Equity Market Misvaluation, Financing, and Investment

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Abstract

We quantify the extent to which nonfundamental movements in a firm’s stock price affect its policies. We estimate a version of a constant returns neoclassical investment model in which equity financing is costly, the firm can accumulate cash, and, most importantly, equity values can be subject to misvaluation shocks. In the model, firms naturally issue equity when it is overvalued and repurchase equity when it is undervalued. Depending on the model parameters, the funds flowing to and from these activities can come from either changes in cash balances or changes in investment. We find that a model in which we allow no mispricing fits the data worse than a model in which we do allow mispricing. In particular, the mispricing model does a much better job of matching moments related to cash balances and equity issuance. Our counterfactual exercises show that firms do issue equity in response to misvaluation shocks, but the proceeds from these issuances augment cash balances rather than increase investment. Finally, managers’ rational responses to possible misvaluation increase intrinsic shareholder value from 0.1% to 0.9%. 
1 Introduction

We estimate a dynamic model of a firm’s investment and financing policies to understand and quantify the distortions to these policies that arise because of equity mispricing. This question is of interest in light of the marked increase in technology stock boom in the 1990s and bust in the early 2000s, and also in light of the sharp stock market crash of 2008, which was followed by the almost complete rebound over the subsequent two years. The mere existence of such wide swings in equity values begs the question of whether these swings reflect movements in intrinsic firm values. It is then natural to wonder whether possible nonfundamental movements in equity values affect managerial decisions.

These questions are both interesting and challenging. Equity misvaluation is by nature unobservable, and firms’ potential reactions to any misvaluation shocks are endogenous. Tackling this question via regression analysis thus requires finding proxies for misvaluation. Regression analysis also requires instruments that are highly correlated with misvaluation and orthogonal to both the measurement error in the misvaluation proxy and the unobservable components of firm policies. Although it might be conceivable to find an instrument satisfying one of these exclusion restrictions, there are no obvious instruments that satisfy both of these exclusion restrictions.

A feasible alternative method for tackling this question is estimation of an economic model. Our baseline model captures decisions about a firm’s dividends, investment, cash, equity issuances, and repurchases in a dynamic setting. Its backbone is a standard neoclassical model of physical and financial capital accumulation in the face (1) uncertain demand, (2) constant returns to scale, (3) costs of adjusting the capital stock, and (4) underwriting costs in the equity market. The model then incorporates a new feature that is motivated by the behavioral finance literature. We allow for the market value of equity in the model to diverge from its true value, and this misvaluation can be persistent.

Misvaluation affects the firm because it affects the rate at which managers discount the
future. The link between misvaluation and discounting arises as follows. First, even in the absence of misvaluation, equity repurchases and issuances affect the dilution of long-term shareholders’ shares. Second, because we assume that managers maximize the value of these long-term shareholders, and because issuances lower the future fraction of the firm owned by long-term shareholders, issuances then imply that the manager values current cash flows more relative to future cash flows. This effect is analogous to discounting the future at a higher rate. Third, misvaluation exaggerates this effect. In response to misvaluation, firms predictably repurchase shares when equity is underpriced and issue shares when equity is overpriced. The latter effect is much more pronounced than the former because the model incorporates a feature that mirrors the “safe harbor” provisions in the tax code that restrict the amount of equity repurchases that are immune from dividend taxes.

Fourth, misvaluation has the potential to affect real decisions because the model also features frictions related to external financing. However, the quantitative extent of this connection depends on model parameters because these parameters dictate whether the funds required for repurchases or received from issuances flow to and from cash balances or to and from investment. Quantifying the relative magnitudes of these different effects therefore requires estimating the model’s parameters. We use SMM, which matches model generated moments to real-data moments, that is, which minimizes model errors. We obtain estimates of parameters describing the firm’s technology, equity market frictions, and most importantly, the variance and persistence of misvaluation shocks.

Briefly, we find that a baseline model without any misvaluation shocks is unable to reconcile many features of our data. When we add misvaluation shocks to the model, its fit improves significantly, and we obtain significant estimates of the variance and serial correlation of misvaluation shocks. These findings are stronger for small firms than for large firms and for firms during the dot-com bubble than for firms in the 2000s. However, our parameter estimates imply that although firms issue equity when equity is overvalued, they only use a small fraction of the proceeds for capital investment. Instead, they tend for the most part to
hoard the proceeds as cash, and then to use the proceeds to repurchase shares when equity is undervalued. Thus, although equity misvaluation appears important for financial policies, its impact on real policies is much smaller.

One of the advantages of structural estimation is that we can conduct counterfactual exercises in order to quantify the effect of misvaluation on fundamental firm value. We compare a firm with parameters estimated in the data to one that is identical except that it is never misvalued. Not surprisingly, we find that the volume of repurchases and especially of issuances is smaller for the perfectly valued firm. Of more interest is our finding that equity market timing actually increases intrinsic shareholder value from 0.1% to 0.9%, depending on the estimates of our model parameters.

We also examine the extent to which average investment, dividends, and equity transactions vary with the model parameters that govern the variance and serial correlation of the misvaluation shocks. We find that cash balances rise sharply with the misvaluation shock standard deviation but that investment rises less strongly. In addition, we find a modest positive relationship between equity issuance and the misvaluation shock standard deviation, we find a much stronger tendency of firms to substitute repurchases for dividends as the misvaluation shock standard deviation increases.

Finally, we compute impulse response functions that contrast the responses of various policies with respect to one standard deviation shocks in either a profit shock or a misvaluation shock. We find no effect of either shock on dividends. Repurchase and issuance respond more strongly to the misvaluation shock than they do to the profit shock, but these reactions are short lived. In contrast, we find that the strong effect of the cash balances to the misvaluation shock takes four years to die out. Finally, we find a must stronger effect of profit shocks than of misvaluation shocks on investment.

Our paper falls into several literatures. The first is the literature on structural estimation of dynamic models in corporate finance, such as Hennessy and Whited (2005, 2007), DeAngelo, DeAngelo, and Whited (2011), Morellec, Nikolov, and Schürhoff (2012), and Matvos
and Seru (2011). These papers examine such issues as capital structure, financial constraints, agency problems, and corporate diversification. Our paper departs from these predecessors specifically by asking whether behavioral factors affect firm decisions.

Our paper also falls into the large empirical behavioral literature that has examined the effects of market misvaluation on firm policies. For example, Graham and Harvey (2001) find survey evidence that managers explicitly consider the possibility of equity overvaluation when deciding whether to issue shares. Eckbo, Masulis, and Norli (2007) and Baker and Wurgler (2012) provide excellent surveys of the empirical literature that has tested the more general proposition that market timing is important for many firm decisions. More recently, Jenter, Lewellen, and Warner (2011) find managerial timing ability by examining firms’ sales of put options on their own stock, and DeAngelo, DeAngelo, and Stulz (2010) find that both fundamental factors and market timing affect capital structure. Our results add to this literature by pointing out that timing is more likely to be important for financial than for real decisions.

The papers most closely related to ours are Bolton, Chen, and Wang (2011), Yang (2011), and Alti and Tetlock (2011). The first paper uses a model similar to ours but does not attempt to estimate the model or quantify any effects of misvaluation. Instead, it focuses on understanding the directional implications of mispricing and the comparative statics of risk management. Yang (2011) examines the theoretical implications for capital structure of mispricing that arises from differences in beliefs. Our goal, in contrast, is not to understand where mispricing comes from, but to quantify its effects empirically. Alti and Tetlock (2011) is similar to our work in that it also performs a structural estimation of a neoclassical investment model augmented to account for behavioral biases. However, Alti and Tetlock (2011) do not explicitly examine the role of financing and instead examine the effects of specific behavioral biases on asset returns.

