

IPO underpricing and after-market liquidity

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Abstract

The underpricing of the shares sold through Initial Public Offerings (IPOs) is generally explained with asymmetric information and risk. We complement these traditional explanations with a new theory. Investors who buy IPO shares are also concerned by expected liquidity and by the uncertainty about its level when shares start trading on the after-market. The less liquid shares are expected to be and the less predictable their liquidity, the larger will be the required underpricing. We present a model that integrates such liquidity concerns within a traditional framework with adverse selection and risk. The model's predictions are supported by evidence from a sample of 337 British IPOs effected between 1998 and 2000. Using various proxies for liquidity, we find that expected after-market liquidity and liquidity risk are important determinants of IPO underpricing.

Keywords: liquidity, initial public offering, post-IPO market, after-market trading.

JEL classification: G1, G2, G3.

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1. Introduction

The underpricing of the shares sold through Initial Public Offerings (IPOs) is generally explained in the literature with asymmetric information about the security's value and with its fundamental risk. For the IPO to attract sufficient interest, the issuer must leave enough "money on the table" to compensate investors for the uncertainty about the security's value.¹ However, until now the literature has largely disregarded how after-market liquidity may impact on the IPO underpricing. This is a striking omission in view of the established evidence that the returns of seasoned securities include a liquidity premium. One would expect such premium to be paid also by stocks in the process of being floated. Moreover, at the IPO stage investors do not know precisely how liquid the after-market will be. This suggests that they will not only care about expected liquidity but also about the uncertainty about it, that is, about liquidity risk.

Our paper fills this gap. It complements traditional explanations with theory and evidence showing that after-market liquidity is an important determinant of IPO underpricing. We provide a simple model showing that an IPO that is expected to be more illiquid and to have higher liquidity risk should feature higher underpricing. The model nests this prediction with those of more traditional models. We then test for the presence of these liquidity effects on IPO underpricing, controlling for the variables suggested by other theories of IPOs. Our sample includes data for all the companies that went public on the London Stock Exchange (LSE) between June 1998 and December 2000. In line with our model and previous market microstructure studies, the main

¹ A large empirical literature documents that unseasoned common stocks sold when a company goes public yield positive abnormal returns in the very first few days of trading (after-market), starting from the study conducted by the U.S. Securities and Exchange Commission in 1963 and subsequently by Logue (1973) and Ibbotson (1975). Although much work focuses on U.S. evidence, IPO underpricing is observed in many countries, to different extents (see Loughran, Ritter and Rydqvist, 1994). For example, it is 4.2 percent in France (187 IPOs carried out in 1983-92), 11.1 percent in Germany (172 IPOs carried out in 1978-92), 27.1 percent in Italy (75 IPOs carried out in 1985-91), and 12 percent in the U.K. (2133 IPOs carried out in 1959-92). It also varies significantly over time, with the so-called "hot issue" and "cold issue" periods producing widely different abnormal returns (see Ibbotson and Jaffe, 1975).

measure of liquidity we employ is the after-market's bid-ask spread, though we also consider other liquidity measures. Our main empirical challenge is to devise appropriate measures of the market's estimate of after-market liquidity and of its variability, conditional on information known at the time of the IPO. We use various methodologies to tackle this issue.

Using IPOs on the LSE between June 1998 and December 2000 we find that expected after-market liquidity and liquidity risk are important determinants of IPO underpricing. Consistent with our hypotheses, we find that the lower the expected liquidity and the higher liquidity risk the higher is the IPO underpricing. The liquidity impacts are found to be robust to (a) the inclusion of the other factors that have traditionally been used to explain IPO underpricing (variables that capture the issues of asymmetric information and fundamental risk), and (b) use of alternative econometric methodologies.

To put our contribution in perspective, it is worthwhile setting it against the background of the two main explanations proposed in the literature to account for IPO underpricing: asymmetric information and fundamental risk.

Many models explain IPO underpricing with some form of information asymmetry about the true value of the IPO shares. In Baron (1982), underpricing follows from the fact that the issuer knows more about the true value of the company than the investment bank entrusted with the sale. In Rock (1986) the information asymmetry is among potential IPO investors: some are "informed" and others "uninformed", generating a winners' curse problem. The only way to keep uninformed investors in the IPO market is to offer the shares at a discount relative to the after-market price. A by-product of the informational asymmetry is that investors may bid for IPO shares relying also on other buyers' behavior, leading to an informational cascade. This happens in the model by Welch (1992), where issuers underprice IPO shares to induce the first potential investors to participate in the IPO, and thus attract other investors.

A complementary explanation for underpricing turns on underwriters' risk aversion. According to this view, investment bankers underprice unseasoned equity to reduce their exposure risk and the implied underwriting costs. Ritter (1984) conjectures that large

investment banks will even avoid underwriting small IPOs of speculative, start-up firms, so as to keep their reputation.

Little attention has been instead devoted to the link between secondary market liquidity and IPO underpricing. The only exception is the study by Booth and Chua (1996), who suggest that IPO underpricing aims to elicit the interest of a target number of potential investors. They assume that expanding the number of dispersed investors raises the valuation of the firm, by creating liquidity in the after-market, but requires drawing into the market investors with higher information collection costs. The optimal price will weigh the liquidity benefit of added investor participation with its cost. Our paper is based on a similar logic, but turns Booth and Chua's argument on its head. To the extent that different IPO shares are expected to feature different degrees of after-market liquidity, also the IPO underpricing required to induce uninformed investors to bid for the shares will differ. In addition, we highlight that also liquidity risk should affect IPO underpricing, because at the IPO stage investors do not know precisely the liquidity of the shares they are bidding for.

The relationship between returns and liquidity has been formerly modeled and tested with reference to seasoned securities. Many studies – both theoretical and empirical – have argued that illiquid securities must provide investors with a higher expected return to compensate them for the larger trading costs they have to bear. The first paper offering both a formal statement and an empirical test of this relationship is Amihud and Mendelson (1986). Their model predicts that expected returns are an increasing concave function of the bid-ask spread, the concavity resulting from the fact that for high trading costs investors lengthen their holding horizon and thus require a smaller compensation for illiquidity. Their evidence for the period 1961-80 is consistent with this hypothesis. Other studies find a significant cross-sectional association between liquidity (as measured by the tightness of the bid-ask spread or trading volume) and asset returns, controlling for risk: among these, Brennan and Subrahmanyam (1996), Chordia, Roll and Subrahmanyam (2000), Datar, Naik and Radcliffe (1998), Eleswarapu (1997), and

Eleswarapu and Reinganum (1993). However, Chordia, Subrahmanyam and Anshuman (2001) find a negative relationship between returns and trading volume.²

Our paper can be seen as extending the insight from this literature to the primary equity market. If seasoned securities provide a liquidity premium in their returns, it is reasonable to expect also stocks on the primary market to provide such premium to investors. The very nature of the primary market, however, requires the argument to be given a special twist: at the IPO stage investors do not know yet how liquid the after-market will be, and therefore will want to be compensated also for liquidity risk.

The paper is organized as follows. Section 2 presents a model nesting the impact of liquidity on IPO underpricing with the more traditional theories, and providing the basis for our empirical tests. Section 3 reviews the data. Section 4 presents the empirical methodology and the results. Section 5 concludes.

2. The Model

In this section, we develop a simple theoretical model to explain the relationship between after-market liquidity and IPO underpricing and derive the hypotheses to be tested. In this model there are three stages: at $t = 0$, the IPO occurs; at $t = 1$, the company's shares are traded on the after-market, and at $t = 2$ the shares are liquidated (or

² Similar findings are reported by several studies of fixed-income securities. Amihud and Mendelson (1991) show that the yield to maturity of treasury notes with six months or less to maturity exceeds the yield to maturity on the more liquid treasury bills. Other studies on U.S. public debt securities by Warga (1991), Daves and Ehrhardt (1993), Kamara (1994) and Krishnamurthy (2000) confirm these findings. However, using more recent data Strebulaev (2001) finds that the yield spread between bills and matched notes is much smaller than previously found, especially when bills are on-the-run. Some studies apply the same basic idea, by comparing securities with identical cash flows but different trading opportunities. Silber (1991) compares stocks with different trading restrictions. Eldor and Hauser (2001) analyze non-traded Israeli options. Dimson and Hanke (2001) examine equity-linked bonds with the same cash flows as an investment in an equity index. They find that these securities sell at a discount relative to their underlying value – a mispricing that can be attributed to the illiquidity of the bonds.

can be traded) at their fundamental value. The time line in Figure 1 illustrates these three stages, as well as the information and actions of market participants in each stage.

The model captures the presence and interaction of two distinct adverse selection problems: those that affect the primary market (as in the classic Rock's model of IPO underpricing) and those that determine secondary market liquidity (as in the equally classic model by Kyle). In the model's baseline version, developed assuming risk neutrality, IPO underpricing is determined not only by adverse selection in the IPO process, but also by the magnitude of the spread in the after-market. When uninformed investors are assumed to be risk-averse, IPO underpricing is also affected by fundamental risk, by its interaction with adverse selection in the IPO and with the after-market spread, and by a quadratic term in the bid-ask spread. Finally, we extend the model to encompass also liquidity risk, assuming that at the IPO stage investors do not know the precise level of the after-market bid-ask spread. In this extended version, IPO underpricing is also an increasing function of liquidity risk: investors require compensation not only for the expected level of trading costs in the after-market, but also for their variability.

Before turning to the model, it is worth stressing that its ideas are more general than the specific modeling strategy chosen to render them. For instance, the results would be qualitatively unchanged if the bid-ask spread in after-market trading resulted from the inventory costs of risk averse dealers or from their order processing costs. The result that IPO underpricing must include a reward for the expected liquidity costs and the corresponding risk borne by investors would still stand. It does not depend on the specifics of the market microstructure, but simply on the recognition that the after-market may be less than perfectly liquid, and its liquidity may be not perfectly known ex ante.

2.1 Information Structure

The company's fundamental value is $\tilde{V} = V + \tilde{u}_1 + \tilde{u}_2$, where V is a positive constant and \tilde{u}_1 and \tilde{u}_2 are independently distributed random variables that represent "news" publicly disclosed at stages 1 and 2 respectively. The variable \tilde{u}_1 equals $-\eta$ or η with probability 1/2 each: if $\tilde{u}_1 = \eta$ the company is disclosed to be of high quality in after-

market trading, while if $\tilde{u}_1 = -\eta$ the company is revealed to be of low quality. Similarly, \tilde{u}_2 equals $-\varepsilon$ or ε with probability $1/2$, implying that in after-market trading there is still some residual uncertainty about the final value of the company. Therefore, the expected value of a share based only on public information is V at $t = 0$, $V + \tilde{u}_1$ at $t = 1$, and $V + \tilde{u}_1 + \tilde{u}_2$ at $t = 2$.

