What Drives Corporate Excess Cash? Evidence from a Structural Estimation*

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Abstract

We develop a dynamic model in which firms choose their optimal financing, investment, dividends and cash holdings while facing risky debt, costly equity issuance and taxed interest on cash balances. We numerically solve the model to estimate the optimal level of cash holdings. Comparing these results with a large sample of U.S. firms from 1987 to 2005, we show that on average firms maintain larger than optimal levels of cash (excess cash) on their balance sheets. We further extend the base-case model to capture the effect of a self-interested manager, who enjoys private benefits from avoiding the discipline of capital markets. Applying simulated method of moments (SMM) to the dynamic model we infer the magnitude and the curvature of the private benefits. Estimated private benefits of cash-piling is higher for smaller firms. Applying SMM to a recent subsample of the data (2001-2005), we show that the increase in the cash flow volatility in recent years is mainly the reason behind the increase in corporate excess cash. However, the parameters of managerial private benefit of cash-piling remain statistically and economically significant.

JEL Classification: G31; G32; C15
Keywords: Corporate Cash Policy; Simulated Method of Moments

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Abstract

We develop a dynamic model in which firms choose their optimal financing, investment, dividends and cash holdings while facing risky debt, costly equity issuance and taxed interest on cash balances. We numerically solve the model to estimate the optimal level of cash holdings. Comparing these results with a large sample of U.S. firms from 1987 to 2005, we show that on average firms maintain larger than optimal levels of cash (excess cash) on their balance sheets. We further extend the base-case model to capture the effect of a self-interested manager, who enjoys private benefits from avoiding the discipline of capital markets. Applying simulated method of moments (SMM) to the dynamic model we infer the magnitude and the curvature of the private benefits. Estimated private benefits of cash-piling is higher for smaller firms. Applying SMM to a recent subsample of the data (2001-2005), we show that the increase in the cash flow volatility in recent years is mainly the reason behind the increase in corporate excess cash. However, the parameters of managerial private benefit of cash-piling remain statistically and economically significant.

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1 Introduction

The question of why corporations accumulate liquid assets has remained largely unanswered in the corporate finance literature. This is despite the close ties decisions on corporate cash holdings have with corporate financial policies such as debt policy, and perhaps more importantly, the association with strategic corporate decisions such as investment policy. In recent years the question has become more economically relevant as cash holdings among US corporations have increased. For example, in 2006, the sum of all cash and marketable securities represented more than 18% of the sum of all assets for publicly traded US firms, reflecting a substantial increase from 5% in 1990. Dittmar and Mahrt-Smith (2007) put the value of these amounts in perspective and show that the aggregate cash held by publicly traded US firms in 2003 is approximately 10% of the annual US GDP.

Corporate cash policy should be designed to balance trade-offs between internal and external resources for financing current and future investments. When raising capital is costly, internal cash holdings form a reliable alternative to using the equity markets. Such holdings also reduce the probability of default, which results in a decline in borrowing costs in the presence of risky debt. The trade-off of increasing cash holdings is a postponement of immediate dividends and a tax penalty on interest earned. It is also feasible that self-interested managers, responsible for both financial and real decisions of the firm, deviate from first-best level of cash holdings by stockpiling cash within the firm. In the spirit of Jensen (1986), managers may divert cash resources away from activities maximizing equity value, resulting in an agency problem between shareholders and managers.[1] While Harford et al. (2008) provide some empirical evidence consistent with excessive spending of free cash flow for firms with weaker corporate governance, they acknowledge that it is theoretically unclear how a self-interested manager will choose between spending and stockpiling free cash flow. The more general question of what motivates a high level of corporate excess cash holdings remains in large part unanswered.

The goal of this paper is to first present a model which captures the trade-offs described above and to exploit this model to predict optimal levels of cash holdings for firms which invest in capital, save cash, raise equity, issue/retire debt, and pay dividends, all under uncertain productivity. We propose a dynamic structural model of optimal financial and investment policy for a firm facing a broad set of frictions: corporate and personal taxation, bankruptcy costs, tax penalty for holding cash, and linear-quadratic costs of external equity. First, we consider this model under first-best assumptions where the manager maximizes the value of equity and does not partake in any private benefits. Parameters of this model are exogenously chosen. The

[1]Empirical studies such as Dittmar and Mahrt-Smith (2007) and Faulkender and Wang (2006) show that $1.00 of retained cash is valued at only $0.42 to $0.88. This is consistent with the agency cost of free cash flow proposed by Jensen (1986) .

first-best solution forms the base-case for our later investigation of the set of second-best policies. We propose an agency model to provide an answer to what motivates excessive cash holdings. The agency model considers a maximization problem faced by a self-interested manager enjoying private benefits when making financial and real decisions within the corporation.

Contrasting our first-best solution with empirical data shows that firms on average over-invest and maintain significantly more cash than can be explained through the dynamic trade-off model alone. The average cash-to-assets ratio from the simulated panel (0.0610) is three times smaller than the average empirical moment of this ratio (0.1837). This is consistent with the empirical literature on cash holdings which argues that firms on average maintain too much cash.[2]. The optimal panel also implies that managers tend to overinvest as the average investment-to-assets ratio in the simulated panel (0.0518) is smaller than the same ratio in the empirical panel (0.0659). Except Bertrand and Mullainathan (2003) who argues that an average manager might be better characterized by "quiet life models", the rest of the empirical evidence is in support of managerial empire-building preferences. Bertrand and Mullainathan (2003) shows that the average manager does not appear to try to increase firm size. Instead, he seems to avoid creating new plants as much as he avoids destroying old ones. On the other hand studies such as Moeller et al. (2005) argues that number of M&As (correlated with "empire building" managerial preferences) increased drastically after 1991, especially during 1994-2000. The results of our base-case model with no managerial private benefits appear to support Moeller et al. (2005).

To rigorously investigate the motives behind these deviations from optimality, we use observed corporate financing choices and infer the value of hidden parameters describing private benefits of self-interested managers. Using Simulated Method of Moments (SMM), parameters describing manager's private benefits for cash-piling are estimated for the agency model. In particular, in the agency model the manager's objective function is extended from solely maximizing value of equity with a pair of non-linear power function for manager's private benefits from avoiding the discipline of capital markets. This allows insight into both the magnitude and curvature of these private benefits. We also solve for the persistence and volatility of the shocks to cash flow. These parameters are highly influential on the precautionary motives for cash holdings. Endogenizing these parameters within the SMM assures a robust estimation for the agency parameters. Furthermore, we calibrate the bankruptcy cost represented as a proportion of the debt face value and also the depreciation rate. These two parameters influence cash holdings and investments directly, thus they are included as unknown parameters in the SMM. Under the SMM procedure, the distance between model-generated moments and real-world moments are minimized yielding consistent estimates of the unknown parameters. One can view the estimates as answering the following question: What magnitude of managerial private benefits for "cash-

[2] See Dittmar and Mahrt-Smith (2007), Faulkender and Wang (2006), Opler et al. (1999)

piling" best explains observed financing and investment patterns?

In our agency model private benefits of cash-piling are in the form of private benefits of not facing the capital markets. That is, raising equity is associated with a direct reduction in the manager's utility. A self-interested manager who tends to avoid the discipline of capital market will keep high cash levels to decrease both the probability of raising capital and the amount of capital required.

An important step in the SMM procedure involves selecting the moments to be matched. Following Hennessy and Whited (2007), we use three selection criteria. First, each of the moments must be informative about the private benefit parameters we seek to estimate. For example, the first and the second moments of the ratio of cash-to-assets are informative about the private benefits of cash-piling, leverage ratio is informative about bankruptcy costs, and the first moment of the ratio of investment-to-assets is indirectly informative about the private benefits of cash-piling. Second, the moments should involve financial ratios commonly discussed in the empirical literature, that is, we use a set of moments that any dynamic model of corporate finance should be able to fit. In addition to the above moments, we include the first moment of the ratio of equity issuance-to-assets, the mean debt-to-assets ratio, and the mean payout ratio. Equally important, we also include moments that are informative about the firm's real technology; particularly, we make use of the second moment of investment, the serial correlation of net income, and the standard deviation of shocks to income-to-assets.