The paper is organized as follows. Section 2 describes our data and presents descriptive evidence. Section 3 presents the model and discusses its optimal policies. Section 4 outlines
the estimation and describes in detail our identification strategy. Section 5 presents the estimation results and counterfactual exercises. Section 6 discusses model robustness, and Section 7 concludes. The Appendix contains proofs.

2 Data and Summary Statistics

Our data are from the 2011 Compustat files. Following the literature, we remove all regulated utilities (SIC 4900-4999), financial firms (SIC 6000-6999), and quasi-governmental and non-profit firms, with a one digit SIC code equal to 9. Observations with missing values for the SIC code, total assets, the gross capital stock, market value, and cash are also excluded from the final sample. As a result of these selection criteria, we obtain a panel data set with 55,726 observations for the time period between 1987 and 2010 at an annual frequency. We use this specific time period because distribution taxes play an important role in our model. Therefore, we need to examine time periods in which tax policy is relatively constant. Our first time period runs from the 1986 tax reforms until the major tax cuts at the end of 2002. Our second period then runs from 2002 to 2010.

We define total assets as Compustat variable AT, the capital stock as GPPE, investment as capital expenditures (CAPX) minus sales of capital goods (SPPE), cash and equivalents as CHE, operating income as OIBDP, equity issuances as SSTK, equity repurchases as PRSTK, dividends as the sum of common and preferred dividends (DVC + DVP), depreciation as DP, and Tobin’s q as the ratio of \((AT + PRCC_F \times CSHO − TXDB − CEQ)\) to AT. All other variables except investment and depreciation are expressed as fractions of total assets. Investment and depreciation are expressed as fractions of the capital stock.

Suggestive evidence of a role for stock market mispricing in firm decision making is contained in Figure 1, which plots the yearly cross-sectional averages of several variables, each of which is scaled by total assets. The top panel of Figure 1 plots equity issuance and SEO proceeds, along with a variable we refer to as “Return,” which is the average percent
change in firm equity value. The second panel contains an analogous plot for average equity repurchases and dividends, and the third panel contains an analogous plot for investment, cash, and saving. We define this last variable as the change in cash balances, and multiply saving by 10 to make its magnitude comparable to those of the other variables.

We find several patterns of interest. In the first panel, we see that equity returns and equity issuance (both total equity issuance and SEO proceeds) track one another fairly closely, especially in the mid-1990s and the late 2000s. In the second panel we see that although repurchases are much smoother over time than equity issuances, they do appear to be slightly negatively correlated with capital gains. The second panel also shows that dividends are the smoothest series of all, and they appear uncorrelated with the other variables in the graph.

The third panel contains plots of cash, investment, saving, and again equity returns. The most striking result here is the strong positive comovement between saving and capital gains. Interestingly, investment in physical assets appears, if anything, slightly negatively correlated with capital gains, and the level of cash appears unrelated to capital gains, but negatively related to investment, especially in the latter part of the sample, in which cash increases dramatically and investment also falls noticeably.

To quantify these visual patterns, in Table 1 we present simple time-series correlations among these aggregate variables. We add more texture to the picture by computing these correlations for small firms (below the median of total assets in a given year) and large firms. As also seen in Figures1, for both groups of firms, saving and capital gains are strongly positively correlated. Investment is also strongly negatively correlated with capital gains. This second pattern occurs because investment is strongly positively with Tobin’s $q$, and Tobin’s $q$ is strongly negatively correlated with returns via the well-documented value effect. The other large effect in this table is the negative correlation between cash and dividends for both groups of firms.

Table 1 also highlights several important differences between these two groups. In particular, equity transactions (issuance and repurchases) are more strongly correlated with
capital gains for the large than for the small firms. The final important difference is the positive correlation between investment and equity issuance for the small firms, but the slight negative correlation for the large firms.

We have for the most part avoided interpreting these results because a correlation between equity returns and corporate policies might or might not indicate market timing. Market timing is important if equity values contain a component unrelated to the intrinsic value of the firm and if managers react to this misvaluation component. If this is the case, then the high correlations between equity transactions and capital gains are clearly consistent with timing. Further, if timing is indeed occurring, then the high positive correlation between saving and capital gains suggest that the funds to conduct equity transactions flow in and out of cash stocks. Of course, if equity is not misvalued or if managers do not pay any attention to misvaluation, these high correlations could also simply be a result of managers’ attempts to fund profitable investment projects, which are naturally correlated with intrinsic firm value. To disentangle these competing explanations, we therefore estimate a dynamic model.

3 Model

This section presents the model. It then describes the optimal policies implied by the model solution.

3.1 Model Components

As a basis for our estimation we use a simple model that captures a firm’s dividend, investment, cash and equity issuance/repurchase decisions in a dynamic setting. The model is based on a standard neoclassical model with financing frictions (Gomes 2001; Hennessy and Whited 2005, e.g.). However, it deviates from this basic framework in two important ways. First, it contains a much richer specification of the payout process. Second, it incorporates a
new feature that is motivated by the strand of the behavioral literature that studies equity misvaluation and investor sentiment. In particular, we allow for the market value of equity in the model to diverge from its true value. This divergence affects the cost of capital for the firm and therefore affects its real and financial decisions. We start by describing the firm’s production technology. Then we move on to explain financing, taxation, and equity misvaluation.

We consider an infinitely lived firm in discrete time. At each time period the firm’s risk-neutral manager chooses how much to invest in capital goods and how to finance these purchases. The firm is characterized by a constant returns to scale production technology, $zK$, that uses only capital, $K$, and that is subject to a profitability shock, $z$. The shock follows an $AR(1)$ in logs:

$$\ln (z') = \mu + \rho_z \ln (z) + \varepsilon'_z,$$

in which a prime denotes a variable in the next period, $\mu$ is the drift of $z$, $\rho_z$ the autocorrelation coefficient, and $\varepsilon_z$ is an $i.i.d.$ random variable with a truncated normal distribution. It has a mean of 0 and a variance of $\sigma_z$.

Firm investment in physical capital is defined to be

$$I = K' - (1 - \delta) K,$$

in which $\delta$ is the depreciation rate of capital. When the firm invests, it incurs adjustment costs, which can be thought of as profits lost as a result of the process of investment. These adjustment costs are convex in the rate of investment, and are given by

$$A (I, K) \equiv \frac{\lambda I^2}{2K},$$

in which $\lambda$ is a parameter governing the curvature of the adjustment cost function.

The firm finances its production activities by retaining its earnings and by issuing equity.
When the firm retains earnings, it holds them as one-period bonds that earn the risk-free rate, $r_f$, and which we denote as $C$. Equity issuances are denoted by $E$, with a negative number indicating repurchases. When the firm issues equity, it pays a proportional cost, $a_1$. This cost can be thought of as an intermediation cost for a seasoned offering. As we discuss below, it can also be interpreted as a price concession the firm makes to the intermediary.