Some investors base their actions not only on public but also on private information, at the IPO stage as well as in after-market trading. At $t = 0$, the investors who can buy the company's shares are of two types: while M of them are uninformed, N have advance knowledge of the realized value of \tilde{u}_1 , that is, know the company's quality. Similarly, at $t = 1$, with probability Q a trader has advance information about the realized value of \tilde{u}_2 , that is, knows the company's final value and places his orders based on such information.

2.2 Primary and Secondary Market Structure

The primary market is modeled as in Rock's model. The company sells S shares in the IPO, and chooses the highest offer price P_0 consistent with selling them. If possible, the S shares are sold by filling all the bids made at the preset price P_0 ; otherwise, they are allocated via a lottery that gives the same probability of receiving one share to each bidder. The uninformed investors are wealth constrained: each of them can buy at most one share with his initial wealth and the credit he can obtain, at the equilibrium price P_0 (which is to be determined). Investors cannot buy fractional values of a share in the IPO.

Uninformed investors are sufficiently numerous that they can buy all the shares on sale if they all bid ($M > S$), while informed investors cannot, if they bid for one share each ($S > N$). Since informed investors must bid for one unit each to avoid giving themselves away, the IPO price must be chosen so as to attract also bids from uninformed investors.

The secondary market that opens at $t = 1$ is a dealer market. Apart from its analytical convenience, this assumption is attuned to our data, which refer to a dealer market. Dealers are assumed to be risk neutral and perfectly competitive. Each order is to be

filled at the quoted price for one unit: at the time of accepting a trade, dealers do not know whether another buy or sell order has also arrived on the market. Hence the ask price at which they are willing to offer one unit is the expected value of the security, given a buy order by a trader of unknown identity. Symmetrically, the bid price is the expected value of the security, given a sell order by a trader of unknown identity.

2.3 Investors' Preferences and Liquidity Needs

We assume all investors to be risk-neutral – an assumption that we shall relax later. In addition, all investors have potential liquidity needs: anyone who buys shares at $t = 0$ has to liquidate them with probability z at $t = 1$, and therefore holds them until $t = 2$ only with probability $1 - z$. For notational simplicity (and with no loss of generality), we standardize the number of dealers active at $t = 1$ to S , that is the number of investors purchasing shares at the IPO. As a result, z is also the probability with which a dealer will receive a liquidity-motivated sell order in the after-market. At $t = 1$ each dealer receives also orders from liquidity-motivated buyers with probability x . We do not model the process that generates these buy orders, but this is not relevant for our results about IPO underpricing, since these are affected only by the sell side of after-market. (In fact, IPO underpricing would be unaffected even if dealers were to receive only sell orders in the after-market.)

To decide whether bidding for a share in the IPO, each investor will consider if the expected value of the share to him, conditional on the information that he has, exceeds the IPO offer price P_0 . To compute this expected value, the investor will consider that with probability z he will have to liquidate his shareholdings at the bid price \tilde{P}_1 that the dealer will post at $t = 1$. With probability $1 - z$, instead, he will be able to hold them until $t = 2$ and then sell them at the price \tilde{P}_2 . Investor j , where $j = \{i, u\}$ indexes informed and uninformed investors respectively, will bid price P_0 for a share in the IPO if:

$$zE(\tilde{P}_1^B | \Omega_0^j) + (1 - z)E(\tilde{P}_2 | \Omega_0^j) \geq P_0, \quad (1)$$

\tilde{P}_1^B being the price at which the investor can resell the share at $t = 1$ (the dealer's bid price) and Ω_0^j the investor's information set at $t = 0$, so that $\Omega_0^i = \{\Omega_0^u, \tilde{u}_1\}$. In computing the expectations in (1), uninformed investors have to take into account the probabilities that by bidding P_0 they get high or low quality shares. We shall denote these probabilities by π_u and $1 - \pi_u$ respectively.

2.4 Market Equilibrium with Risk-Neutral Investors

The equilibrium is found by backward induction. Since at $t = 2$ all information is public, the final price of a share equals its fundamental value: $\tilde{P}_2 = \tilde{V}$.

At $t = 1$, the quality of the company sold at the IPO is public knowledge: \tilde{u}_1 is known by all investors. However, some uncertainty remains for dealers and most investors, \tilde{u}_2 being known at most to an insider. The insider observes \tilde{u}_2 with probability Q , and thus sees $\tilde{u}_2 = \varepsilon$ or $\tilde{u}_2 = -\varepsilon$ with probability $Q/2 \equiv q$ each. To maximize the expected gain from his trades, the insider will place a buy order if $E(\tilde{V}|\tilde{u}_2) - P_1^A = \tilde{V} - P_1^A > 0$ and a sell order if $E(\tilde{V}|\tilde{u}_2) - P_1^B = \tilde{V} - P_1^B < 0$. To avoid revealing his identity, the insider's order size will be equal to that of liquidity traders' orders.

Recalling that at $t = 0$ each investor bid for one share, liquidity traders will sell a unit at $t = 1$, and therefore also the insider will sell at most one unit if $\tilde{V} - P_1^B < 0$. Since a liquidity trader sells a unit with probability z , the conditional probability that a sell order comes from the liquidity trader is $z/(q+z)$ and the conditional probability that it comes from the informed trader is $q/(q+z)$. The bid price set by the competitive dealers is the conditional expectation of the share's value:

$$\tilde{P}_1^B = E(\tilde{V}|\tilde{u}_1) = \frac{q}{q+z}(V + \tilde{u}_1 - \varepsilon) + \frac{z}{q+z}(V + \tilde{u}_1) = V + \tilde{u}_1 - \frac{q}{q+z}\varepsilon. \quad (2)$$

Similarly, recalling that a liquidity trader buys a unit with probability x , the ask price is:

$$\tilde{P}_1^A = E(\tilde{V}|\tilde{u}_1) = \frac{q}{q+x}(V + \tilde{u}_1 + \varepsilon) + \frac{x}{q+x}(V + \tilde{u}_1) = V + \tilde{u}_1 + \frac{q}{q+x}\varepsilon. \quad (3)$$

The bid-ask spread therefore is:

$$S \equiv \tilde{P}_1^A - \tilde{P}_1^B = \underbrace{\frac{q}{q+x}\varepsilon}_{S_A} + \underbrace{\frac{q}{q+z}\varepsilon}_{S_B}, \quad (4)$$

The terms S_A and S_B are the spread's bid-side and ask-side portion respectively, that is, the trading costs that an uninformed buyer or seller pays relative to his estimate $V + \tilde{u}_1$ of the share value. The spread S increases in the probability of the insider's buy or sell orders (q) and decreases in that of liquidity buy (x) and sell orders (z). Notice that the spread's bid-side portion S_B increases in q and decreasing in z , but is unaffected by x : the liquidity faced by a seller is unaffected by the assumed behavior of liquidity buyers.

Now let us turn to the equilibrium at $t = 0$. From equation (1), we know that investors informed about \tilde{u}_1 bid for shares at the IPO only if

$$zE(\tilde{P}_1^B|\Omega_0^i) + (1-z)E(\tilde{P}_2^B|\Omega_0^i) \geq P_0. \quad (5)$$

So these investors will condition their bids on their private information \tilde{u}_1 only if

$$zE(\tilde{P}_1^B|\tilde{u}_1 = \eta) + (1-z)E(\tilde{P}_2^B|\tilde{u}_1 = \eta) \geq P_0 > zE(\tilde{P}_1^B|\tilde{u}_1 = -\eta) + (1-z)E(\tilde{P}_2^B|\tilde{u}_1 = -\eta),$$

which, using (2) and recalling that $\tilde{P}_2^B = V + \tilde{u}_1 + \tilde{u}_2$, can be rewritten as

$$V + \eta - z\frac{q}{q+z}\varepsilon \geq P_0 > V - \eta - z\frac{q}{q+z}\varepsilon. \quad (6)$$

Condition (6), which will be shown to hold in equilibrium, ensures that the informed traders' optimal strategy is to bid only if the company is of good quality ($\tilde{u}_1 = \eta$). Otherwise, they would always bid or never bid irrespective of their private information.

As for uninformed investors, from equation (1) they will bid if

$$zE(\tilde{P}_1^B | \Omega_0^u) + (1-z)E(\tilde{P}_2 | \Omega_0^u) \geq P_0, \quad (7)$$

where, as explained before, expectations are computed using the firm's quality probability distribution conditional on the uninformed bid's success. If π_u denotes the probability that an uninformed investor bidding P_0 gets shares of a high-quality company ($\tilde{u}_1 = \eta$) and $1 - \pi_u$ the probability that he will get shares of a low-quality company ($\tilde{u}_1 = -\eta$), the prices that this investor expects to face in the two subsequent periods are:

$$\begin{aligned} E(\tilde{P}_1^B | \Omega_0^u, P_0) &= \pi_u \left(V + \eta - \frac{q}{q+z} \varepsilon \right) + (1 - \pi_u) \left(V - \eta - \frac{q}{q+z} \varepsilon \right) = \\ &= V - \frac{q}{q+z} \varepsilon - (1 - 2\pi_u)\eta \end{aligned} \quad (8)$$

and

$$E(\tilde{P}_2 | \Omega_0^u, P_0) = \pi_u(V + \eta) + (1 - \pi_u)(V - \eta) = V - (1 - 2\pi_u)\eta. \quad (9)$$

From the last three equations, the condition ensuring that uninformed investors participate in the IPO can be rewritten as:

$$V - (1 - 2\pi_u)\eta - z \frac{q}{q+z} \varepsilon \geq P_0. \quad (10)$$

The company will set the offer price at the highest level consistent with participation by the uninformed investors in the IPO, that is, will choose P_0 so that condition (10) holds with equality. This implies also that condition (6) concerning informed investors is satisfied. Therefore, if the company is of high quality, both types of investors bid, and uninformed investors get shares with probability $\lambda = M / (M + N)$. If the company is of

low quality, only uninformed investors bid, and get shares with probability 1. Since the unconditional probability of the firm being of high quality is $1/2$, the probability that the company is of high quality conditional on uninformed investors being allocated shares is:

$$\pi_u = \frac{\lambda/2}{\lambda/2 + 1/2} = \frac{\lambda}{1 + \lambda}. \quad (11)$$

Using this result in condition (10) taken with equality, we get the equilibrium offer price:

$$P_0 = V - \frac{1 - \lambda}{1 + \lambda} \eta - z \frac{q}{q + z} \varepsilon = V - \frac{1 - \lambda}{1 + \lambda} \eta - z S_B, \quad (12)$$

where in the second step we used the fact that the spread's bid-side portion $S_B = \frac{q}{q + z} \varepsilon$.

