

# Capital Structure Dynamics and Transitory Debt

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## Abstract

This paper develops a model in the spirit of Hennessy and Whited (2005) in which the capital structure dynamics associated with transitory debt fully explain the long-horizon leverage paths documented by Lemmon, Roberts, and Zender (2008). The model shows how and why debt serves as a transitory financing vehicle to meet the funding needs associated with random shocks to investment opportunities. It yields a variety of new testable predictions about the time paths of leverage and the link between investment and capital structure dynamics. Although these dynamics also reflect financing frictions, predictable variation in capital structure primarily reflects the attributes of firms' investment opportunities—e.g., the volatility and serial correlation of investment shocks, the marginal profitability of investment, and the nature of capital stock adjustment costs—with the linkage between investment attributes and leverage dynamics reflecting firms' usage of transitory debt.

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# 1. Introduction

Lemmon, Roberts, and Zender (2008, LRZ) document that the majority of variation in leverage ratios is driven by an unobserved time-invariant effect, with high (low) levered firms tending to remain as such for over two decades, and they conclude that previously identified determinants of capital structure are unable to explain their findings. We develop and estimate a dynamic model in the spirit of Hennessy and Whited (2005) in which firms' incurrence and subsequent repayment of transitory debt generates leverage paths qualitatively identical to those documented by LRZ. In our model, firms tailor their *ex ante* optimal capital structures to preserve the option to borrow *ex post* in order to economize on the costs associated with alternative sources of capital. The key to our results is that the option to borrow to fund future investment is valuable today, a fact that tax/distress cost models fail to consider. More troublingly, Jensen (1986) and the agency literature that builds on his analysis implicitly treat that option as valueless by positing that very high debt levels are optimal for mature companies, although such capital structures leave firms with little ability to borrow to meet any imperfectly anticipatable future financing needs.

In our model, the option to borrow to fund future investment is valuable because of the interplay of three assumptions under which all sources of capital (external equity, corporate cash balances, and borrowing) are costly. First, equity issuance entails adverse selection and/or flotation costs. Second, firms with higher cash balances face greater agency costs, corporate taxes, and/or an interest rate differential on precautionary liquid asset holdings in the spirit of Keynes (1936). Finally, debt capacity is finite, an assumption motivated by the view that firms face financial distress costs and/or asymmetric information problems that prevent creditors from perfectly gauging their ability to support debt. As a result, when a firm borrows in a given period, the relevant "leverage-related cost" includes the opportunity cost of its consequent future inability to borrow—a cost inherently absent from traditional tax/distress cost and all other static capital structure models. Nor does the opportunity cost of borrowing play any role in Myers and Majluf's (1984) pecking order model, which considers only a "one-shot" financing decision and thereby ignores any future reduction in unused debt capacity.

The opportunity cost of borrowing can be captured only in a dynamic framework in which

the debt decision at any given date affects the set of feasible borrowing decisions at future dates. It implies that firms' target capital structures are more conservative than predicted by an otherwise similar static model, since the cost of borrowing today includes the value lost by failing to preserve the option to borrow in future periods, thus forcing firms to use more costly alternative sources of capital (and perhaps to forego otherwise attractive new investment opportunities). This valuable option, moreover, radically changes the nature of predicted leverage dynamics from those of traditional tradeoff and pecking order models. Although firms have long-run capital structure targets as in static tradeoff models, in our model managers sometimes deliberately deviate from target by borrowing temporarily to meet imperfectly anticipated capital needs. They subsequently rebalance to target by reducing debt with a lag determined in part by the time path of investment opportunities and earnings realizations.

Our model predicts that capital structures have both permanent and transitory debt components—the former is the long-run target, whereas the latter is borrowing undertaken to meet funding needs from current and previous shocks to investment opportunities (hereafter “investment shocks”).<sup>1</sup> Intuitively, a firm's long-run target capital structure is the theoretically ideal debt level that, when viewed *ex ante*, optimally balances its corporate tax shield from debt against not only distress costs, but also against the opportunity cost of borrowing now rather than preserving the option to borrow later. More precisely, in our model a firm's target capital structure is the optimal matching of debt and assets to which the firm would converge if it were to receive no investment shocks for many periods in a row. In general, the target debt level is a function of the probability distribution of investment opportunities, and of agency, distress, and external equity financing costs. We show that the target is a single ratio of debt to assets, except when firms face fixed costs of adjusting their stock of physical capital, in which case there is a range of target leverage ratios.