The firm’s profits are taxed at a rate $\tau_c$, with the tax bill, $T$, given by

$$T = (zK - \delta K + Cr_f)\tau_c. \tag{4}$$

Note that the tax schedule is linear, so that the tax bill can be negative. This simplifying feature is intended to capture tax carryforwards and carrybacks. The final financing option available to the firm is adjustment of its level of dividends, $D$. These are given by a standard sources and uses of funds identity:

$$D = zK - I - \lambda I^2 2K + C(1 + r) - C' - T + E - a_1E\mathcal{I}(E > 0), \tag{5}$$

in which $\mathcal{I}(\cdot)$ is an indicator function. In words, this definition states that the cash flow net of taxes and equity issuance or repurchases equals the total dividend payout. Dividends are taxed at a rate $\tau$, and $D > 0$. The tax rate $\tau$ should be interpreted as the tax rate on dividends relative to the tax rate on capital gains, inasmuch as we do not model capital gains taxation. In this model, the differential taxation of repurchases and dividends implies that it is optimal for firms to distribute funds to shareholders solely through repurchases. Therefore, we next specify a constraint on firms’ equity repurchases:

$$-E \leq b_0K. \tag{6}$$

This constraint captures the notion that firms cannot systematically avoid dividends through repurchases, as specified in the U.S. tax code. The constraint is linear in capital, implying that firms can pay out a certain amount via repurchases before they have to issue dividends,
with larger firms being able to pay out more.\footnote{It is also possible to specify a constraint that is linear in both capital and dividends. However, attempts to estimate the coefficient on dividends uniformly result in a coefficient near zero, so we omit this feature from the model.}

Thus far the model is a standard neoclassical model of investment with financing. We now depart from this setting by allowing the firm to be subject to misvaluation shocks. First, let $V(K, C, \psi, z)$ denote the intrinsic value of the firm’s equity, in which $\psi$ is the state variable denoting a misvaluation shock that affects observed ex-dividend equity values, $V^*$. In particular, $V^*$ is a stochastic multiple of ex-dividend intrinsic equity value:

$$V^* = \psi (V(K, C, \psi, z) - D(1 - \tau)).$$  \hfill (7)

The misvaluation shock, $\psi$, the following first order autoregressive process:

$$\ln \psi' = \mu_\psi + \rho_{z\psi} \ln z + \rho_\psi \ln \psi + \varepsilon_\psi'. \hfill (8)$$

Here, $\rho_\psi$ is the serial correlation of the shock, and $\varepsilon_\psi$ is a truncated normally distributed i.i.d. shock with mean zero and variance $\sigma_\psi$. This specification allows for correlation between the misvaluation and profitability processes. This correlation occurs through the $\rho_{z\psi}$ term, which implies that the current profitability level impacts the conditional expectation of the future misvaluation level. The $\mu_\psi$ term is set such that the unconditional expectation of the misvaluation term equals 1. This calculation is detailed in the Appendix. When $\psi = 1$, the firm is valued correctly; when $\psi < 1$, the firm is undervalued, and when $\psi > 1$, the firm is overvalued. We define the Markov transition function associated with (1) and (8) as $g \left( \varepsilon_\psi', \varepsilon_z', | \varepsilon_\psi, \varepsilon_z \right)$.

Three features of this misvaluation shock are important. First, the manager can observe the shock; that is, he knows the intrinsic value of the firm and can therefore observe deviations of intrinsic from market values. This assumption in turn implies that managers know more about the valuation of the firm than do market participants. It also implies that managers
do not manipulate market expectations about firm value. We discuss below the importance of this issue. Second, intrinsic equity value is a function not only of capital, cash, and the profitability shock, but also of the misvaluation shock. As shown below, managers’ optimal reactions to these shocks affect their decisions regarding cash and capital, and thereby the intrinsic value of the firm. Finally, the misvaluation shock does not affect current period dividends given by (5). This model feature is important because it makes it difficult to argue that the shock, $\psi$, is simply a component of intrinsic value.

### 3.2 Dilution and concentration of holdings

Equity issuances and repurchases act to dilute and concentrate the dividend claims of long-term shareholders, that is, those long-term investors that neither provide equity to the firm nor repurchase shares. We assume that the equity issuance or repurchase, $E$, is priced according to the current market value, $V^*$. The degree of dilution/concentration then depends on the misvaluation of the firm because managers attempt to engage in market timing by issuing or repurchasing equity when the firm is misvalued. This market-timing activity will create value for long-term shareholders. The degree of dilution/concentration equals:

$$\frac{V^*}{V^* + E} = \frac{\psi(V - D(1 - \tau))}{\psi(V - D(1 - \tau)) + E},$$

where the degree of dilution for a given level of equity issuance (positive $E$) decreases as the level of misvaluation, $\psi$, increases. Symmetrically, the degree of concentration of dividend claims of long-term shareholders from repurchases (negative $E$) increases as the firm becomes increasing undervalued (as $\psi$ declines).

In the model thus far, nothing limits firms from engaging in very large equity transactions in response to misvaluation. However, market participants are likely to infer the size of the potential misvaluation from the relative size of the equity transaction. See, for example, the evidence in Brockman and Chung (2001). To capture this effect and thus to restrain the size of equity transactions, we assume that the size of the dilution/concentration
is also affected by the size of the transaction scaled by the capital stock. The modified dilution/concentration ratio is then given by:

\[
\frac{V^*}{V^* + E + \frac{\nu E^2}{2K}} = \frac{\psi(V - D(1 - \tau))}{\psi(V - D(1 - \tau)) + E + \frac{\nu E^2}{2K}},
\]

where \(\nu\) is a parameter that determines the degree of market reaction to the equity transaction. Note that \(\nu > 0\) implies that equity issuances create more dilution than they would otherwise and that equity repurchases create less concentration than they would otherwise. Both effects dampen the firm’s incentives to react to misvaluation shocks.

### 3.3 Value Maximization

In a model in which firms can be misvalued, it is important to be precise about specifying the exact payoff to shareholders that the firm wishes to maximize. The total payoff includes dividends and net equity issuances. However, if we wish to think about market timing by managers, we cannot simultaneously maximize both components of the total payoff.

Therefore, we assume that the manager aims to maximize the payoff to a long-term investor that neither provides equity to the firm nor repurchases shares. We denote the actual net payout to long-term shareholders by \(P\), which is given by \(P \equiv D(1 - \tau)\).

We can now write the valuation equation that managers wish to maximize as a Bellman equation, in which we take account the dilution/concentration of dividend claims that arises through equity issuance and repurchases.\(^2\) Let \(\beta = (1 + r_f)^{-1}\). Then the Bellman equation is

\[
V(K, C, \psi, z) = \max_{K', C', E} \left\{ D(1 - \tau) + \beta \frac{\psi(V - D(1 - \tau))}{\psi(V - D(1 - \tau)) + E + \frac{\nu E^2}{2K}} \int V(K', C', \psi', z') \, dg \left( \epsilon', \epsilon'_z, | \epsilon_z, \epsilon_z \right) \right\}.
\]

Here, we define the Markov transition function associated with (1) and (8) as \(g \left( \epsilon'_\psi, \epsilon'_z, | \epsilon_\psi, \epsilon_z \right)\).

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\(^2\)Bazdresch (2005) uses a similar specification.
The Bellman equation thus shows that the value of the firm for long-term shareholders $V(K, C, \psi, z)$ equals the present value of dividends adjusted for dilution/concentration. The Bellman equation also reveals the intuition that the misvaluation shock affects the firm’s discount rate, with overvaluation leading the manager to discount future cash flows at higher rate. Further, this effect on discounting only operates when the manager is either issuing or retiring equity.

The relevant constraints in the maximization problem are the capital stock accumulation identity (2), the definition of dividends in (5), the repurchase constraint (6), and the following nonnegativity constraints

$$ C' \geq 0, \quad K' \geq 0, \quad D \geq 0. $$

It is not obvious that a solution to (10) exists, inasmuch as the discount factor need not always be less than one. However, the following proposition allows the Bellman equation (10) to be written with a constant discount factor.