This immediately yields the following expression for average IPO underpricing:

$$E(\tilde{P}_1) - P_0 = \frac{1 - \lambda}{1 + \lambda} \eta + z S_B, \quad (13)$$

where $E(\tilde{P}_1)$ is the average transaction price in the after-market.³ Notice that, as percentage of the offer price, IPO underpricing is a convex function of expression (13). Denoting the latter by A , it is easy to see that (one plus) percentage underpricing is:

$$\frac{E(\tilde{P}_1)}{P_0} = \frac{V}{V - A}, \quad (13')$$

Equation (13) has a simple interpretation. In equilibrium, IPO underpricing compensates uninformed investors not only for the adverse selection costs borne at the

³ To obtain (13), we have used the fact that $E(\tilde{P}_1) = V$. To see this, notice that in computing $E(\tilde{P}_1)$ each of the prices quoted by the dealer is weighted by the frequencies of the corresponding orders. The dealer receives a buy order with probability $(q + x)/(2q + x + z)$, so that the transaction price is the bid price \tilde{P}_1^B in (2). He receives a sell order with probability $(q + z)/(2q + x + z)$, so that the transaction price is the ask price \tilde{P}_1^A in (3). As a result, the average transaction price conditional on a given realization of \tilde{u}_1 is $E(\tilde{P}_1 | \tilde{u}_1) = V + \tilde{u}_1$. Since the expected value of \tilde{u}_1 is zero, the unconditional average of the after-market price $E(\tilde{P}_1) = V$.

IPO stage (the first term) but also for the expected trading costs that they will bear by liquidating their shares in the after-market (the second term). As in Rock's model, the adverse selection cost at the IPO stage is decreasing in the fraction of informed investors, λ , and increasing in the standard deviation of the signal they observe, η , which measures their informational advantage. The expected trading costs are increasing both in the probability of reselling shares in the after-market, z , and in the bid-side portion of the spread, S^B , which in this model reflects the severity of the adverse selection problem in secondary market trading. However, the after-market bid-ask spread would contribute to IPO underpricing exactly as does in equation (13) even if it were to result from causes *other* than adverse selection, such as for instance order-processing costs. The idea captured by this equation is more general than the model presented so far suggests.

Even remaining within the framework of the present model, however, it is possible to generalize it to include the case of risk-averse investors, allowing for IPO underpricing to be affected by risk. This case is developed in the next subsection.

2.5 Market Equilibrium with Risk-Averse Investors

Suppose that the investors with no private information at the IPO maximize expected utility $E[U(\tilde{W})]$, where $U(\cdot)$ is concave and twice differentiable in final wealth W . For simplicity, other market participants and dealers are still assumed risk-neutral. Thus, only the condition for the participation of uninformed investors now changes from (7) into:

$$zE\left[U(\tilde{P}_1^B)\middle|\Omega_0^u\right] + (1-z)E\left[U(\tilde{P}_2)\middle|\Omega_0^u\right] \geq P_0, \quad (14)$$

where, as before, expectations are computed using the probability distribution of the firm's quality conditional on the uninformed bid's success.

As in the previous section, in equilibrium the offer price makes uninformed investors just indifferent between bidding and not bidding for the company's shares: it is the value

of P_0 that makes condition (14) hold with equality. As shown in the appendix through steps similar to those used in the previous section, the equilibrium offer price P_0 solves:

$$U(P_0) = U(V) - U'(V) \left(\frac{1-\lambda}{1+\lambda} \eta + zS_B \right) + \frac{U''(V)}{2} \left[\eta^2 + (1-z)\varepsilon^2 + z \left(S_B^2 + 2 \frac{1-\lambda}{1+\lambda} \eta S_B \right) \right].$$

Given the properties of $U(\cdot)$, one can write $U(V) - U(P_0) = f(V - P_0)$ where $f(\cdot)$ is an increasing and concave function. Using this fact and recalling that $E(\tilde{P}_1) = V$, IPO underpricing can be written as $E(\tilde{P}_1) - P_0 = h(U(E(\tilde{P}_1)) - U(P_0))$, where $h(\cdot) = f^{-1}(\cdot)$, which is an increasing and convex function. Using this result in the last equation yields the following expression for average IPO underpricing:

$$E(\tilde{P}_1) - P_0 = h \left\{ \alpha \left(\frac{1-\lambda}{1+\lambda} \eta + zS_B \right) + \frac{\alpha\rho}{2} \left[\eta^2 + (1-z)\varepsilon^2 + z \left(S_B^2 + 2 \frac{1-\lambda}{1+\lambda} \eta S_B \right) \right] \right\}, \quad (15)$$

where $\alpha \equiv U'(V)$ and ρ is the coefficient of absolute risk aversion.

Expression (15) nests various sub-cases:

- (i) As expected, it reduces to equation (13) in the case of risk neutrality (where $V - P_0 = (1/\alpha)[U(V) - U(P_0)]$ and $\rho = 0$).
- (ii) The equation yields a purely risk-based model of IPO underpricing if investors are risk-averse ($\rho > 0$) but adverse selection problems are absent both at the IPO stage ($\lambda = 1$) and in the after-market ($q = 0$, implying $S_B = 0$). In this case, underpricing is $E(\tilde{P}_1) - P_0 = h \left\{ (\alpha\rho/2)[\eta^2 + (1-z)\varepsilon^2] \right\}$, that is, it compensates investors only for fundamental risk (the variance of fundamentals decreases in z , because investors do not bear the risk deriving from the shock \tilde{u}_2 if they liquidate at $t = 1$).
- (iii) With adverse selection at the IPO stage ($\lambda < 1$), but not in the after-market ($S_B = 0$), we have the additional term $\alpha[(1-\lambda)/(1+\lambda)]\eta$. Instead, the risk-premium component (the term in square brackets multiplied by ρ) stays unchanged. This

shows that in the context of a Rock-style model there is no interaction between the adverse selection and the risk premium components of IPO underpricing.

- (iv) If there is also adverse selection in the after-market, i.e. with a positive bid-ask spread ($S_B > 0$), underpricing is higher for three reasons. First, as in the risk-neutrality case, there is the direct disutility due to the expected trading cost ($\alpha z S_B$). Second, the bid-ask spread increases the risk to be borne by the investor ($\alpha \rho z S_B^2 / 2$): the interaction between informed traders and dealers impounds advance information about \tilde{u}_2 in the after-market price, and thereby increases the risk borne in case of early liquidation of the shares. The illiquidity of the after-market exacerbates risk, and increases the risk premium component of IPO underpricing. Thirdly, equation (15) shows that underpricing also includes an interaction term between risk, adverse selection at the IPO stage, and after-market illiquidity ($\alpha \rho z [(1 - \lambda) / (1 + \lambda)] \eta S_B^2$).

Since IPO underpricing is generally expressed as a percent of the offer price, it is worth noting that, if equation (15) is rewritten as $E(\tilde{P}_1) - P_0 = h(\alpha A)$, also the percentage IPO underpricing is an increasing and convex function of A :

$$\frac{E(\tilde{P}_1)}{P_0} = \frac{V}{V - h(\alpha A)}. \quad (15')$$

For instance, if utility is logarithmic, then $E(P_1) / P_0 = \exp(A / V)$. And for power utility functions $U(x) = x^\gamma$, with $\gamma \leq 1$, then $E(\tilde{P}_1) / P_0 = [V / (V - \gamma A)]^{1/\gamma}$, which reduces to expression (13') for the risk-neutral case ($\gamma = 1$).

2.6 Market Equilibrium with Uncertain Liquidity

So far, investors were assumed to anticipate perfectly the degree of secondary market liquidity, as summarized by the bid-ask spread S_B . But this may not be a reasonable

assumption for shares that are not traded yet: when the offer price is set, investors may not know how liquid the secondary market will be.

The uncertainty about liquidity can be captured in the model by assuming that there can be two liquidity regimes, characterized by a different incidence of insider trading and therefore by a different bid-ask spread. More precisely, let the fraction of insider traders be a random variable \tilde{q} that takes a low value q_L or a high value q_H with equal probability. Accordingly, the (bid-side portion of the) spread becomes itself a random variable:

$$\tilde{S} = \frac{\tilde{q}}{\tilde{q} + z} \varepsilon \quad (16)$$

The distribution of \tilde{q} (and therefore that of \tilde{S}) is independent of those of \tilde{u}_1 and \tilde{u}_2 . With this change to the model, there are four possible states on the after-market, depending on the quality of the company (high or low: $\tilde{u}_1 = \eta$ or $\tilde{u}_1 = -\eta$) and on the liquidity regime (high or low: $\tilde{q} = q_L$ or $\tilde{q} = q_H$), with probability 1/4 each.

As in the previous section, the equilibrium offer price is the value of P_0 that makes the uninformed investors' participation constraint (14) hold with equality. As shown in the appendix through steps similar to those of the previous section, in equilibrium the average level of IPO underpricing in this expanded model is:

$$E(\tilde{P}_1) - P_0 = h \left\{ \alpha \left(\frac{1-\lambda}{1+\lambda} \eta + zE(\tilde{S}_B) \right) + \frac{\alpha\rho}{2} \left[\eta^2 + (1-z)\varepsilon^2 \right] + \frac{\alpha\rho}{2} z \left[Var(\tilde{S}_B) + [E(\tilde{S}_B)]^2 + 2 \frac{1-\lambda}{1+\lambda} \eta E(\tilde{S}_B) \right] \right\}. \quad (17)$$

This expression differs from its analogue (15) obtained under perfect foresight about liquidity only in two respects. The bid-ask spread S_B is replaced by its expected value $E(\tilde{S}_B)$, and its square S_B^2 by $E(\tilde{S}_B^2) = Var(\tilde{S}_B) + [E(\tilde{S}_B)]^2$. We recover expression (15) as a special case of (16) for $q_H = q_L = q$, where the spread is non-stochastic ($\tilde{S}_B = S_B$).

Therefore, the extended model with uncertain liquidity predicts that IPO underpricing is an increasing function of the expected bid-ask spread $E(\tilde{S}_B)$ and of its variance $Var(\tilde{S}_B)$. The model nests this prediction with those of models based on adverse selection in the IPO – the first term in (17) – and those of models based on fundamental risk – the terms in square brackets in the first line of (17). In keeping with this feature of the model, therefore, our tests for the presence of liquidity effect on underpricing will control for variables designed to capture adverse selection and risk, along the lines of previous empirical studies on this matter.

