PREMARKET PRICING UNCERTAINTY AND THE UNDERPRICING OF INITIAL PUBLIC OFFERINGS

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ABSTRACT

All participants in an IPO must evaluate the stock without existing equilibrium price information as a reference point for its fair value. This problem of missing prior price information creates uncertainty in IPO pricing. We show that this uncertainty exists in the premarket valuation process and that IPO underpricing as a premium to investors for bearing this uncertainty increases with valuation volatility. We form IPO portfolios and find a strong, positive relationship between the portfolio mean and the portfolio standard deviation of IPO initial returns. We also find that the portfolio standard deviation alone explains approximately 90% of the variation in the portfolio mean.

JEL classification: G14, G24

Keywords: Initial public offerings, underpricing, premium for pricing uncertainty

1. INTRODUCTION

Despite the extensive literature on initial public offering (IPO) pricing, our understanding of the IPO underpricing phenomenon remains inconclusive. The finding of Lowry et al. (2010) highlights this point. They document that IPO initial returns display extremely high volatility and that volatility varies considerably over time:

> *"While underpricing averages 22% between 1965 and 2005, a relatively small portion of offerings have underpricing that is close to this average: only about 5 percent of the initial returns are between 20% and 25%. Moreover, nearly one-third of the initial returns are negative. The standard deviation of these initial returns over the 1965-2005 period is 55 percent."* (p.1)

Existing IPO pricing theories focus on *intentional* underpricing mechanisms. However, the large and time-varying dispersion of IPO initial returns is difficult to explain as reasonable cross-IPO variations in expected or deliberate underpricing. No clear economic reasons seem to exist for underwriters to deliberately and frequently allow extremely large underpricing and, in particular, overpricing.[2]

A tentative conclusion here is that much of the variation in the initial returns is unanticipated, meaning that considerable pricing errors exist in the pre-issue market. Previous studies do not formally examine the role of pricing errors. For instance, many asymmetric information models explore IPO underpricing in various asymmetric information settings, in which an informed party exists who knows *ex ante* the stock's true value. Since the underwriter is either informed or becomes informed after collecting information, all of those models obtain the offer price as a determinate outcome. Therefore, although the aftermarket price volatility affects the initial return, there is no uncertainty in the offer price. Beatty and Ritter (1986) present a case that further explains this point. In their extended adverse selection model from Rock (1986), the level of information asymmetry depends on *ex ante* uncertainty, and the offer price is a function of the new issue's expected value and the level of uncertainty. In their solution, while *ex ante* uncertainty increases underpricing due to increased asymmetric information costs, it does not make the offer price less accurate. In other words, if the same IPO was priced multiple times in a repeated experiment, the model consistently predicts the same offer price each time, leaving the initial return to change only with the aftermarket price and, thus, display a volatility consistent with the stock's fundamental risk.

Many factors can contribute to the uncertainty and, thus, the difficulty inherent in the pricing problem that limits underwriters' ability to evaluate IPOs accurately. One apparent fact is that no one observes the market value of a new issue until it starts trading in the public market. This fact highlights a universal lack-of-information problem: all participants in an IPO, including the banks and all investors, must evaluate the new stock without prior fair-value information as a reference point for the equilibrium price.[3] Because of this problem, no participant is truly informed, and the usefulness and availability of the premarket information is inevitably constrained by inherent uncertainty. Therefore, we ask about the direct effect of the missing information of prior equilibrium prices *per se* on IPO pricing, leaving aside its possible roles in causing asymmetric information problems. In particular, empirically, how much of the initial return volatility can be explained by this effect?

Figure 1 graphically shows the intuition of the research question. Panel A shows the price dynamics of a stock in a secondary market, where an investor observing the current market value at any point in time only faces the price volatility from the stock's fundamental risk. In contrast, investors in an IPO at, say, time t_0, have no prior equilibrium price information other than the offer price. If they knew the equilibrium price (as in Panel B), they would know the expected value V_0 and only face fundamental risk, as in the secondary market case. However, because

[2] Using a sample of IPOs from 1980 to 1997, Purnanandam and Swaminathan (2004) even find that the median IPO at the offer price was significantly overvalued relative to valuations based on industry peer price multiples.

[3] In real-world IPO markets, investors and underwriters obtain useful valuation information from comparable firms.

they do not observe the equilibrium price in a real IPO (as in Panel C), they face two sources of uncertainty: (i) the unknown expected value; and (ii) the aftermarket price fluctuations around the unknown expected value. In the absence of the equilibrium price V_0, the market aggregate belief V_M^b is nothing but the random realization of a volatile premarket valuation. An offer price that must rely on market beliefs is inevitably uncertain. For example, price multiples from industry peers are commonly used in IPO valuations, which can determine V_M^b at a value approximating V_0 in a certain range, as shown by the shadowed area in the figure. This offer price uncertainty, which arises from the first source, is reflected in volatile premarket valuations. We refer to this as IPO pricing uncertainty. Various factors, including those unrelated to issuer fundamentals, such as stock market trends and investor sentiment, can significantly influence premarket beliefs and, thus, the uncertainty.

The notion of underpricing as a premium for pricing uncertainty highlights IPO initial return as a random variable driven by premarket pricing errors instead of by aftermarket price volatility. The latter is from the issuer's fundamental risk and, on an overnight basis, very small. In contrast, the former can vary considerably and, thus, be very large depending on the difficulty and complexity of the pricing task facing the underwriter. The distinction between these two sources of uncertainty is conceptually new and empirically appealing. By treating the offer price as a random variable, we address an important dimension of IPO underpricing—its volatility. The volatility associated with underpricing predominantly comes from IPO pricing uncertainty instead of secondary market return volatility (see, e.g., Loughran and McDonala, 2013). Because this dimension can be sufficiently flexible to generate high and time-varying initial return volatilities, the interpretation of underpricing as a premium for pricing uncertainty squares with the finding of Lowry et al. (2010).

In this paper, we empirically test the effect of IPO pricing uncertainty on the initial return using a sample of U.S. IPOs. One of our key tests faces a challenge: Without prior price information, which is the very reason for pricing uncertainty, we cannot calculate the mean and variance of an IPO's initial return as we can for a seasoned stock using its historical return data. For this reason, we form IPO portfolios and conduct the test by examining the relationship between the mean and standard deviation of the portfolio IPOs' initial returns. In this approach, we sort IPOs by a valuation uncertainty ranking (with cross-sections) or by listing date (in time series) and form portfolios such that the IPOs in each portfolio have relatively similar pricing uncertainty, and their variations in uncontrolled factors are substantially averaged out. We then use the portfolio mean of the initial returns as a proxy for the expected initial return and the standard deviation as a proxy for pricing uncertainty. We form alternative portfolios. For each formation, we run regressions of the portfolio mean on the portfolio standard deviation. As expected, we identify an unusually strong, positive relationship between the portfolio mean and the standard deviation of IPO initial returns. In various specifications, the standard deviation presents the dominant explanatory variable, which alone explains as high as 94% of the variation in the portfolio mean.

