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## Do stock price bubbles influence corporate investment? ☆

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### Abstract

Dispersion in investor beliefs and short-selling constraints can lead to stock market bubbles. This paper argues that firms, unlike investors, can exploit such bubbles by issuing new shares at inflated prices. This lowers the cost of capital and increases real investment. Perhaps surprisingly, large bubbles are not eliminated in equilibrium nor do large bubbles necessarily imply large distortions. Using the variance of analysts' earnings forecasts to proxy for the

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dispersion of investor beliefs, we find that increases in dispersion cause increases in new equity issuance, Tobin's Q, and real investment, as predicted by the model.

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## 1. Introduction

Research on asset prices is increasingly sympathetic to the idea that stock price bubbles are possible. Some theories of bubbles rely on a common bias in investors' beliefs. But there also exists an important class of theories in which bubbles can arise even when beliefs are, on average, unbiased. If pessimists are constrained in their ability to short, then prices disproportionately reflect the beliefs of optimists, thus causing prices to rise above their fundamental value.<sup>1</sup> That stock price bubbles could arise under these conditions has been pointed out by Miller (1977) and Chen et al. (2002), among others. Refinements and extensions have also been examined, including the effect of dynamic speculative trading (Harrison and Kreps, 2004) and the endogenous formation of heterogeneous beliefs (Scheinkman and Xiong, 2003).<sup>2</sup> This type of stock price bubble is the focus of this paper.

What should corporate managers do when they believe that their firms' stock prices are inflated for the above reasons? In particular, what should they do when, as in the above setting, investor beliefs are dispersed and the pessimists cannot short the stock?<sup>3</sup> We make two key observations. First, unlike other agents, firms are unconstrained in their ability to sell short—they can simply issue new shares. Second, in contrast to textbook models of corporate finance, the above environment implies that firms face downward-sloping demand curves for new share issues. Consequently, since the firm is a monopolist in the supply of its own shares and since resale in the secondary market prevents price discrimination, the optimal quantity of shares issued is that which equates marginal revenue with marginal cost. This occurs where price is above fundamental value. Thus, somewhat counter-intuitively, the bubble survives the firms attempt to exploit it.

We derive a model to investigate the effect of exogenous changes in the dispersion of investor beliefs on equilibrium stock prices, financing behavior, and real

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<sup>1</sup>Of course, this class of models does not *preclude* the possibility that average beliefs are also biased. Such a bias provides a second source of bubbles that we do not examine.

<sup>2</sup>See also Lakonishok et al. (1994); Shleifer and Vishny (1997); Duffie et al. (2001); Hong and Stein (2003) and Allen et al. (2003). For more general surveys of behavioral asset pricing models, see Barberis and Thaler (2003), Hirshleifer (2001) and Shleifer (2000).

<sup>3</sup>Stein (1996) explores rational capital budgeting in the presence of irrational market prices. Focusing on the firm's investment decision, he assumes that the market has a biased view of the firm's future. In this class of problems, our paper considers the special case when market pricing irrationalities are generated by heterogeneous beliefs and short-sale constraints (as in Miller, 1977).

investment. An important assumption in the model is that investors agree on the value of cash on the firms balance sheet. That is, investor disagreement about the value of the firm applies only to the firms operating assets. This assumption eliminates the manager's incentive to use the proceeds from the issuance of over-valued stock to invest in cash, marketable securities, dividend payments, or retirement of the firms own debt. There remains, however, a real distortion: managers over-invest in operating assets because the market over-values them.

The model's quantitative predictions are perhaps surprising. Most notably, it is possible to generate large stock price bubbles with relatively small distortions to financing activity and real investment. Roughly speaking, this happens when the demand curve for new shares is steep. Analogous to the monopolist's problem, a steep demand curve implies a high price over marginal cost and therefore also accompanied by a large bubble. This large bubble, however, is accompanied by a small quantity of new shares issued and therefore also accompanied by a small reduction in the cost of capital. This arguably provides a good description of many stocks that were often described as bubbles during the tech boom of the late 1990s. Despite sky-high valuations, firms like Amazon and Yahoo, for example, issued a surprisingly small fraction of total equity to the public. Such behavior is consistent with our model. For policy makers, these findings suggest that while large stock price bubbles can have real consequences, they may be less distortionary than one might otherwise think.

A recent paper by Diether et al. (2002) uses the dispersion of a firms stock analysts' forecasts of its future earnings to proxy for the dispersion of investors' beliefs about the fundamental value of the firm.<sup>4</sup> Their proxy for bubbles is clean in ways that others are not. Lagged stock returns, Tobin's Q, market-to-book ratios, and new equity issues, for example, have all been used in past research to identify over-valued equity, but these variables are difficult to interpret in regressions. They also endogenously reflect shocks unrelated to bubbles, such as information about the firms investment opportunities. Consistent with the view that a high dispersion of investor beliefs interacts with short-sale constraints to cause overvaluation, Diether et al. find that high-dispersion stocks have abnormally low future returns

The dispersion proxy derived in Diether et al. allows for a direct test of our model predictions. Using their data to construct similar proxies, we find the following results. First, as predicted by the model, aggregate dispersion is correlated with aggregate measures of Tobin's Q, net new share issuance, and real investment. Second, exploiting the panel dimension of the data, we estimate vector autoregressions (VARs) and identify dispersion shocks orthogonal to current investment opportunities. Again, as predicted by the model, the impulse response functions for Tobin's Q, higher equity issuance, and higher real investment are all positive in response to positive dispersion shocks. Finally, the variance decomposition from the estimated VAR reveals that, as a fraction of the explainable variation in the data, dispersion shocks have a large impact on equity issuance, a modest impact on Tobin's Q, and a relatively small impact on real investment. These relative

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<sup>4</sup>See also Park (2001).

magnitudes are consistent with another important quantitative property of our model, namely that large bubbles do not necessarily imply large investment distortions.

Recent research in finance provides additional empirical support for our model assumptions. Most notably, Diether et al. (2002) report that high dispersion forecasts low future returns. A portfolio of stocks in the highest quintile of dispersion underperforms a portfolio of stocks in the lowest quintile of dispersion by 9.48% per year. Chen et al. (2002) report related evidence. Instead of using data on analysts' forecasts, they define a measure of "breadth" based on the number of funds prevented from taking a short position due to legal constraints. They find that "short-constrained" stocks have low future returns. Additional evidence on the price effects of short-sale constraints is provided by Jones and Lamont (2002). They show that stocks that were expensive to short during the 1920s and 30s delivered lower returns than other stocks. Using more recent data, Ofek and Richardson (2003) report that the spring 2000 collapse of the internet bubble coincided with a substantial supply of new shares created by the expiration of lock-up restrictions. Finally, D'Avolio's (2002) detailed description of the market for borrowed stock provides extensive direct evidence that short selling is costly.

Polk and Sapienza (2002) also attempt to measure the distortionary effect of stock price bubbles on real investment. They argue that new equity issues, discretionary earnings accruals, and lagged returns can be used as proxies for bubbles. Using Tobin's Q to control for investment opportunities, they find that, consistent with their predictions, these bubble proxies enter positively and statistically significantly in a regression for investment.<sup>5</sup> While many of their results are consistent with our model's predictions, their use of Tobin's Q to control for investment opportunities is problematic. In our model Tobin's Q simultaneously depends on the bubble. This fact contaminates the estimated coefficient on the bubble proxy which in theory could even be serious enough to produce the "wrong" sign. Our dispersion proxy, by contrast, avoids this problem, and our econometric approach further minimizes such endogeneity concerns about investment opportunities.