We begin by fitting the model to our entire sample of Compustat firms. Our sample includes nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files.[3]The typical firm behaves as if it has a manager who takes private benefits of cash-piling equal to ($140,000) for the first million dollars of shareholders' equity value. The cash-piling private benefits function has an estimated curvature of (0.801). These SMM parameter estimates support the view that on average managers 1) enjoy fairly large private benefits of cash-piling, and 2) that corporations are sensitive to these managerial agency parameters.

After estimating parameters using the full sample, we reestimate the model using sub-samples obtained by splitting the sample according to size of the firms. We find large differences between the magnitude and curvature of the private benefits for the managers of small and large firms. This suggests the full sample parameter estimates mask heterogeneity across firms and managers. Although the observed average cash-to-assets ratio is higher for smaller firms, at first glance, it is not obvious if this is due to larger private benefits alone. Estimated Smaller firms behave as

[3]We do not include data from 2005-2008 because our model is not intended to capture exogenous shocks on firm's borrowing costs. The source of uncertainty in our model is only due to income shocks, represented by a first-order autoregressive process. A model with structural breaks and shocks on borrowing costs is more appropriate to explain the observed data in the recent era in the financial markets. This could be an interesting extension that is beyond the current scope of the paper.

if they have managers with larger preferences for cash-piling. The high level of cash holdings in small firms can be explained by higher volatility of cash flow shocks resulting in a higher level of optimal cash. Alternatively, it may also by the possibility that these firms have weaker corporate governance.[4] Hand in hand, these two factors cause higher precautionary cash and higher excess cash leading to higher cash-to-assets ratio.

We obtain our most distinct results by restricting the sample to recent years. A 2009 empirical study by Bates et al. (2009) argues that the recent increase in US corporate cash holdings is because the firms' cash flows have become riskier. We find that the increase in the volatility of cash flows in recent years can only partly explain the higher level of cash holdings in the last five years. The results of our SMM estimates on this interval indicate that private benefits of cash-piling, remain positive and statistically significant. However, the estimate of this parameter is smaller in magnitude when compared to the estimate resulting from SMM applied to the full sample. Our finding suggests managers value cash-piling to a lesser extent within this interval. This could be due to a stronger corporate governance emerging in recent years. Nevertheless, the importance of the agency explanation for high levels of cash-piling is not out of the picture. Even significantly higher levels of uncertainty in firm cash flows, which causes higher precautionary cash balances, cannot justify the enormous level of observed cash holdings.

These findings are also consistent with the flexibility hypothesis first proposed by Harford et al. (2008): Self-interested managers tend to keep more cash than can be explained by any dynamic trade-off model in order to avoid facing the discipline of capital markets in upcoming periods. This hypothesis indicates that as cash balances increase managers enjoy less marginal private benefits. Then, consistent with the curvature observed in the SMM results, preference for cash-piling is saturating in the cash levels.

The remainder of this article proceeds as follows. In Section 2, we introduce the related studies and situate the paper within the existing literature. Section 3 presents the model. In Section 4, we first present the results of the base-case model and then describe the SMM procedure and present estimation results for various sample splits. Finally, Section 5 concludes. Explanations of the computational methods used in this paper are included in the Appendix.

2 Related Literature

This paper primarily relates to two major areas of corporate finance literature: the theoretical literature on dynamic corporate savings and the empirical literature on cash holdings.

Theoretical dynamic studies such as Riddick and Whited (2008) and Gamba and Triantis (2008) investigate the role of cash holdings when the firm invests and saves in the face of costly

[4] This has been suggested by numerous studies such as Harford et al. (2008).

external equity finance. Gamba and Triantis (2008) present a quite general dynamic model, allowing for cash holding as well as separate debt and equity finance, although, unlike us, they do not include risky debt. The exclusion of risky debt makes their model unable to accurately match empirical findings related to corporate financial policy. Moreover, their model does not include any source of managerial and debt-related agency problems. Their main contribution is an explanation of how debt flotation costs can lead to simultaneous cash and debt holdings.

Riddick and Whited (2008) also investigates why corporations accumulate liquid assets. They show theoretically that intertemporal trade-offs between interest income taxation and the cost of external finance determine optimal savings. The main focus of the paper is to explain why firms change their cash holdings. They also document a negative corporate propensity to save, that is, the firm counteracts movements in cash flow with opposite movements in saving. Unlike our model they do not include any sort of debt (risky or riskless). They also exclude any agency issues as their focus is on the propensity to save and not on explaining the motives behind the high level of excess cash holdings observed in the data.

Our paper is also closely related to Hennessy and Whited (2007), which studies a firm that invests in the face of costly external equity financing and fixed costs of capital adjustment. Our model is quiet different to Hennessy and Whited (2007), as we focus on corporate saving rather than investment. However, we apply their estimated quasi-linear cost of equity issuance in our model. We also apply Simulated Method of Moments to estimate agency related parameters rather than the magnitude of financing friction, as in Hennessy and Whited (2007).

The theoretical model in this paper is most closely related to that in Moyen (2004) and Moyen (2007). These papers study investment and financing decisions of a firm within an infinite-horizon discrete-time dynamic stochastic framework. Our base-case model is an extension of her model where firms not only trade off a tax benefit of debt against a default cost of debt but also make decisions on the level of cash holdings in the presence of costly equity issuance. In her model, unlike ours, there is no need for cash since raising capital is not costly to the firm. The main purpose of her model significantly differs from ours as she studies the differences in financial and investment characteristics of firms that face no financing constraint with financially constrained firms.

In a recent study Moyen and Boileau (2009) presents a model in which precautionary savings can also arise because of firm's liquidity constraints. They argue that the capital share of revenues has become smaller by time, thus, the prudence motive is no longer empirically relevant. In a model with riskless debt and no agency, they show that the liquidity constraint motive can by itself explain the observed increase in cash holdings. In contrast, we investigate the role of agency and cash flow shocks in explaining the increase in the cash levels.

Acharya et al. (2007) examines why cash is not the same as negative debt. Their static model emphasizes that cash is retained when investment opportunities are likely to occur in low cash flow states and the firm has external financial constraints, whereas if investment opportunities occur in high cash flow states, cash flow is directed toward paying down debt. They suggest that cash should not be viewed as negative debt in the presence of financing frictions. Our model, which incorporates additional features such as, taxes, bankruptcy costs, and equity issuance costs, also documents the coexistence of debt and cash in the presence of equity issuance cost.

Within the empirical stream, Harford et al. (2008) finds that, in the US, firms with weaker corporate governance structures actually have smaller cash reserves. Moreover, these weakly controlled managers choose to spend cash quickly on acquisitions and capital expenditures, rather than hoard it.

Our work is related not only to Harford et al. (2008), but also to a large empirical literature which finds that excess cash can lead to value decreasing decisions, and that the market value of cash reserves is lower when firms are poorly governed and there is weak shareholder protection. This includes the works of Dittmar and Mahrt-Smith (2003), Harford (1999), Kalcheva and Lins (2007), Pinkowitz et al. (2006) and Mikkelson and Partch (2003). Moreover, Opler et al. (1999) find support for a more traditional static trade-off model of cash holdings related to factors such as growth opportunities, risk, and access to external financing, which we capture in our model.

These papers focus primarily on the effects of excess cash rather than the motives behind the accumulation of excess cash in the first place. The only empirical paper that focuses on possible explanation for the high level of observed excess cash is Bates et al. (2009). However, they claim that riskier cash flows in recent years, particularly concentrated among smaller high tech firms have caused the dramatic growth of excess cash. Our theory allows us to investigate such a claim more robustly. We match simulated moments of the model with empirical moments from the more recent panel to estimate agency related parameters and also the volatility and persistence of the shock to firms' cash flow. The higher volatility of income observed in the US in recent years does result in a lower estimated parameter for managerial cash-piling. However, the results indicate that, these agency parameters remain statistically and economically significant.