3. Data and Institutional Setting

In this study we analyze all the IPOs undertaken on the London Stock Exchange (LSE) between June 1998 and December 2000. From the entire sample of new issues, we eliminate closed-end funds, open-end funds and investment companies. This leaves us with 337 IPOs, of which 37 went public in 1998, 121 in 1999 and 179 in 2000. Table 1 illustrates the composition of the sample: Panel A reports the size and sector distribution of the companies.

For each company, we collect two types of data: (i) tick-by-tick transaction and quote data provided by the LSE, and (ii) company-level data, drawn from IPO prospectuses filed with the Financial Services Authority (FSA), the UK Listing Authority.

The LSE data include: (a) date and time of each trade executed in the after-market, (b) quantity transacted in each trade, (c) transaction price, and (d) trade direction (buyer- or seller-originated). All these data are available for each company from inception of trading up to the end of 2000.

The FSA data concern the terms of the IPO (offer price, IPO mechanism, number of shares issued in the IPO, stabilization agreement with the underwriter, etc.), firm

characteristics (age,⁴ sector, sales, assets, leverage, presence of venture capitalists), and ownership and control (shares sold by the initial shareholder, percentage of shares held by private investors after the IPO, changes in stock options held by insiders, etc.). When the prospectus was not available from the FSA, these data were drawn from Worldscope.

[Enter Table 1 here]

The companies in our sample list either on the Main Market (MM) or on the Alternative Investment Market (AIM) of the LSE, depending on their accounting records. The two markets have the same trading system (they are both dealer markets with designated market-makers), but list different types of companies. The AIM caters exclusively to small companies with a short track record, while the MM lists companies with no less than three years of accounting profits, though this requirement was relaxed in our sample period to accommodate some young, high-growth firms with no earnings. As a result, the companies listed on the MM are generally larger and older than those listed on AIM. As shown by Panel B of Table 1, 71 percent of the companies under two years from incorporation went public on the AIM. The sector distribution of the two markets is roughly the same. Due to the different listing requirements of the two market segments, companies have little discretion as to the market they will list on, so that their distribution across the two segments can be regarded as largely exogenous.

The design of the IPO sale also differs considerably within our sample. Most small companies go public via a fixed-price auction, where the price is set before the bidding and, in case of overbidding, rationing occurs according to a scheme set in the IPO prospectus. Large companies set their IPO price either through a fixed-price auction or via a book-building process, as illustrated in Panel C of Table 1. The IPO prospectuses reveal that some companies listing on the Main Market enter into a price stabilization agreement with the underwriter, and in this case they generally provide the underwriter with a “green shoe” option.

⁴ In this paper, the age of the company dates from the year of incorporation. If the company results from a merger, its assumed birth date is the year of incorporation of the oldest merged company.

[Enter Table 2 here]

Table 2 provides descriptive statistics for the IPOs in our sample. The Table shows that the typical firm making an IPO operates for more than four years prior to the IPO, has total sales of £25.8 millions in the year before the IPO, fixed assets totaling £41.5 millions and is valued at £108.6 millions at the time of the IPO. Of interest are the changes in the insiders' holdings that occur during the IPO stage. The insiders sell about 3.25% of their stake (in the pre-IPO share capital) during the IPO. These sales, together with the amount of new shares issued by the company, typically reduces the insiders' holdings by 16.5% in the post-IPO company. Furthermore, (executive and non-executive) directors hold, on average, options entitling them to about 4 percent of the post-IPO firm.

As for after-market liquidity, Table 2 reports that the average quoted and effective spreads for the first four weeks of trading are 5.82 and 5.34 percent respectively. Not surprisingly, shares listed on the Main Market are more liquid than those listed on the AIM: the average effective (quoted) spread on the MM is 3.96 percent (4.25 percent), whereas the corresponding figure for the AIM is 5.88 percent (6.46 percent).

Table 3 illustrates how underpricing and measures of liquidity evolve over the first four weeks of after-market trading. As measures of liquidity, we consider the quoted and effective spreads, volume transacted, turnover (defined as the number of shares traded per week divided by the number of shares outstanding), number of trades, time interval (in seconds) between successive trades and order imbalance (defined as buyer-initiated volume less seller-initiated volume). Table 3 shows that underpricing (defined as the percentage change from the offer price to the closing price in each week) decreases, with average underpricing declining from 48.62 percent after the first week to 38.95 percent after the fourth week. Also the quoted and effective spreads decline steadily over the first four weeks of trading. For example, the effective spread declines from 5.78 to 5.11 percent from the first to the fourth week.

[Enter Table 3 here]

Table 3 shows that there is heavy trading activity in the first week of trading. All the relevant measures – volume transacted, turnover, number of trades, and waiting time

between trades – agree on this point. More than 15 percent of the shares outstanding are traded in the first week, against 2.10 percent in the fourth week. On average, 787 trades per firm occur in the first week, against 137 trades in the fourth week. In the first week only 3.18 minutes elapse on average between trades, while traders must wait 8.8 minutes in the fourth week. Also the order imbalance pattern provides a similar picture. There is heavy demand for the IPO shares in the first week of trading, with the buying pressure declining substantially from the second week of trading and stabilizing thereafter.

4. Methodology and Results

The main objective of our research strategy is to measure how IPO underpricing is affected by (a) expected liquidity, and (b) liquidity risk, as perceived by investors at the time of the IPO. In this exercise, we control for other factors affecting IPO underpricing, whose role has already been tested in the literature. Our baseline methodology is to measure expected liquidity and its variability by the sample moments of the bid-ask spread in the first four weeks of after-market trading, and to use these moments as explanatory variables in OLS regressions. These sample moments are estimated regressors, and therefore we adjust the standard errors of the coefficients accordingly.

An additional problem is that these sample moments may measure the market's expectations of liquidity with some error. To overcome this problem, we implement two further estimation methods: an errors-in-variables regression and an instrumental variables regression.

The sample moments of the bid-ask spread are unconditional estimates of the expected value and the variance of liquidity. The IPO offer price should instead reflect conditional expectations, that is, the expected value and the variance of liquidity conditional on the variables known to investors at the time of the IPO. To take into account this point, we also implement a fourth methodology, whereby our measure of expected liquidity and of liquidity risk is based solely on information on firm characteristics known to investors at the time of the IPO.

4.1 Liquidity Measures

Since our hypothesis is that IPO underpricing is not only related to fundamental risk and adverse selection, but also to the expected level of liquidity and its variability, the accurate measurement of the liquidity variables is crucial for our study. The bid-ask spread, which measures the cost of trading at each point in time, is the most accurate measure of liquidity, especially in the context of a dealer market such as the LSE, where market makers post their quote continuously on the market. The bid-ask spread can be regarded as the opportunity cost of undertaking an immediate execution at the current quotes, rather than waiting for a more favorable price.

There are two measures of the spread: (a) the quoted spread, which is the difference between the best ask quote Q_A and the best bid quote Q_B , as a fraction of the mid-quote M (i.e., $S_1 = (Q_A - Q_B)/M$); and (b) the effective spread, generally computed as (twice the absolute value of the) percentage difference between the transaction price P and the mid-quote M (i.e. $S_2 = 2|P-M|/M$). The effective spread takes into account the possibility that trades can occur either inside or outside the quoted spread. It is perceived to be a better measure of liquidity on dealership platforms, because it takes into account trading practices whereby dealers give preferential treatment to some customers (preferencing) or match the best quote on the market with their transaction price (internalization of the order flow). It also avoids the risk of using stale quotes, which is particularly acute on thin markets such as AIM.

Both the quoted and the effective spread suffer from a potential bias, since they do not take into account the depth of the market. The quoted spread refers to an officially determined Minimum Marketable Quantity (MMQ), which is generally proportional to the volume transacted in a specific stock. Therefore, for companies with thin trading this spread is quoted for smaller MMQs. Assuming that the spread widens with trade size, this leads the quoted spread to underestimate the true spread, and thus overestimate liquidity for small stocks.

The effective spread suffers from a similar bias, since it generally refers to bigger transactions for large share issues than for small ones. To exemplify, two share issues of

different size may both feature an effective spread of one percent, but this spread applies to a £100,000 average trade for the larger issue and to a £10,000 average trade for the smaller one. Thus, also the effective spread overestimates the liquidity of smaller issues.

A solution to this problem is to control for market depth in measuring the effective spread S_2 , by computing it for transactions of comparable dimensions for all the stocks considered. An alternative solution is to rely on a measure of price impact, which by construction takes market depth into account. A simple measure of price impact is $S_3 = 2(P - M)/T$, where T is the value of the transaction associated with the price P . Using data on trade direction (buyer- or seller-originated), this measure can be decomposed into two separate measures of price pressure on the buy and on the sell side: $S_A = (P_A - M)/T_A$ and $S_B = (M - P_B)/T_B$, where P_A and P_B are transaction prices originated by buy and sell orders respectively, while T_A and T_B are the values of the corresponding trades. This is particularly relevant to our model, which predicts that IPO-stage investors should be concerned about the level and variability of the sell-side component of the spread S_B .

We capture the firm's liquidity risk by the variability of the spreads. Our microstructure data allow us to measure the variability of spreads at different frequencies and in various ways. We can compute the standard deviation of the spreads sampling high-frequency data over small intervals, for example every five trading minutes, or instead using only data recorded at the close of each trading day. In addition, we can consider measures of dispersion different from the standard deviation, such as the range between the highest and the lowest spread. Experimenting both with different sampling frequencies and with different measures of dispersion appears to yield highly correlated measures of the variability of effective spreads. We choose to use the highest-to-lowest range, calculated using all the values recorded for every trading day, since it appears (a) closest to normally distributed among the measures considered, and (b) the most intuitive form an investor's standpoint.

4.2 Model Specification

In our specification, we wish to nest our liquidity-based explanation of IPO underpricing with the two main hypotheses advanced in the literature: fundamental risk and asymmetric information. To do so, the natural starting point is the set of specifications used in previous work to test these hypotheses. Table 4 lists the variables already used, and groups them in two categories, depending on whether the authors of the corresponding empirical studies consider them as capturing asymmetric information or fundamental risk.

[Enter Table 4 here]

For some of these variables, the literature does not offer explicit motivations to interpret them as proxies for the corresponding theory. For instance, no motive has been offered to explain why the level of the offer price should be seen as a proxy for fundamental risk. Perhaps, this reflects the view that riskier firms recognize that retail investors will want to buy a smaller amount of their shares. Moreover, some of these variables can proxy for both fundamental risk and adverse selection. For example, the age of the firm can be inversely related to risk, insofar as companies often grow into more diversified businesses over time, as well as to adverse selection, since mature companies have a longer track record.