Panageas (2004) similarly argues that Tobin's Q cannot be used to proxy for investment opportunities. In his model, the marginal investor has infinite wealth. As a result, share issuance has no marginal effect on price, new share issuance is indeterminate, and Tobin's Q is a sufficient statistic for investment even in the presence of bubbles. By contrast, in our model, the downward-sloping demand for shares drives a wedge between average and marginal Q, and Tobin's Q is no longer a sufficient statistic for investment.

Evidence in favor of a downward sloping demand for shares is documented by Asquith and Mullins (1986), who report that equity prices drop following announcements of secondary stock offerings. Additional evidence is offered in Scholes (1972) and Holthausen et al. (1990), who study block trades, Shleifer (1986),

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<sup>5</sup>Polk and Sapienza (2002) also point out that abnormally high investment levels may be caused in part by stock bubbles, in which case they should predict low subsequent returns. This is indeed what they find.

who studies additions to the S&P 500 index, Loderer et al. (1991), who examine share issues, and Bagwell (1992), who studies Dutch auction repurchases.

Several other empirical papers are related in various ways. Motivated in part by the possibility of bubbles in stock prices, Mørck et al. (1990a, b) and Blanchard et al. (1993) compare the responsiveness of investment to Tobin's Q and fundamentals, and broadly conclude that investment is driven primarily by fundamentals.<sup>6</sup> Chirinko (1996) and Chirinko and Schaller (2001) implement similar tests by including both fundamental and market Q measures, but conclude instead that the evidence favors the existence of bubbles. Erickson and Whited (1999) and Bond and Cummins (2000) estimate investment-Q equations and speculate that stock price bubbles are a likely source of measurement error in Tobin's Q.<sup>7</sup>

The next section of the paper begins by exploring the implications for firm behavior of a simple equilibrium model of heterogeneous investor beliefs under short-selling constraints. Section 3 describes the data and econometric approach and is followed by a description of our empirical results. Section 4 concludes.

## 2. A model of real investment, equity issuance, and bubbles

This section develops a simple model of firm behavior when investors with heterogeneous beliefs face short-selling constraints in the equity market.<sup>8</sup> The first step is to aggregate heterogeneous portfolio demands of individuals to obtain the demand for new shares facing the firm. Demand is shown to be increasing in the degree of dispersion in beliefs. A manager who is fully rational and aware of this demand curve, will issue new shares while taking into account the effect this has on the stock price. Comparative static exercises show that increased dispersion not only leads to new share issuance but also to a lower cost of capital and to an increased real investment. Increased dispersion also increases the equilibrium value of Tobin's Q. This happens, in part for the usual Q-model reason, namely that the marginal adjustment costs of investment have risen (e.g., Hayashi, 1982). But Tobin's Q is also higher because the bubble has increased. The section concludes with a discussion of the model's empirical implications.

### 2.1. The demand for new share issues

We assume that an investor's demand for shares is driven by the difference between perceived value and current price. For simplicity, we rule out speculative

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<sup>6</sup>Baker et al. (2003) similarly ask whether some firms are intrinsically more dependent on equity for their external financing, and thus more sensitive to stock prices.

<sup>7</sup>Less closely related to our article are papers that examine the behavioral biases of *executives* rather than market prices, and ones that explore the potential impact on corporate investment decisions. Heaton (1999) develops a model in which CEOs are both overconfident and overoptimistic. Malmendier and Tate (2001) use the timing of stock option exercise to measure overconfidence. Bertrand and Schoar (2002) report evidence that CEOs appear to have managerial "styles" that accompany them when they change jobs. By contrast with these papers, we assume managers have rational (unbiased) expectations.

<sup>8</sup>We are grateful to Andy Abel for encouraging us to formalize our arguments in the context of "the world's simplest Q model."

demand based on the difference between the current and the likely future price of shares. In contrast to investors, the manager has unbiased beliefs about the firms “fundamental” value, denoted by  $V$ .

Heterogeneous investor valuations are denoted by  $vV$ , where  $v \in [0, \infty]$  is a random variable that measures idiosyncratic variation in investors beliefs. Let  $P$  denote the market value (price) of the firm. We assume the investor’s portfolio demand for a firms shares (i.e., the fraction of the investor’s wealth invested in the firm) is given by

$$\omega_v = \gamma(vV - P). \tag{1}$$

Cross-firm variation in  $\gamma$  may also arise from differences in attitudes toward risk, such as limits to diversification. For example, firms prone to agency problems may require less diversified investors for incentive reasons and may therefore have a higher  $\gamma$ .<sup>9</sup> As shown below, the size of real distortions depends on  $\gamma$ .

Multiplying Eq. (1) by investor wealth,  $W$ , and dividing by the market value of the firm,  $P$ , translates the investor’s demand from a fraction of investor wealth to a fraction of firm value,  $n_v = \gamma W(vB^{-1} - 1)$ , where  $B = P/V$ . We refer to  $B$ —the ratio of price over fundamental value—as the “bubble.” Without loss of generality, we assume  $W = 1$ .

Under short-selling constraints, the only investors who take non-zero positions in the stock are those for whom  $vV \geq P$ , or  $v \geq B$ . Hence, assuming  $v$  has the distribution function  $F(v; \sigma)$ , the aggregate demand for shares is

$$n^d(B; \sigma, \gamma) = \gamma \int_B^\infty (vB^{-1} - 1) dF(v; \sigma). \tag{2}$$

To characterize this demand function we assume that  $v$  is log-normally distributed with  $\ln v \sim N(-0.5\sigma^2, \sigma^2)$ , so that  $E(v) = 1$ . This normalization imposes the assumption that average beliefs are unbiased. It also implies that the net demand for shares is zero when the ratio of price to fundamental value equals one and short-sale constraints are not binding. Let  $\phi$  and  $\Phi$  denote the p.d.f. and c.d.f. of the standard normal distribution respectively, and  $b$  denote a normalized log transformation of  $B$ :

$$b \equiv \frac{\ln B + 0.5\sigma^2}{\sigma}. \tag{3}$$

Using properties of the log-normal distribution, Eq. (2) can be expressed as

$$n^d(B; \sigma, \gamma) = \gamma(1 - \Phi(b)) \left[ \frac{h(b)}{h(b - \sigma)} - 1 \right], \tag{4}$$

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<sup>9</sup>Although a number of empirical studies attempt to compute the price elasticity of demand with respect to share issues, these numbers are difficult to interpret because it is difficult to control for news effects. We are not aware of any studies providing estimates from which we could infer the model parameter  $\gamma$ .

where  $h(b)$  denotes the hazard rate for the standard normal distribution:

$$h(b) \equiv \frac{\phi(b)}{1 - \Phi(b)}.$$

The first term in Eq. (4) measures the mass of market participants as a function of the bubble  $B$ . The second term in Eq. (4),  $h(b)/h(b - \sigma)$ , measures the average demand conditional on market participation.<sup>10</sup> Because the hazard rate is strictly increasing, the ratio  $h(b)/h(b - \sigma)$  is greater than one. Hence market demand is strictly positive for  $B > 0$ . As the bubble increases, market participation falls while demand conditional on participation rises. On net, the first effect dominates and demand for share falls.