3 The Model

3.1 The Base-Case Model

As the base-case model, we construct a discrete-time, infinite-horizon, partial equilibrium, stochastic model of debt, investment and cash holdings. In our model, firms trade off a tax benefit of debt against a default cost of debt. Different firms are characterized by different realizations of the stochastic process. The firm maximizes equity value subject to fairly pricing any debt issue by choosing its dividend, investment, cash holdings, and debt policy. All claimants, equity and debt, are risk neutral. The equity value V_t takes the form:

$$V_t = \max\left\{0,\ D_t + \frac{1}{1+r}E_t[V_{t+1}]\right\} \tag{1}$$

where r is the discount rate and E_t is the conditional expectation at period t. For simplicity dividends and capital gains are assumed to be untaxed. Equation (1) shows that the equity value is the sum of the expected discounted stream of dividends, D_t. Equation (1) also shows that equity claimants are protected by limited liability as they will default whenever $D_t + \frac{1}{1+r}E_t[V_{t+1}] \leq 0$. The firm may ask its equity claimants for additional funds ($D_t < 0$), but the equity claimants may choose to relinquish their equity claim rather than contribute more. In this setup a negative dividend is interpreted as equity issues. Moreover, equity issuance is associated with a cost. To preserve tractability, we do not model costs of external equity as the outcome of an asymmetric information problem. Instead, consistent with Riddick and Whited (2008), we capture adverse selection costs and underwriting fees in a reduced form fashion. The equity issuance cost is linear-quadratic and weakly convex:

$$\Lambda(D_t) = (-\lambda_0 + \lambda_1 D_t - \frac{1}{2}\lambda_2 D_t^2)\mathbf{1}_{(D_t<0)} \tag{2}$$

where function $\mathbf{1}_{(D_t<0)}$ equals one if $D_t < 0$, and zero otherwise. λ_0, λ_1 and λ_2, are positive constants. Convexity of $\Lambda(D_t)$ is consistent with the evidence on underwriting fees in Altinkiliç and Hansen (2000). In the case where the equity issuance is not justified by the expected discounted future equity value ($D_t + \frac{1}{1+r}E_t[V_{t+1}] \leq 0$), equity claimants exercise their option of not contributing additional funds to the firm and trigger default instead.

The firm's sources-and-uses of funds equation defines the dividend:

$$\begin{aligned} D_t &= (1-\tau_c)f(K_t;\theta_t) + \tau_c\delta K_t - I_t + \Delta B_{t+1} - (1-\tau_c)i_t B_t + \Lambda(D_t) \\ &\quad +(1+(1-\tau_c)r)C_t - C_{t+1} \end{aligned} \tag{3}$$

where τ_c is the firm's tax rate, K_t is the capital stock, θ_t describes the firm's underlying income shock, $(1-\tau_c)f(K_t;\theta_t)$ is the after tax operating income before depreciation, $\tau_c\delta K_t$ is the depreciation tax shield, I_t is the investment, ΔB_{t+1} is the new debt issue, i_t is the interest rate, B_t is the debt level and $(1-\tau_c)i_t B_t$ is the after-tax interest payment. The depreciation rate used for tax purposes is assumed to be equal to the true economic depreciation rate of the capital stock. The stock of cash has to be non negative as we do not model line of credits separately from debt issuance.[5]

$$C_{t+1} \geq 0 \tag{4}$$

The firm's operating income before depreciation is the difference between its revenues and expenses. Revenues exhibit decreasing return to scale when $0 < \alpha < 1$.

$$f(K_t; \theta_t) = \theta_t K_t^{\alpha} \tag{5}$$

The firm's income shock is represented by a first-order autoregressive process with persistence ρ and volatility σ:

$$\ln \theta_{t+1} = \rho \ln \theta_t + \sigma \epsilon_{t+1} \tag{6}$$

where $\epsilon_t \sim N(0, 1)$. Because the persistence parameter ρ is not zero, the income shock is somewhat predictable. The firm anticipates the income shock it will face next period and chooses its investment, debt policy and cash holdings accordingly. The firm cannot perfectly anticipate the income shock it will face next period. However, the firm positions itself to limit the possibility of default next period. The firm defaults when next period's income shock θ_{t+1} turns out to be so much lower than expected that the equity claim becomes worthless.

This period's depreciated capital stock and investment form next period's capital stock. The capital accumulation is thus presented as:

$$K_{t+1} = (1 - \delta)K_t + I_t \tag{7}$$

The new debt issue is the difference between the new debt level chosen this period B_{t+1} and the beginning-of-period debt level B_t:

$$\Delta B_{t+1} = B_{t+1} - B_t \tag{8}$$

The debt is specified with a maturity of one period, but can be viewed as longer term debt with a floating rate.[6] In each period, the firm can roll over its existing debt $\Delta B_{t+1} = 0$, retire some debt $\Delta B_{t+1} < 0$, or issue more debt $\Delta B_{t+1} > 0$ at the current interest rate, i_{t+1}.[7]

Fairly pricing of debt requires that

$$B_{t+1} = \frac{1}{1+r} E_t[(1 + (1 - \tau_b) i_{t+1}) B_{t+1} \mathbf{1}_{(V_t > 0)} + (R(K_{t+1}, C_{t+1}; \theta_{t+1}) - \Omega B_{t+1}) \mathbf{1}_{(V_t \leq 0)}] \tag{9}$$

[5] Here we do not include any sort of agency cost of retained cash simply because the purpose of the base-case model is to capture all the trade offs that are not due to agency issues.

[6] We assume there are "perfect" debt covenants restricting the manager from asset sales, dividends, etc.

[7] We do not assume a recapitalization cost for debt. Previous studies such as Myers and Majluf (1984) argue that adverse selection cost of issuing equity is higher than debt. Therefore, the equity issuance cost $\Lambda(D_t)$ can be interpreted as an incremental cost over the recapitalization cost of debt.

Equation (9) shows that debt claimants demand an interest rate such that the debt lent to the brim this period equals next period's expected discounted payoff. The payoff on the debt claim consists of the face value B_{t+1} and the after-tax interest payment $(1-\tau_b)i_{t+1}B_{t+1}$ if equity claimants do not default, or the net residual value $R(K_{t+1};\theta_{t+1})-\Omega B_{t+1}$ if they default, where τ_b is the debt claimant's interest income tax rate, Ω is the dead weight default cost as a proportion of the debt face value, and the function $\mathbf{1}_{(V_t>0)}$ indicates no default (i.e. it is equal to one if $V_t > 0$ and it is equal to zero other wise).

The residual $R(K_{t+1}, C_{t+1}; \theta_{t_1})$ going to the debt claimant upon default is the value of the firm after reorganization. Debt claimants may then recapitalize the firm in an optimal manner. $R(K_{t+1}, C_{t+1}; \theta_{t_1})$ captures the optimal recapitalization:

$$\begin{aligned} R(K_{t+1}, C_{t+1}; \theta_{t=1}) \;=\;& (1-\tau_c)f(K_t;\theta_t) + \tau_c\delta K_t - I_t + B_{t+1} + \Lambda(D_t) + (1+(1-\tau_c)r)C_t \\ & -C_{t+1} + \frac{1}{1+r}E_t[V_{t+1}] \end{aligned} \tag{10}$$

The net residual value $R(K_{t+1}, C_{t+1}; \theta_{t_1})$ going to the debt claimants upon bankruptcy (i.e. when $D_t + \frac{1}{1+r}E_t[V_{t+1}] \leq 0$) is always less than the no-default principal and after tax interest payment $(1+(1-\tau_b)i_t)B_t$.[8]

Using Equations (3), (4), (5) (7) and (8), we can implicitly express the income shock at which equity claimants trigger default $\bar{\theta}(K_t, B_t, i_t, C_t)$. This is easily calculated by solving $D_t + \frac{1}{1+r}E_t[V_{t+1}] = 0$ and leads to the following expression for $\bar{\theta}(K_t, B_t, i_t, C_t)$:

$$\begin{aligned} & (1-\tau_c)(\bar{\theta}(K_t, B_t, i_t, C_t)K_t^{\alpha}) + (1-(1-\tau_c)\delta)K_t - K_{t+1} + B_{t+1} - (1+(1-\tau_c)i_t)B_t \\ & +(1+(1-\tau_c)r)C_t - C_{t+1} + \Lambda(K_t, B_t, i_t, C_t; \bar{\theta}(K_t, B_t, i_t, C_t)) \\ & +\frac{1}{1+r}E_t[V_{t+1}|\theta_t = \bar{\theta}(K_t, B_t, i_t, C_t)] \;=\; 0 \end{aligned} \tag{11}$$

where $\Lambda(K_t, B_t, i_t, C_t; \bar{\theta}(K_t, B_t, i_t, C_t))$ is calculated from Equation (2) when $\theta_t = \bar{\theta}(K_t, B_t, i_t, C_t)$.