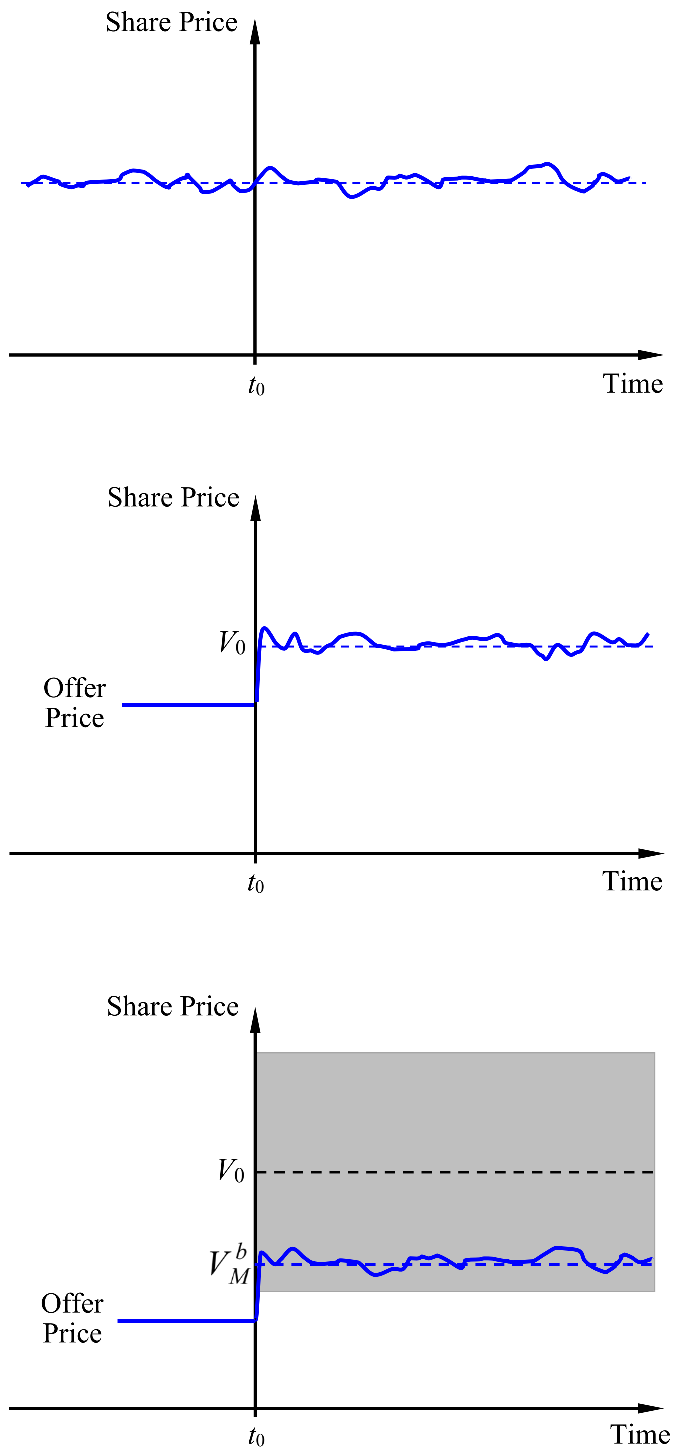
This paper proceeds as follows. Section 2 provides a brief literature review with a focus on short-term IPO performance. Section 3 develops the hypotheses. Section 4 presents our empirical tests. Section 5 concludes the paper.

FIGURE 1. Illustration of Price Dynamics: IPO vs. Seasoned Stock

A. Price dynamics of a seasoned stock

B. Price dynamics of an IPO surrounding the offering date t_0: the *informed* perspective

C. Price dynamics of an IPO surrounding the offering date t_0: the *uninformed* perspective



2. LITERATURE REVIEW

Two groups of papers study IPO underpricing. The first group assumes asymmetric information among issuers, underwriters and investors. Rock (1986) presents a model assuming that some investors are informed and have better information than other investors. If the new shares are priced at the expected value, then the informed investors crowd out the uninformed ones. Therefore, the shares must be underpriced to attract the participation of uninformed investors. Benveniste and Spindt (1989) model the IPO book-building process that induces informed investors to truthfully reveal their private information on the new issue. Underpricing is hence a natural outcome as compensation to investors for disclosing the true value. Sherman and Titman (2002) model book-building IPOs as an information acquisition process in the presence of the moral hazard problem facing investors. They conclude that information is costly, and the underwriter underprices the new issue according to the value of information. Darrien (2005) shows how noise traders' sentiment affects the offer price and the returns in aftermarket trading, where the initial return reflects the private information collected in the book-building process and the sentiment of noise traders. More recently, Chen, Goyal, Veeraraghavan, and Zolotoy (2020) find that high media coverage before an IPO reduces the degree of underpricing.

The second group of papers examines IPO pricing factors other than information asymmetry. Hughes and Thakor (1992) argue that issuers/underwriters underprice stocks to reduce their potential legal liability. Cliff and Denis (2004) find that initial IPO returns are positively related to analyst coverage by lead underwriters. Hence, underpricing is used at least partially as compensation for post-IPO analyst coverage. Our paper fits in with this group of research. We highlight the observation that before the public listing, the issuer's stock had not been traded in the market, so there is no information on its current value (i.e., the equilibrium market price). In the presence of this missing information problem, investors in the IPO require a premium as compensation for this premarket uncertainty in IPO pricing. Specifically, we examine how much initial return volatility can explain underpricing. The notion of underpricing as a premium for pricing uncertainty is consistent with the finding of Lowry et al. (2010) that IPO initial returns display extremely high volatility. Recent studies also address issues related to premarket uncertainty. Chang, Chiang, Qian and Ritter (2017) examine a unique emerging market that requires premarket trading and find that premarket trading prices help set more accurate offer prices and, thus, less price discounts.

Existing IPO pricing theories have focused on intentional underpricing mechanisms that do not consider pricing errors but model the offer price as a determinate outcome. In this study, we focus on the effect of pricing uncertainty due to the lack of prior market equilibrium prices. Intuitively, since this missing information problem reduces the premarket demand, underpricing occurs as an efficient outcome when the premarket demand imposes a binding constraint on the sale of the new issue.

3. HYPOTHESES DEVELOPMENT

To derive our hypotheses, consider the underwriter and the investors in an IPO, where the underwriter represents the risk-neutral issuer, and the investors are risk averse and have heterogeneous preferences. All participants in the IPO are equally uninformed in the sense that no prior equilibrium price information exists so the new issue's expected value is unknown to all participants. To determine the offer price, the underwriter needs to collect information on investors' beliefs through the book-building process and uses the information to derive the premarket demand curve. The timeline for the underwriter's decision is as follows. At time $t_0 = 0$, the underwriter determines the offer price P_0 and allocates shares based on the distribution of the shares demanded at the offer price; at time $t_0 + \Delta t = \Delta t$, the first-day closing price (as the proxy for the immediate aftermarket price), $P_{\Delta t}$, and the initial return, $R = P_{\Delta t} - P_0$, are realized.

The investors face not only fundamental risk from the secondary market but also premarket uncertainty due to missing market equilibrium price information. Their decisions to purchase in the primary market depend on their belief in the new stock's value, which is essentially their best estimate of the true value from their personal preference and any public information available on the new issue. The level of difficulty facing the investors in the valuation determines the degree of the pricing error. Various factors can contribute to the pricing error, including investor heterogeneity and market sentiment.

The underwriter determines the market demand based on information on all investors' intended bids collected during the book-building process. In the absence of the current market price, the underwriter's decision is subject to the market-wide uncertainty in investors' premarket beliefs. This uncertainty presents a source of pricing error in the underwriter's decision. Investors facing uncertainty only purchase the new issue if the offer price is sufficiently lower than their believed value. This discount—the difference between their believed value and the offer price—represents the compensation to the investor for bearing the offer price uncertainty. Therefore, our first hypothesis is the following:

> ***Hypothesis 1.*** *In the presence of pricing uncertainty, underpricing occurs when uncertainty is sufficiently high.*

The economic rationale of this hypothesis is that since the uncertainty from pricing errors reduces the market demand (relative to the case when the stock's current market price was publicly observed), underpricing occurs when the reduced demand imposes a binding constraint on the sale of the new issue.

When the premarket beliefs are inherently uncertain and the underwriter's decision must rely on them, the offer price is inevitably uncertain and bound to vary with market belief fluctuations. One implicit assumption here is that the new issue uncertainty due to imprecise pricing is undiversifiable. Hypothetically, when investors regularly participate in the IPO market and purchase as many shares as needed and at all times, they substantially diversify away this uncertainty by holding a portfolio of all-time IPOs. However, common sense suggests the opposite: IPO pricing uncertainty is difficult for either retail investors or institutions to diversify away. Indeed, because of enormous uncertainty in the timing and availability of future IPOs and the long horizon needed to acquire a diversified portfolio, achieving diversification by relying on new stocks is extremely difficult. A further question is whether investors can diversify away the uncertainty by using stocks from the secondary market. Given the large difference in IPO initial returns and seasoned stock returns (e.g., on an overnight basis, 20% on IPOs vs. 0.05% on seasoned stocks), reducing the initial return uncertainty by holding a portfolio of diversified seasoned stocks is also difficult.

Market beliefs can deviate from the true value for various reasons unassociated with the stock's fundamental risk (e.g., market sentiment). In previous studies, the offer price is modeled as a determinate outcome, where the only source of the uncertainty in the initial return is aftermarket price fluctuations from the stock's fundamental risk. While this conventional component of uncertainty is relatively negligibly small, the pricing uncertainty component as a random draw from the premarket belief distribution becomes dominant. The finding of Lowry et al. (2010) suggests very high volatility of IPO initial returns associated with imprecise pricing. As an illustration, consider a hypothetical IPO with an expected initial return of 20% and a pricing error standard deviation of 25%. A normal distribution of the initial return results in a probability of 0.2 for the realized return to be below -1% and the same probability for the return to be above 41%, leaving a probability of merely 0.16 for the return being within the range of 15–25%. Our second hypothesis is as follows.