Inverting the demand curve in Eq. (4) solves for  $B$  as a function of the number of shares issued. We denote the fraction of total shares supplied to the public by  $n$ , and let  $B(n; \sigma)$  denote the inverse demand function. In a working paper version of this paper, we show that this inverse demand curve slopes downward in the size of the equity issue, and that it shifts outward in response to an increase in dispersion.<sup>11</sup>

Specifically, the partial derivatives satisfy

$$B_n = \frac{-B^2}{\gamma(1 - \Phi(b - \sigma))} < 0, \quad (5)$$

and

$$B_\sigma = Bh(b - \sigma) > 0. \quad (6)$$

The derivatives in Eq. (5) and (6) lead to simple expressions for the respective demand elasticities. In particular, the inverse-price elasticity of demand  $\eta_n \equiv -\partial \ln B / \partial \ln n$  is

$$\eta_n = 1 - \frac{h(b - \sigma)}{h(b)}. \quad (7)$$

Since the ratio  $h(b - \sigma)/h(b)$  is bounded between zero and one, the inverse-demand curve is inelastic over its entire range. The semi-elasticity of the bubble with respect to dispersion,  $\eta_\sigma \equiv \partial \ln B / \partial \sigma$ , is

$$\eta_\sigma = h(b - \sigma).$$

The shift in demand caused by an increase in dispersion depends on the degree of truncation, and hence the hazard rate of the normal distribution evaluated at the bubble. To understand the implications of such a demand shift for investment, we now turn to the firms problem.

<sup>10</sup>To obtain Eq. (4), we note  $1 - \Phi(B - \sigma) = E(v|v > B) \Pr(v > B)$  so that Eq. (2) may be written as

$$n^d(B; \sigma, \gamma) = \gamma[(1 - \Phi(b - \sigma))B^{-1} - (1 - \Phi(b))]$$

(see Johnson et al., 1994). Eq. (3) may be equivalently expressed as  $B = \phi(b - \sigma)/\phi(b)$ . Inserting this expression into  $n^d(B; \sigma)$  yields the result.

<sup>11</sup>The appendix provided in Gilchrist et al. (2004) establishes a number of mathematical results used in the model section.

2.2. *Equity issuance and the equilibrium price bubble*

Let the value of installed capital,  $K$ , be given by

$$V(K) = \Pi(K) + (1 - \delta)K, \tag{8}$$

where  $\Pi(K)$  is the firms variable profit function and  $\delta$  is the depreciation rate on capital. To install new capital, the firm incurs an adjustment cost  $\frac{1}{2}\psi K^2$ . Rational managers choose  $K$  to maximize the true value of the firm from the perspective of old shareholders.<sup>12</sup> Managers can finance this investment using risk-free debt at the rate  $r$ , or, fully recognizing the downward-sloping demand for new shares, they can issue new equity by selling a fraction  $n$  of the firms equity. They can invest the proceeds in  $K$ , or pay them out as a dividend to the old shareholders. The market value of equity is given by  $B(n; \sigma)V(K)$ , so proceeds from new equity issues are given by the discounted value of the new shareholders' claim, or

$$X = \frac{1}{1+r} nB(n; \sigma)V(K). \tag{9}$$

Thus the firms optimization problem is

$$\max_{K, X, n} -K - \frac{1}{2} \psi K^2 + X + (1 - n) \frac{1}{1+r} V(K) \tag{10}$$

subject to Eq. (4). Note that the future value of the firm in Eq. (10) is multiplied by  $1 - n$  to reflect the dilution of old shareholders.

The first-order condition for equity issuance derived from Eq. (10) implies

$$B(n; \sigma) + nB_n(n; \sigma) = 1. \tag{11}$$

Applying the result that the inverse demand curve is downward sloping ( $B_n < 0$ ), it follows that the bubble satisfies  $B > 1$  when the firm is issuing new shares ( $n > 0$ ).

The firm is a monopolist in the supply of its own shares, hence the share-issuance decision is analogous to the standard monopoly problem. In Eq. (11) marginal cost is unity while marginal benefit equals  $B(n; \sigma) + nB_n(n; \sigma)$ . These costs and benefits are proportional to  $V(K)$ , which therefore drops out of the equation.<sup>13</sup> The result that the bubble is positive in equilibrium is analogous to the result that a monopolist always sets price above marginal cost. Thus a key feature of our model is that the firm issues new shares but never drives the bubble down to its fundamental value.

<sup>12</sup>For example, managers might own a stake in the firm for incentive reasons, in which case their incentives are to act on behalf of old rather than new shareholders.

<sup>13</sup>Because share issuance represents a dilution of the claims of existing share holders, the marginal cost of issuance is proportional to  $V(K)$ , the fundamental value of the firm. Similarly, because heterogenous beliefs are defined relative to fundamental value, the marginal benefit of issuance is also proportional to  $V(K)$ .

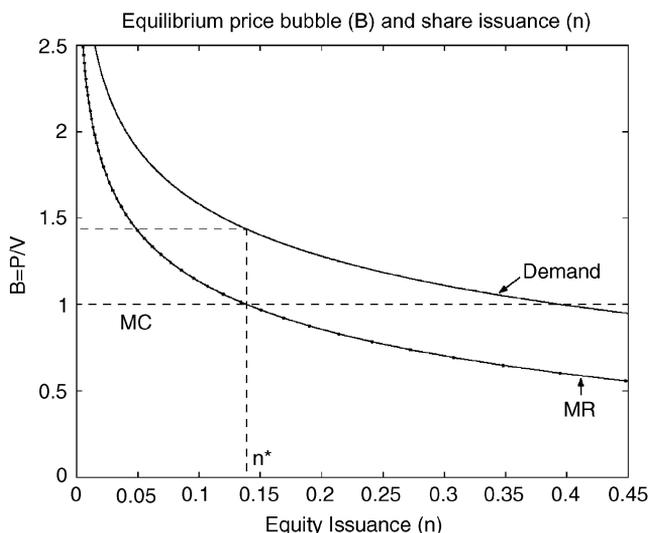


Fig. 1. Equilibrium price bubble ( $B$ ) and share issuance ( $n$ ).

Applying Eq. (7), the equilibrium price satisfies<sup>14</sup>

$$B(\sigma) = \frac{h(b)}{h(b - \sigma)}. \tag{12}$$

Eq. (12) defines a unique mapping  $B(\sigma)$ , that is, for any  $\sigma > 0$  there is a unique equilibrium price  $B$ <sup>15</sup> Given the equilibrium price  $B(\sigma)$ , the equilibrium value of equity issuance is determined by

$$n(\sigma, \gamma) = \gamma(1 - \Phi(b))(B(\sigma) - 1). \tag{13}$$

This equilibrium is depicted in Fig. 1, which plots the market demand curve and the marginal revenue curve for new equity issuance for the parameter values  $\sigma = 0.5$  and  $\gamma = 1$ . Equilibrium equity issuance is denoted by  $n^*$ . For these parameter values, the equilibrium stock price is overvalued by nearly 50%, and the firm sells around 14% of its equity to the public. Note that the equilibrium stock price in Eq. (12) is solely determined by the level of dispersion, whereas the equilibrium size of the

<sup>14</sup>From the monopolist’s viewpoint, the bubble is analogous to the markup of price over marginal cost, where the marginal cost of new share issues is unity. The equilibrium bubble in Eq. (11) can be expressed as a relationship between the markup and the inverse demand elasticity:

$$B = \frac{1}{1 - \eta_n}.$$

<sup>15</sup>Eq. (12) implies that the equilibrium value  $B(\sigma)$  is independent of other model parameters, notably the demand parameter  $\gamma$ . Thus, a monopolist facing a demand curve of the form specified in Eq. (4) chooses a constant markup that only depends on demand characteristics through  $\sigma$ , the degree of consumer heterogeneity. This result can be applied to a variety of consumer settings characterized by a log-normal distribution of underlying demand characteristics.