An even more problematic aspect of past empirical work is that many of the explanatory variables used in the literature and listed in Table 1 are potentially endogenous, being chosen by the issuers jointly with the level of underpricing at the time of the IPO. This applies to variables such as the over-subscription rate, the underwriter's and auditor's prestige, the offer price, the IPO mechanism, and the amount of proceeds.

To minimize endogeneity problems, we choose a specification whose explanatory variables are either firm characteristics predetermined at the time of the IPO or characteristics of the after-market, such as its liquidity. Table 5 presents the list of explanatory variables that we employ in our specification.

[Enter Table 5 here]

Liquidity. Consistently with the model presented in Section 2, we expect the coefficients of both after-market liquidity and liquidity risk measures to be positive. In other words, the more liquid the secondary market is expected to be, the lower the liquidity premium that IPO underpricing must incorporate; and the harder it is to predict liquidity, the higher the return required by investors at the IPO stage. The results that we report rely on the effective spread and its variability as a measure of after-market liquidity. However, future versions of this paper will report also results based on the quoted spread and on price impact as alternative measures of liquidity.

The key problem with liquidity variables is that according to our model they should refer to expectations formed by investors at the time of the IPO, and before the actual inception of secondary market trading. As already mentioned, there are various ways to measure expectations, and to use them as explanatory variables in a regression context. Therefore, we shall present results obtained with a variety of estimation strategies.

Asymmetric information. The amount of shares sold by the insiders – which, being announced in the prospectus, is predetermined relative to underpricing – is a key variable to gauge the presence of asymmetric information in the IPO process. If the initial owners know that their company is of high quality, at the IPO stage they should retain a large stake, as in the adverse selection model by Leland and Pyle (1977). The same prediction holds in a moral hazard model such as Jensen and Meckling (1976): the higher the stake retained by controlling shareholders, the lower is their incentive to extract private benefits at the expense of minority shareholders. In both cases, the insiders' decision to retain a large stake in the company is good news for the market, and therefore should induce lower underpricing.

In an environment where managers are increasingly compensated via options, especially in young, small and R&D intensive firms, the attribution of options to management should play the same role as increasing the insiders' stake, both in signaling the firm's quality and as an incentive device. Up to now, the underpricing literature has not used this variable, perhaps due to lack of data. But since such information is announced in firms' prospectuses (and thus is predetermined relative to underpricing), we treat it as a further way to test the Leland-Pyle and Jensen-Meckling predictions.

However, the logic of these models is not unchallenged: Habib and Ljungqvist (2001) argue that initial owners who sell a large number of shares will not want to underprice their company's shares, and can prevent such outcome by spending more resources on "promotion activities". Their prediction is that underpricing is decreasing in the amount of shares that insiders sell at the IPO.

In the presence of asymmetric information, the presence of a venture capitalist can be a quality signal and induce lower underpricing. A dummy variable for the presence of a venture capitalist should therefore carry a negative coefficient. Since venture capitalists typically enter the shareholder base when the company is founded and anyway long time before the IPO, it can be treated as exogenous relative to the IPO offer price.

The offer price of each company can also be affected by the earlier IPO activity in the market or in the same sector, due to an information spillover. Previous IPOs can provide guidance about the investors' appetite for the company's shares and thus about the price they are willing to pay. Benveniste, Wilhelm and Yu (2000) provide evidence that underpricing is lower when many IPO issues have been previously floated. Consistently with such evidence, we expect a negative coefficient on the number and the proceeds of the IPOs carried out in the previous and current quarter, up to the date of the current one.

Fundamental risk. We control for fundamental risk by predetermined variables such as size (measured by sales), age and sector, and more directly by the volatility of returns in the after-market, measured by the standard deviation of the daily open-to-close returns. Investors should require less underpricing to purchase shares with lower after-market security return volatility, to the extent that they correctly anticipate it. By the same token, since issues of older and larger companies generally feature less risk, they should feature lower underpricing. The opposite should be true of IPOs undertaken by companies with a large fraction of intangible assets, such as R&D-intensive and Internet-related sectors, as shown by Loughran and Ritter (2001) on U.S. data. This is particularly important for our sample, which includes the years of the Internet bubble. Hence, the coefficients of return

volatility, size and age should be negative, whereas the coefficient on the variable capturing intangibles intensity should be positive.

4.3 OLS Estimates

The simplest approach is to measure the expected value and the variance of the after-market liquidity level by the two corresponding sample moments, computed over the first weeks of trading. This method rests on the assumption that at the time of the IPO investors correctly anticipate the true moments of these variables, of which the corresponding sample moments are unbiased estimates.

Suppose that one can neglect the error with which these sample moments measure the expected liquidity level and its variance, and the potential inconsistency induced by the correlation of this measurement error with the disturbance of the IPO underpricing equation. Then, the OLS method produces unbiased and consistent estimates.

OLS coefficient estimates and the (corrected) standard errors are displayed in the first column of Table 6. Consistent with the model presented in Section 2, the level of underpricing is measured as the natural log of the ratio of the after-market price and the offer price, where the after-market price is the last transaction price of the first day of trading. The overall explanatory power of the regression is satisfactory compared with those reported in previous studies of IPO underpricing, since it accounts for more than 40 percent of the variance in the dependent variable. All of the coefficients of the explanatory variables carry the signs predicted by the theory and are precisely estimated, except for the coefficient of the number of IPOs in the previous quarter.

[Enter Table 6 here]

The average effective spread in the four weeks of after-market trading has a positive coefficient, and so does its variability. These coefficients are not only statistically significant at the 1-percent confidence level, but also economically significant. Considering that fundamental risk is already controlled for by the volatility of after-market returns, firm age, size, sector and the stabilization behavior of underwriters, it is

remarkable that the level and the variability of the bid-ask spread have such a large and precisely estimated impact on IPO underpricing.

Consistently with asymmetric information models, underpricing is lower the higher the directors' holdings of options in the post-IPO firm or when a venture capitalist has a stake in the company at the time of the IPO. In line with the information spillover hypothesis, underpricing decreases as more IPOs are carried out in the same quarter, although the coefficient is not statistically significant at the 5% level. Replacing the number of recent IPOs by the proceeds from recent IPOs produces almost identical estimates (the estimates are not reported for brevity). If the explanatory variables include also the number of recent IPOs within the same sector or their proceeds, their coefficients are not precisely estimated. However, in agreement with the findings by Habib and Ljungqvist (2001), underpricing is decreasing in the amount of shares that insiders sell at the IPO stage.

As predicted by risk aversion models, older companies face less underpricing when they go public, while the opposite holds for companies with more volatile after-market returns, other things equal. The coefficient of sales is negative, as predicted, but it is not precisely estimated. This probably reflects collinearity with the age variable: the level of firm sales is highly correlated (0.468) with the age of the firm. The coefficient estimates are almost identical when sales are replaced with total assets (not reported for brevity). These two variables – age and sales - are jointly significant (the F-test rejects the null hypothesis that their coefficients are zero at the 1 percent level).

The industry dummy identifying internet-related and R&D-intensive IPOs has a positive coefficient but is not statistically significant. Furthermore, the presence of non-executive directors, that many consider as a mechanism to improve the monitoring of the firm's management, does not produce a significant impact on the level of underpricing, possibly because of its endogeneity.

There are two additional control variables which we use in our model and which are not reported: (a) underwriter's stabilization in the after-market, and (b) the size of the IPO. The literature shows that underwriters do stabilize the IPO in the very first days of

after-market trading. Stabilization could be a potential problem for our estimates if we do not control for it since it is likely to impact the liquidity in the market. We control for stabilization via a dummy variable that indicates if a stabilization agreement is mentioned in the IPO prospectus, which happens in many medium-sized and large IPOs (mainly undertaken on the Main Market).

The other control variable that we use is the size of the IPO itself. We measure the IPO size by the total proceeds from the IPO. The argument behind the inclusion of such a variable is based on the notion of capacity constraints in the market. If such constraints exist then large IPOs are more difficult to be “digested” by the market and hence there must be higher underpricing in order to attract sufficient investors to take up the shares floated in the IPO. The coefficient estimate for the proceeds is positive, as predicted, and significant at the 10% level. However, it must be said that the coefficient estimates of the other variables do not change significantly when the size of the IPO is dropped.

One should also discuss briefly the measure of underpricing we employ. In this paper, underpricing is calculated as the natural log of the ratio of the after-market price to the offer price ($\log(P_1 / P_0)$), whereas the literature extensively uses the percent return from the offer price to the after-market price ($(P_1 - P_0) / P_0$). We use the former measure of underpricing for two distinct reasons. First, according to the theoretical model presented in Section 2 the ratio between the after-market price and the offer price holds a non-linear relationship with the explanatory variables that we employ. If the utility function is logarithmic, the relationship becomes linear by a logarithmic transformation of the dependent variable. Secondly, from a statistical point of view, the $\log(P_1 / P_0)$ is much closer to a normally-distributed variable than the measure $(P_1 - P_0) / P_0$ hitherto used by the literature. In particular, the skewness and kurtosis of our underpricing measure are 1.0002 and 3.9100, respectively, compared with 1.9177 and 6.7114 for the traditional measure. However, we also test our empirical model by using the traditional measure of underpricing, and find that the estimates are qualitatively unchanged.

The OLS estimates reported in column 1 may suffer from two types of problems. First, the ex-post average and variance of the effective spread may measure the corresponding

estimates held by investors with error, which can be correlated with the error of the underpricing equation. The inconsistency induced by measurement error may be compounded by the potential endogeneity of after-market liquidity. In the next subsection, we try to address this problem via instrumental variables (IV) estimation.

A second potential problem may derive from the very use of after-market data to measure the expected level of liquidity and its perceived volatility. This may impute to investors more information than that they truly have at the time of the IPO. We shall address this problem in section 4.5 by constructing measures of investors' expectations based only on information publicly known at the time of the IPO.

4.4 Instrumental variables estimates

If our measures of expected liquidity and liquidity risk are subject to substantial measurement error, the estimated coefficients on these variables are biased toward zero, with the magnitude of the bias proportional to the variance of the measurement error. These coefficients may be biased also if liquidity were endogenous with respect to the degree of IPO underpricing. For instance, higher underpricing may induce greater market participation by small investors (as argued by Booth and Chua, 1996, and by Brennan and Franks, 1995). If the latter makes the after-market more liquid, our measures of liquidity may be correlated with the error of the underpricing equation.