> ***Hypothesis 2.*** *The expected value of an IPO's initial return is positively associated with the initial return volatility.*

When the initial return volatility can be measured, it can be used as a proxy for undiversifiable pricing uncertainty. Hence, this hypothesis predicts a positive association between the uncertainty in IPO pricing and the level of underpricing as a premium for taking on the uncertainty.

Lowry et al. (2010) report a positive correlation between the average initial return of IPOs each month and the dispersion of the initial returns each month and conclude that the finding contrasts markedly with the negative correlation between the volatility and mean of secondary market returns. Hypothesis 2 provides a premium for the pricing uncertainty explanation of their observation: When the IPOs each month exhibit similar pricing volatilities, the average initial return is associated with the dispersion of the initial returns dictated by the underlying pricing uncertainty.

4. EMPIRICAL ANALYSIS

In this section, we first examine the link between IPO underpricing and premarket pricing uncertainty (Hypothesis 1) and then conduct a test for the relationship between the expected level and the volatility of IPO initial returns (Hypothesis 2).

4.1. Data and Sample

We collect data on IPOs for 1991–2015 from the Securities Data Company's (SDC) New Issues Database. Following previous studies, we eliminate ADRs, closed-end funds, REITs, spin-offs, and unit issues by choosing only common stocks with an IPO flag equal to one. For each IPO, we collect information on the offer date, preliminary filing price range, offer price, proceeds, SIC code, and VC backing. We also obtain information from SDC on pre-IPO accounting variables for the 12-month period immediately before the filing date, which include revenues, net income, shareholder equity, and long-term debt. Our main empirical results are based on the period from 1991 to 2008, and we use the remaining period from 2009 to 2015 as the robustness check.

To obtain pricing volatility measures, we calculate the volatilities of three price multiples from industry peers: the price-to-earnings ratio, the price-to-EBIT (earnings before interest and taxes) ratio, and the price-to-sales ratio. Investors and investment banks commonly use these multiples to estimate the fair value for IPOs. Purnanandam and Swaminathan (2004) value IPOs using industry peers' price multiplies (such as the price-to-EBITDA, price-to-sales, and price-to-earnings ratios) to determine whether an IPO is underpriced or overpriced. Roosenboom (2012) confirms that the price-multiple approach is one of the main methods underwriters use to determine the fair value for IPOs. Intuitively, for a given IPO, the usefulness of its industry peers' price multiples directly depends on how close or comparable they are. The more divergent the multiples are, the greater is the disagreement among investors and investment banks and hence the higher is the uncertainty and the greater is the difficulty of the IPO valuation. Therefore, although true uncertainty is not observable and cannot be directly measured, the standard deviation of industry peers' price multiples presents a reasonable proxy for uncertainty.

The presumption for this approach is that the price multiples of industry peers do not depend on an IPO's offer price or initial return. Given the IPO pricing process and the scale of the whole market or industry in contrast to that of a new issue, this presumption seems to hold intuitively and is consistent with the common perception that a new issue's price depends on the aggregate market condition but not vice versa. However, the exceptional situation in which an important company's IPO in turn affects the market sentiment—and, consequently, the industry peers' price multiples become endogenous to the IPO—cannot be ruled out. We argue that this possibility does not pose a serious problem to our volatility measures. One apparent reason is that such cases are uncommon. Moreover, any potential effect of such exceptional IPOs can be further mitigated by controlling market sentiment variables. More importantly, our measures are multiple standard deviations, which are not directly or strongly affected by market sentiment, as are stock prices.

Notably, a GARCH model is widely used to describe the variance in the stock return error term when it is serially auto-correlated, which helps capture secondary market uncertainty. By treating the sequence of IPOs as a time-series process, Lowry et al. (2010) use the GARCH model proposed by Nelson (1991) to estimate the time variation in possibly serially correlated IPOs.

A challenge to our test for Hypothesis 2 is the lack of time series data; for each IPO, there is only one observation of the realized initial return, so there is no such measure of return volatility or variance as that we can obtain for a seasoned stock. For this reason, we form IPO portfolios and then examine the relationship between the expected initial return and the initial return variance on a portfolio basis. When the portfolios are adequately constructed such that the IPOs in each portfolio share common features and, thus, have comparable pricing uncertainty, we can use the portfolio mean and variance in the initial returns as a proxy for $E(P_{\Delta t} - P_0)$ and $Var(P_{\Delta t} - P_0)$, respectively, and test their relationship using the portfolio data. Specifically, we form IPO portfolios in two alternative ways: sorting on pricing volatility and listing date. To measure pricing volatility, for each IPO, we identify its industry peers and use the standard deviation of the peers' price multiples (e.g., the price-to-earnings ratio) as a proxy for its pricing volatility. We expect the within-industry dispersion of a price multiple to reflect the difficulty and uncertainty of IPO valuations in that industry. To the extent that the within-industry dispersion is vulnerable to uncontrolled industry heterogeneity, we alternatively form monthly (as in Lowry et al., 2010) and quarterly portfolios. Such listing-date-based time series portfolios have the advantage of capturing over-time variations in pricing uncertainty that are driven by aggregate market conditions instead of by issuer-specific factors.

Our use of the standard deviation of the portfolio IPO initial returns is similar to that by Boeh and Dunbar (2014). To identify the determinates of IPO waves, the authors examine several variables, including ex ante uncertainty, which they measure using the standard deviation of IPO initial returns during a pre-IPO period. The authors argue that this measure captures the market-wide difficulty of banks in valuing new issues ex ante.[4]

In a GARCH model, Lowry et al. (2010) estimate simultaneous equations for the mean and volatility of IPO initial returns. While their data show a positive relationship between the two (Figure 2 and Table II), they do not formally test this relationship but instead focus on the determination of volatility. We conduct a formal test for this relationship, in which we treat volatility as the key determinant of the mean of IPO initial returns, following the predictions of Hypothesis 2.

Our approach of using the industry standard deviation of pricing multiplies is natural, noting that larger standard deviations of pricing multiplies increase the complexity of the pricing problem. As stated in Lowry et al. (2010), this complexity limits the underwriter's ability to accurately price IPOs. Kim and Ritter (1999) argue that since most firms pursuing IPOs in the

[4] To estimate the relationship between the premarket due diligence and book-building processes, Crain, Parrino and Srinivasan (2021) examine how these two processes change with uncertainty. The authors use growth opportunity measures as proxies for uncertainty.

U.S. are young, the discount cash flow approach is not suitable because of the difficulty in forecasting future cash flows. They show that the use of comparable firm multiplies is widely recommended. In particular, Roosenboom (2012) uses a unique dataset of 228 reports from French underwriters that allows him to access the pre-IPO valuation process used in practice by investment banks. He finds that the price multiplication approach is one of the main methods that underwriters use to determine the fair value of IPO firms.

More specifically, for each IPO, we identify its industry peers by choosing all seasoned stocks in the same industry under the Fama–French 48 industry classification that had traded at least three years prior to the IPO. We then compute the standard deviation of each price multiple of the seasoned stocks for the pre-IPO year and use it as a proxy for the IPO's pricing volatility. The implication here is that if the industry has more diverse price multiples at the time of the IPO, then it is more difficult for investors and underwriters to evaluate the new issue using the industry valuation information. This proxy has one distinct advantage: because it is purely from industry peers, it has no direct association with the IPO firm's own information structure, such as information asymmetry.

As usual, we use the IPO initial return to measure the degree of underpricing, which is calculated as the difference between the closing price on the first trading day and the final offer price divided by the offer price. The price update is the difference between the final offer price and the midpoint of the preliminary offer prices divided by the mid-preliminary price, and this update is used to capture the underpricing effect of information revelation by institutional investors (Benveniste and Spindt, 1989). To describe underwriter reputation, we follow Carter and Manaster (1990) and Carter et al. (1998) to identify the lead underwriter from SDC and assign a rank on a 10-point scale based on the Loughran and Ritter (2002) classification. For IPOs with more than one lead manager, the average rank of all leading underwriters is used.