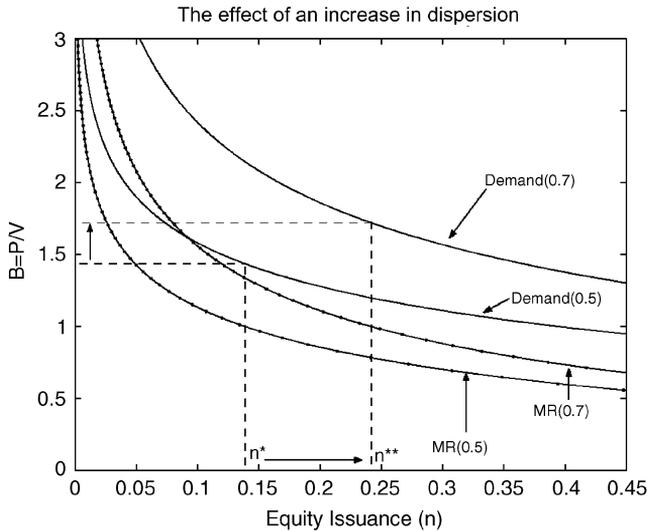


Fig. 2. The effect of an increase in dispersion.

equity issue depends not only on dispersion but also on the parameter  $\gamma$ . Thus, for any size bubble, the size of the equity issue is arbitrarily small or large, depending on the value of  $\gamma$ .

We next consider the effect of an increase in dispersion on the equilibrium bubble  $B$  and equity issuance  $n$ . Totally differentiating Eq. (12) yields

$$\frac{dB}{d\sigma} = \frac{B[b[h(b - \sigma) + \sigma - h(b)] + \sigma[h(b) - b]]}{\sigma + [h(b - \sigma) + \sigma - h(b)]} > 0. \tag{14}$$

Thus an increase in dispersion causes an increase in the equilibrium size of the bubble.<sup>16</sup> We further establish that

$$\frac{d \ln B}{d\sigma} < h(b - \sigma) = \eta_\sigma. \tag{15}$$

In words, the equilibrium response of the bubble to an increase in dispersion is less than the implied elasticity obtained from the demand curve. Intuitively, a firm issues new equity in response to an increase in dispersion, partially offsetting the effect of a rise in  $\sigma$  on price. To formally see the effect of an increase in dispersion on equity issuance, we totally differentiate Eq. (13) to obtain

$$\frac{dn}{d\sigma} = \gamma \frac{[(1 - \Phi(b - \sigma))]}{B} \left( h(b - \sigma) - \frac{d \ln B}{d\sigma} \right) > 0. \tag{16}$$

As shown in Fig. 2, an increase in dispersion from  $\sigma = 0.5$  to  $\sigma = 0.7$  causes an outward shift in the market demand for shares and increases the equilibrium size of

<sup>16</sup>To establish the inequality  $dB/d\sigma > 0$ , we rely on the fact that the hazard rate  $h(b)$  is log-concave so that  $h(b - \sigma) + \sigma - h(b) > 0$ . See the appendix for full details of the derivation of Eqs. (14) and (15).

the bubble. It also increases the fraction of equity issued (from  $n^*$  to  $n^{**}$ ). As shown in Eq. (13), equity issuance depends on both the average demand per participant,  $\gamma(B-1)$ , and the percentage of market participants,  $1-\Phi(b)$ . The rise in demand per participant increases enough to offset the drop in market participation, and an increase in dispersion causes an increase in share issuance.

### 2.3. Investment and the cost of capital

It is straightforward to show that an increase in dispersion leads to a lower cost of capital and an increase in investment. The first-order condition with respect to capital from the firms problem in Eqs. (9) and (10) is

$$1 + \psi K = \frac{1 + n(B-1)}{1+r} V_k. \quad (17)$$

For the case where there is no bubble ( $B=1$ ), Eq. (17) simplifies to  $1 + \psi K = (1/(1+r))V_k$ . This is the usual first-order condition for investment, which says that the firm invests up to the point where the marginal cost of investment,  $1 + \psi K$ , equals the discounted marginal value of capital,  $(1/(1+r))V_k$  (or marginal  $Q$ ).

To see the effect of the bubble on the cost of capital, consider the case of no adjustment costs ( $\psi=0$ ). Using Eq. (8) to substitute for  $V_k$ , Eq. (17) can be written

$$\Pi_k = \frac{1+r}{1+n(B-1)} - (1-\delta). \quad (18)$$

This expression reveals the effect of the bubble on the Jorgensonian cost of capital, which is defined as the right side of Eq. (18). When  $n(B-1)$  is zero (that is, when there is no bubble or when there is a bubble but the firm does not issue), Eq. (18) is the familiar optimality condition which sets the marginal profitability of capital equal to its user cost. That is,  $\Pi_k = r + \delta$ .

If, however, the bubble is positive *and* the firm actively exploits the bubble by issuing shares, then this has the effect of reducing the cost of capital. Assume  $r=0.10$  and  $\delta=0.10$ , so that in the absence of bubbles the baseline cost of capital is 20%. Consider again the numerical example illustrated in Fig. 1. Here, the level of dispersion is  $\sigma=0.5$ , which causes an equilibrium bubble of  $B=1.4$  and an optimal equity issuance of  $n=0.14$ . Then according to Eq. (18), the bubble reduces the Jorgensonian cost of capital from 20% to 14.2%. This distortion depends not only on the size of the bubble but also on the size of new share issues. To see this, reduce the value of  $\gamma$  by half (to  $\gamma=0.5$ ). The magnitude of the bubble is identical ( $B=1.4$ ), but now it is optimal for the firm to issue only half as much equity as it issued before ( $n=0.07$  instead of  $n=0.14$ ). For the same size bubble, the distortion is smaller; the Jorgensonian cost of capital is reduced from 20% to 17.0%. In short, as shown in Eq. (18) and as illustrated in this example, the magnitude of the bubble is not sufficient to reveal the distortion of the cost of capital. Firms with small  $\gamma$  have little incentive to issue new shares. For such firms, large bubbles could theoretically persist in equilibrium while having only a small impact on the cost of capital.

Finally, in the more general case of non-zero adjustment costs for investment, it is useful to write Eq. (18) as

$$\frac{\Pi_k + 1 - \delta}{1 + \psi K} = \frac{1 + r}{1 + n(B - 1)}. \quad (19)$$

An increase in dispersion causes the equilibrium values of  $B$  and  $n$  to increase, so that the right side of this equation is decreasing in dispersion. Assuming that the marginal profit of capital,  $\Pi_k$ , is weakly decreasing in  $K$ , the left side of this equation is monotonically decreasing in  $K$ . Hence, an increase in dispersion clearly implies higher investment.