We tackle this problem by the standard solution to these errors-in-variables problems, which is to estimate the equation by Two-Stage Least Squares (2SLS). This requires appropriate instruments, that is, variables correlated with liquidity and its variability but not with the error in the underpricing equation. We use the following instruments: (a) the concentration of the share capital held by the major shareholders after the IPO, (b) the amount of new shares issued in the IPO, (c) the IPO mechanism ("placing" versus "public offer"), (d) the market on which the IPO is carried out, and (e) the industrial sector.

The concentration in the share capital, i.e. the amount of the share capital closely held by the major shareholders, determines how much of the firm's share capital is publicly

traded and thus directly influences the firm's liquidity. We leave the changes in the original (major) shareholders to capture the signals sent to the market regarding the firm's quality. Another instrument is the IPO mechanisms used by the firm, i.e. whether the IPO is through (i) a "placing" (similar to the firm commitment in the US), which is entirely addressed to institutional investors, or (ii) a "public offer", addressed both to institutional investors and retail investors. The last instrument is the type of market used for the IPO – the Main Market or AIM. Both of these are likely to affect underpricing primarily via their impact on aftermarket liquidity.

Column 2 of Table 6 report the resulting 2SLS estimates. These suggest that indeed the OLS coefficient on the effective spread is biased toward zero. The 2SLS estimated coefficient is almost twice as large that obtained from the OLS method, hinting at a much larger effect of after-market liquidity on underpricing. The effect of the variability of the spread remains instead approximately the same. Also most of the other coefficients are virtually unchanged relative to the OLS estimates. The only other difference worth noting is that the coefficient of the change in insiders' holding is half the size of the corresponding OLS estimate, and is not significantly different from zero, in contrast both with the OLS estimate and with the results by Habib and Ljungqvist (2001).

4.5. Forecasting Liquidity from Firm Characteristics

Finally, we obtain the expected levels and uncertainty of the spread through a different approach which is based on identifying comparable companies to the issuer and inferring the measures of expected values from the realized spread for previously-listed comparable companies.

Every IPO is matched with a similar firm, in terms of (a) industrial sector, (b) size (by total assets), and (c) book-to-market that has already undergone the IPO process. After matching these firms, we measure the quoted and effective spread (together with other measures of liquidity) over the first month and its variability. The resulting statistic is the expected value of liquidity and liquidity risks that the market expects for the issuer under consideration.

Column 3 of Table 6 report the coefficient estimates when we use the expected values of liquidity and liquidity risk. The coefficient estimates shows that using the predicted spread and expected spread volatility leads to a lower impact of the effective spread but a larger impact from the variability of the effective spread on underpricing when compared with OLS estimates. Most of the other coefficient estimates remain unchanged relative to the OLS estimates. There are, though, some differences which are worth noting: (a) the impact of the return volatility is somewhat lower relative to the OLS estimate, and (b) the coefficient of the change in insiders' holding is greater than the corresponding OLS estimate which again gives credence to the results obtained by Habib and Ljungqvist (2001).

4.6 Holding Period

Another major issue is to decide over which period we should measure liquidity and its volatility. In this regard, we also have to take into consideration the clientele effects in terms of the investors' preference for liquidity and the compensation required for illiquidity. For example, Amihud and Mendelson (1986) have shown that, not only wide-spread securities (low liquidity) must compensate investors through a higher expected return, but also that such securities are likely to be held by investors with a long time horizon.

In view of this, we have to determine the time over which we can measure liquidity in that choosing a short-time framework rather than a long-term framework is likely to impact on the "type" of liquidity-motivated trader we have in mind. If we were to take, for example, the spread's dynamics in the very first day/s, then we would be implicitly assuming a short-term liquidity trader, one who intends to buy the IPO and divest her shares immediately. On the other hand, assuming a long term to analyze the spread would imply that what we have in mind is a liquidity-motivated trader who intends to stick with her shares for a longer term.

Moreover, the trading dynamics that we see in Table 3 show that trading activity is high in the first few days in the after-market, after which period trading decreases to more

“normal” (systematic) levels. Considering that (i) an underpriced IPO attracts substantial interest from the investing community, and (ii) given the amount of rationing that occurs in such cases, it is likely that the large volumes transacted in the very first days is not entirely due to the liquidity parameters but also due to pent-up demand in the market for these securities.

Finally, the decision on the optimal time period for our analysis must consider, on one hand, the benefit that a longer time period (say one or two months after the initial trading) will provide a more accurate measurement of the liquidity dynamics cleaned of any short-term pent-up demand.

On the other hand, there are the “costs” that such long periods are likely to contain confounding events, such as news about the firm, that can interfere with the liquidity and its risk, which could capture information unrelated to the IPO. One can, however, correct for the latter effect by considering news issued by the firm that are likely to impact on the firm's fundamental risk.

We investigate the impact of the effective spread and the variability of the effective spread, both measured over different time periods, on the underpricing. We use (a) spread and its variability in the first trading day, (b) spread and its variability in the first two trading days, (c) spread and its variability in the first trading week, and (d) spread and its variability in the first two trading weeks. When we compare the coefficient estimates obtained from using the measures in (a) – (d) above with those shown in Table 6 (Method 1), we find that the impact from liquidity and its risk on underpricing is robust to the choice of the holding period. The only difference is that the impact from the effective spread is lower (but still significant) when the spread is measured over the first day of trading and over the first two trading days. This could be due to the excessive noise in the effective spread over the first few days of trading when high volume is transacted. As trading activity converges to its normal level, less noise is induced in the spread leading to more robust estimates.

5. Conclusions

Does a firm's liquidity in the after-market matter for IPO underpricing? In this paper we argue that investors participating in IPOs are concerned not only with issues of the firm's fundamental risk and adverse selection but also by the expected liquidity and the uncertainty about its level once shares start trading on the after-market. We argue that the less liquid shares are expected to be and the less predictable their liquidity, the larger will be the required underpricing. We have presented a model that integrates the investors' liquidity concerns within a traditional framework with adverse selection and risk. The model complements traditional explanations with theory and evidence showing that after-market liquidity is an important determinant of IPO underpricing. We test for the presence of liquidity effects on IPO underpricing after controlling for the variables suggested by other theories of IPOs. The main measure of liquidity we employ is the after-market's effective spread and we use the variability of the effective spread to measure liquidity risk.

Using a sample of companies that went public on the LSE between June 1998 and December 2000 we find that expected after-market liquidity and liquidity risk are important determinants of IPO underpricing. The liquidity impacts are found to be robust even to (a) the inclusion of the other factors that have traditionally been used to explain IPO underpricing, and (b) use of alternative econometric methodologies.

This paper shows that liquidity is an important link between secondary markets and primary markets and suggests that more attention needs to be devoted in evaluating the link further.

Appendix

1. Derivation of equation (15)

Under risk aversion, equation (1) must be restated in terms of expected utility: investor j bids for shares at the IPO only if

$$zE\left[U(\tilde{P}_1|\Omega_0^j)\right] + (1-z)E\left[U(\tilde{P}_2|\Omega_0^j)\right] \geq U(P_0). \quad (\text{A1})$$

Therefore, informed investors condition their bids on their private information \tilde{u}_1 only if

$$\begin{aligned} zE\left[U(\tilde{P}_1^B|\tilde{u}_1 = \eta)\right] + (1-z)E\left[U(\tilde{P}_2|\tilde{u}_1 = \eta)\right] &\geq U(P_0) \\ &> zE(\tilde{P}_1^B|\tilde{u}_1 = -\eta) + (1-z)E(\tilde{P}_2|\tilde{u}_1 = -\eta), \end{aligned} \quad (\text{A2})$$

which, using (2) and recalling that $\tilde{P}_2 = V + \tilde{u}_1 + \tilde{u}_2$, can be rewritten as

$$\begin{aligned} zU\left(V + \eta - \frac{q}{q+z}\varepsilon\right) + \frac{1-z}{2}[U(V + \eta + \varepsilon) + U(V + \eta - \varepsilon)] &\geq U(P_0) \\ &> zU\left(V - \eta - \frac{q}{q+z}\varepsilon\right) + \frac{1-z}{2}[U(V - \eta + \varepsilon) + U(V - \eta - \varepsilon)]. \end{aligned} \quad (\text{A3})$$

If condition (A3) holds, the informed traders' optimal strategy is to bid only if $\tilde{u}_1 = \eta$. We shall see that this condition is met in equilibrium, if uninformed investors participate.

From (A1), uninformed investor instead bid for shares if:

$$\begin{aligned} &z\left[\pi_u U(\tilde{P}_1^B|\tilde{u}_1 = \eta) + (1 - \pi_u)U(\tilde{P}_1^B|\tilde{u}_1 = -\eta)\right] + \\ &(1-z)\pi_u\left[\frac{1}{2}U(\tilde{P}_2|\tilde{u}_1 = \eta, \tilde{u}_2 = \varepsilon) + \frac{1}{2}U(\tilde{P}_2|\tilde{u}_1 = \eta, \tilde{u}_2 = -\varepsilon)\right] + \\ &(1-z)(1-\pi_u)\left[\frac{1}{2}U(\tilde{P}_2|\tilde{u}_1 = -\eta, \tilde{u}_2 = \varepsilon) + \frac{1}{2}U(\tilde{P}_2|\tilde{u}_1 = -\eta, \tilde{u}_2 = -\varepsilon)\right] \geq U(P_0), \end{aligned} \quad (\text{A2}')$$

which, using equation (2) and the definition of \tilde{P}_2 , becomes:

$$\begin{aligned} &z\left[\pi_u U\left(V + \eta - \frac{q}{q+z}\varepsilon\right) + (1 - \pi_u)U\left(V - \eta - \frac{q}{q+z}\varepsilon\right)\right] + \\ &\frac{1-z}{2}\{\pi_u[U(V + \eta + \varepsilon) + U(V + \eta - \varepsilon)] + (1 - \pi_u)[U(V - \eta + \varepsilon) + U(V - \eta - \varepsilon)]\} \geq U(P_0). \end{aligned}$$

The company will set the offer price at the highest level consistent with participation by the uninformed investors in the IPO, that is, will choose P_0 so that this condition holds with equality. This implies that condition (A3) concerning informed investors is satisfied, since $U(P_0)$ is an average of its left-hand and right-hand-side expressions, with weights π_u and $1 - \pi_u$. It follows that, as under risk neutrality, $\pi_u = \lambda / (1 - \lambda)$. Using this result in the previous condition taken with equality, we obtain the following condition defining the equilibrium offer price:

$$U(P_0) = z \left[\frac{\lambda}{1-\lambda} U \left(V + \eta - \frac{q}{q+z} \varepsilon \right) + \frac{1}{1-\lambda} U \left(V - \eta - \frac{q}{q+z} \varepsilon \right) \right] + \frac{1-z}{2} \left\{ \frac{\lambda}{1-\lambda} [U(V + \eta + \varepsilon) + U(V + \eta - \varepsilon)] + \frac{1}{1-\lambda} [U(V - \eta + \varepsilon) + U(V - \eta - \varepsilon)] \right\}. \quad (\text{A4})$$