Because ϵ_t is normally distributed, the income shock follows a log-normal distribution. Therefore, the probability of default $\Phi(\bar{\theta}(K_t, B_t, i_t, C_t)$ is a log-normal cumulative density function.

In this model, the manager maximizes the equity value of the firm such that equations (2)-(9) are satisfied[9]. This is the base-case model where the manager acts in the interest of all the equity holders, including himself. He does not extract any private benefits from stockpiling cash within the firm. In the following section we will introduce a model with a self-interested manager who

[8]The fact that the interest is deductible by the firm at a higher rate than the interest income is taxable to debt claimants ($\tau_c > \tau_b$), implies that the residual is smaller than the principal and after-tax interest going to the debt claimants when no default occurs: $R(K_{t+1};\theta_{t_1}) < (1+(1-\tau_b)i_t)B_t$.

[9]This could be justified by simply assuming that the manager owns a proportion of firm's equity.

enjoys private benefits on the firm's cash balances. In the base-case model, the manager selects optimal levels of dividend payments or equity issue. If equity claimants do not find it worthwhile to provide the equity financing they trigger default. Also, investment I_t and debt issues ΔB_{t+1} are not restricted to be non negative, while stock of cash C_{t+1} has to be nonnegative. The firm is allowed to sell some assets and to retire debt.

In a model with no cost of raising equity, there would be no need for stocks of cash. That is, if $\Lambda(D_t) = 0$ then the firm can effectively manage its probability of default by buying and selling its capital stock and changing its financial structure. However, due to costly equity issues $\Lambda(D_t)$, the firm saves some cash to reduce the expected future financing costs. Additionally, the firms optimal level of cash holdings depend not only on the cost of issuing equity, but also on the firm's expected future financing needs. These factors in turn depend on the firm's production function $f(K_t; \theta_t)$ and especially on the uncertainty it faces θ_t. The optimal cash holdings also relates to firm's holdings of risky debt and the probability of default it faces. If debt were not risky, the firm could avoid costly equity issues and raise more debt to finance its new investments. By modeling the expected cost of default on the risky debt hand in hand with the cost of issuing equity, we are able to address the simultaneous existence of debt and cash balances in the firm.

Our dynamic model describes a firm which at each period chooses how much dividend D_t to pay, how much to invest I_t, how much debt to issue ΔB_{t+1} at the interest rate i_{t+1} and how much cash to keep C_{t+1}. Constrained by the bond-pricing Equation (9) and equations (2) - (8), the firm makes these choices in order to maximize the equity value in Equation (1). The firm makes these decisions after observing the beginning-of-the-period value for the income shock θ_t and last period's choices of capital stock k_t, debt B_t, interest rate i_t and cash stock C_t. The Bellman equation describing the firm's intertemporal problem is:

$$\begin{aligned} & V(K_t, B_t, i_t, C_t; \theta_t) = \\ & \max_{D_t, K_{t+1}, \Delta Bt+1, i_{t+1}, C_{t+1}} \max \left\{ 0,\ D_t + \frac{1}{1+r} E_t[V(K_{t+1}, B_{t+1}, i_{t+1}, C_{t+1}; \theta_{t+1}] \right\} \end{aligned} \tag{12}$$

subject to Equations (2)-(9).

The model cannot be solved analytically. The solution is approximated using numerical methods. Once decision rules are obtained, a panel of firms is simulated and studied. The employed numerical method is discussed in the Appendix. However, to develop some intuition behind the optimal policy we consider the Euler equation relating the dynamics of interest and probability of default with changes in cash. Utilizing the envelope condition, the Euler equation can be presented as follows:

$$
\begin{aligned}
&1+(\lambda_1-\lambda_2 D_t)\mathbf{1}_{(D_t<0)} \\
&+\frac{1}{1+r}E_t[(\tau_c-\tau_b)i_{t+1}+\Omega]B_{t+1}\times \\
&\times\Big(\frac{\partial\Phi[\bar{\theta}(K_{t+1},B_{t+1},i_{t+1},C_{t+1}]}{\partial C_{t+1}}+\frac{\partial\Phi[\bar{\theta}(K_{t+1},B_{t+1},i_{t+1},C_{t+1}]}{\partial i_{t+1}}\cdot\frac{\partial i_{t+1}}{\partial C_{t+1}}\Big) = \\
&=\frac{1+r(1-\tau_c)}{1+r}E_t[1+(\lambda_1-\lambda_2 D_{t+1})\mathbf{1}_{(D_{t+1}<0)}] \\
&+\frac{1}{1+r}E_t[(\tau_c-\tau_b)B_{t+1}\mathbf{1}_{(V_{t+1}>0)}]\cdot\frac{\partial i_{t+1}}{\partial C_{t+1}}
\end{aligned}
\tag{13}
$$

The optimal interior financial policy has to satisfy this condition. The right hand side represents the shadow value of cash balances, and the left hand side represents the marginal cost of external equity finance plus the marginal cost of default on the debt obligations. If a firm saves a dollar today, it reduces the probability of having to issue new equity tomorrow. It also influences both the probability of default and the interest rate promised to the debt claimants in the next period. The firm continues to save just to the point where the gain from reducing future equity costs and bankruptcy costs outweighs the tax penalty on saving.

Inspection of this equation also reveals that optimal cash policy, optimal investment policy and optimal debt policy are clearly intertwined. This equation shows that the firm accounts for the effects of its cash holding decision on the interest rate requested by debt claimants and on the default probability. A higher interest rate i_{t+1} promised to debt claimants translates into a larger tax benefit to the firm, but this higher rate also increases the probability that equity claimants will default on their debt obligation.

3.2 The Agency Model

In this section we present an agency model where the objective function of the manager is modified to capture possible private benefits which he can exploit from cash-piling. We focus on a particular type of private benefits. The manager's objective function incorporates a disutility for raising equity through capital markets as he dislikes the discipline of capital markets.[10] He can avoid this discipline by maintaining higher cash holdings. The private benefit for cash-piling is in the form of reduction in the magnitude of this disutility. The Bellman equation describing the manager's intertemporal problem is

[10] This disutility is beyond the cost of raising capital denoted by Λ in the base-case model.

$$V(K_t, B_t, i_t, C_t; \theta_t) = \max_{D_t, K_{t+1}, \Delta Bt+1, i_{t+1}, C_{t+1}} \left(\max \left\{ 0,\ D_t + \frac{1}{1+r} E_t[V(K_{t+1}, B_{t+1}, i_{t+1}, C_{t+1}; \theta_{t+1}] \right\} + \beta_1 (D_t \mathbf{1}_{(D_t<0)})^{\beta_2} \right) \tag{14}$$

subject to Equations (2)-(9).