#### 2.4. Tobin's Q

Tobin's Q is defined as the ratio of the market value of equity to the replacement value of capital, which in the notation of the model is

$$Q \equiv \frac{BV}{K}. \quad (20)$$

In other words, the value of Tobin's Q is the usual (fundamental) average value of installed capital,  $V/K$ , multiplied by the bubble,  $B$ . Under Hayashi's (1982) assumptions, profits are homogenous of degree one, which implies that  $V_k = V/K$  (that is, marginal Q equals Tobin's Q) and lets us write Eq. (20) as  $Q = BV_K$ . That is, Tobin's Q is just true marginal Q times the size of the bubble. To solve for the relationship between investment and Tobin's Q (as opposed to marginal Q), use this expression to replace  $V_K$  in the first-order condition for investment (Eq. (17)) to get

$$Q = (1 + \psi K) \left( \frac{1 + r}{1 + n(B - 1)} \right) B. \quad (21)$$

In the absence of a bubble ( $B = 1$ ), this equation reproduces Hayashi's (1982) well-known result that the equilibrium value of Tobin's Q equals one plus the marginal cost of adjustment, denoted here by  $\psi K$ . When the bubble is positive, however, the numerator of the Q-investment relationship in Eq. (21) contains an additional term,  $B$ , which reflects the wedge between the valuations of the manager and the marginal (overly optimistic) outside investor. When making real investment decisions, managers ignore this wedge because they only care about future fundamental value, not market value. Hence, the equilibrium value of Tobin's Q exceeds one for two reasons: first, adjustment costs, and second, bubbles.

This characterization of Tobin's Q has two interesting implications (beyond providing testable implications of the model). First, even though firms exploit the bubble by issuing new shares and increasing real investment, this does not drive Tobin's Q down to the marginal cost of investment. Hence, previous research is justified in using Tobin's Q (or market-to-book ratios) as a proxy for bubbles, although econometricians still need to recognize that Q also reflects investment opportunities. Second, because Tobin's Q partly reflects the magnitude of the bubble, regressions of investment on "bubble proxies" using Tobin's Q to control for

investment opportunities are likely to be highly misleading. To see this formally, consider a linear approximation of Eq. (21), which yields  $Q \simeq \psi K + (1 - n)B$ . Inverting this equation to solve for investment ( $K$ ) reveals that the predicted coefficient on the “bubble” term is actually *negative*. The intuition for this result reflects the wedge between the average and marginal value of the bubble mentioned in the previous paragraph. That is, the coefficient on the bubble term is negative because the regression wants to adjust Tobin’s  $Q$  downward by the amount of this wedge between Tobin’s  $Q$  and marginal  $Q$ , and this wedge is proportional to the bubble. Hence, conditional on Tobin’s  $Q$ , bubble proxies would enter negatively. Failing to recognize this could obviously lead to a faulty inference.

Summarizing these results, heterogeneous beliefs and short-selling constraints can generate bubbles. When the distribution of investor valuations is lognormal, increases in dispersion increase both the size of the bubble and the amount of new equity issued. This lowers the cost of capital and therefore stimulates investment. The magnitude of the bubble alone is not sufficient to determine the magnitude of this distortion. Rather, it is the interaction between the bubble and the fraction of new equity issued that matters. Finally, we show that the equilibrium value of Tobin’s  $Q$  is increasing in not only the rate of investment but also in the size of the bubble. Thus, our results provide support for the common practice of using Tobin’s  $Q$  (or market-to-book ratios) as indirect measures of stock price bubbles. By the same logic, our model cautions against using Tobin’s  $Q$  as a proxy for investment opportunities when testing for the effects of bubbles on real investment.

### 3. Empirical analysis

Our empirical analysis focuses on the predicted causal relation running from the dispersion of investor beliefs to net equity issuance, real investment, and Tobin’s  $Q$ . We first compare trends in dispersion, new equity issues, Tobin’s  $Q$  and investment over the period 1986–2000.<sup>17</sup> We divide firms into those listed on the New York Stock Exchange and those listed on Nasdaq, because the stock price movements of the latter are commonly thought to have been driven by bubbles (more so than the former). We then consider a more detailed analysis of the data at the firm-level where it is easier to control for a firm’s investment opportunities.

The discussion in the previous section highlights the difficult identification issues presented by the  $Q$  framework. Specifically, because net equity issuance, Tobin’s  $Q$ , and real investment all respond endogenously to dispersion, one cannot econometrically identify the existence or magnitude of bubbles by regressing real investment on Tobin’s  $Q$  and new share issues. Our empirical strategy addresses this identification problem by pursuing two ideas. First, following Diether et al., the variance of analysts’ earnings forecasts arguably provides a good proxy for the dispersion of investor opinion about a firm’s stock value. This variable is ideally suited for testing our model, because it solely determines the magnitude of the

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<sup>17</sup>This time frame is set by data availability.

bubble in equilibrium. It is furthermore desirable because, in contrast to bubble proxies used in previous research (e.g., equity issues or lagged stock returns), there is no obvious reason why dispersion should be correlated with investment opportunities. The second ingredient in our empirical strategy is a recursively ordered VAR which further isolates and identifies the exogenous component of our dispersion proxy. This approach is a (minimally) structural attempt to improve identification.

Annual, firm-level data are gathered from two sources. First, Compustat is used to construct both aggregate and firm-level measures of the rate of investment,  $I_t/K_t$ , net new equity issuance as a fraction of total equity,  $neq_t$ , Tobin's Q ratio,  $Q_t$ , and the marginal product of capital,  $mpk_t$ . The appendix in Gilchrist et al. (2004) provides more complete details on the construction of these variables.

Second, data on analysts' earnings forecasts available from IBES are used to construct aggregate and firm-level measures of the dispersion of investor opinion. Diether et al. (2002) show that historical IBES data suffer from measurement errors induced by the truncation of significant digits. To fix this problem, they collect original source data from IBES, which they graciously shared with us. Unfortunately, these data do not extend beyond the year 2000. Therefore, to maximize the length of our time series, we use the standard IBES data in our aggregate analysis (these data extend through 2002). At the firm level, however, we use the bias-free IBES data because the added time dimension is not as critical, whereas the bias identified by Diether et al. is potentially severe.

At the firm level, our annual proxy for dispersion exploits all of the forecasts issued by analysts over the year. Dispersion is defined as the logarithm of the fiscal year average of the monthly standard deviation of analysts' forecasts of earnings per share, times the number of shares, scaled by the book value of total assets. That is,

$$d_t = \log \left( \frac{\sum_{j=1}^{12} N_{t-j} SD_{t-j} / 12}{Total\ Assets_t} \right),$$

where  $N_{t-j}$  is the number of shares outstanding, and  $SD_{t-j}$  is the standard deviation of the per-share earnings forecasts for all analysts making forecasts for month  $j$  (we use the value of  $SD_t$  as reported on the IBES summary tape).

Finally, to reduce the effect of outliers, we set the variables  $I_t/K_t$ ,  $Q_t$ ,  $d_t$ , and  $mpk_t$  to missing if their values are below zero or higher than their 99th percentile;  $neq_t$  is trimmed at the 1st and 99th percentiles. Observations are also dropped if the lag between consecutive fiscal-year-ends is not exactly 12 months. The final sample contains 22,522 non-missing firm-year observations, of which 18,421 have non-missing values for the first two lags as well. Aggregate variables are constructed by taking equal-weighted averages of the firm-level data.