Taking a second-order Taylor-series approximation of the right-hand-side and collecting terms, one can rewrite expression (A4) as:

$$U(P_0) = U(V) - U'(V) \left(\frac{1-\lambda}{1+\lambda} \eta + z \frac{q}{q+z} \varepsilon \right) + \frac{U''(V)}{2} \left\{ z \left[\eta^2 + \left(\frac{q}{q+z} \right)^2 \varepsilon^2 + 2 \frac{1-\lambda}{1+\lambda} \frac{q}{q+z} \eta \varepsilon \right] + (1-z) (\eta^2 + \varepsilon^2) \right\}. \quad (\text{A4}')$$

and, collecting terms and recalling that the spread's bid-side portion $S_B = \frac{q}{q+z} \varepsilon$:

$$U(P_0) = U(V) - U'(V) \left(\frac{1-\lambda}{1+\lambda} \eta + z S_B \right) + \frac{U''(V)}{2} \left[\eta^2 + (1-z) \varepsilon^2 + z \left(S_B^2 + 2 \frac{1-\lambda}{1+\lambda} \eta S_B \right) \right],$$

which yields equation (15) through the steps explained in the text.

2. Derivation of equation (17)

For the sake of brevity, for this case we shall concentrate on the condition that ensures the participation of uninformed investors, which determines the equilibrium price P_0 . Based on (A1), uninformed investor bid for shares if:

$$z \frac{\pi_u}{2} \left[U(\tilde{P}_1^B | \tilde{u}_1 = \eta, \tilde{q} = q_H) + U(\tilde{P}_1^B | \tilde{u}_1 = \eta, \tilde{q} = q_L) \right] + z \frac{1-\pi_u}{2} \left[U(\tilde{P}_1^B | \tilde{u}_1 = -\eta, \tilde{q} = q_H) + U(\tilde{P}_1^B | \tilde{u}_1 = -\eta, \tilde{q} = q_L) \right] +$$

$$(1-z)\frac{\pi_u}{2}\left[U(\tilde{P}_2|\tilde{u}_1 = \eta, \tilde{u}_2 = \varepsilon) + U(\tilde{P}_2|\tilde{u}_1 = \eta, \tilde{u}_2 = -\varepsilon)\right] +$$

$$(1-z)\frac{1-\pi_u}{2}\left[U(\tilde{P}_2|\tilde{u}_1 = -\eta, \tilde{u}_2 = \varepsilon) + U(\tilde{P}_2|\tilde{u}_1 = -\eta, \tilde{u}_2 = -\varepsilon)\right] \geq U(P_0). \quad (\text{A5})$$

Taking this condition with equality, substituting the conditional values of \tilde{P}_1^B and \tilde{P}_2 for this case and setting $\pi_u = \lambda/(1-\lambda)$, one obtains the following condition for the equilibrium offer price P_0 :

$$U(P_0) = \frac{z}{2} \frac{\lambda}{1-\lambda} \left[U\left(V + \eta - \frac{q_H}{q_H+z} \varepsilon\right) + U\left(V + \eta - \frac{q_L}{q_L+z} \varepsilon\right) \right] +$$

$$\frac{z}{2} \frac{1}{1-\lambda} \left[U\left(V - \eta - \frac{q_H}{q_H+z} \varepsilon\right) + U\left(V - \eta - \frac{q_L}{q_L+z} \varepsilon\right) \right] +$$

$$\frac{1-z}{2} \left\{ \frac{\lambda}{1-\lambda} [U(V + \eta + \varepsilon) + U(V + \eta - \varepsilon)] + \frac{1}{1-\lambda} [U(V - \eta + \varepsilon) + U(V - \eta - \varepsilon)] \right\}. \quad (\text{A6})$$

Taking a second-order Taylor-series approximation of the right-hand-side and collecting terms, one can rewrite expression (A6) as:

$$U(P_0) = U(V) - U'(V) \left[\frac{1-\lambda}{1+\lambda} \eta + \frac{z}{2} \left(\frac{q_H}{q_H+z} + \frac{q_L}{q_L+z} \right) \varepsilon \right] + \quad (\text{A6}')$$

$$\frac{U''(V)}{2} \left\{ \eta^2 + \frac{z}{2} \left[\left(\frac{q_H}{q_H+z} \right)^2 + \left(\frac{q_L}{q_L+z} \right)^2 \right] \varepsilon^2 + (1-z)\varepsilon^2 + z \frac{1-\lambda}{1+\lambda} \left(\frac{q_H}{q_H+z} + \frac{q_L}{q_L+z} \right) \eta \varepsilon \right\}.$$

Since $E(\tilde{S}_B) = \frac{1}{2} \left(\frac{q_H}{q_H+z} + \frac{q_L}{q_L+z} \right) \varepsilon$ and $E(\tilde{S}_B^2) = \frac{1}{2} \left[\left(\frac{q_H}{q_H+z} \right)^2 + \left(\frac{q_L}{q_L+z} \right)^2 \right] \varepsilon^2$, one

can rewrite expression (A6') as:

$$U(P_0) = U(V) - U'(V) \left\{ \left(\frac{1-\lambda}{1+\lambda} \eta + zE(\tilde{S}_B) \right) + \frac{U''(V)}{2} [\eta^2 + (1-z)\varepsilon^2] + \right.$$

$$\left. + \frac{U''(V)}{2} z \left[\text{Var}(\tilde{S}_B) + (E(\tilde{S}_B))^2 \right] + 2 \frac{1-\lambda}{1+\lambda} \eta E(\tilde{S}_B) \right\},$$

which yields equation (17) through steps similar to those explained in the text for the derivation of equation (15).

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Table 1. Composition of the Sample

The Table illustrates the composition of the sample, which refers to the 337 IPOs carried out between July 1998 and December 2000 on the London Stock Exchange. Panel A shows the breakdown of the sample by sector and size (as measured by total assets). Each cell reports the number of companies in the corresponding sector and size quartile. Panel B shows the breakdown of the sample by age (as measured by years from incorporation to the date of the IPO) and market of listing (Main Market or Alternative Investment Market).

Panel A

Sector:	1st size quartile	2nd size quartile	3rd size quartile	4th size quartile	Total
1. Resources	0	0	2	3	5
2. Basic Industries	0	1	3	2	6
3. General Industries	2	5	3	7	17
4. Cyclical Consumer Goods	1	6	1	6	14
5. Non-Cyclical Consumer Goods	7	7	8	8	30
6. Cyclical Services	25	18	34	18	95
7. Non-Cyclical Services	19	4	4	6	33
8. Financials	8	6	10	16	40
9. Information Technology	29	30	20	18	97

Panel B

Age (Years):	Main Market	Alternative Investment Market	Total
Age ≤ 1	22	84	106
1 < Age ≤ 2	23	52	75
2 < Age ≤ 3	18	16	34
3 < Age ≤ 4	16	15	31
4 < Age ≤ 5	12	11	23
5 < Age ≤ 6	7	8	15
6 < Age ≤ 7	4	1	5
7 < Age ≤ 8	1	8	9
8 < Age ≤ 9	4	1	5
9 < Age ≤ 10	3	4	7
Age > 10	16	11	27

Table 2. Descriptive Statistics

The Table shows statistics for the 337 IPOs carried out between June 1998 and December 2000 on the London Stock Exchange. Trading data were supplied by the London Stock Exchange. Data about firm characteristics were drawn from the prospectuses filed with the Financial Services Authority (the UK Listing Authority). The Quoted Spread is calculated as $[(ask - bid)/mid\ quote]*100$. The Effective Spread is measured as $[2*dummy*(price - mid\ quote)]*100$. The Volatility of the Quoted (Effective) Spread is measured as the average of the range between the highest and lowest quoted (effective) spread, calculated for each trading day. Return Volatility is the variance of the open price to closing price returns. For the quoted and effective spread, the volatility of the quoted and effective spread and the return volatility the table shows the pooled time-series and cross-sectional averages across sample firms for the first four weeks of trading on the aftermarket. Volume is the average number of shares transacted on the first day of the aftermarket. Turnover is the volume transacted on the first day of trading divided by the number of shares placed on the market in the IPO. All figures concerning firm and IPO characteristics are cross-sectional statistics. Firm Sales are the sales in the year preceding the IPO. Firm Capitalization is the market capitalization at the time of the IPO. Firm Age is the number of years from the firm's original incorporation to the time of the IPO. In case of mergers and takeovers, the date of incorporation refers to the oldest firm. Fixed Assets is the firms' fixed assets at the time of the IPO. Leverage reports the cross-sectional average of long term debt to assets held by the firm at the time of the IPO. Underpricing is calculated as the return in the first day of trading, from the offer price to the price of the last trade on the first day of trading. Shares Offered by the Company is the number of shares placed on the market in the IPO. Shares Offered by the Main Shareholders is the number of shares offered by the major shareholders (defined as the shareholders holding 3 percent or more of the share capital at the time of the IPO). Equity Issued is the share capital placed on the market by the firm in the IPO. Change in Insiders Holdings is the change in the major shareholders' holdings, expressed as a percent of the outstanding shares, from the pre- to the post-IPO stage. Directors' Options are the directors' holdings of options as a percent of outstanding shares after the IPO stage. Non-Executive Directors' Presence reports the presence of non-executive directors in the board of directors at the time of the IPO.