**Proposition 1** The solution to equation (10) is identical to the solution of

$$ V(K, C, \psi, z) = \max_{K', C', E} \left\{ D(1 - \tau) - \frac{E}{\psi} - \frac{\nu E^2}{2 \psi K} + \beta \int V(K', C', \psi', z') \, dg \left( \varepsilon'_\psi, \varepsilon'_z \mid \varepsilon_\psi, \varepsilon_z \right) \right\}. $$

(11)

It is straightforward to demonstrate that (11) satisfies the conditions necessary to prove existence and uniqueness in Stokey and Lucas (1989). It is worth noting that the Bellman equation (11) does not imply that the model contains stochastic issuance costs, as in Jermann and Quadrini (2012). Instead, the misvaluation shock directly affects equity value and thus affects both repurchases and issuances.
3.4 Constant returns to scale specification

The problem can be further simplified by taking advantage of the constant returns to scale nature of the problem, and redefining all of the quantities in the model as a fraction of the capital stock, $K$. Define the following scaled variables:

\[ c \equiv \frac{C}{K}, \quad d \equiv \frac{D}{K}, \quad e \equiv \frac{E}{K}, \quad i \equiv \frac{I}{K}, \quad v(c, \psi, z) \equiv \frac{V(K, C, \psi, z)}{K}. \]

Then, one obtains the following Bellman equation:

\[
v(c, \psi, z) = \max_{c', \psi', z'} \left\{ d(1 - \tau) - \frac{e}{\psi} - \frac{\nu e^2}{2\psi} + \beta \int v(c', \psi', z') (1 - \delta + i) dg \left( \varepsilon'_\psi, \varepsilon'_z, \mid \varepsilon_\psi, \varepsilon_z \right) \right\},
\]

and the constraints become

\[
d - e + I(e > 0)\alpha_1 e = z(1 - \tau_c) - i - \frac{\lambda i^2}{2} + c(1 + r - r\tau_c) - c'(1 - \delta + i) + \delta \tau_c,
\]

\[-e \leq b_0,
\]

\[c' \geq 0, \quad d \geq 0.\]

3.5 Solution algorithm

We use value function iteration to solve (12). The solution algorithm is conceptually simple. We can think of the firm as choosing the optimal value for next period investment and cash, given the optimal allocation of the total payout into equity issuance/repurchases and dividends. Thus, given a particular choice for future cash and investment, we solve for the optimal allocation of the payout using the first-order conditions of (12), and the constraint on the size of repurchases. Once we have the optimal allocations, we can then search over the optimal policies for next period investment and cash.
We construct our simulated variables as follows. “Cash” is \( c \), “investment” is \( i \), “saving” is \( c' - c \), “equity issuance” is \( e \) when \( e > 0 \), “repurchases” are also \( e \) but when \( e < 0 \), and Tobin’s \( q \) is given by

\[
q \equiv \int \int \psi(v(c',\psi',z')) (1 - \delta + i) dg^\psi(\varepsilon_{\psi},\varepsilon_{\psi'}) dg^z(\varepsilon_z,\varepsilon_z).
\]

### 3.6 Optimal Policies

Figure 3 plots the policy functions for investment, cash, issuances/repurchases, and dividends, which we denote as \( \{c', i, e, d\} = h(c, \psi, z) \). Note that a positive value for \( e \) indicates an equity issuance, and a negative value indicates a repurchase. We parameterize the model using the results from the first estimation reported in Table 3. (Exercises using parameterizations from our other estimations are qualitatively similar.) Because we use data estimates to parameterize our model, these policy functions can be interpreted as empirically relevant.

The top panel depicts the optimal choices of cash, investment, equity issuances/repurchases, and dividends as a function of the misvaluation shock, where a value near 1 indicates no misvaluation. The profit shock is fixed at its mean value, and the choice of next period’s cash is fixed at the sample mean. The most salient feature of this panel is that the policy functions are not flat. This result implies that misvaluation shocks can affect firm policies, given the parameterization from our data. Interestingly, the two policies that appear most responsive to the misvaluation shock are cash and equity issuances, but this responsiveness is only apparent for shocks that are greater than 1.5 standard deviations from the mean. In this case, we see a modest response of investment, but sharp increases in both cash and equity issuances. The increase in equity issuance makes sense given the Bellman equation (12), which shows that high values of the misvaluation shock, \( \psi \), increase the payout to long-term shareholders by making equity issuance implicitly less expensive. What is interesting is the distribution of the proceeds from the issuances between investment in capital and cash accumulation. The modest increase in investment also makes sense, given the presence of investment adjustment costs. It is worth noting that the modest response of investment is
not necessarily hardwired into the model. The investment adjustment cost parameter is not picked arbitrarily but is instead estimated from the data.

This pattern is not symmetric. For undervaluation shocks, the firm does not repurchase large quantities of equity because of the constraint on repurchases given by (6), which is motivated by the safe harbor tax provisions for repurchases. Repurchases do increase for shocks more than 2 standard deviations below the mean, but this response is muted at best. Taken together, the main conclusions we can draw from examining these policy functions is that misvaluation shocks have almost no effect on dividend policy, only modest effects on investment policy, and strong effects on equity issuance and cash policy, but only for large positive shocks.

The next panel depicts the response of investment, cash, issuances/repurchases, and dividends to the profitability shock, \( z \). In contrast to the result in the first panel, investment responds strongly and positively to the profitability shock. The sawtooth pattern in the response of cash to \( z \) is interesting in that it indicates that cash is an important source of funding for the firm. When the response of investment to \( z \) is flat, the response of cash is positive, and when the response of investment to \( z \) is positive, the response of cash to \( z \) is negative. That is, it appears that the firm saves in periods of no investment and then disgorges part of these funds to help finance periods in which the firm does invest. Finally, dividends, equity issuances, and repurchases do not respond strongly to the profitability shock.

In the end, the main conclusions to be drawn from Figure 3 are as follows. First, investment is mostly affected by shocks to profitability and not by equity market misvaluations. Second, cash policy appears to respond to both profitability and misvaluation shocks, but the reasons are different. The response to profitability shocks results from firms needing to use internal funds for investment in the face of costly external finance. The response to misvaluation shocks results from firms saving the proceeds of equity issuances. Third, equity issuance does appear to respond to very large positive misvaluation shocks, but repurchases
do not respond strongly to negative misvaluation shocks.

4 Estimation and Identification

In this section, we explain how we take the model derived in Section 2 to the data. We first outline the estimation procedure. We then discuss our identification strategy and present our results.

4.1 Estimation

We estimate most of the structural parameters of the model using simulated method of moments. However, we estimate some of the model parameters separately. For example, we estimate the risk-free interest rate, $r_f$, to equal 0.03, which is the average over our sample period of the three-month t-bill rate. Similarly, we estimate the depreciation rate, $\delta$, as the average depreciation of the gross capital stock. Finally, we set the corporate tax rate equal to its statutory rate of 35%. Finally, we set the tax rate on dividends, $\tau$ equal to the difference between the statutory rates on dividends and capital gains.

We then estimate the following 11 parameters using simulated method of moments: the equity issuance cost parameter, $a_1$; the drift, standard deviation, and autocorrelation of the profitability process, $\mu, \sigma_z$ and $\rho_z$; the quadratic adjustment cost parameter, $\lambda$; the standard deviation and autocorrelation of the misvaluation process, $\sigma_\psi$ and $\rho_\psi$, the parameter governing the equity repurchase constraint, $b_0$, the market-timing penalty, $\nu$, the correlation between the misvaluation and profitability shocks, $\rho_{z\psi}$, and the depreciation rate, $\delta$.

Simulated method of moments, although computationally cumbersome, is conceptually simple. First, we generate a panel of simulated data using the numerical solution to the model. Specifically, we take a random draw from the distribution of $(\varepsilon_z', \varepsilon_\psi')$, conditional on $(\varepsilon_z, \varepsilon_\psi')$, and then compute $v(c, \psi, z)$, $(c', e, i) = h(c, \psi, z)$, and various functions of $v(c, \psi, z)$, $c'$, $e$, and $i$, such as dividends and Tobin’s $q$. We continue drawing values of $(\varepsilon_z', \varepsilon_\psi')$
and use these computations to generate an artificial panel of firms. Next, we calculate interesting moments using both these simulated data and actual data. The objective of SMM is then to pick the model parameters that make the actual and simulated moments as close to each other as possible. Details regarding the estimation can be found in DeAngelo, DeAngelo, and Whited (2011).

The next issue in SMM is whether to match moments using an identity or optimal weight matrix. Using an identity matrix implicitly puts the most weight on the moment that is the largest in absolute value. Because the size of a moment rarely corresponds to a relevant economic or statistical objective, we match moments using the optimal weight matrix, which is the inverse of the covariance matrix of the moments. Roughly speaking, this scheme puts the most weight on the most precisely estimated moments, which is a sensible statistical objective. See DeAngelo, DeAngelo, and Whited (2011) for details concerning the estimation of the weight matrix.