To ensure that very small issuers do not disproportionately affect our results, we exclude from the sample IPOs with an offer price below $5 per share (see, e.g., Lowry et al., 2004; Bradley and Jordan, 2002). After removing observations with missing data, our final sample consists of 5,832 IPOs. Table 1 presents the descriptive statistics of the selected variables. The numbers indicate similar IPO characteristics as those in previous studies. On average, IPOs are sold at $13 per share, raise capital of $105 million, and earn an initial return of 19%. Approximately 36% of all issuing firms receive funding from venture capitalists.

The three proxy variables of pricing volatility show reasonable variations across IPOs. Their median values are 35.2%, 7.9%, and 1.6% for the standard deviation of the price-to-earning, price-to-EBIT, and price-to-sales ratios, respectively, which are compared with these volatility measures' corresponding standard deviations of 111.7%, 14.1%, and 1.9%, respectively. In Table 2, the Pearson correlation coefficients show strong correlations between the proxy variables. All three proxy variables are positively correlated with the first-day return, and the correlation coefficients are significant at the 1% level. On the other hand, these pricing volatility proxies are only weakly related or unrelated to issuer size and book-to-market ratio. This observation suggests that the difficulties related to new issue pricing are not closely associated with the issuer's size or growth potential.

Table 1. Summary Statistics

The sample is from the SDC database, which consists of common stock IPOs conducted during 1991-2008. The offer price is the finalized offer price. The price update is the percentage change from the midpoint of initial filing range to the final offer price. The initial return is the percentage change from the final offer price to the first trading day closing price. Proceeds are the total proceeds of the IPO. Market capitalization is the number of shares outstanding times the first trading day closing price. Underwriter ranking dummy is the 10-point scale for leading underwriter ranks assigned by Carter and Manaster (1990) and Carter, Dark and Singh (1998), modified by Loughran and Ritter (2004). VC dummy equals one if the IPO is backed by venture capitalists and equals zero otherwise. Book-to-market ratio is the first book value of equity available from Compustat divided by the first trading day closing price. We obtain three alternative proxy variables for IPO pricing volatility as follows: for each IPO, we identify its industry peers by choosing all seasoned stocks that are in the same industry as the IPO under the Fama-French 48 industry classification and have traded more than three years prior to the IPO; from the industry peers' financial data one year before the IPO date we calculate their price-to-earnings, price-to-EBIT, and price-to-sales ratios, respectively, and then obtain the industry standard deviation of each price multiple as a proxy for the IPO's pricing volatility.

	Observation	Mean	Median	Standard deviation	Minimum	Maximum
<u>Panel A. IPO variables</u>						
Offer price ($)	5,832	13.257	12.500	5.979	5	97
Price update (%)	5,832	0.588	0	22.808	-98.419	400
Initial return (%)	5,832	18.752	6.920	44.894	-100	636.364
Proceeds ($million)	5,832	104.502	39.200	293.499	0.200	8680
Market capitalization ($million)	5,832	898.855	97.576	7484.30	0	213142
Book-to-market ratio	5,832	0.411	0.288	3.081	-2.374	173.006
Top-tier underwriter dummy	5,832	0.564	1	0.496	0	1
VC dummy	5,832	0.355	0	0.478	0	1
NASDAQ dummy	5,832	0.661	1	0.474	0	1
<u>Panel B. Proxy variables for pricing volatility</u>						
Standard deviation of industry peer price/earnings ratio (%)	5,832	53.941	35.192	111.653	1.213	238.942
Standard deviation of industry peer price/EBIT ratio (%)	5,832	12.446	7.899	14.099	0.079	371.270
Standard deviation of industry peer price/sales ratio (%)	5,832	2.237	1.568	1.932	0.026	22.099

Table 2. Correlation Coefficients for Selected Variables (1991–2008)

This table reports the correlation coefficients between the selected variables. The initial return is the percentage change from the final offer price to the first trading day's closing price. The price update is the percentage change from the midpoint of the initial filing range to the final offer price. Proceeds are the total proceeds of the IPO. Market capitalization is the number of shares outstanding times the first trading day's closing price. The book-to-market ratio is the first book value of equity available from *Compustat* divided by the first trading day's closing price. The standard deviations of industry peer price multiples as proxies for IPO pricing volatility are calculated as in Table 1. *p*-values are reported in parentheses.

	Initial return	Std dev of industry peer price/earnings ratio	Std dev of industry peer price/EBIT ratio	Std dev of industry peer price/sales ratio	Price update	Proceeds	Market cap	Book-to-market ratio
Initial return	1	0.037	0.231	0.271	0.473	0.005	0.022	-0.034
		(0.012)	(<0.001)	(<0.001)	(<0.001)	(0.770)	(0.146)	(0.044)
Std dev of industry peer price/earnings ratio		1	0.218	0.081	0.013	-0.018	-0.008	-0.009
			(<0.001)	(<0.001)	(0.359)	(0.251)	(0.572)	(0.588)
Std dev of industry peer price/EBIT ratio			1	0.597	0.082	-0.074	-0.015	-0.023
				(<0.001)	(<0.001)	(<0.001)	(0.310)	(0.178)
Std dev of industry peer price/sales ratio				1	0.137	0.167	-0.008	-0.018
					(<0.001)	(<0.001)	(0.595)	(0.286)
Price update					1	0.130	0.035	-0.018
						(<0.001)	(0.019)	(0.284)
Proceeds						1	0.366	0.037
							(<0.001)	(0.034)
Market capitalization							1	-0.010
								(0.555)
Book-to-market ratio								1

4.2. IPO Initial Return and Pricing Volatility

Table 3 presents our test for the link between underpricing and pricing volatility (Hypothesis 1). In this test, we run a regression of the IPO initial return on each of the pricing volatility proxies, alternatively controlling for conventional issuer and market characteristics variables.

To also control for secondary market factors, we obtain the Fama–French three factors, the momentum factor and the Pastor-Stambaugh value-weighted traded liquidity factor from WRDS. Because each IPO is supposed to be associated with different factor loadings, we cannot directly include the factors in the cross-sectional regression. For this reason, we define the control variables for these factors as follows. For each IPO, we determine a matching stock by choosing a seasoned firm that has traded for at least three years and is in the same industry, in the same size decile, and has the closest book-to-market ratio as the issuer. We then run a time series regression using the monthly return data to obtain the matching stock's factor loadings on the IPO day and use the product of the factor and its factor loading as the control for the factor risk premium.

Following Green and Huang (2012), we also control for the expected skewness of the IPOs, which is a measure of intra-industry skewness estimated from industry peers' recent stock returns. The authors argue that when individual investors trading in the secondary market exhibit a higher preference for skewness than do institutions participating in the primary market, the skewness preference difference between these two types of investors contributes to the IPO initial returns. Aissia (2014) finds that IPOs with high initial returns have higher idiosyncratic skewness, turnover rate and momentum.

In Table 3, the coefficient on the proxy of pricing volatility is positive and statistically significant in all nine regressions. Consistent with Hypothesis 1, these regressions confirm that the first-day IPO return increases with the difficulty related to premarket valuation. This effect is also economically significant. For instance, the ninth regression indicates that for an increase in the volatility proxy (the price/EBIT ratio) of one standard deviation, the initial return increases by three percentage points. It is worth noting that when volatility also affects the cost of information asymmetry (Beatty and Ritter, 1986),[5] this effect could be partially due to the adverse selection problem. Therefore, it is important to control for issuer characteristic variables, including the price update, so that any uncaptured influence of asymmetric information is minimized.

The parameter estimates for the control variables are consistent with those in previous studies. As in Hanley (1993), Loughran and Ritter (2004), and Liungqvist and Wilhelm (2002), the coefficient on the price update is significantly positive, which captures the asymmetric information effect on underpricing (presumably resulting from a partial price adjustment that works to compensate informed investors for revealing favorable private information). The coefficient on the top-tier underwriter dummy is significantly positive in all regressions, supporting the agency cost argument for the role of underwriters in IPO pricing (e.g., Loughran and Ritter, 2004).[6] Our estimates also indicate a positive effect of venture capital backing on the initial return. Although this effect is inconsistent with the certification effect of venture capital (Barry et al., 1990; Megginson and Weiss, 1991; Schultz, 1993), it is in line with more recent

[5] Beatty and Ritter (1986) model the role of ex ante uncertainty under the adverse selection framework of Rock (1986). They show that when the uncertainty increases the benefit to informed investors, it increases the cost to the issuer that allows the uninformed to break even, thus increasing underpricing.

