0.0013	0.0308	0.0415	-0.0451	0.0223	-2.0167**
Post-IPO Insider Ownership (%)	0.0627	0.1171	0.5357	0.2218	0.1066	2.0812**	0.1503	0.4257	0.3530
Chemicals, Oil and Gas	-0.0656	0.1224	-0.5362	-0.0112	0.0831	-0.1351	-0.0784	1.4568	-0.0538
Computers	0.0833	0.0683	1.2184	0.0953	0.0775	1.2303	-0.0714	0.2380	-0.3001
Electronics	0.1357	0.0913	1.4857	0.1568	0.1078	1.4543	0.3429	0.3355	1.0221
Health and Scientific	-0.0713	0.1267	-0.5626	0.0227	0.0880	0.2581	-0.1801	0.2062	-0.8734
Communications	0.4515	0.1072	4.2106***	0.1032	0.1381	0.7470	-0.1542	0.2431	-0.6343
Retail	0.1284	0.1167	1.1003	-0.3431	0.1264	-2.7143***	0.4126	0.4823	0.8554
Financial	-0.0805	0.1669	-0.4825	-0.2974	0.0858	-3.4652***	0.3406	0.6822	0.4992
Panel B: Det. of Underpricing									
Constant	1.8784	0.2526	7.4375***	2.2929	0.2046	11.2047***	-0.9792	0.6011	-1.6291*
Underwriter Rank	-0.2273	0.0228	-9.9791***	-0.1984	0.0191	-10.3845***	-0.0477	0.0115	-4.1620***
Up Dummy				-0.1486	0.0770	-1.9293*	1.7628	1.0311	1.7096
Hot	1.5397	0.6092	2.5274**	-0.0643	0.9748	-0.0659	0.1875	0.1638	1.1451
Venture Capital Dummy	-0.0368	0.0550	-0.6699	0.0225	0.0537	0.4194	0.1155	0.7633	0.1513
Panel C: Diagnostics									
LR Test of u = 0 (Chi square)			107.8943***			104.0988***			29.7089***
Sigma-squared	0.2644	0.0156	16.8964***	0.2581	0.0153	16.9012***	0.3173	0.1003	3.1626***
Gamma	0.0000	0.0232	0.0015	0.0000	0.1181	0.0000	1.0000	0.0000	777348***
Number of Firms	593			565			63		

Note: *,** and ***, respectively, denote statistical significance at the 10%, 5% and 1% levels.

Table 4: Descriptive Statistics of Underpricing Estimates

	# of Firms	Mean	SD	Minimum	Q1	Median	Q3	Maximum
All Years	1221	0.397	0.134	0.181	0.270	0.398	0.472	0.884
Year								
1999	348	0.477	0.112	0.395	0.403	0.406	0.515	0.884
2000	245	0.400	0.093	0.339	0.347	0.350	0.468	0.846
2001	50	0.358	0.112	0.208	0.325	0.328	0.450	0.640
2002	44	0.289	0.111	0.205	0.209	0.213	0.365	0.482
2003	47	0.328	0.136	0.206	0.213	0.220	0.478	0.653
2004	114	0.357	0.138	0.250	0.262	0.268	0.405	0.857
2005	110	0.392	0.145	0.255	0.262	0.399	0.512	0.858
2006	112	0.367	0.137	0.250	0.260	0.267	0.403	0.824
2007	83	0.359	0.148	0.232	0.244	0.348	0.386	0.845
2008	8	0.332	0.084	0.291	0.298	0.305	0.307	0.538
2009	14	0.258	0.100	0.181	0.194	0.197	0.316	0.461
2010	46	0.284	0.113	0.205	0.215	0.220	0.356	0.812

Note: The firm-level underpricing estimates summarized in this table are those resulting from the stochastic frontier model estimated for the entire 1999 – 2010 sample.

Table 5: Descriptive Statistics of Aftermarket First Day Returns

	# of Firms	Mean	SD	Minimum	Q1	Median	Q3	Maximum
All Years	1219	0.413	0.718	-0.746	0.009	0.163	0.487	6.975
Year								
1999	347	0.740	0.971	-0.746	0.057	0.427	1.082	6.975
2000	245	0.656	0.859	-0.278	0.051	0.347	1.000	5.075
2001	50	0.164	0.188	-0.136	0.014	0.146	0.283	0.767
2002	44	0.100	0.158	-0.331	0.006	0.097	0.146	0.667
2003	47	0.152	0.157	-0.155	0.038	0.143	0.264	0.471
2004	114	0.144	0.179	-0.110	0.000	0.088	0.248	0.657
2005	110	0.114	0.179	-0.125	0.000	0.064	0.174	0.946
2006	111	0.134	0.203	-0.295	0.006	0.093	0.212	1.254
2007	83	0.171	0.240	-0.197	0.000	0.113	0.286	0.972
2008	8	0.116	0.247	-0.199	-0.068	0.072	0.268	0.575
2009	14	0.173	0.201	-0.127	0.004	0.135	0.271	0.595
2010	46	0.115	0.153	-0.108	0.000	0.070	0.197	0.553

Note: the first day return for each firm is calculated as (close price / offer price) – 1.

Table 6: OLS Estimates of IPO First Day Returns as a Function of Underpricing

Model: $FDRET_i = \beta_0 + \beta_1 UDPR_i + e_i$

	Full Sample	Jan. 1999-Dec. 2000	Jan. 2001-Jun. 2008	Jul. 2008-Dec. 2010
β_0	0.3710	1.4142	0.2125	0.1990
	(5.7711)***	(9.1745)***	(9.5156)***	(3.3662)***
β_1	0.1068	-1.5919	-0.2030	-0.2803
	(0.6953)	(-4.7410)***	(-3.4934)***	(-1.4177)
R^2	0.0004	0.0367	0.0212	0.0324
N	1219	592	565	62

Model: $FDRET_i = \beta_0 + \beta_1 UDPR_i + \beta_2 HOT_i + \beta_3 (HOT_i \times UDPR_i) + e_i$

	Full Sample
β_0	-0.1801
	(-1.7735)*
β_1	0.1937
	(0.7276)
β_2	6.6504
	(9.8043)***
β_3	-7.7960
	(-5.0386)***
R^2	0.1852
N	1219

Notes: t-statistics are provided in parentheses below coefficient estimates. $FDRET_i$ = first day return for firm i, $UDPR_i$ = ex-ante estimate of underpricing of firm i based on stochastic frontier model, HOT_i = value of hot index during year of IPO offer date. *, ** and ***, respectively, denote significance at the 10%, 5% and 1% levels.