One final issue is unobserved heterogeneity in our data from Compustat. These firms differ along a variety of dimensions, such as technology and access to external finance. In contrast, our simulations produce \textit{i.i.d.} firms, with the only source of heterogeneity being the individual draws of \((\varepsilon_z, \varepsilon_\psi)\). Therefore, in order to render our simulated data comparable to our actual data, we can either add heterogeneity to the simulations, or remove the heterogeneity from the actual data. We opt for the latter approach, using fixed firm and year effects in the estimation of our regression-based data moments and the estimation of variances.

This issue of heterogeneity implies that SMM estimates the parameters of an average firm—not the average of the parameters across firms. These two quantities are not the same because the model is nonlinear. Because it is often difficult to conceptualize an average firm in a large population of firms over a long time span, we examine subsamples of firms that are homogeneous along two dimensions. In particular, Figures 1 and 2 and Table 1 indicate that small firms are different in important ways from large firms, and 1980s and 1990s are different from the 2000s. We therefore analyze four separate groups of firms. We examine
separately the time periods before and after the Jobs and Growth Tax Relief Reconciliation Act of 2003. Within these two time periods we then analyze small and large firms.

4.2 Identification

The success of this procedure relies on model identification. Global identification of a simulated moments estimator obtains when the expected value of the difference between the simulated moments and the data moments equal zero if and only if the structural parameters equal their true values. A sufficient condition for identification is a one-to-one mapping between the structural parameters and a subset of the data moments of the same dimension. Because our model does not yield such a closed-form mapping, we take care to choose moments that are sensitive to variations in the structural parameters such as the adjustment cost parameter, \( \lambda \). On the other hand, we do not “cherry-pick” moments. Instead, we examine the mean, variance, and serial correlation of the all of the variables we can compute from our model: investment, profits, equity issuances, equity repurchases, cash, dividends, and Tobin’s \( q \).

We now describe and rationalize the 19 moments that we match. Of particular interest is the identification of the variance and serial correlation of the misvaluation shock, \( \rho_\psi \) and \( \sigma_\psi \). Because of the feedback in the model from misvaluation to firm investment and financing decisions, this task is difficult. However, it is plausible to imagine that the misvaluation shocks affect moments involving market values more directly than they affect moments involving real quantities, such as investment, or especially profits, which are also driven by demand shocks. Therefore, our identifying assumption is that by including both market-value moments and real moments, we will be able to infer the moments of the misvaluation process.

We use three moments related to market values: the mean, variance, and serial correlation of Tobin’s \( q \). The variance and serial correlation of Tobin’s \( q \) are useful for identifying the variance and the serial correlation of the misvaluation process, \( \sigma_\psi \) and \( \rho_\psi \). Because changes
in almost all of the model parameters induce significant changes in firm value, the mean of Tobin’s $q$ ends up being a “catch-all” identifying moment. The fourth moment we use to identify misvaluation shocks is the covariance between equity issuance and Tobin’s $q$. This moment is particularly useful for identifying the parameter $\rho_{z\psi}$.

Our next three moments are the mean, variance and serial correlation of operating profits, which are defined in the model as $z$. These three moments are useful for identifying the drift, variance, and serial correlation of the profitability shock, $\varepsilon_z$.

Our next moments are the mean, serial correlation, and variance of the rate of investment, $i$. The variance is useful for identifying the adjustment cost parameter, $\lambda$, because higher $\lambda$ produces less volatile investment. The serial correlation is primarily affected by the smooth adjustment cost parameter but also by the serial correlation of the profitability process, $\rho_z$. Although the mean of investment in this class of models is primarily determined by the depreciation rate of capital, it is also affected to the variance of the profitability shocks and the adjustment cost parameter. When investment is more variable, because it is also naturally skewed, its mean rises.

The rest of the moments pertain to the firm’s financing decisions. We include the mean, serial correlation, and variance of the ratio of cash to capital $c$. We also include the mean and variance of the ratio of equity issuance to capital, $e$, as well as the mean and variance of the ratio of repurchases to capital and the ratio of dividends to capital. These seven moments are useful for identifying the equity issuance cost parameter, $a_1$, the parameters defining the repurchase constraint, $b_0$ and $b_1$, and the parameter restricting equity transactions, $\nu$.

## 5 Results

In the first part of this section, we present estimations from two versions of the model: one as presented in Section 2 and one in which the variance and serial correlation of the misvaluation shocks are set to be near zero. In the second part of this section, we perform
comparative statics exercises and examine impulse response functions.

5.1 Estimation Results

Table 2 shows that a version of the model without misvaluation shocks fits the data poorly. In part this poor performance is to be expected inasmuch as we are confronting the model with many moments. In comparison to previous studies in corporate finance that use SMM, our model is overidentified by many more degrees of freedom. Because all models by definition eventually fail when confronted with data, the intent behind using a large number of moments is to find out on which important dimensions the model fails and on which it succeeds, and why.

The top panel shows the actual and simulated moments for each of our four subsamples, with t-statistics in parentheses under the simulated moments. In each sample most of the simulated moments are statistically different from their real-data counterparts. One important exceptions to this general pattern are the mean and variances of repurchases, which are well-matched. This result makes sense in that variation in the parameter, $b_0$ directly affects these two moments, without affecting other moments to a large degree.

Nonetheless, although the differences in the two sets of moments are almost all statistically significant, only some of these differences are economically significant. In particular, in economic terms the model does an acceptable job of matching the means of both investment and Tobin’s $q$, as well as most of the serial correlation coefficients. However, the model has a difficult time generating average cash levels, average dividends, and average equity issuance that approach those seen in the data. In this simplified version of the model, costly external finance is the only reason firms hold cash, and these results suggest that this motive is not sufficient for the model to be able to fit this feature of the data. The biggest failure of the model is its inability to match average equity issuance. Model-simulated average issuances are up to seven times smaller than actual average issuances. This large difference also manifests in the near zero simulated variances of equity issuance. Finally, the variance
of Tobin’s $q$ is much larger in the actual than in the simulated data. This result mirrors those from the production based asset pricing literature, which finds that these sorts of models have a hard time matching both the means and variances of asset returns (Liu, Whited, and Zhang 2009). Anticipating, many but not all of these model failures are improved with the addition of misvaluation shocks to the model.

The bottom panel of Table 2 presents the parameter estimates we obtain from each of our four samples. Most are statistically significant. The exceptions are the estimates of the issuance cost parameter, $a_1$, and the estimates of the repurchase constraint parameter, $b_0$.

Table 3 shows that adding misvaluation shocks to the model improves its performance along many but not all dimensions. In the top panel we see many fewer instances in which the model and data moments are statistically different from one another. The economic significance of these differences also decreases in many cases. First, although the model fails to match average cash balances in three out of four cases, the differences between the actual and simulated moments are several times smaller. Second, the model does a much better job of matching average equity issuance. The simulated moments are now only smaller than the actual moments by a factor of two to three, instead of by a factor of seven. The results on cash and equity issuance make sense in light of the policy functions from Figure 2, which show that equity issuance can respond strongly to misvaluation shocks, with most of the proceeds going into cash balances. Finally, the variance of Tobin’s $q$ is now much higher than it was in the vanilla model, with only one of the simulated moments significantly different from the actual moments. This result indicates that equity market inefficiencies are significant contributors to equity market volatility.

Although adding misvaluation shocks to the model improves its fit in some dimensions, it fails in others. In particular, whereas the vanilla model did a good job of matching average repurchases, the model with misvaluation shocks generates share repurchases that are both statistically and economically greater than actual repurchases. The reason for this failure can be seen in the estimate of the repurchase constraint parameters, which are all quite high.
Clearly, the repurchase constraint does not bind in this model, and the estimated value of $\nu$ restricts issuance to a sufficient degree, but not repurchases.