Actual debt levels deviate from target as firms borrow in response to investment shocks that manifest. Managers work their way back to target as circumstances permit to position their firms optimally to raise capital once again in response to future shocks that might materialize. For

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<sup>1</sup>Transitory debt is not synonymous with short-term debt. Indeed our model includes only perpetual debt, which managers issue and later retire or leave outstanding permanently as future circumstances dictate. In reality, transitory debt can include bonds, term loans, and borrowing under lines of credit that managers intend to pay off in the short to intermediate term to free up debt capacity.

example, with no tax or other permanent benefit from corporate debt, zero debt is the target because it provides firms with maximal debt capacity to meet their future financing needs. Paying down any existing debt (issued to fund imperfectly anticipated investment needs in prior periods) frees up debt capacity, which reduces the expected future costs of capital access, hence managers always have incentives to return their firms to zero debt in the absence of taxes. They may not be able to accomplish this objective quickly, however, since multiple sequential investment shocks may arrive, requiring additional funds and, perhaps, more borrowing.

The prediction that firms deliberately deviate from target differentiates our analysis from existing trade-off models with exogenous investment and positive leverage rebalancing costs, e.g., Fischer, Heinkel, and Zechner (1989) and Goldstein, Ju, and Leland (2001). The latter models universally predict that all management-initiated changes in capital structure move firms toward target, although Welch (2004) and others show that this prediction is wide of the mark empirically. An important implication of our analysis is that future empirical studies that seek to gauge the strength of firms' incentives to rebalance their capital structures should differentiate between (i) pro-active decisions to incur transitory debt and deliberately, but temporarily, deviate from target, and (ii) pro-active and passive capital structure changes that move firms back toward target.

Our model generates long-horizon average leverage paths that conform closely to those reported by Lemmon, Roberts, and Zender (2008), who analyze average leverage ratios for four groups of firms sorted by initial (high versus low) leverage, and show that all groups converge slowly, but incompletely, toward moderate leverage. The mean reversion of average debt ratios and their incomplete convergence over 20 years suggests that firms have positive leverage targets that differ cross-sectionally, while the slow rate of convergence suggests a transitory debt component in capital structures. We present the results of two versions of our model to compare to LRZ's findings. The first, which is an excellent match and the one we emphasize, is our full (corporate tax-inclusive) model. The only drawback of this specification is that the model's complexity makes it difficult to see the reason why our model's results match LRZ's so closely. To clarify that mechanism, we present a no-tax simplification of our model. Although the results from this version of the model are not as close a match to LRZ's, they illustrate more clearly the mechanics of our model because

in the no-tax case (i) all firms have stable and identical leverage targets, (ii) all firms' leverage targets are zero, and (iii) all debt is transitory.

Our model-generated average leverage ratios for each of LRZ's groups stabilize over time, but not at values in the neighborhood of target leverage, as is readily apparent in our no-tax model, in which the target debt level is zero and long-run average leverage is strictly positive for all groups. This difference occurs because the capital structure of the average firm (in groups formed as in LRZ) approaches the target debt level plus the amount of transitory debt expected to be outstanding at a randomly selected point in time. Since the latter value is strictly positive and varies cross-sectionally and predictably with or without taxes, the model generates LRZ's qualitative leverage paths even when target debt levels are zero and all debt is transitory, as in our no-tax model. This implication of our model suggests that cross-firm variation in average leverage to a significant degree reflects variation in transitory debt due, e.g., to cross-firm heterogeneity in the volatility of prospective investment shocks. A related finding is that cross-firm variation in leverage targets (which occurs only in our full with-tax model) is systematically related to heterogeneity in investment opportunities that determine the value of preserving debt capacity to address funding needs associated with prospective future investment shocks.