[6] However, the underpricing–underwriter ranking relation can be complex because an offsetting underwriter–reputation or certification effect can also exist. Indeed, recent studies find mixed results for this relation, which is negative in the 1980s and turns positive in the 1990s (see Lee and Wahal, 2004; Loughran and Ritter, 2003).

studies that find more severe underpricing among venture capital-backed firms during the 1990s (Hamao et al., 2000; Brav and Gompers, 1997; Bradley and Jordan, 2002).[7]

The inclusion of the five secondary market factors and the expected skewness of industry peers does not materially change the major coefficients, although the adjusted R-squared slightly increases with them. As in Green and Huang (2012), the expected skewness is shown to be a significant factor affecting the initial return. When including the expected skewness, three of the secondary market factors (market risk, HML and momentum) show a significantly positive effect on the first-day return.

[7] It is argued that in addition to providing funds, venture capital adds value to the firm by monitoring and governing management, thus a certification effect for venture capital reduces underpricing (Megginson and Weiss, 1991).

Table 3. Regressions of IPO Initial Return on Pricing Volatility

This table reports the regression results for IPO initial return on pricing volatility. The proxy variable for each IPO's pricing volatility is obtained from its industry peers' price multiples (as explained in Table 1). The control variables include the price update, logarithm of IPO proceeds, and the dummy variables for underwriter rank, VC backing, technology stocks, NASDAQ stocks, and the bubble period. To capture potential effects of secondary market factors, we define relevant control variables as follows: For each IPO, we choose a matching stock by picking the seasoned firm that has been listed for at least three years, and is in the same industry, in the same size decile and with the closest book-to-market ratio as the issuer. We run time-series regression using 12-month moving window to obtain the factor loadings for the matching stock on the IPO day, and then use the product of a factor and the factor loading as the control for that factor. Five control variables are thus obtained for market risk premium, small (size) minus big (SMB), high (book/price) minus low (HML), momentum, and liquidity, respectively. Eskewness is the expected skewness of industry peers defined as in Green and Hwang (2012). The signs ***, **, and * represent significance levels at 1%, 5%, and 10%, respectively.

	Pricing volatility based on price/earnings ratio			Pricing volatility based on price/EBIT ratio			Pricing volatility based on price/sales ratio		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	12.561*** (4.64)	12.673*** (4.65)	4.451 (1.24)	11.141*** (4.02)	11.280*** (4.06)	3.583 (1.00)	12.003*** (4.30)	12.173*** (4.35)	2.449 (0.68)
Proxy for pricing volatility	0.010*** (2.37)	0.010*** (2.44)	0.019*** (3.56)	0.214*** (3.35)	0.212*** (3.34)	0.147*** (3.35)	0.704** (2.13)	0.671** (2.03)	1.639** (2.32)
log(Proceeds)	-2.375*** (-4.53)	-2.450*** (-4.66)	-0.938*** (-3.37)	-2.355*** (-4.50)	-2.429*** (-4.63)	-0.834 (-1.22)	-2.574*** (-4.93)	-2.641*** (-5.03)	-1.115 (-1.63)
Underwriter rank dummy	4.588*** (4.55)	4.490*** (4.46)	4.452*** (3.94)	4.568*** (4.53)	4.470*** (4.41)	4.575*** (3.02)	4.552*** (4.51)	4.456*** (4.43)	4.566*** (3.02)
VC dummy	5.990*** (4.73)	5.923*** (4.70)	7.031*** (4.57)	5.293*** (4.12)	5.236*** (4.10)	6.391*** (4.12)	5.896*** (4.65)	5.839*** (4.63)	6.914*** (4.51)
Tech dummy	8.367*** (5.86)	8.235*** (5.90)	7.868*** (4.95)	7.643*** (5.43)	7.520*** (5.39)	7.447*** (4.62)	8.189*** (5.88)	8.073*** (5.84)	6.887*** (4.29)
NASDAQ dummy	4.329*** (3.61)	4.337*** (3.62)	4.343** (2.54)	4.170*** (3.49)	4.179*** (3.50)	4.604*** (2.69)	4.764*** (3.81)	4.751*** (3.81)	4.796*** (2.81)
Bubble dummy	32.071*** (12.45)	32.390*** (12.35)	29.612*** (11.74)	29.431*** (11.41)	29.754*** (11.30)	30.343*** (12.04)	30.471*** (11.85)	30.875*** (11.74)	28.137*** (11.08)
Price update	0.807*** (10.82)	0.806*** (10.78)	0.798*** (25.94)	0.809*** (10.85)	0.808*** (10.81)	0.796*** (25.88)	0.808*** (10.83)	0.807*** (10.80)	0.787*** (25.63)
Market risk premium		1.610 (1.58)	2.852*** (4.22)		1.589 (1.56)	2.753*** (4.07)		1.525 (1.48)	2.774*** (4.12)
SMB		-1.691 (-1.13)	-0.226 (-0.28)		-1.747 (-1.17)	-0.337 (-0.41)		-1.719 (-1.15)	-0.278 (-0.34)
HML		-2.889* (-1.78)	4.246*** (3.66)		-2.833* (-1.75)	4.070*** (3.51)		-2.942* (-1.80)	4.082*** (3.53)
Momentum		1.374 (1.26)	3.200** (2.08)		1.422 (1.31)	2.983* (1.94)		1.392 (1.28)	2.894* (1.89)
Illiquidity		0.156 (1.12)	0.266 (0.26)		0.146 (1.05)	0.224 (0.22)		0.159 (1.14)	0.271 (0.26)
Eskewness			8.143** (2.60)			7.180** (2.28)			6.798** (2.17)
Observation	5,832	5,832	5,832	5,832	5,832	5,832	5,832	5832	5,832
Adjusted R^2	0.307	0.311	0.314	0.309	0.312	0.312	0.308	0.311	0.317

4.3. Pricing Uncertainty and Expected Initial Return: Evidence from Cross-Sectional Portfolios.

For our test for Hypothesis 2, we form IPO portfolios and run a regression of the portfolio mean (as the proxy for the expected initial return or premium) on the portfolio standard deviation (as the proxy for the pricing uncertainty) of IPO initial returns. We first examine three portfolio formations based on valuation volatility: for each of the three pricing volatility proxies discussed above, we sort all sample IPOs by the proxy and divide them into 50 equal-sized portfolios, each of which on average consists of 98 IPOs. The first three plots (A, B and C) in Figure 2 show the relationship between the portfolio mean and standard deviation of IPO initial returns for the three formations.

In these plots, the standard deviation exhibits considerable variations, implying a large variation in the average pricing uncertainty of the IPO portfolios. Consistent with the prediction of Hypothesis 2, the plots indicate a strong, positive relationship between the portfolio mean and the portfolio standard deviation of the initial returns, stretching out from the origin.

Table 4 reports the result of our test, where the dependent variable is the portfolio mean of the initial returns and the key independent variable is the corresponding portfolio standard deviation. In these regressions, we also control for firm age, which is defined as the difference between the firm's founding year and its IPO year. The founding year information is obtained from Jay Ritter's website. The results from the three portfolio formations are very similar. In regressions (1), (4) and (7), the coefficient on the portfolio standard deviation—the only explanatory variable—is positive and statistically highly significant, which alone explains 89% to 94% of the variation in the portfolio mean of the initial returns. The high explanatory power of the single-variable models suggests that the relationship is economically very strong: for a one percentage-point increase in the portfolio standard deviation, the portfolio mean increases by 0.57 to 0.66 percentage points. After IPO characteristics variables (as those in Table 3, but in the corresponding portfolio means) are included, the model's explanatory power in regressions (2), (5), and (8) increases to 94% to 96%.

The observation that the portfolio standard deviation is the dominant factor that alone explains approximately 90% of the variation in the portfolio mean is striking. While this finding is highly consistent with Hypothesis 2, it is difficult to explain using other underpricing mechanisms.

In regressions (3), (6) and (9), we further include the five secondary market factors (also in their portfolio means). Whereas the models' explanatory power further increases slightly, these controls have no material impact on the estimation, and none of their coefficients is statistically significant. This observation lends support to the notion that the uncertainty in IPO pricing is fundamentally different from conventional secondary market risks. When the expected skewness is also included, the coefficient on the portfolio standard deviation slightly improves. The coefficient of firm age is negative but not significant. We leave a more detailed discussion of the role of the expected skewness to a robustness check (the next section).