### 3.1. The 1990s boom: Nasdaq versus NYSE

Fig. 3 plots the time-series averages of dispersion, Tobin's Q, the sales to capital ratio (a measure of MPK), the investment rate and net equity issuance for the sub-samples of firms listed on Nasdaq versus NYSE over the period

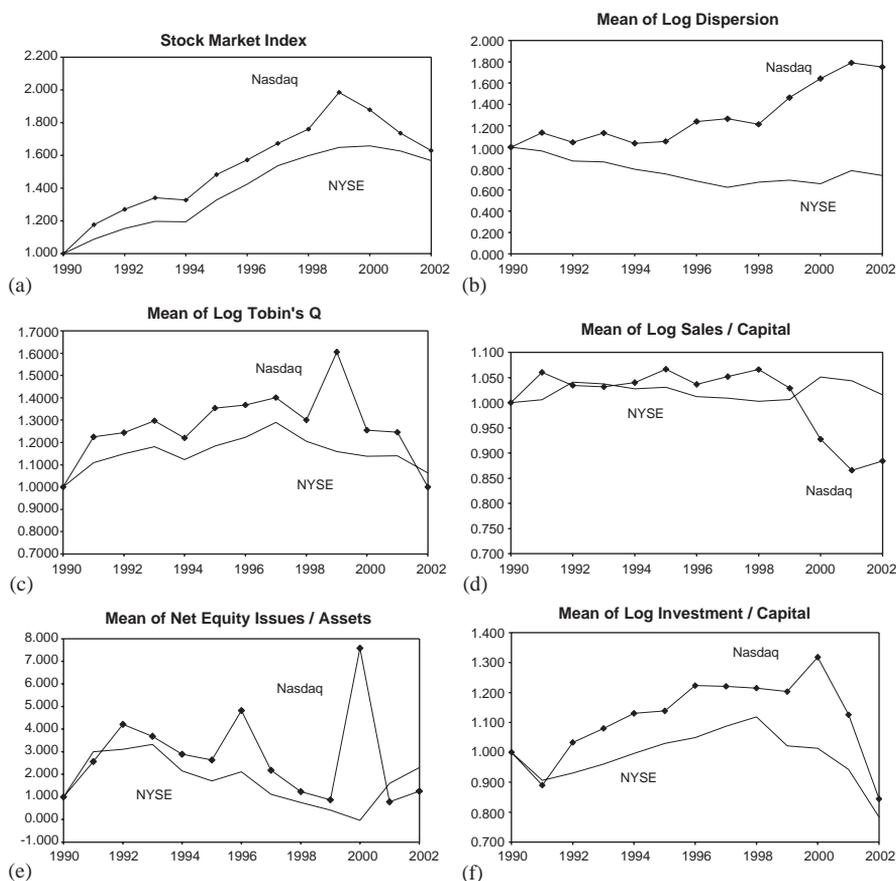


Fig. 3. Comparison of Nasdaq vs. NYSE firms for the time period 1990–2002. Figure (a) plots the stock market index. Figures (b)–(f) plot the log of the (trimmed) sample means in each year, normalized to one in 1990.

1990–2002.<sup>18</sup> For comparison's sake, we also plot the Nasdaq versus NYSE stock price indices as well.

Nasdaq firms experienced a steady increase in dispersion relative to NYSE firms over the period 1990–2001, followed by a slight decline in 2002.<sup>19</sup> Nasdaq firms experienced a steady increase in their investment rate relative to NYSE firms over most of this period. Nasdaq firms also show a relatively sharp increase in both

<sup>18</sup>With the exception of the net-equity issuance, we report the mean of the log of all variables for each sub-sample. For all variables, we trim outliers using a 1% of cutoff rule applied to the combined NYSE and Nasdaq sample.

<sup>19</sup>Because of reporting issues with IBES vs. Compustat, we lose approximately 20% of our observations in the last year of the sample. Thus the mean dispersion estimates for 2002 may not be entirely representative. Consistent with the idea that increases in dispersion contributed to the stock market boom, using medians rather than means, we see a sharper reduction in dispersion in the last year of our sample.

Tobin’s Q and net equity issuance during the later part of the boom. This sharp increase coincides with a rise in the growth rate of dispersion for the 1998–2001 period. Although timing between these variables is not exact, the latter part of the 1990s is characterized by sharp increases in dispersion, Tobin’s Q, net equity issuance, and investment for Nasdaq firms relative to NYSE firms. These patterns are broadly consistent with our model’s predictions.

The divergence in investment rates between Nasdaq and NYSE firms is difficult to explain based on investment fundamentals alone (as measured by the sales to capital ratio). In fact, during the early sample period, there is little difference between the marginal product of capital for NYSE versus Nasdaq firms. Then in 1999, MPK for Nasdaq firms begins to collapse while dispersion, Tobin’s Q, new equity issuance, and investment all continue to rise. This is all consistent with the bubble view. To provide additional evidence, we now consider an empirical analysis based on the microeconomic data.

### 3.2. Panel data VAR analysis

We start with a three-variable VAR system, estimated in logs, that includes the marginal product of capital, dispersion and investment. To allow for the possibility that dispersion may contain information about current investment opportunities, we consider the effect of an innovation to dispersion that is uncorrelated with the innovation to MPK.<sup>20</sup> Hence, when computing impulse responses, we use a Choleski decomposition using the ordering  $mpk_t, d_t, I_t/K_t$ .<sup>21</sup>

Table 1 reports the coefficient values of this three-variable VAR system. Table 1 also reports the  $t$ -statistics for the coefficients.<sup>22</sup> Consistent with a key implication of our model, we observe a statistically significant positive link between dispersion and investment, controlling for the marginal product of capital. The marginal product of capital is also highly significant in the investment equation, as we would expect. We also see a positive relation between dispersion and  $mpk$ , a finding which suggests that

<sup>20</sup>Dispersion would contain information about investment opportunities if shocks to fundamentals trigger disagreement among analysts.

<sup>21</sup>Formally, we estimate the model  $y_{it} = Ay_{it-1} + f_i + e_t + v_{it}$ , where  $y_{it} = \{mpk_{it}, d_{it}, I_{it}/K_{it}\}'$ ,  $A$  is a  $3 \times 3$  matrix of coefficients,  $f_i$  is a vector of fixed firm effects, and  $e_t$  is a vector of common time shocks. We estimate the model following the procedure described in Arellano and Bover (1995). Our ordering for the three-variable case implies that the vector of residuals  $v_{it}$  is related to a set of mutually orthogonal structural shocks  $\eta_{it} = \{\eta_{it}^{mpk}, \eta_{it}^d, \eta_{it}^{I/K}\}'$  according to the following recursive structure:

$$\begin{aligned} v_{it}^{mpk} &= \eta_{it}^{mpk}, \\ v_{it}^d &= \rho_{dq}\eta_{it}^{mpk} + \eta_{it}^d, \\ v_{it}^{I/K} &= \rho_{dq}\eta_{it}^{mpk} + \rho_{di}\eta_{it}^d + \eta_{it}^{I/K}. \end{aligned}$$

<sup>22</sup>We do not report  $R^2$  statistics because we estimate the model using instrumental variables.