In comparison to the base-case model, the constraints of the maximization problem remain unchanged. To our knowledge this model is the first study which estimates the private benefits managers take for cash-piling.We first investigate whether, in comparison to the base-case results, the self-interested manager's problem results in higher levels of cash holding.The magnitude and the curvatures (convexity/concavity) of the private benefit function is captured by parameters β_1 and β_2, respectively. For $0 < \beta_2 < 1$ the manager enjoys diminishing marginal private benefits in cash holdings.

The chosen form of the objective function is consistent with the evidence from the literature on self-interested managers stockpiling cash inside the firm to provide themselves flexibility and freedom from capital markets discipline (Easterbrook (1984), Harford et al. (2008) and Jensen (1986)). This leads to managerial preferences for large cash reserves within the corporation. In this model, we try to test for this effect while we employ SMM to endogenously solve for the vector of unknown agency parameters $\vec{\beta} = [\beta_1, \beta_2]$. Furthermore, we allow the persistence and the volatility to the cash flow shocks (ρ, σ) and also the bankruptcy cost parameter and the depreciation rate (Ω, δ) to be endogenously selected alongside the agency parameters.

4 Estimated Optimal Cash holdings

4.1 The Calibration

The numerical method explained in the Appendix requires parameter values for r, δ, τ_c, τ_b, Ω, α, ρ, σ, λ_0 , λ_1 , λ_2 , β_0 and β_1.

We follow Hennessy and Whited (2007) and Riddick and Whited (2008) to parametrize the financing function, setting $\lambda_0 = 0.389$, $\lambda_1 = 0.053$, $\lambda_2 = 0.0002$. These settings are their estimates of the cost of equity issues for large firms. Therefore, these are conservative estimates, lying just slightly above the estimates for underwriting costs in Altinkiliç and Hansen (2000).

Following most dynamic investment studies since Kydland and Prescott (1982), we set the discount rate r so that $\frac{1}{1+r} = 0.95$, and the depreciation rate δ to 0.1. The tax rates are calibrated to reflect the US corporate and personal tax rates of 40% and 20%: $\tau_c = 0.4$ and $\tau_b = 0.2$.

Following Gamba and Triantis (2008), the serial correlation of shock ρ is set at 0.62 and the standard deviation of the shock σ is set at 0.15. These values are between Hennessy and Whited (2007) and Moyen (2004), which respectively calibrate the persistence to 0.66 and 0.60, and the standard deviation of the shock to 0.121 and 0.20. When solving the agency model we calibrate these two parameters endogenously.

Similar to Moyen (2004), the default cost is set to $\Omega = 0.1$ to compromise between Fischer et al. (1989) and Kane et al. (1986), who calibrate this cost to 5% and 15% of the debt face value. Furthermore, following Moyen (2004) and Gamba and Triantis (2008) we set the production return-to-scale parameter α at 0.45.

Given these parameter values, the base-case is solved numerically as described in the Appendix. The resulting series K_{t+1}, ΔB_{t+1}, i_{t+1}, C_{t+1} and V_t are simulated from random outcomes of the income shock θ_t. A sample of 20,000 firms is generated, where each series for which no default occurs ($V_t > 0$) for at least 20 consecutive periods defines a firm.[11] Dropping the first part of the series allows us to observe the firm after it has worked its way out of a possibly suboptimal starting point. The firms sometimes default. For example, 0.40% of the firms default in periods 21 to 40. Equity claimants sometimes choose a debt level that is too difficult to service when the realized next period's income shock turns out to be much lower than expected.

In the agency model, we estimate unknown parameters using SMM. This procedure chooses the agency parameters, the volatility and persistence of the cash flow shocks, the bankruptcy parameter and the depreciation rate to minimize the distance between model-generated moments and the corresponding moments from actual data. Because the moments of the model-generated data depend on the structural parameters utilized, minimizing this distance will provide consistent estimates under the conditions discussed in the Appendix.

4.2 Selection of Moments

In this section we discuss the moments that we attempt to match when we solve the agency model. If chosen moments are not a priori informative about both the managerial private benefits parameters and the technological parameters we seek to estimate, then the results would suffer from large model standard errors in finite samples or lack of identification. Clearly, informative moments are those which are highly influenced with changes in the parameters.

In order to estimate (β_1, β_2, σ, ρ, Ω, δ) we attempt to match the first and second moments

[11] Michaelides and Ng (2000) find that good finite-sample performance of an indirect inference estimator requires a simulated sample that is approximately 10 times as large as the actual data sample. This is chosen simply because we intend to employ SMM on the agency model in the next section.

of the ratio of cash holdings to assets, the first moment of equity issuance-to-assets, the first moment of debt to asset and the payout ratio.

The mean of cash-to-assets is directly informative about the managerial private benefits of cash-piling. The variance of cash-to-assets is informative about the curvature of the cash-piling private benefits function(β_2) The first moment of equity issuance is informative about the costs of issuing equity. Costly equity issuance is part of the trade off model and is one of the reasons firms should keep cash balances. Therefore, they are informative about the extent of the firm's precautionary motive for saving, which hinges upon all the parameters of the private benefits function. The private benefits function is based on the size of equity issuances, thus, the first moment of equity issuance is also informative about the managerial private benefits.

The average debt to-asset ratio is informative about bankruptcy cost in case of default Ω. This is also informative about the position of debt in the financing pecking-order, which indirectly hinges upon the parameters of the cash-piling private benefit function. The payout ratio should be informative about cash holdings, as in the model the dividends are the residuals after the cash levels are chosen. Hence, it directly influences β_1 and β_2. It is clear that, the first and second moments of investment-to-assets are indirectly informative of the private benefits function. They are also directly informative about the depreciation rate δ.

Finally, we use moments which are informative about the production side of the firm. The final two moments capture the features of the shock's stochastic process θ: the autoregressive parameter, ρ, and the shock standard deviation, σ. The moments used to identify these parameters come from estimating a first-order panel autoregression of operating income on lagged operating income using the technique in Holtz-Eakin et al. (1988). The two moments that we match from this exercise are the autoregressive parameter and the standard deviation of the regression residual. The two moments are directly informative about ρ and σ. They also influence the precautionary motive of cash, as higher volatility of shocks and lower persistence of shocks would lead to higher optimal levels of cash holdings. Thus, these two moments are also indirectly informative about the parameters of private benefits of cash-piling function.

4.3 Estimation Results

We define the following variables in order to mimic the real-world data variables.

$$\frac{NetIncome_t}{TotalAssets_t} = \frac{(1-\tau_c)(f(K_t;\theta_t) - \delta K_t - i_t B_t)}{K_t}$$

where $f(K_t;\theta_t)$ is from equation (6).

$$\frac{Investment_t}{TotalAssets_t} = \frac{K_{t+1} - (1-\delta)K_t}{K_t}$$

$$\frac{Debt_t}{TotalAssets_t} = \frac{(1 + (1-\tau_b)i_t)B_t\mathbf{1}_{(V_t>0)} + (R(K_t;\theta_t) - \Omega B_t)\mathbf{1}_{(V_t\leq 0)}}{K_t}$$

$$PayoutRatio = \frac{D_t^+}{NetIncome_t} = \frac{D_t^+}{(1-\tau_c)(f(K_t;\theta_t) - \delta K_t - i_t B_t)}$$

where the superscript + refers to the max operator $D_t^+ = \max\{0, D_t\}$ (a superscript $-$ refers to the min operator, e.g., $D_t^- = \min\{0, D_t\}$).

$$\frac{EquityIssuance_t}{TotalAssets_t} = \frac{D_t^-}{K_t}$$

$$\frac{cashflow_t}{TotalAssets_t} = \frac{(1-\tau_f)(f(K_t;i_t) - i_t B_t) + \tau_c \delta K_t}{K_t}$$

The data are described in Appendix C. Table 1 contains estimation results for the full sample. This table compares the actual moments with those from the simulated model using exogenously selected parameters. The largest inconsistency for the simulated moments from the structural model is that it predicts a lower average cash-to-assets ratio. This supports the empirical literature arguing that the high level of cash holdings observed in the data cannot be explained by a trade-off model. The variance of cash-to-assets is also lower than the empirical moment. In general, the base-case model underestimates most of the moments when compared to the observed moments of the data. The only moment that is overestimated is the average equity issuance.