Variable:	Mean	Median	Standard Deviation	Minimum	Maximum
Liquidity and Volatility Variables:					
Quoted Spread (percent)	5.82	4.52	4.17	0.62	24.01
Volatility of Quoted Spread	3.51	2.53	3.75	0.1	25.55
Effective Spread (percent)	5.34	4.11	3.77	0.51	20.93
Volatility of Effective Spread	4.76	3.63	3.88	0.12	23.33
Return Volatility (x 100)	4.86	4.05	1.78	0	25.26
Volume, 1 st Day of Trading (1,000 shares)	8,149	1,334	30,800	2000	303,000
Daily Turnover, 1 st Day of Trading (percent)	9.75	7.26	6.76	0.001	14.81

Table 2 continues overleaf

Table 2, continued

Variable:	Mean	Median	Standard Deviation	Minimum	Maximum
Company Characteristics:					
Firm Size (by sales, £ million)	25.78	1.14	221.95	0	3,424
Firm Size (by market cap, £ million)	108.62	24.45	422.24	0.25	5,726
Firm Age (years)	4.15	2.25	7.75	0.08	104
Fixed Assets (in £ million)	41.46	1.34	299.19	0.025	4,060
Leverage (Short-term Debt) (percent)	19.85	18.11	36.18	0	91
Leverage (Long-term Debt) (percent)	21.22	18.44	24.29	0	96
IPO Characteristics:					
Underpricing (percent)	42.21	22.36	55.52	-43.45	260.16
Shares Offered by the Company (in 1,000)	29,600	11,400	54,600	500	414,000
Shares Offered by the Main Shareholders (in percent)	3.25	0.25	8.38	0	58.18
Equity Issued (percent)	38.09	30.34	24.72	1.8	99
Change in Insiders Holdings (percent)	-16.43	-10.53	16.01	-75	15.97
Directors' Options (percent)	4.01	1.53	5.89	0	26.5
Venture Capitalists' Presence (dummy)	0.33	0.1	0.47	0	1
Non-Executive Directors' Presence (percent)	41.09	40	16.50	0	90

Table 3. Underpricing and Liquidity at Different Horizons

The Table reports statistics about underpricing and aftermarket liquidity for the 337 IPOs carried out between June 1998 and December 2000 on the London Stock Exchange. The 1st week is the first five days of aftermarket trading. The 2nd, 3rd and 4th weeks are defined similarly. Underpricing is defined as the percentage change from the offer price to the closing price for each week. Turnover is the number of shares traded per week divided by the number of shares outstanding. Number of Trades is the number of all the customer seller- and buyer-initiated trades performed in the LSE in the relevant week. Waiting Time between Trades is the number of seconds between successive trades in the relevant trading week. Order Imbalance is the difference between the total number of buyer-initiated trades and the total number of seller-initiated trades in the relevant trading week.

Variable:	Mean	Median	Standard Deviation “Within” Firms	Standard Deviation “Between” Firms
Underpricing				
(percent):				
1 st week	48.62	24.97	8.1086	174.1135
2 nd week	44.26	20.41	0.9947	158.4025
3 rd week	41.28	12.8	0.1391	155.5471
4 th week	38.95	12.5	0.0024	150.2431
Quoted Spread				
(percent):				
1 st week	6.02	4.59	0.3498	5.7802
2 nd week	5.93	4.43	0.0052	5.7189
3 rd week	5.87	4.48	0.0671	5.5692
4 th week	5.73	4.38	0.0021	5.5048
Effective Spread				
(percent):				
1 st week	5.78	4.24	0.3852	5.4097
2 nd week	5.51	4.18	0.0592	5.2941
3 rd week	5.36	4.15	0.0573	5.1787
4 th week	5.11	4.08	0.0054	5.0534
Turnover (percent):				
1 st week	15.36	6.54	3.025	31.13
2 nd week	2.73	0.94	0.060	5.40
3 rd week	2.22	0.59	0.021	5.18
4 th week	2.10	0.58	0.016	5.87

Table 3 continues overleaf

Table 3, continued

Variable:	Mean	Median	Standard Deviation (variation "within" firms)	Standard Deviation (variation "between" firms)
Volume Transacted (number of shares)				
1 st week	17,400,000	2,349,645	1,792,194	69,970,000
2 nd week	3,119,698	416,788	485,038	9,049,172
3 rd week	2,778,727	382,754	103,518	10,128,154
4 th week	2,250,940	235,985	5,800	7,149,012
Number of Trades:				
1 st week	787	173	84	1902
2 nd week	215	39	20	519
3 rd week	180	33	14	431
4 th week	137	26	5	311
Waiting Time between Trades:				
1 st week	191	15	789	1602
2 nd week	387	49	1179	3158
3 rd week	419	55	1186	3085
4 th week	528	68	1411	2928
Order Imbalance:				
1 st week	746,750	4,500	5,006,709	15,900,000
2 nd week	87,889	1,561	620,562	618,364
3 rd week	54,143	811	450,122	929,406
4 th week	33,144	406	287,964	748,099

Table 4. Variables Used in Previous Empirical Studies of IPO Underpricing

Source of underpricing	Variables employed	Existing literature
<i>Informational Asymmetries</i>	Insider shares	Downes and Heinkel (1982); Garfinkel (1993); Logue (1973)
	Oversubscription, level or relative to the IPO issue	Tan, Eng and Khoo (1999); Koh and Walter (1989); Levis (1990); Cheung, Cheung, and Ho (1993)
	Underwriter's prestige	Beatty and Ritter (1986); Booth and Chua (1996); Booth and Smith (1986); Carter and Manaster (1990); Michaely and Shaw (1994)
	Auditor's prestige	Balver, McDonald and Miller (1988); Beatty (1989); Titman and Trueman (1986)
	Venture capitalists' presence	Barry, Muscarella, Peavy and Vetsuypens (1990); Megginson and Weiss (1991)
	Probability of future issues	Jegadeesh, Weinstein, and Welch (1993)
	Relative volume (ratio of turnover to capitalization)	Tan, Eng and Khoo (1999)
	Lock-up clauses	Cho (1992)
	IPO mechanism	Booth and Chua (1996); Ritter (1987)
	Number of IPO issues in the sector	Benveniste, Wilhelm, and Yu (2000); Booth and Chua (1996)
<i>Fundamental risk</i>	Offer price	Booth and Chua (1996)
	Price-earnings ratio	Tan, Eng and Khoo (1999)
	Market chosen for listing	Tan, Eng and Khoo (1999)
	Amount of proceeds	Beatty and Ritter (1986); Ritter (1984)
	Firm's age	Ritter (1984)

Table 5. Model Specification

Source of underpricing	Explanatory Variables	Predicted Sign of Coefficient
<i>Liquidity</i>	Quoted spread	Positive
	Effective spread	Positive
	Price impact	Positive
<i>Liquidity risk</i>	Variability of the effective spread	Positive
<i>Adverse selection</i>	Changes in the holdings of insiders	Negative
	Directors' holdings of options	Negative
	Venture capitalists' presence	Negative
	Presence of non-executive directors	Negative
	Number of IPOs in the market and in the sector	Negative
	Proceeds of IPOs in the market and sector	Negative
<i>Fundamental risk</i>	Size (sales, total assets)	Negative
	Firm's age	Negative
	Return volatility	Positive
	High-risk sector	Positive
	Underwriter stabilization	Negative
<i>Size of IPO</i>	Proceeds from the IPO	Positive

Table 6. Regression Results

The dependent variable is the IPO underpricing, defined as [natural log (price of the last trade on the first day of trading)/(IPO offer price)]. Method (1) employs the actual realization of the effective spread (in logs) and its variability over the first four weeks of trading. Method (2) is a 2SLS approach. Method (3) employs different firm characteristics, of companies that already underwent an IPO process, to predict the effective spread and its variability. The Effective Spread is measured as $[2 \cdot \text{dummy} \cdot (\text{price} - \text{mid quote})] \cdot 100$ over the first four weeks of trading. Variability of the Effective Spread is measured as the average of the range between the highest and lowest effective spreads, calculated for each trading day over the first four weeks of trading. Change in Insiders Holdings is the shares sold by the main shareholders (defined as the shareholders holding three percent or more of the share capital at the time of the IPO) at the IPO stage as percentage of the total shares outstanding at the time of the IPO. Directors' Options are the directors' holdings of options as a percent of outstanding shares after the IPO. Venture Capitalist's Presence is a dummy variable taking the value of 1, if the company had a venture capitalist as one of its main shareholders at the time of the IPO, and a value of 0 if no venture capitalist was present. Firm Sales are the sales in the year preceding the IPO. Firm Age is the number of years from the firm's original incorporation to the time of the IPO. Governance is the ratio of non-executive directors to the total number of directors in the firm's Board of Directors. Return Volatility is the variance of the open price to closing price returns for the first four weeks of trading. Internet-related Dummy is a dummy variable that takes the value of 1 if the company operates in the Information Technology sector and 0 if it operates in the other industrial sectors. Number of IPOs in the Same (Previous) Quarter is the total number of IPOs carried out on the London Stock Exchange in the same (previous) quarter relative to every IPO in the sample. Underwriter Stabilization is a dummy variable that takes the value of 1 when a stabilization agreement is mentioned in the IPO prospectus and a value of 0 when no stabilization agreement is in place. Size of the IPO is the total proceeds from the IPO. Asterisks (*, ** and ***) indicate statistical significance (at the 10%, 5% and 1% level respectively).

	Method (1)	Method (2)	Method (3)
Intercept	0.0939* (1.86)	0.9762 (1.13)	0.1365** (2.65)
Effective Spread	0.0168*** (4.06)	0.0304** (2.18)	0.0093** (2.03)
Variability of Effective Spread	0.0298*** (4.93)	0.0256*** (3.12)	0.0335*** (5.57)
Changes in Insiders' Holdings	-0.0031** (-2.57)	-0.0016 (1.09)	-0.0036*** (-2.96)
Directors' Options Holdings	-0.0116*** (-5.79)	-0.0108*** (-5.28)	-0.0119*** (-5.84)
Venture Capitalist's Presence	-0.0861*** (-3.20)	-0.0851*** (-2.83)	-0.0941*** (-3.42)

Table 6 continues overleaf

Table 6, continued

	Method (1)	Method (2)	Method (3)
Firm Age	-0.0042** (-2.03)	-0.0051** (-2.27)	-0.0046** (-2.12)
Firm Sales (x 1,000)	-0.0010 (-0.82)	0.0122 (0.18)	0.0203 (0.36)
Governance	-0.0013 (-1.60)	-0.0009 (-1.06)	-0.0014 (-1.70)
Return Volatility (x 10,000)	0.0059*** (2.73)	0.0068** (2.37)	0.0049*** (2.10)
Internet-related Dummy	0.0378 (1.15)	0.0355 (1.01)	0.0398 (1.20)
Number of IPOs in the Same Quarter	-0.0009* (1.86)	0.0006 (1.08)	0.0008 (1.22)
Number of IPOs in the Previous Quarter	0.0005 (0.98)	-0.0004 (1.26)	0.0011 (1.51)
Underwriter Stabilization	-0.0025 (1.04)	-0.0038 (1.28)	0.0081 (0.98)
Size of the IPO	0.0023*** (2.72)	0.0041*** (2.98)	0.0029*** (2.56)
Adjusted R^2	48.03	43.67	46.32
Number of Observations	337	337	262