Table 1  
Estimates of three-variable VAR

	$\ln mpk_t$	$\ln d_t$	$\ln(I/K)_t$
$\ln mpk_{t-1}$	0.933 (30.408)	0.436 (10.920)	0.459 (9.523)
$\ln mpk_{t-2}$	-0.093 (4.117)	-0.229 (7.267)	-0.308 (8.647)
$\ln d_{t-1}$	0.044 (3.996)	0.531 (27.754)	0.091 (4.322)
$\ln d_{t-2}$	0.029 (4.871)	0.121 (10.582)	0.097 (7.948)
$\ln(I/K)_{t-1}$	-0.164 (13.763)	-0.080 (4.416)	0.459 (22.042)
$\ln(I/K)_{t-2}$	0.052 (5.972)	0.087 (6.416)	0.134 (8.266)

Notes: Robust *t*-statistics appear in parentheses. Sample contains 18,421 firm-year observations.

our orthogonalization scheme will be helpful when identifying increases in dispersion that are not related to fundamentals.

Fig. 4 reports the impulse response functions from this three-variable VAR. We report the effects of shocks to  $mpk_t$  which, we interpret as a shock to the fundamental investment opportunities of the firm, and we report the effects of a shock to dispersion, which in our model leads to an increase in the bubble (price relative to fundamentals).

The effect of a one-standard deviation shock to  $mpk_t$  is reported in the first row of Fig. 4. The immediate effect of the shock is to increase both  $mpk_t$  and investment by approximately the same magnitude (0.2), following which both variables return to steady-state at approximately the same rate. This finding implies a unit elasticity between investment and the marginal product of capital following a shock to fundamentals.

The effect of a one standard deviation shock to dispersion is reported in the second row of Fig. 4. Consistent with our model, an innovation to dispersion leads to a pronounced increase in investment. The peak response of investment is on the order of 0.1 percent and occurs in the year following the shock. The increase in dispersion also causes a rise in  $mpk_t$  but, the magnitude is relatively small. Using unit elasticity as a reasonable measure of how investment should respond to fundamentals, most of the increase in investment following a shock to dispersion can be attributed to changes in dispersion that are orthogonal to future  $mpk$ .<sup>23</sup>

<sup>23</sup>If we interpret approximately unit elasticity response of investment to the innovation in  $mpk$  as providing a reasonable measure of how investment responds to fundamentals, then we would attribute 1/3 (0.03 out of 0.1) of the rise in investment to fundamentals following a shock to dispersion. The remaining 2/3 response (0.07 out of 0.1) would be attributable to movements in dispersion not linked to fundamentals.

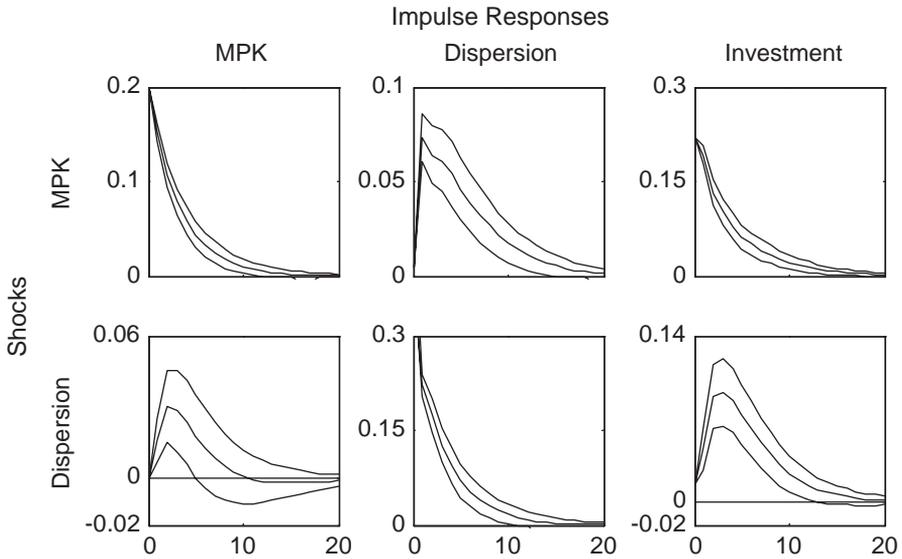


Fig. 4. Impulse response functions for 3-variable VAR model. Response variables appear across columns; shocks appear across rows (only shocks to LMPK and LDSPRA are shown; shocks to LCXK are omitted). Horizontal axis shows 20-year response horizon.

To examine the empirical link between dispersion, Tobin’s Q and net equity issuance, we add these variables to the baseline VAR. For parsimony, we focus on the impulse response functions rather than coefficient values.<sup>24</sup> We again consider innovations based on a Cholesky decomposition using the following ordering:  $[mpk_t, d_t, I/K_t, Q_t, neq_t]$ . The model is again estimated in logs (except for net equity issuance, which is measured as a percentage of equity outstanding). The results are reported in Fig. 5.

The impulse response to a one standard deviation shock to  $mpk_t$  is reported in the first row of Fig. 5. Adding the additional variables does not change the basic relation between fundamentals and investment that we observed in Fig. 4. A shock to  $mpk_t$  leads to a modest rise in Tobin’s Q and a small increase in equity issuance upon impact of the shock. Both of these responses are consistent with the notion that Tobin’s Q and equity issuance respond endogenously to fundamental investment opportunities.

The response of investment and fundamentals to an innovation in dispersion is also similar to the results obtained using the three-variable VAR system albeit slightly weaker. Investment responds with some lag and shows a peak response on the order of 0.08. The increase in  $mpk_t$  is again positive but relatively small in

<sup>24</sup>Our model suggests that in a regression of investment on Tobin’s Q and dispersion, we should find a negative effect of dispersion on investment. Adding Tobin’s Q to the investment equation reduces the coefficient on dispersion but, they remain positive. Because such regressions do not control for the contemporaneous correlations however, we do not necessarily interpret this as a rejection of the model. Rather, it highlights the need for additional identification through the Choleski decomposition.