There has been an extensive literature on self-interested managers with empire building preferences. These managers tend to invest more than what is required to maximize the equity value of the firm. They prefer spending cash on expansions of their firms resulting in over-investment (Jensen and Meckling (1976), Moeller et al. (2005), and Harford et al. (2008)). In contrast, Bertrand and Mullainathan (2003) presents empirical evidence that active empire building may not be the norm and that managers may instead prefer to enjoy the "quiet life". In this case they will exploit private benefits for under-investment. The estimated first and second moments of investment-to-assets ratio are quite close to the empirical moments; however, they are both slightly overestimated. The observed over-investment reported in Table 1 is consistent with "empire building" preferences.

The exogenously chosen parameters also lead to underestimation of the payout ratio and the average debt-to-assets ratio. These results hand in hand with the low estimate of the first moment of the cash-to-assets ratio suggests the existence of some external agency parameters influencing the objective function of the firm's manager. More importantly, the overestimation of the average equity issuance suggests that this agency problem is due to avoidance of capital markets.

The standard deviation of the shocks to income-to-assets and the serial correlation of the shocks to income-to-assets are lower in the simulated panel than the empirical panel (0.3504 and 0.1092 versus 0.5630 and 0.3824, respectively). This suggest the possibility of inappropriate choices for the exogenously chosen parameters of ρ and σ. Therefore, when we employ SMM to estimate the agency parameters of the second-best model, we also endogenize the persistence and the volatility of the cash flow shocks in the model.

[Insert Table 1 Here]

Table 2 contains estimation results for the full sample. The table compares the actual moments with those from the simulated agency model. Overall, the first panel's results indicate small differences between the simulated moments and the empirical moments. The mean cash-to-assets ratio is still slightly underestimated but has been increased by almost three times in comparison to the results of the base-case model.[12] The first moment of equity-to-assets ratio is decreased to slightly below the empirical moment. This result suggests that the agency model in which the manager's private benefits for cash-piling is due to disutility from facing capital markets, has done quite a good job in matching the simulated moments with the empirical moments.

The second panel of Table 2 contains point estimates of the parameters. Estimated persistence and volatility of the cash flow shocks for the full sample are 0.653 and 0.122, and are also statistically significant at the 10% level. The estimates of the bankruptcy cost parameter and the depreciation are both statistically significant at the 10% level. The estimated bankruptcy cost is equal to 0.910 of the face value of debt. The parameters β_1 and β_2 are both statistically significant at the 10% level. The sign of β_1 indicates that managers on average do exploit private benefits for cash-piling. The cash-piling private benefits function is concave as β_2 is smaller than one. The estimated coefficients β_1 and β_2 are equal to 0.055 and 0.801, respectively. To consider these estimates from an economic perspective, we calculate the ratio of managerial private benefits to equity value. The results illustrate that, on average, for every million dollars of shareholders' equity value, managers exploit a value equivalent to $140,000 in private benefits. The estimated curvature of the private benefits is equal to 0.801 indicating marginal diminishing returns in cash levels.

[12]There has been a concern with the high level of positive skewness of cash holdings as some firms maintain enormous level of cash causing a long right tail. When comparing the skewness of cash-to-assets of the empirical panel (1.4959) with the simulated panel (1.4655) we find minimal difference. Therefore, we do not include the third moment of cash-to-assets as a moment in the SMM.

[Insert Table 2 Here]

The results in Table 2 mask substantial heterogeneity in private benefits of cash-piling across firms. This is illustrated in Tables 3 and 4, which report parameter estimates for small and large firms, respectively. Investigating the differences of the estimated agency parameters between the largest and smallest quartiles of the firms, sheds light on the existing heterogeneity of managerial preferences. Firm size is highly correlated with firm age. Larger and older firms may have managers with longer tenures. Arguably longer tenure could result in more CEO power and lead to managers exploiting larger private benefits.[13] However, larger firms may experience stronger corporate governance, resulting in lower managerial private benefits.[14] The effect of tenure and governance move in opposite directions.

At the same time, small firms may be subject to different real shocks compared to large mature firms. The empirical volatility of the shocks to income-to-assets are significantly higher for smaller firms. Thus, smaller firms would need a higher level of cash balances as a precautionary device for possible shortfalls in future cash flow. Although the observed average cash-to-assets ratio is higher for the smaller firms, it is not obvious that this is due to larger managerial private benefits of cash-piling. For these reasons, we split the sample according to firm size to look into the differences between the estimated agency parameters across firms.

Our results support the governance explanation as smaller firms tend to allow higher managerial private benefits for cash-piling. The estimated coefficient β_1 is equal to 0.059 for the small firms. This is larger than the coefficient of 0.031 estimated for the large firms. The curvature of the private benefits function does not change with size as β_2 remains around 0.8 for both subsamples. The curvature of the private benefits function and the persistence of the shocks to income-to-assets are not statistically significant for the subsample of small firms. However, for the large firms subsample, all of the parameters are statistically significant at the 10% level. In general, the behavior of larger firms seems to be more closely aligned with the simulated results. This may follow from larger firms following policies that are similar in nature to policies resulting from a trade-off model such as ours.

[Insert Table 3 Here]

[Insert Table 4 Here]

We further investigate if the recent growth in cash holdings is due to higher level of managerial private benefits. We match the same simulated moments with moments from data limited to

[13]See Bebchuk and Fried (2003) for a detailed analysis of CEO power as an agency problem.

[14]Harford et al. (2008) showed that larger firms have lower insider ownership, larger institutional ownership, and stronger boards. All these could result in stronger governance and lower managerial private benefits.

the years 2001 to 2005. We find evidence that the high observed cash-to-assets ratio (0.22) is mostly due to a higher standard deviation of shocks to income-to-assets since the estimated β_1 is not higher than its estimate for the full sample. This finding is consistent with the empirical study of Bates et al. (2009). During the period of 2001-2005 a typical manager has exploited the equivalent of \$130,000 for every million dollars of equity value. However, β_1 and β_2 remain statistically and economically significant indicating that managers still enjoy private benefits for cash-piling in the form of avoiding the discipline of capital markets. The reduction of managerial private benefits could be due to firms strengthening their corporate governance during the recent years. This could also be attributed to the regulation changes such as the implementation of SOX which requires more transparency within firms.

[Insert Table 5 Here]

In our model we have not included any flotation cost for debt. Potentially, a model with debt issuance cost could lead to higher optimal cash levels in the base-case model without including agency parameters. Within our model, any residual cash not explained by the trade-off hypothesis is entirely explained by the private benefits of cash-piling. Our estimates of private benefits of cash-piling may therefore be upwardly biased. But, given the magnitude of the discrepancy in the cash levels it is doubtful that debt issuance costs could eliminate the agency explanation. More importantly, we focus on how the motives for holding cash has changed since 1987. We expect that our comparative results on the driving force behind cash piling to remain unchanged, as there is no need to believe that debt issuance cost has changed dramatically in the last two decades.

5 Conclusion

We develop a discrete-time, infinite-horizon, partial equilibrium, stochastic model of debt, investment and cash holdings. In our model, firms trade off a tax benefit of debt against a default cost of debt. They also save cash in the presence of costly equity issuance and a tax penalty on the cash savings accounts. First, we solve the base-case model numerically by using exogenously chosen parameters from the literature. In the base-case model the manager maximizes the value of equity. The moments of this first-best solution are compared to empirical moments computed from a large sample of U.S. firms from 1987 to 2005. While the simulated moments underestimate most of the observed real moments, the main inconsistency is in the average cash-to-assets ratio where the simulated moment is three times lower than the empirical moment. However, the actual investment-to-assets and equity issuances-to-assets ratios are larger than the optimal levels.