FIGURE 2. IPO Portfolio Initial Returns: Mean and Standard Deviation

Our sample includes all common stock IPOs conducted during 1991–2008 in the U.S. We form IPO portfolios on pricing volatility or overtime. Plots A, B and C present three cases of portfolio formation on pricing volatility. For each IPO, we identify all seasoned stocks in its industry, calculate each stock's price multiple (price-to-earnings, price-to-EBIT, or price-to-sales ratio), and use the industry standard deviation of the multiple as the proxy for the IPO's pricing volatility. We then rank all IPOs by the proxy and divide them into 50 equal-sized portfolios. Plots D and E present two cases of time-series IPO portfolios: monthly and quarterly. In all plots, the vertical axis represents the portfolio mean, and the horizontal axis represents the portfolio standard deviation of IPO initial returns.

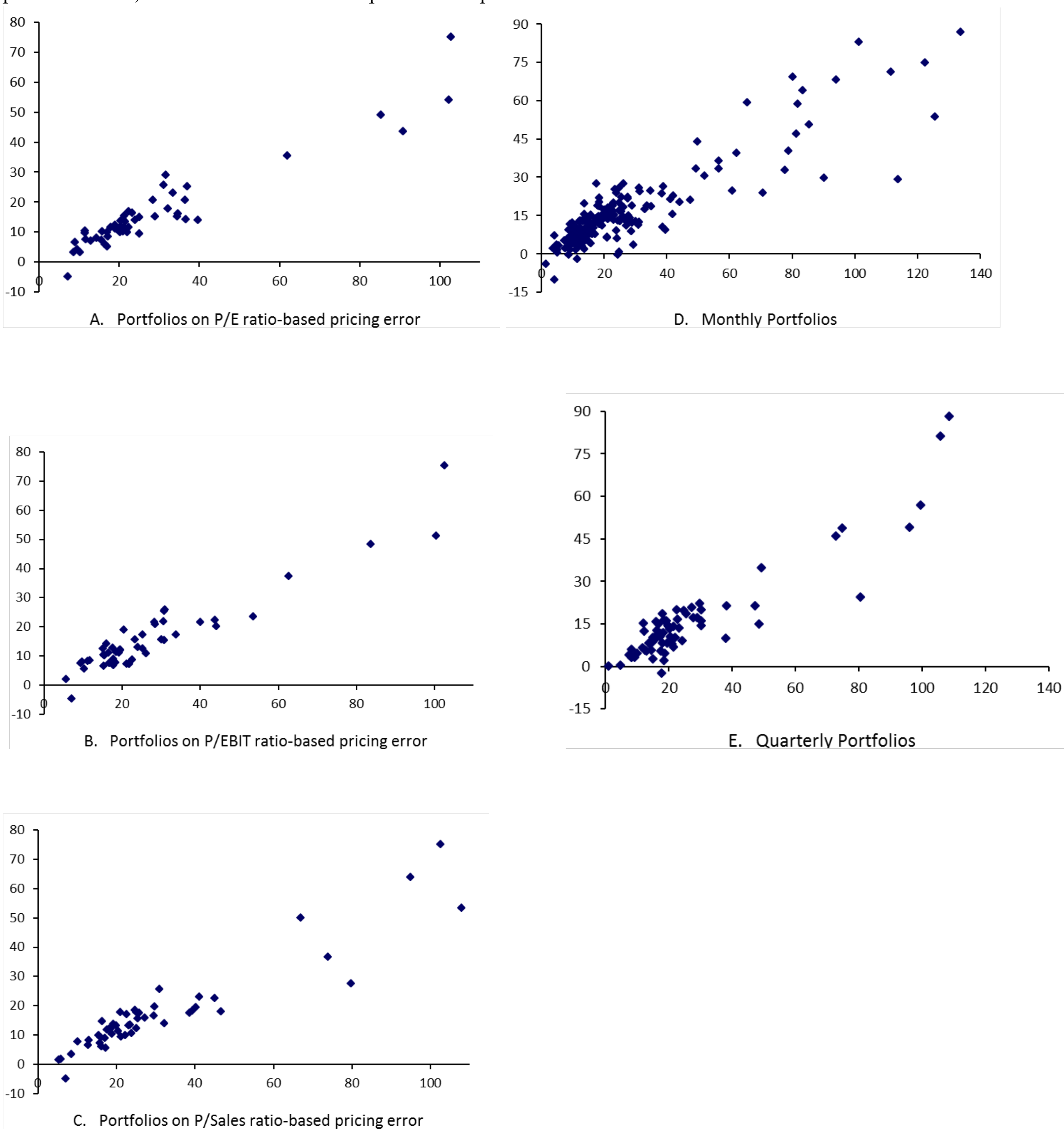


Table 4. Regressions with Cross-Sectional Portfolios of IPOs (Sample Period 1991-2008)

For each IPO, we obtain three alternative proxy variables for the pricing volatility from its industry peers' price multiples (as explained in Table 1). Using each proxy, we rank all IPOs and divide them into 50 equal-sized portfolios. In all regressions, the dependent variable is the portfolio equally weighted average of IPO initial returns (as a measure of the portfolio's expected pricing uncertainty premium), and the key independent variable is the portfolio standard deviation of the initial return (as a measure of the portfolio's pricing uncertainty). The same control variables for IPO characteristics and secondary market factors are as in Table 3 but in portfolio means of each control variable are included. Firm age is defined as the calendar year of the IPO minus the calendar year of the firm's founding. We obtain the founding date of each firm from Professor Jay Ritter's website. The signs ***, **, and * represent significant levels at 1%, 5%, and 10%, respectively.

	IPO portfolios Sorted on Std dev of price/earnings ratio			IPO portfolios Sorted on Std dev of price/EBIT ratio			IPO portfolios Sorted on Std dev price/sales ratio		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	-0.312 (-0.28)	5.465 (0.55)	7.207 (0.63)	0.253 (0.24)	17.834 (1.36)	19.766 (1.37)	-2.608*** (-2.63)	-9.311 (-0.63)	-3.523 (-0.24)
Portfolio std dev of IPO initial returns	0.589*** (20.19)	0.381*** (18.73)	0.384*** (17.44)	0.568*** (20.47)	0.500*** (17.44)	0.533*** (16.78)	0.657*** (26.85)	0.619*** (14.87)	0.270*** (8.75)
log(Proceeds)		0.576 (0.78)	0.609 (0.59)		-1.671 (-0.68)	-2.295 (-0.76)		2.111 (0.63)	0.706 (0.21)
Underwriter rank dummy		12.318*** (2.56)	14.137 (0.54)		6.143 (0.76)	5.174 (0.54)		-5.883 (-0.72)	-1.569 (-0.18)
VC dummy		-12.900** (-2.37)	-12.533** (-2.08)		-7.461 (-1.09)	-6.407 (-0.87)		14.811 (1.61)	22.926** (2.31)
Tech dummy		-0.886 (-0.76)	-1.111 (-0.31)		2.558 (0.72)	1.610 (0.40)		0.611 (0.07)	4.174 (0.44)
NASDAQ dummy		14.313** (2.02)	14.528* (1.89)		8.307 (0.72)	7.401 (0.22)		6.187 (0.52)	4.467* (0.35)
Bubble dummy		16.467*** (4.14)	16.347*** (3.69)		13.823** (2.10)	10.993 (1.32)		15.247*** (3.18)	8.364** (2.15)
Price update		0.609*** (5.16)	0.604*** (4.31)		0.638*** (4.11)	0.561*** (6.78)		0.755*** (4.12)	0.895*** (4.93)
Age		-0.246 (-1.64)	-0.202 (-1.14)		-0.114 (-0.82)	-0.135 (-0.91)		-0.142 (-0.65)	-0.171 (-0.75)
Market risk premium			-1.184 (-0.19)			1.861 (0.58)			1.021 (0.05)
SMB			2.113 (0.26)			-6.254 (-0.66)			-5.355 (-0.89)
HML			-4.539 (-0.43)			-14.916 (-0.99)			-8.424 (-1.17)
Momentum			10.827 (1.12)			9.780 (0.83)			8.084 (0.77)
Illiquidity			-5.169 (-0.23)			-0.593 (-0.68)			-1.424 (-1.17)
Observation	50	50	50	50	50	50	50	50	50
Adjusted R^2	0.892	0.961	0.969	0.895	0.962	0.964	0.936	0.950	0.956

4.4. Pricing Uncertainty and Expected Initial Return: Evidence from Time-Series Portfolios

The cross-sectional portfolios are sorted on pricing volatility that depends on the divergence in the valuations of industry peers. With as many as approximately 100 IPOs being included in each portfolio, the sorting is unlikely to be seriously affected by issuer-specific characteristics. This feature of the portfolio data is important because issuer-specific factors, such as asymmetric information and strategic pricing—the main mechanisms examined by previous studies on IPO pricing—are often difficult to quantify or control empirically. On the other hand, however, the cross-sectional portfolios may still be subject to industry heterogeneity to the extent that new issues of different industries inherently have different degrees of valuation uncertainty. For this reason, we further the test by forming time-series portfolios. We sort IPOs by listing date and obtain monthly and quarterly portfolios, alternatively. To ensure a reasonable variability of IPO initial returns within each portfolio, we exclude calendar months that have fewer than 10 IPOs. These time-series formations result in 198 monthly portfolios and 73 quarterly portfolios. The last two plots in Figure 2 (D and E) illustrate the relationship between the initial return means and standard deviations for the time series portfolios, which is also strongly positive and stretches out from the origin.