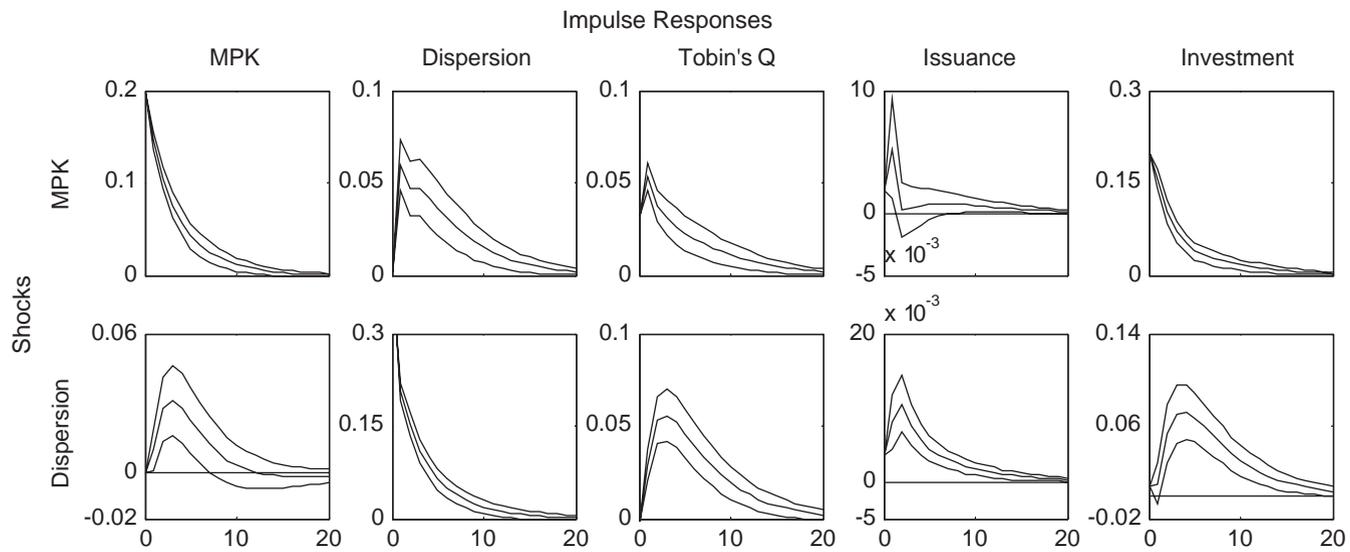


Fig. 5. Impulse response functions for 5-variable VAR model. Response variables appear across columns; shocks appear across rows (only shocks to LMPK and LDSPRA are shown; shocks to LTQ1, ENIV and LCXK are omitted). Horizontal axis shows 20-year response horizon.

magnitude—on the order of 0.04. Again, using unit elasticity as a benchmark, this finding suggests that slightly less than half of the response of investment to the dispersion shock can be explained by the response of fundamentals. The other half is attributable to a non-fundamental component and is therefore consistent with the notion that bubbles drive investment.

The innovation to dispersion leads to an increase in Tobin's  $Q$  and a rise in equity issuance. Both of these responses are consistent with the model's predictions. They are also large in magnitude relative to the investment response. Following a shock to  $mpk_t$ , the peak increase in Tobin's  $Q$  is one third the size of the peak increase in investment. In contrast, following a shock to dispersion, the peak increase in Tobin's  $Q$  is nearly the same size as the increase in investment. The model implies that in the absence of bubbles, investment is a sufficient statistic for Tobin's  $Q$  regardless of the source of the shock. In the presence of bubbles, however, Tobin's  $Q$  should reflect both the increase in investment and the increase in the bubble (see Eq. (21)). This additional impact on  $Q$  through the bubble implies that  $Q_t$  should respond more to dispersion shocks, controlling for investment. The model thus rationalizes the finding that  $\Delta \ln Q_t / \Delta \ln(I_t/K_t)$  is larger in response to shocks to dispersion relative to shocks to  $mpk_t$ .

In both the three-variable and the five-variable VAR results, innovations in dispersion cause increases in investment, Tobin's  $Q$ , and net equity issuance that are consistent with our model predictions. Identification is complicated by the tendency of  $mpk_t$  to respond positively to increases in dispersion, but the response is relatively weak, suggesting that most of the movement in investment,  $Q$  and net equity issuance following a shock to dispersion can be attributed to non-fundamental components, such as dispersion shocks.

Although not reported, we also consider the effects of a shock to Tobin's  $Q$  that is orthogonal to  $mpk_t$  and dispersion. Such a shock also causes an increase in Tobin's  $Q$ , investment, and net equity issuance, but a pronounced fall in  $mpk_t$ . This drop is inconsistent with the view that these impulse responses reflects a rise in fundamentals. It is, however, consistent with the view that the orthogonalized shock to Tobin's  $Q$  reflects a reduction in the cost of capital. Such variation in Tobin's  $Q$  may reflect time-variation in covariance risk, or it may reflect movements in bubbles not driven by dispersion.

To assess the quantitative importance of these results, we compute a variance decomposition of the five-variable VAR based on the above ordering. We report results at the 10-year horizon; similar results are obtained at shorter horizons. Because we control for time dummies and fixed effects in our panel-data framework, these variance decompositions provide information about the within-firm variation only, and hence cannot be used to quantify the importance of bubbles in the aggregate.

Table 2 reveals that most of the variation in each variable is determined by its own shock. The exception is investment, for which fundamentals play the dominant role. Dispersion explains only a small fraction of the total variance of investment. When compared to the fraction explained by Tobin's  $Q$  (7.5 percent), this number is reasonably large however. Dispersion also explains 1.5 percent of the variation in

Table 2  
Variance decomposition at a 10-year horizon

Shocks	Fraction of total variance explained				
	$\ln mpk$	$\ln d$	$\ln Q$	$neq$	$\ln(I/K)$
$\ln mpk$	0.869	0.068	0.153	0.043	0.480
$\ln d$	0.015	0.897	0.015	0.059	0.014
$\ln Q$	0.002	0.012	0.727	0.003	0.075
$neq$	0.002	0.000	0.083	0.884	0.015
$\ln(I/K)$	0.111	0.023	0.021	0.010	0.416

$mpk$  and Tobin's Q. Interestingly, dispersion accounts for more of the variance of net equity issuance (6 percent) than any other variable besides net equity issuance itself. In the absence of mispricing, the firm is indifferent between equity issuance and other forms of finance. Thus, from the model's perspective, it is not surprising that dispersion shocks would account for a large fraction of the variation in share issuance.

The variance decompositions suggest that dispersion only accounts for a small fraction of investment. This finding is not surprising for several reasons. First, as mentioned above, our panel data estimates do not identify the macro variation in the bubble component.<sup>25</sup> Second, analysts are reasonably informed agents. Dispersion in analysts' forecasts is therefore likely to understate the true amount of disagreement in the market place. Finally, the model itself implies that the effect of bubbles on investment will be limited, since the firm is unwilling to fully exploit the bubble in equilibrium.

#### 4. Conclusion

This paper develops a model in which increases in dispersion of investor opinion cause stock prices to rise above their fundamental values. We consider the optimal share issuance and investment decisions of rational managers in response to such mispricing, and also consider how these actions, in turn, influence equilibrium prices. Our model predicts that an increase in dispersion causes increases in Tobin's Q, net new share issues, and real investment. A proxy for the dispersion of investor beliefs is constructed using the variance of analysts' earnings forecasts. Using a recursive ordering of a panel data VAR for identification, we find that shocks to dispersion have positive and statistically significant effects on Tobin's Q, net equity issuance, and real investment. These results all confirm the model's key predictions.

Although we find that dispersion-driven bubbles distort real investment, it is important to note that large stock price bubbles do not necessarily imply large

<sup>25</sup>Our aggregate plots, though anecdotal, suggest that the distortion caused by dispersion could be more substantial than our panel data estimates suggest.

distortions of financing activity or real investment. Roughly speaking, this happens when the demand curve for new shares is steep. For policy makers, this finding suggests that while deviations of stock prices from fundamentals can have real consequences, large stock price bubbles may be less distortive than one might otherwise think.

Substantial room for future research remains. It would be desirable to extend our model to allow for the endogenous formation of beliefs (as in [Scheinkman and Xiong, 2003](#), for example). Extending our model to include debt issuance may also help explain the capital structure dynamics documented in [Baker and Wurgler \(2002\)](#). Finally, adding investment dynamics would provide a more suitable structural framework for quantifying the real effects of bubbles.

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