Then, we propose an agency model which can explain the high level of cash holdings. The objective function of the manager is extended to capture the possibility of private benefits of cash-piling in the form of disutility for facing the discipline of capital markets. We employ SMM by matching a set of empirical moments with simulated moments, calibrating for agency parameters with the managers private benefits function. We also endogenize the calibration of the persistence and the standard deviation of the shock to income-to-assets, the deadweight cost of default and the depreciation rate.

The results indicate that a manager of a typical firm exploits private benefits equivalent to ($140,000) for the first million dollars of shareholders' equity value. The cash-piling private benefits function has an estimated curvature of (0.801). These SMM parameter estimates support the view that on average managers 1) enjoy fairly large private benefits of cash-piling, 2) and this private benefit is marginally diminishing. Moreover, our assumption on the form of the agency problem is validated as our model is able to explain both lower than optimal levels of equity issuance and higher than optimal levels of cash holdings concurrently.

We further explore the existing heterogeneity of the agency parameters across the firms. By employing SMM and splitting the sample based on firm size, we provide evidence that smaller firms behave as if they have managers with larger cash-piling preferences. This could be due to the existence of stronger corporate governance in larger firms. Consistent with Harford et al. (2008),firms with stronger corporate governance would not allow their managers to exploit a high level of private benefits.

We also look into a recent subsample from 2001-2005. We find evidence supporting Bates et al. (2009) as managerial private benefits for cash-piling have decreased in recent years. We also illustrate that the recent increase in cash holdings is due to higher volatility of cash flows. However, we still find the private benefits for cash-piling statistically and economically significant.

Appendix

A. Computational Method

In this section we present a method for solving the bellman equation described in Equation 12. To simplify the exposition, we consider a slightly abstracted version consistent with conventions in dynamic programming theory. In particular, Equation 12 can be represented in the following form:

$$V(S_t;\theta_t) = \max\left\{0, D(S_t, g(S_t;\theta_t)) + \frac{1}{1+r}E_t[V(tr(S_t, g(S_t;\theta_t);\theta_t);\theta_{t+1})\right\} \tag{15}$$

A solution consists of a policy $g : \mathcal{S} \times \Theta \rightarrow \mathcal{A}$ which maps a non-stochastic state in $\mathcal{S}$ and stochastic state in Θ to an action in $\mathcal{A}$. The non-stochastic state space $\mathcal{S}$ accounts for the capital K_t, cash C_t and debt B_t. The action space accounts for K_{t+1}, C_{t+1} and ΔB_{t+1}. The function $D_t : \mathcal{S} \times \mathcal{A} \rightarrow \mathbb{R}$ is equal to the dividend payment described in Equation (3). The transition function $tr(\cdot)$ calculates the outstanding debt, and capital and cash on hand at period $t+1$. For capital and cash the transition function is trivially equal to the respective action variables and for debt is updated as described by Equations (9).

The interest i_t is fully constrained by the fair pricing of debt and thus neither a manager action nor state variable. Since fair-pricing is dependent on the value function, the constraint on interest does not allow the bellman equation to fit into the standard dynamic programming structure. However, under reasonable restrictions on the size of interest payments, the Blackwell sufficient condition can be used to show that this Equation 15 does result in a contraction mapping. This result is sufficient to show the uniqueness and existence of a stable optimal solution.

An approximate solution is found by discretizing the state and action space and using a modified value function iteration algorithm. In particular, probability of default Φ is calculated for the product of states and actions resulting in a significant increase in computational complexity. The state space uses an evenly spaced grid with 10 points per variable. The auto-regressive process underlying the stochastic state is approximated with a discrete state Markov chain using the method described in Tauchen (1986). The process is created with 7 states spanning $e^{\pm 3\sigma}$. In addition, the action space must also be discretized. This is done again via an evenly spaced grid selected with 7 points per variable. The discretized transition function selects the closest grid point to the output of the continuous transition function.

B. Simulated Method of Moments

SMM can be used to estimate a vector of unknown structural parameters, say β^*, by matching a set of simulated moments, denoted as m^*, with corresponding data moments, denoted as M. The candidates for the moments to be matched include simple summary statistics and ordinary least squares regression coefficients.

Without loss of generality, the data moments can be represented as the solution to the maximization of a criterion function

$$\hat{M}_N = \underset{M}{\operatorname{argmax}}\, J(X_N, M)$$

where X_N is a data matrix of length N.We first estimate $\hat{M}_N$. Then we construct S data sets based on simulations of the model under a given parameter vector, β. For each simulated data set, we estimate $m*$ by maximizing an analogous criterion function

$$\hat{m}_n^s = \underset{m}{\operatorname{argmax}}\, j(x_n^s, m)$$

where x_n^s is a simulated data matrix of length n, and where, $m_n^s(\beta)$ is expressed as an explicit function of the structural parameters utilized in that particular round of simulations. The SMM estimator of β^* solves

$$\hat{\beta} = \underset{\beta}{\operatorname{argmin}} \left(\hat{M}_N - \frac{1}{S}\sum_{s=1}^{S} m_n^s(\beta)\right)' \hat{W}_N \left(\hat{M}_N - \frac{1}{S}\sum_{s=1}^{S} m_n^s(\beta)\right)$$

where $\hat{W}_N$ is an arbitrary positive definite matrix that converges in probability to a deterministic positive definite matrix W. However, the optimal weighting matrix is

$$\hat{W}_N^{opt} = (N\text{var}(\hat{M}_N))^{-1}.$$

Following Hennessy and Whited (2007), we use the influence-function approach in Erickson and Whited (2000) to calculate this covariance matrix. Specifically, we stack the influence functions for each of our moments and then form the covariance matrix by taking the sample average of the inner product of this stack.

Hennessy and Whited (2007) show that the indirect estimator (β) is asymptotically normal for fixed S.[15] Further, the technique provides a test of the overidentifying restrictions of the model, with

[15] In this study we choose $S = 6$.

$$\frac{NS}{1+S}\Big(\hat{M}_N - \frac{1}{S}\sum_{s=1}^{S} m_n^s(\beta)\Big)' \hat{W}_N \Big(\hat{M}_N - \frac{1}{S}\sum_{s=1}^{S} m_n^s(\beta)\Big)$$

converging in distribution to a χ^2 with degrees of freedom equal to the dimension of M minus the dimension of β.

Minimizing the error involves a computational search through the space of parameters. We employ a gradient descent approach augmented by an iterated local search metaheuristic (ILS). Using ILS, select parameters are perturbed when the gradient descent is unable to find an improving direction ($\frac{\partial E(\beta)}{\partial \beta_i} = 0$ for each parameter β_i). Intuitively, ILS provides a framework for a directed search through the set of local minima.

C. Data

The data are from the annual 2006 COMPUSTAT industrial files. The sample is selected by first deleting any firm-year observations with missing data, or for which total assets, or sales are either zero or negative. A firm is included in the sample only if it has at least three consecutive years of complete data. Finally, a firm is omitted if its primary SIC is between 4900 and 4999, between 6000 and 6999, or greater than 9000, as the model is inappropriate for regulated, financial, or public service firms. After winsorizing the top and bottom 1% of the variables in the data set, we end up with an unbalanced panel of firms from 1987 to 2005 with between 1957 and 3155 observations per year. Data variables are defined as follows: book assets is Compustat Item 6; gross capital stock is Item 7; investment is the difference between Items 30 and 107; cash flow is the sum of Items 18 and 14; equity issuance is Item 108; total long-term debt is Item 9 plus Item 34; total cash distributions is the sum of Item 19, Item 21, and Item 115; the stock of cash is Item 1; and sales is Item 12. The market-to-book ratio's numerator is defined as book assets minus book equity (item 60) minus balance sheet deferred taxes (item 7) plus the market value of equity (item 199 times item 25). The denominator is book value of assets.