The second panel of Table 3 contains the parameter estimates. Most importantly, for all four samples, the standard deviation and serial correlation of the misvaluation shocks are highly statistically significant. In addition, we estimate that the misvaluation shocks and profit shocks are positively correlated, with the $\rho_{z\psi}$ parameter estimated to be about 0.3 in all four samples. The estimates of the standard deviation range from 0.128 to 0.22, and the estimates of the serial correlation range from 0.19 to 0.31. Interestingly, the estimates of the standard deviation are higher in the early period, which contains the dot-com bubble and the 1987 market crash. Although statistically significant, the estimates of the standard deviations of $\varepsilon_\psi$ are in three out of four cases smaller than the estimates of the standard deviation of $\varepsilon_z$, and the estimates of the serial correlation of the misvaluation shocks are both economically and statistically much smaller than the estimates of the serial correlation of the profit shocks. Thus, our estimates imply that misvaluation shocks are much less important than profitability shocks in the firm’s decision making process. The rest of the parameter estimates are largely the same as those in Table 2.

We now ask whether our model is just picking up the effects of risk. Otherwise, it is hard to rule out the interpretation that our model is just picking up movements in equity values that are induced by a time varying expected returns rather than by misvaluation. To address this concern, we add a pricing kernel to our model that is calibrated to match the duration and severity of expansions and recessions in the United States. See the Appendix for details. Table 4 presents our estimates of the serial correlation and standard deviation of the misvaluation shock, as well as the estimates of the correlation between the profit and misvaluation shocks. We find that the standard deviation and serial correlation estimates remain statistically significant and fall only slightly relative to the estimates of a model without a pricing kernel. In contrast, we find that the estimate of the correlation between the shocks is insignificantly different from zero and quite small in magnitude. Thus, we
conclude that we have not simply picked up the effects of time-varying expected returns.

5.2 Counterfactual Experiments

Although the economic significance of many of our model parameters is not immediately obvious, it is possible to gauge their economic significance by conducting counterfactual exercises. First, we ask how much intrinsic equity value would be lost if the standard deviation and serial correlation of the misvaluation shocks were near zero. We find only modest losses, which range from 0.1% of equity value for the large firms in the later period to 0.9% of equity value in the case of the small firms in the early period. Thus, although managerial exploitation of equity misvaluation can create value for long-term shareholders, the magnitudes are small. We do find a large effect on equity issuance, which falls by as much as a factor of ten. The effect on repurchases is much more modest, as they fall only by two.

Second, we use comparative statics exercises to examine the extent to which average firm policies vary when we change the model parameters that govern the misvaluation shock process. The results from these exercises are in Figure 3. To construct this figure, we solve the model 10 times, each time corresponding to a different value of a parameter of interest ($\sigma_\psi, \rho_{ps}$). Each time we solve the model, we simulate 500,000 firm/year observations, and then compute the averages of five variables: cash, investment, equity issuance, dividends, and repurchases.

Several interesting patterns emerge from this exercise. First, both cash and investment rise with the standard deviation and serial correlation of the misvaluation shock, but the effect on investment is quite small, whereas the effect on cash is substantial. Indeed, average investment hardly moves when we vary the serial correlation. Second, equity issuance rises with the standard deviation and serial correlation of misvaluation shocks, and dividends fall. The effect of the serial correlation on average repurchases is near zero, but the effect of the standard deviation on average repurchases is positive. Thus, when the intensity of misvalu-
ation shocks rises, we see both buy and sell equity transactions increase in size, and we see a substitution of repurchases for dividends. Thus, we conclude from these experiments that although misvaluation shocks have modest real effects, they have economically important effects on cash and equity transactions.

Third, we examine the impact of misvaluation shocks by calculating impulse response functions. Once again, we parameterize the model using the estimates from the small firms in the early period. Calculating an impulse response function with real data requires estimating, inverting, and orthogonalizing a vector autoregression because the shocks that drive the variables of interest are unobservable. However, in our simulated data we do observe our shocks, so to calculate our impulse response functions, we simply regress our variables of interest on each of our two shocks, which we standardize and orthogonalize using a Cholesky decomposition.

The results are in Figure 4. The most striking result is that for average cash balances. A one standard deviation misvaluation shock raises cash balances from their average level of approximately 0.12 by 0.04 to approximately 0.16. This substantial effect dies out only slowly over the course of five years. The obvious conclusion from this exercise is that misvaluation shocks help ease financial constraints by allowing firms to accumulate cash. This lasting effect on cash can also be seen in the bottom panel, which depicts the impulse response for saving. We see an immediate uptick in saving, but the subsequent dissaving is of much smaller magnitude than the initial uptick. The effects of a one standard deviation misvaluation shock are also noticeable on issuances and repurchases (and to a much lesser extent investment), but these effects die out after only one period.

The effects of the profit shock are noticeably different in both sign and magnitude. First, a one standard deviation profit shock lowers average cash balances. The intuition is that as capital becomes more productive, firms substitute out of financial assets (cash) and into real assets. However, this effect dies out relatively quickly. Next, we find that although the responses of issuance and repurchases to profit shocks are also positive, they are of much
smaller magnitude than the responses to the misvaluation shock. In contrast, profit shocks have a much stronger effect on investment than do misvaluation shocks. Finally, we find that neither shock has much of an effect on dividends.

Finally, we conduct an “out-of-sample” test of the validity of the model, in the sense that we want to ascertain whether the model can reconcile patterns in the data that were not used to estimate it. We therefore compute a version of Table 1 with simulated data instead of with actual data. For this experiment we use the estimates from the sample of small firms in the late period and we compare these correlations with those of the small firms in Table 1. Table 3 contains this correlation matrix. The striking result is that we match the signs of 17 out of these 21 unique correlations. In particular, recall that in the data on small firms, the percent change in firm value is highly positively correlated with the change in cash, the change cash is highly positively correlated with equity issuance, and repurchases are negatively correlated with the percent change in firm value. This is the case in our simulated data as well.

6 Conclusion

This paper quantifies the extent to which nonfundamental movements in the price of a firm’s stock affect its various policies. Although this topic has been addressed by a large number of studies, we approach the problem in a new way—structural estimation. We estimate a version of a constant returns neoclassical investment model in which equity financing is costly, the firm can accumulate cash, and, most importantly, equity values can be subject to misvaluation shocks. In the model, firms naturally issue equity when it is overvalued and repurchase equity when it is undervalued. Depending on the model parameters, the funds flowing to and from these activities can come from either changes in cash balances or changes in investment.

We produce several findings First, a version of the model in which we allow mispricing
fits the data better than a model in which we restrict mispricing to be almost negligible. In particular, we do a much better job of matching moments related to cash balances and equity issuance. Allowing mispricing does not help much in matching moments related to investment. Our counterfactual exercises show that firms do issue equity in response to misvaluation shocks, but the proceeds from these issuances are not used to fund investment. Instead, they augment cash balances. Finally, managers’ rational responses to possible misvaluation increase intrinsic shareholder value from 0.1% to 0.9%.
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Appendix

This appendix contains the proof of Proposition 1 and the derivation of $\mu_\psi$.