Compared with the cross-sectional portfolios, the time-series portfolios have a further advantage: while cross-sectional variations in issuer-specific factors are substantially averaged out in each portfolio, intertemporal variations in pricing uncertainty associated with market-wide uncertainty are highlighted. Hence, unless the IPO dates are frequently clustered by industry, the time-series portfolios are ideal for the test because they are no longer associated with issuer-specific or industry-specific characteristics. To further minimize potential effects due to industry-clustered IPOs, we use a dummy variable to indicate portfolios that exhibit notable industry clustering. Specifically, the dummy variable equals one for a monthly or quarterly portfolio if any industry's IPOs in that portfolio account for 30% or more of all of the IPOs in the portfolio. Applying this threshold percentage to the 12 Fama–French industries, we identify that 33% of the time-series IPOs show industry clustering.

Table 5. Regressions with Time-series Portfolios of IPOs (Sample Period 1991–2008)

We form time-series portfolios by grouping IPO firms over months and quarters alternatively. In all of the regressions, the dependent variable is the portfolio equally weighted average of IPO initial returns (as the measure of the portfolio's expected pricing uncertainty premium), and the key independent variable is the portfolio standard deviation of the initial returns (as the measure of the portfolio's pricing uncertainty). The same control variables for IPO characteristics and secondary market factors as in Table 3 but in portfolio means are included. The industry cluster dummy is defined as follows: for each portfolio, we calculate the number of IPOs for each industry (based on the 12 Fama–French industry classification), and the dummy variable equals one if any of the industries in the portfolio conducted 30% or more of the total IPOs in that portfolio. Firm age is defined as the calendar year of the IPO minus the calendar year of the firm's founding. We obtain the founding date of each firm from Professor Jay Ritter's website. The signs ***, **, and * represent significance levels at 1%, 5%, and 10%, respectively.

	Portfolio mean of IPO initial return					
	(1)	(2)	(3)	(4)	(5)	(6)
	Monthly portfolios					
Intercept	0.223	-12.398**	-11.132**	-26.763***	-21.580***	-28.744**
	(0.26)	(-2.46)	(-2.29)	(-3.72)	(-3.09)	(-2.06)
Portfolio std dev of IPO initial returns	0.618***	0.482***	0.480***	0.547***	0.336***	0.455***
	(26.96)	(16.23)	(16.96)	(18.86)	(6.15)	(5.24)
log(Proceeds)		1.119	1.261	4.969***	4.847***	2.937*
		(1.28)	(1.49)	(2.89)	(2.92)	(1.92)
Underwriter rank dummy		3.093	2.112	0.438	0.700	0.439
		(1.08)	(0.76)	(0.14)	(0.23)	(0.16)
VC dummy		9.556**	9.695***	9.242**	9.443**	8.831***
		(2.64)	(2.65)	(2.30)	(2.45)	(2.79)
Tech dummy		8.509**	7.919**	9.419**	6.301	5.761*
		(2.16)	(2.10)	(2.37)	(1.63)	(1.83)
NASDAQ dummy		6.293*	5.021	5.545***	5.911***	5.600
		(1.69)	(1.42)	(2.66)	(3.14)	(1.47)
Bubble dummy		3.134	1.534	2.465	-4.747*	10.156***
		(1.11)	(0.55)	(0.91)	(-1.79)	(4.25)
Price update		0.253***	0.354***	0.194***	0.209***	0.529***
		(5.37)	(6.76)	(3.52)	(3.98)	(8.70)
Market risk premium			-0.164***	2.931*	3.174*	1.036
			(-2.81)	(1.73)	(1.95)	(0.76)
SMB			-0.345***	1.558	0.242	1.680
			(-3.42)	(0.64)	(0.10)	(0.86)
HML			0.157*	-0.979	-0.722	-0.186
			(1.85)	(-0.37)	(-0.28)	(-0.90)
Momentum			-0.350	1.300	1.359	1.867
			(-0.86)	(0.85)	(0.93)	(1.32)
Illiquidity			0.013*	0.133	0.157	0.138
			(1.71)	(0.87)	(1.07)	(1.04)
Year				-0.537	-0.587	-0.437
				(-1.15)	(-1.31)	(0.98)
Year × Year				0.002	0.008	0.001
				(0.10)	(0.36)	(0.07)
Industry cluster dummy					-9.791***	-8.051***
					(-4.48)	(-2.79)
Industry cluster dummy × Portfolio std dev of IPO initial returns					0.474***	0.360***
					(4.48)	(3.60)
Age						-0.595
						(-1.59)
Observation	198	198	198	198	198	
Adjusted R^2	0.785	0.838	0.863	0.867	0.880	
	Quarterly portfolios (N=73)					
Intercept	-1.01	-15.85**	-16.39**	-18.06***	-14.38***	
	(-0.90)	(-2.22)	(-2.22)	(-3.61)	(-3.05)	
Portfolio std dev of initial IPO return	0.63***	0.44***	0.44***	0.51***	0.36***	
	(19.61)	(8.93)	(8.81)	(9.73)	(7.09)	

Table 5 presents the regression results from the time-series portfolios, where the upper panel is for monthly portfolios and the lower panel is for quarterly portfolios (the coefficients on the portfolio standard deviation only).[8] The results are qualitatively the same as those from the cross-sectional portfolios in Table 4. Again, the portfolio standard deviation of IPO initial returns represents the dominant factor in all regressions and alone accounts for approximately 80% of the variation in the portfolio mean. To allow for a time trend and industry clustering effect, we include the year variable and its quadratic term in the regression in column 4, and also the industry clustering dummy and its interaction with the portfolio standard deviation in the regression in column 5. While all of the coefficients on the time trend variables are insignificant, those on the industry cluster dummy and the interaction term are statistically highly significant and economically large, indicating a strong industry clustering effect. Clearly, our main result of the coefficient on the portfolio standard deviation of IPO initial returns remains highly significant and is robust to the specification for the various controls. Because the time-varying pattern of the portfolios is unlikely to be driven by issuer- or industry-specific factors, we view these results from the time-series portfolios as stronger evidence than those from the cross-sectional portfolios.

The price update is the independent variable other than the portfolio standard deviation that has a significant impact in all regressions. On the one hand, this variable captures the widely discussed partial price adjustment mechanism (Benveniste and Spindt, 1989; Hanley, 1993) due to information asymmetry. On the other hand, this variable also reflects the imprecision of the filing price and, thus, the difficulty and uncertainty in the IPO valuation; therefore, it may partially capture the impact of pricing uncertainty.

4.5. Further Test and Robustness

Given the very high explanatory power of the IPO portfolio regressions, we need to further check that our results are not driven by some possible effects of extreme data but are robust to the sample period. We also need to check that the portfolio formation processes do not cause any unexpected mechanical relationships. It is easy to rule out data outliers. The plots in Figure 2 show the well-shaped distributions of the portfolio data, where the positive relationship between the portfolio mean and standard deviation of IPO initial returns are strong in all ranges, suggesting that our results are unlikely to be driven by outliers. We also examine the regressions using the portfolio median initial return as the dependent variable, controlling for the portfolio medians of the control variables. The untabulated results remain very strong and robust, and our findings are unchanged.