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Table 1: Exogenously Simulated and Empirical Moments for the Full Sample

The table reports the simulated and estimated moments. Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files. The sample period is 1987 to 2005. Estimation is done for the exogenously chosen parameters for the base-case model, The simulated panel of firms is generated from the model in Section 2, and contains 20,000 firms over 40 time periods, where only the last 19 time periods are kept for each firm. ~~

Name of Moments	Empirical Moments	Simulated Moments
Average Cash/Assets	0.1837	0.0610
Variance of Cash /Assets	0.0550	0.0514
Average Investment/Assets	0.0659	0.0518
Variance of Investment/Assets	0.0073	0.0038
Average Equity Issuance/Assets	0.0933	0.1485
Payout ratio	0.2251	0.2174
Average Debt/Assets	0.2357	0.1434
Standard Deviation of the Shocks to Income/Assets	0.1891	0.1090
Serial Correlation of Income/Assets	0.5610	0.4824

Table 2: Simulated Moments Estimation for the Full Sample

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files. The sample period is 1987 to 2005. 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 simulated panel of firms is generated from the model in Section 2, and contains 20,000 firms over 40 time periods, where only the last 19 time periods are kept for each firm. The first panel reports the simulated and estimated moments. The second panel reports the estimated structural parameters, with standard errors in parentheses. β_1 represents the magnitude of managerial private benefits for the first million dollars of cash holdings. β_2 characterizes the curvature of the private benefits power function for cash-piling. Ω is the deadweight cost of default proportional to the face value of debt. δ is the depreciation rate of the assets. σ is the standard deviation of the innovation to $ln(\theta)$, in which θ is the shock to the cash flow function. ρ is the serial correlation of $ln(\theta)$. χ^2 is a chi-squared statistic for the test of the overidentifying restrictions. In parentheses is its p-value.

Panel A: Moments

Name of Moments	Empirical Moments	Simulated Moments
Average Cash/Assets	0.1837	0.1759
Variance of Cash /Assets	0.0550	0.0617
Average Investment/Assets	0.0659	0.0733
Variance of Investment/Assets	0.0073	0.0087
Average Equity Issuance/Assets	0.0933	0.0832
Payout ratio	0.2251	0.1974
Average Debt/Assets	0.2357	0.2466
Standard Deviation of the Shocks to Income/Assets	0.1891	0.1777
Serial Correlation of Income/Assets	0.5610	0.6039

Panel B: Parameter Estimates

β_1	β_2	Ω	δ	σ	ρ	χ^2
0.0550	0.801	0.0910	0.089	0.122	0.653	8.341
(0.091)	(0.081)	(0.054)	(0.092)	(0.062)	(0.076)	0.036

Table 3: Simulated Moments Estimation for Small Firms

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files, in which only firms in the lowest quartile of the distribution of book assets are retained. The sample period is 1987 to 2005. 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 simulated panel of firms is generated from the model in Section 2, and contains 20,000 firms over 40 time periods, where only the last 19 time periods are kept for each firm. The first panel reports the simulated and estimated moments. The second panel reports the estimated structural parameters, with standard errors in parentheses. β_1 represents the magnitude of managerial private benefits for the first million dollars of cash holdings. β_2 characterizes the curvature of the private benefits power function for cash-piling. Ω is the deadweight cost of default proportional to the face value of debt. δ is the depreciation rate of the assets. σ is the standard deviation of the innovation to $ln(\theta)$, in which θ is the shock to the cash flow function. ρ is the serial correlation of $ln(\theta)$. χ^2 is a chi-squared statistic for the test of the overidentifying restrictions. In parentheses is its p-value.

Panel A: Moments

Name of Moments	Empirical Moments	Simulated Moments
Average Cash/Assets	0.1968	0.2171
Variance of Cash /Assets	0.0441	0.0610
Average Investment/Assets	0.0597	0.0762
Variance of Investment/Assets	0.0086	0.0075
Average Equity Issuance/Assets	0.1151	0.101
Payout ratio	0.0942	0.1276
Average Debt/Assets	0.0401	0.0281
Standard Deviation of the Shocks to Income/Assets	0.2391	0.1991
Serial Correlation of Income/Assets	0.5432	0.6740

Panel B: Parameter Estimates

β_1	β_2	Ω	δ	σ	ρ	χ^2
0.0590	0.798	0.101	0.083	0.132	0.450	10.106
(0.090)	(0.168)	(0.081)	(0.058)	(0.079)	(0.104)	0.020

Table 4: Simulated Moments Estimation for Large Firms

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files, in which only firms in the highest quartile of the distribution of book assets are retained. The sample period is 1987 to 2005. 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 simulated panel of firms is generated from the model in Section 2, and contains 20,000 firms over 40 time periods, where only the last 19 time periods are kept for each firm. The first panel reports the simulated and estimated moments. The second panel reports the estimated structural parameters, with standard errors in parentheses. β_1 represents the magnitude of managerial private benefits for the first million dollars of cash holdings. β_2 characterizes the curvature of the private benefits power function for cash-piling. Ω is the deadweight cost of default proportional to the face value of debt. δ is the depreciation rate of the assets. σ is the standard deviation of the innovation to $ln(\theta)$, in which θ is the shock to the cash flow function. ρ is the serial correlation of $ln(\theta)$. χ^2 is a chi-squared statistic for the test of the overidentifying restrictions. In parentheses is its p-value.

Panel A: Moments		
Name of Moments	Empirical Moments	Simulated Moments
Average Cash/Assets	0.1233	0.1023
Variance of Cash/Assets	0.0240	0.0411
Average Investment/Assets	0.0709	0.0708
Variance of Investment/Assets	0.0059	0.0070
Average Equity Issuance/Assets	0.0282	0.0209
Payout ratio	0.2664	0.1982
Average Debt/Assets	0.2418	0.2204
Standard Deviation of the Shocks to Income/Assets	0.0513	0.0728
Serial Correlation of Income/Assets	0.6906	0.6981

Panel B: Parameter Estimates						
β_1	β_2	Ω	δ	σ	ρ	χ^2
0.0310	0.821	0.052	0.078	0.073	0.752	7.820
(0.071)	(0.087)	(0.051)	(0.046)	(0.092)	(0.098)	0.051

Table 5: Simulated Moments Estimation for the Period of 2001-2005

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2006 COMPUSTAT industrial files, in which only firm-years from the sub period of 2001-2005 are retained. The sample period is 2001 to 2005. 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 simulated panel of firms is generated from the model in Section 2, and contains 20,000 firms over 40 time periods, where only the last 19 time periods are kept for each firm. The first panel reports the simulated and estimated moments. The second panel reports the estimated structural parameters, with standard errors in parentheses. β_1 represents the magnitude of managerial private benefits for the first million dollars of cash holdings. β_2 characterizes the curvature of the private benefits power function for cash-piling. Ω is the deadweight cost of default proportional to the face value of debt. δ is the depreciation rate of the assets. σ is the standard deviation of the innovation to $ln(\theta)$, in which θ is the shock to the cash flow function. ρ is the serial correlation of $ln(\theta)$. χ^2 is a chi-squared statistic for the test of the overidentifying restrictions. In parentheses is its p-value.

Panel A: Moments

Name of Moments	Empirical Moments	Simulated Moments
Average Cash/Assets	0.2238	0.2268
Variance of Cash /Assets	0.0583	0.0801
Average Investment/Assets	0.0653	0.0789
Variance of Investment/Assets	0.0071	0.0073
Average Equity Issuance/Assets	0.0637	0.0431
Payout ratio	0.2025	0.2268
Average Debt/Assets	0.2148	0.2346
Standard Deviation of the Shocks to Income/Assets	0.2416	0.1932
Serial Correlation of Income/Assets	0.6082	0.6843

Panel B: Parameter Estimates

β_1	β_2	Ω	δ	σ	ρ	χ^2
0.0521	0.815	0.119	0.085	0.261	0.682	9.371
(0.092)	(0.082)	(0.089)	(0.067)	(0.223)	(0.119)	0.027