Proof of Proposition 1

Let $\tilde{V}$ be a solution to equation (10), with corresponding policy functions $\tilde{D}$ and $\tilde{E}$. Then one obtains from (10):

$$
\tilde{V}(K, C, \psi, z) = \tilde{D}(1 - \tau) + \beta \frac{\psi(V - \tilde{D}(1 - \tau))}{\psi(V - \tilde{D}(1 - \tau)) + \tilde{E} + \frac{\nu E^2}{2K}} \int V(K', C', \psi', z') \, dg(\varepsilon'_\psi, \varepsilon'_z, | \varepsilon_\psi, \varepsilon_z).
$$

Rearranging the dividend term and dividing the numerator and denominator of the left hand side by $\psi$ gives

$$
\tilde{V}(K, C, \psi, z) - \tilde{D}(1 - \tau) = \beta \frac{V - \tilde{D}(1 - \tau)}{(V - \tilde{D}(1 - \tau)) + \frac{E}{\psi} + \frac{\nu E^2}{2\psi K}} \int V(K', C', \psi', z') \, dg(\varepsilon'_\psi, \varepsilon'_z, | \varepsilon_\psi, \varepsilon_z)).
$$

Next, divide the above equation throughout by $\tilde{V}(K, C, \psi, z) - \tilde{D}(1 - \tau)$ and multiply by $\tilde{V}(K, C, \psi, z) - \tilde{D}(1 - \tau) + \tilde{E}/\psi + \nu E^2/2\psi K$ to obtain

$$
\tilde{V}(K, C, \psi, z) - \tilde{D}(1 - \tau) + \frac{\tilde{E}}{\psi} + \frac{\nu E^2}{2K} = \beta \int V(K', C', \psi', z') \, dg(\varepsilon'_\psi, \varepsilon'_z, | \varepsilon_\psi, \varepsilon_z),
$$

Thus $\tilde{V}$, $\tilde{D}$, and $\tilde{E}$ also solve equation (11).

Conversely, let $\hat{V}$ be a solution to equation (11), with corresponding policy functions $\hat{D}$ and $\hat{E}$. One can use a similar approach to the above to show that $\hat{V}$, $\hat{D}$, and $\hat{E}$ also solve (10).
Derivation of $\mu_\psi$

Define the following matrices:

\[ Y = \begin{bmatrix} \ln z \\ \ln \psi \end{bmatrix}, \quad C = \begin{bmatrix} \mu_z \\ \mu_\psi \end{bmatrix}, \quad R = \begin{bmatrix} \rho_z & 0 \\ \rho_{z\psi} & \rho_\psi \end{bmatrix}, \quad \epsilon = \begin{bmatrix} \epsilon_z \\ \epsilon_\psi \end{bmatrix}, \quad \Sigma = \begin{bmatrix} \sigma^2_z & 0 \\ 0 & \sigma^2_\psi \end{bmatrix}. \]

Then, the joint transition equation can be written as the following VAR(1):

\[ Y_{t+1} = C + RY_t + \epsilon, \quad \epsilon \sim N(0, \Sigma). \]

The unconditional mean of $Y$ is given by the following expression:

\[ E[Y] = (I_2 - R)^{-1}C, \]

where $I_n$ denotes a identity matrix of order $n$. The unconditional variance of $Y$ is given by:

\[ \text{Vec}(\text{Var}(Y)) = [(I_4 - (R \otimes R))^{-1} \text{Vec}(\Sigma), \]

where Vec denotes the vectorization operator and $\otimes$ denotes the Kronecker product. For notational convenience, let $M = [(I_4 - (R \otimes R))^{-1}$. One can then derive the unconditional mean and variance of $Y(2) = \ln \psi$ as:

\[
E[\ln \psi] = \frac{1}{(1 - \rho_z)(1 - \rho_\psi)} (\rho_{z\psi}\mu_z + (1 - \rho_z)\mu_\psi), \\
\text{Var}(\ln \psi) = M(4, 1)\sigma^2_z + \frac{\sigma^2_\psi}{(1 - \rho^2_\psi)},
\]

where $M(4, 1)$ denotes the $(4, 1)^{th}$ element of the matrix $M$. The restriction that the unconditional expectation of the misvaluation term equals one implies that

\[ \ln E[\psi] = 0, \quad \Rightarrow \quad E[\ln \psi] + 0.5\text{Var}(\ln \psi) = 0. \]

Some algebra then reveals that

\[ \mu_\psi = -\left[ \frac{1}{2}(1 - \rho_\psi)M(4, 1)\sigma^2_z + \frac{\sigma^2_\psi}{2(1 + \rho_\psi)} + \frac{\rho_{z\psi}\mu_z}{1 - \rho_z} \right]. \]
**Time-Varying Expected Returns**

Let $x_t$ be an aggregate productivity variable that takes one of two values, $x_l, x_h$. Let $x_l$ denote a recessionary state and $x_h$ an expansionary state ($x_h > x_l$). The probability of remaining in a recessionary state is given by $p_l$, and the probability of remaining in an expansionary state is given by $p_h$. This implies expected durations of recessions and expansions of $1/(1 - p_l)$ and $1/(1 - p_h)$, respectively. In addition, we impose the restriction that the unconditional expectation of the aggregate productivity shocks equals 1 so that average income remains unchanged from the previous model.\(^3\)

The expected return varies with aggregate productivity $x_t$. Denote the conditional expected return as

$$\beta_m(x, x').$$

Following the production-based asset pricing literature, the time-varying expected return can be parametrized as a function of current and future aggregate productivity. Thus,

$$\log m(x, x') = m_0 + m_1(x' - x).$$

Economic reasoning suggests that investors place a higher valuation on assets that payoff in bad states of the world. This imposes the requirement that $m_1 < 0$. In order to ensure that average discount rates remain unchanged from the model without aggregate shocks, we require that $E[m(x, x')] = 1$.\(^4\)

\(^3\)Formally, this imposes the restriction that $x_h \frac{1-p_l}{2-p_h-p_l} + x_l \frac{1-p_h}{2-p_h-p_l} = 1$.

\(^4\)This yields the following equation:

$$\exp(m_0) \left[ \frac{1-p_h}{2-p_h-p_l} (p_l + (1-p_l) \exp(m_1(x_h - x_l))) + \frac{1-p_l}{2-p_h-p_l} (p_h + (1-p_h) \exp(m_1(x_l - x_h))) \right] = 1.$$
Given these assumptions, the expanded model can be written as follows:

\[
v(c, \psi, z, x) = \max_{c', d, e, i} d(1 - \tau) - \frac{e}{\psi} - \frac{\nu e^2}{2\psi} + \beta E \left[ m(x, x') v(c', \psi', z', x') \right] (1 - \delta + i).
\]

\[
d - e + I(e > 0)a_1 e = z x(1 - \tau_c) - i - \frac{\lambda_t^2}{2} + c(1 + r - r\tau_c) - c'(1 - \delta + i) + \delta \tau_c,
\]

\[
-e \leq b_0 + b_1 d,
\]

\[
c' \geq 0, \quad d \geq 0.
\]

The solution to the expanded problem takes into account that the static allocation decisions now depend on the aggregate productivity state. It also takes into account the impact of the pricing kernel \( m(x, x') \) and the transition matrix for \( x \) on the expected future value of the firm.

We calibrate \( p_l \) and \( p_h \) to match average durations of recessions and expansions of 16 and 42 months, respectively.\(^5\) We calibrate \( x_l \) and \( x_h \) to generate an average decline in output from its trend growth path of 4 percent, similar to the output declines observed in U.S. post-war recessions. Combined with the restriction that \( E[x] = 1 \), one obtains \( x_h = 1.011 \) and \( x_l = 0.971 \).

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\(^5\)See http://www.nber.org/cycles.html for information on duration of recessions.
Table 1: Simple Time-Series Correlations

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2011 COMPUSTAT industrial files. The sample period is from 1987 to 2010. “Investment” is the ratio of capital expenditures to the gross capital stock. “Cash,” “Dividends,” and “Equity Issuance,” “Saving,” and “Return” “Repurchases” are all scaled by total book assets. Saving is the change in the stock of cash. is the change in the market value of equity dividend by the market value of equity. Each variable is aggregated by taking the average across all firms in the sample in each year. The indicated correlations are then time-series correlations of these aggregated variables.