To check the robustness to the sample period, we redo the regressions in Tables 3 to 5 using IPOs conducted during the extended sample period from 2009 to 2015. Table 6 presents the summarized results for the extended sample tests, where Panels A, B, and C report the regressions with individual IPOs (as in Table 3), cross-sectional IPO portfolios (as in Table 4), and time-series IPO portfolios (as in Table 5), respectively. To save space, we do not report the

[8] To save space, the coefficients on the control variables are not reported in Panel B, which are highly consistent with those in Panel A.

parameter estimates for the various control variables, which are all included in the regressions. The results in this table are highly consistent with those reported in Tables 3−5. The coefficients on the pricing-volatility proxies and the portfolio standard deviations of IPO initial returns are all positive, statistically significant, and economically strong, verifying our findings discussed above. The adjusted R^2 is also very similar in magnitude to those for the corresponding regressions in Tables 3−5, still showing high explanatory powers of the models.

Table 6. Robustness Tests for the Extended Sample Period: 2009–2015

Our sample for the robustness tests in this table includes IPOs from 2009 to 2015. There are a total of 2471 IPOs during this period. All variable definitions are the same as those used in Tables 3, 4 and 5.

Panel A. Regressions using individual IPOs (specifications as in Table 3)			
	(Std dev of price/earnings ratio)	(Std dev of price/EBIT ratio)	(Std dev of price/sales ratio)
Proxy for pricing volatility	0.012**	0.119**	0.978**
	(2.28)	(2.17)	(2.04)
All controls	Yes	Yes	Yes
Observation	2471	2471	2471
Adjusted R^2	0.239	0.254	0.198
Panel B. Regressions using cross-sectional IPO portfolios (specifications as in Table 4)			
	(Sorted on std dev of price/earnings ratio)	(Sorted on std dev of price/EBIT ratio)	(Sorted on std dev of price/sales ratio)
Portfolio std dev of IPO initial returns	0.282***	0.301***	0.412***
	(3.15)	(4.11)	(8.44)
All controls	Yes	Yes	Yes
Observation	50	50	50
Adjusted R^2	0.799	0.851	0.860
Panel C. Regressions using time-series IPO portfolios (specifications as in Table 5)			
	(Monthly portfolios)	(Quarterly Portfolios)	
Portfolio std dev of IPO initial returns	0.412***	0.271***	
	(7.25)	(3.74)	
All controls	Yes	Yes	
Observation	72	24	
Adjusted R^2	0.607	0.426	

To examine whether our portfolio formation strategy creates any unexpected mechanical relationships in the portfolio data, we apply the same strategy to matching seasoned stocks and examine similar regressions using the portfolios of matching seasoned stocks. The logic is that if our results from the IPOs were due to some mechanical relationship caused by the empirical strategy, they should also show up in the regressions for the matching seasoned stocks. To identify matching stocks, for each IPO firm, we choose the seasoned firm that has been listed for at least three years and is in the same industry, in the same size decile, and with the closest book-to-market ratio. We then form seasoned stock portfolios in two dimensions: based on their matched IPOs' pricing volatility proxies and for the same months and quarters. For each of these portfolios, we calculate the mean and standard deviation of the seasoned stock daily returns on the day of the IPO. We then run regressions of the portfolio mean on the portfolio standard deviation of seasoned stock returns, controlling for the secondary market factor variables and the portfolio return skewness.

Table 7 presents the regression results, with Panel A presenting results for the cross-sectional portfolios and Panel B for the time-series portfolios. In all eight regressions, the coefficient on the portfolio standard deviation of matching seasoned stock returns is statistically insignificant, and the sign is mixed. In contrast to the results from the IPO portfolio data, these regressions for the seasoned stock counterparts show no association between the portfolio mean and standard deviation. This observation is echoed by the very low explanatory power of the standard deviation measure of matching seasoned stocks that, together with the constant term, explains less than 3% of the variation in the portfolio mean. This finding is expected. As much of the seasoned stock volatility is diversified away, it has no meaningful predictive power for the mean return. Therefore, we can rule out the possibility that our finding is due to some unknown mechanical relationship caused by the empirical strategy between the portfolio mean and standard deviation.

Table 7. Regressions with Portfolios of Matching Seasoned Stocks

This table presents regressions with portfolios of matching seasoned stocks. To determine each IPO's matching stock, we choose the seasoned firm that has listed for at least three years, and is in the same industry, in the same size decile and with the closest book-to-market ratio as the issuer. We form portfolios of the matching stocks in similar ways as those of the IPOs: on IPO pricing volatility ranking (as in Table 4) and on listing date (as in Table 5). For each portfolio, we compute the equally weighted average and the standard deviation of the matching stocks' return on the IPO day. In all regressions, the dependent variable is the portfolio mean, and the key independent variable the portfolio standard deviation, of the matching stock returns. The same control variables for secondary market factors as in Tables 4 and 5 are included. Pskewness is the skewness of each portfolio. The signs ***, **, and * represent significant levels at 1%, 5%, and 10%, respectively.

	Cross-sectional portfolios formed on the standard deviation of industry peers' price multiples						Time-series portfolios formed on matched IPO date			
	(Price/earnings ratio)		(Price/EBIT ratio)		(Price/sales ratio)		(Monthly portfolios)		(Quarterly portfolios)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	-0.358 (-0.90)	-0.109 (-0.45)	-0.642 (-1.52)	-0.278 (-0.49)	-0.489 (-1.32)	-0.234 (-0.76)	-0.096 (-0.60)	0.023 (0.18)	0.132 (0.64)	0.052 (0.29)
Portfolio std dev of seasoned return	0.116 (0.95)	0.045 (0.70)	0.214 (1.62)	0.510 (0.86)	0.167 (1.48)	0.053 (0.50)	0.052 (0.98)	0.008 (0.19)	-0.017 (-0.27)	-0.001 (-0.02)
Market risk premium		2.170* (2.04)		1.589** (2.01)		2.876*** (3.57)		1.183*** (7.51)		0.778*** (3.22)
SMB		1.708 (1.35)		1.267 (0.98)		2.201** (2.01)		0.829*** (3.02)		1.326*** (2.75)
HML		3.901** (2.51)		1.875* (1.72)		0.543 (0.32)		0.916** (2.39)		1.080 (1.49)
Momentum		1.092* (1.74)		1.001 (1.06)		0.401 (0.67)		0.543 (1.20)		-0.360 (-0.45)
Illiquidity		2.543*** (2.89)		2.789*** (2.65)		2.071** (2.01)		0.167 (0.56)		0.510 (0.95)
Pskewness		2.514*** (2.99)		1.578** (2.57)		2.076*** (2.66)		0.239*** (5.22)		0.171*** (3.74)
Observation	50	50	50	50	50	50	198	198	73	73
Adjusted R^2	0.018	0.355	0.031	0.279	0.023	0.550	0.002	0.366	0.001	0.349

5. CONCLUSION

Given a lack of current or historical stock prices, all participants in an IPO must evaluate the new issue without any equilibrium price information as an anchor point for the fair value. This lack-of-information problem affects not only uninformed individual investors but also the most informed institutional investors and underwriters. As a result, no matter how sophisticated the premarket valuation is, it depends on divergent premarket beliefs and, thus, can significantly deviate from the IPO's fair value. This problem presents a source of uncertainty in IPO pricing that is difficult to diversify. With risk-averse investors who maximize their expected utility, the premarket demand is reduced relative to the case when investors could observe the current market price. Consequently, underpricing occurs as the reduced demand imposes a binding constraint on the sale of the new issue. In this sense, underpricing works as a premium to investors for bearing the uncertainty.

The concept of premarket pricing uncertainty highlights the unpredictability of the offer price. When an IPO's offer price is a random draw from the new issue population subject to pricing error, it can vary greatly depending on investor beliefs and market sentiment. Therefore, the initial return volatility can be considerably higher than the aftermarket price volatility due to the fundamental risk and higher than any expected variation in planned or intentional underpricing. This implication is consistent with the finding in Lowry et al. (2010) that IPO initial returns are unusually volatile, reflecting the phenomenon that a large fraction of overpriced or severely underpriced IPOs are difficult to explain by any intentional underpricing mechanisms.

The notion of underpricing as a premium for premarket pricing uncertainty implies a direct relationship between the expected level and volatility of underpricing. We test this implication by forming IPO portfolios based on the uncertainty ranking or listing date of new issues. We identify an unusually close relationship between the level and dispersion of the initial returns. This relationship is so strong that, for the portfolio data, the dispersion alone explains approximately 90% of the variation in the level.

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