<table>
<thead>
<tr>
<th></th>
<th>Cash</th>
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<th>Capital Gain</th>
<th>Saving</th>
<th>Repurchases</th>
<th>Dividends</th>
<th>Equity Issuance</th>
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<tr>
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Table 2: SIMULATED MOMENTS ESTIMATION: MODEL WITH RESTRICTED MISVALUATION

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2011 COMPUSTAT industrial files. The sample period is from 1987 to 2010. The sample is split into four groups: small firms in the first part of the sample (through 2003), small firms in the second part of the sample, and large firms in each time period. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. The first panel reports the simulated and actual moments and the t-statistics for the differences between the corresponding moments. The second panel reports the estimated structural parameters, with standard errors in parentheses. $a_1$ is the linear equity issuance cost, $\lambda$ is the cost of adjusting the capital stock, $b_0$ is a parameter that constrains firms from repurchasing stock, $\mu$ is the drift of the profitability process, $\rho_z$ is its serial correlation, and $\sigma_z$ governs its variance. $\rho_{z\psi}$ and $\sigma_{\psi}$ are the serial correlation and standard deviation of the misvaluation shock. $\nu$ is penalty for timing the market, and $\rho_{z\psi}$ is a parameter governing the correlation between the two shocks. Standard errors are in parentheses under the parameter estimates.

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<th>Early/Small</th>
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<th>Simulated</th>
<th>Early/Large</th>
<th>Actual</th>
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<th>Simulated</th>
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<td>0.0001</td>
<td>(4.2056)</td>
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<td>0.0015</td>
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<th>$\mu$</th>
<th>$\rho_z$</th>
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<td>0.1557</td>
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<td>Example Large</td>
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<td>(0.0689)</td>
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<td>(0.0281)</td>
<td>(0.0142)</td>
<td>(0.1653)</td>
<td>(0.0877)</td>
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<td>Late Large</td>
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<td>(0.0778)</td>
<td>(0.1588)</td>
<td>(0.1468)</td>
<td>(0.0280)</td>
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Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2011 COMPUSTAT industrial files. The sample period is from 1987 to 2010. The sample is split into four groups: small firms in the first part of the sample (through 2003), small firms in the second part of the sample, and large firms in each time period. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. The first panel reports the simulated and actual moments and the t-statistics for the differences between the corresponding moments. The second panel reports the estimated structural parameters, with standard errors in parentheses.

### A. Moments

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<th>Early/Large Simulated</th>
<th>Late/Small Simulated</th>
<th>Late/Large Simulated</th>
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<td>Average cash</td>
<td>0.1221 (3.8368)</td>
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<td>0.1875 (4.1178)</td>
<td>0.1275 (2.3808)</td>
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<tr>
<td>Variance of cash</td>
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<td>0.0029 (0.0042)</td>
<td>0.0050 (1.1012)</td>
<td>0.0029 (0.0055)</td>
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<tr>
<td>Serial correlation cash</td>
<td>0.6891 (-1.1128)</td>
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<td>0.7791 (-0.3644)</td>
<td>0.6442 (-0.5924)</td>
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<tr>
<td>Average investment</td>
<td>0.1305 (0.1316)</td>
<td>0.1427 (0.1708)</td>
<td>0.1061 (0.1845)</td>
<td>0.1186 (0.1493)</td>
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<tr>
<td>Variance of investment</td>
<td>0.0063 (2.4954)</td>
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<td>Average profits</td>
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<td>Serial correlation profits</td>
<td>0.0965 (-0.3028)</td>
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<td>0.0038 (-2.6188)</td>
<td>0.0026 (-0.6084)</td>
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<td>Residual variance of profits</td>
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<td>0.7932 (0.6962)</td>
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<td>1.5419 (1.6635)</td>
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<td>0.0226 (-0.5961)</td>
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<td>Variance of equity issuance</td>
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<td>0.0010 (0.0055)</td>
<td>0.0013 (0.0029)</td>
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<td>Average repurchases</td>
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<td>0.0146 (-0.5199)</td>
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<td>Variance of repurchases</td>
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<td>Average dividends</td>
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### B. Parameter estimates

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Table 4: Misvaluation Estimates from the Pricing Kernel Model

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2011 COMPUSTAT industrial files. The sample period is from 1987 to 2010. The sample is split into four groups: small firms in the first part of the sample (through 2003), small firms in the second part of the sample, and large firms in each time period. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. $\rho_\psi$ and $\sigma_\psi$ are the serial correlation and standard deviation of the misvaluation shock. $\nu$ is penalty for timing the market, and $\rho_{z\psi}$ is a parameter governing the correlation between the two shocks. Standard errors are in parentheses under the parameter estimates.

<table>
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<th></th>
<th>Early/Small</th>
<th>Early/Large</th>
<th>Late/Small</th>
<th>Late/Large</th>
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<tbody>
<tr>
<td>$\rho_\psi$</td>
<td>0.2508</td>
<td>0.2217</td>
<td>0.1856</td>
<td>0.0628</td>
</tr>
<tr>
<td>(0.0304)</td>
<td>(0.0711)</td>
<td>(0.0294)</td>
<td>(0.0872)</td>
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<tr>
<td>$\sigma_\psi$</td>
<td>0.2008</td>
<td>0.2104</td>
<td>0.1144</td>
<td>0.0756</td>
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<tr>
<td>(0.0604)</td>
<td>(0.0655)</td>
<td>(0.0491)</td>
<td>(0.0386)</td>
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<tr>
<td>$\rho_{z\psi}$</td>
<td>0.0885</td>
<td>0.0005</td>
<td>0.0419</td>
<td>0.0131</td>
</tr>
<tr>
<td>(0.0534)</td>
<td>(0.0601)</td>
<td>(0.0388)</td>
<td>(0.0147)</td>
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</table>

Table 5: Simulated Time-Series Correlations

Calculations are based on a simulated sample from the model with mispricing.

<table>
<thead>
<tr>
<th></th>
<th>Cash</th>
<th>Investment</th>
<th>Return</th>
<th>Saving</th>
<th>Repurchases</th>
<th>Dividends</th>
<th>Equity Issuance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>1.000</td>
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<td></td>
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</tr>
<tr>
<td>Investment</td>
<td>-0.049</td>
<td>1.000</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Return</td>
<td>0.163</td>
<td>-0.379</td>
<td>1.000</td>
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<tr>
<td>Saving</td>
<td>0.336</td>
<td>-0.098</td>
<td>0.257</td>
<td>1.000</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Repurchases</td>
<td>-0.313</td>
<td>-0.471</td>
<td>-0.035</td>
<td>-0.547</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dividends</td>
<td>0.058</td>
<td>0.337</td>
<td>-0.134</td>
<td>-0.047</td>
<td>-0.157</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Equity Issuance</td>
<td>0.314</td>
<td>0.411</td>
<td>-0.042</td>
<td>0.493</td>
<td>0.352</td>
<td>-0.479</td>
<td>1.000</td>
</tr>
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</table>
Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2011 COMPUSTAT industrial files. The sample period is from 1987 to 2010. “Investment” is the ratio of capital expenditures to the gross capital stock. “Cash,” “Dividends,” and “Equity Issuance,” “Saving,” and “Repurchases” are all scaled by total book assets. Saving is the change in the stock of cash. “Return” is the change in the market value of equity dividend by the market value of equity. Each variable is aggregated by taking the average across all firms in the sample in each year. The indicated correlations are then time-series correlations of these aggregated variables.
This figure depicts the optimal response of investment, equity transactions, cash, and dividends in response to the misvaluation shock, $\psi$ in the top panel, and to the productivity shock, $z$, in the bottom panel. Positive equity transactions are issuances, and negative equity transactions are repurchases. All variables are scaled by the capital stock, $K$. 
This figure depicts the changes in average model variables with respect to the standard deviation and serial correlation of the misvaluation shock and to the market timing penalty parameter. All variables are expressed as a fraction of the capital stock.
This figure plots the impulse response functions of investment, cash, dividends, and equity issuances/repurchases with respect to one standard deviation profit and misvaluation shocks.