Our model yields a number of testable predictions that link firms' investment attributes to their capital structure decisions. In our no-tax model, the average debt outstanding is 4.5% of total assets for firms that face high investment shock volatility versus 11.2% for firms with low shock volatility. In the with-tax model, average debt is 6.2% of assets for the former firms and 38.4% for the latter, implying that corporate taxes increase leverage by a substantial 27.2% for low shock volatility firms but only by 1.7% for high shock volatility firms. Firms that face high shock volatility find it especially valuable to preserve debt capacity to address substantial funding needs associated with future investment shocks, and this benefit looms large relative to the interest tax shields they lose by maintaining low debt ratios on average. The more volatile investment outlays of high versus low shock volatility firms also imply that the former rely to a greater degree on costly cash balances to fund investment. For similar reasons, lower average debt ratios and greater reliance on cash balances to fund investment are also predicted for firms that face high as opposed

to low (i) serial correlation of investment shocks, (ii) marginal profitability of investment, and (iii) fixed costs of adjusting the stock of physical capital, and for (iv) firms that face low as opposed to high convex costs of capital stock adjustment.

Variation in investment opportunity attributes is the main determinant of leverage variation in our model, with variation in financing frictions—i.e., the costs of equity access and of maintaining cash balances—having only second-order impact. This theme is evident not only in our own comparative statics results, but also in a small but growing literature of dynamic models that explore the interactions of investment policy and capital structure, e.g., Tserlukevich (2008) and Morellec and Schürhoff (2008) on the leverage impact of real options. It is also implicit in Brennan and Schwartz (1984), Hennessy and Whited (2005), Titman and Tsyplakov (2007), and Gamba and Triantis (2008), all of which treat investment as endogenous while focusing respectively on debt covenants, taxes, agency issues, and cash holdings. Our analysis complements all of these studies by focusing directly on the capital structure impact of variation in investment attributes and, in particular, of variation in the volatility and serial correlation of investment shocks, the marginal profitability of investment, and the properties of capital stock adjustment costs.

Section 2 details the assumptions and solution properties of our model. Section 3 shows that the model generates long-horizon leverage paths that closely conform to those documented empirically by Lemmon, Roberts, and Zender (2008). Sections 4 and 5 respectively present comparative statics analyses of the no-tax and with-tax specifications of the model. Section 6 summarizes our findings.

## **2. A simple dynamic model of capital structure**

Managers select the firm’s investment and financial policies at each date in an infinite-horizon world so that, at every decision node, they must be mindful of the consequences of today’s decisions on the feasible set of decisions at each future date. Their decisions include (i) investment in real assets, (ii) changes in cash balances, (iii) how much to raise externally by issuing equity or debt, and (iv) distributions to debt and equity holders. A firm’s debt capacity is finite, an assumption that reflects the view that financial distress costs and/or asymmetric information problems prevent creditors from determining with precision the firm’s ability to support debt. Equity issuance incurs

exogenously given costs, which can be interpreted as flotation or adverse selection costs, as in Myers and Majluf (1984). Cash balances are also costly, an assumption motivated by differential borrowing and lending rates (Cooley and Quadrini (2001)), agency costs (Jensen (1986), Stulz (1990)), or a premium paid for precautionary liquid asset holdings (Keynes (1936)). We refer to these costs hereafter, for simplicity, as “agency costs.”

## 2.1 Model setup

The model starts with a firm that uses capital,  $k$  to produce output. The firm’s managers select investment and financing decisions to maximize the wealth of owners, which is determined by risk-neutral security pricing in the capital market. The firm’s per period profit function is given by  $\pi(k, z)$ , in which  $z$  is a shock to the profit function, observed by managers each period before making the firm’s investment and financing decisions. For brevity, we often refer to  $z$  as an “investment shock” to capture the idea that variation in  $z$  alters the marginal productivity of capital and therefore the firm’s investment opportunities. The profit function  $\pi(k, z)$  is continuous, with  $\pi(0, z) = 0$ ,  $\pi_z(k, z) > 0$ ,  $\pi_k(k, z) > 0$ ,  $\pi_{kk}(k, z) < 0$ , and  $\lim_{k \rightarrow \infty} \pi_k(k, z) = 0$ . Concavity of  $\pi(k, z)$  results from decreasing returns in production, a downward sloping demand curve, or both. In what follows we use the functional form  $\pi(k, z) = zk^\theta$ , where  $\theta$  is an index of the curvature of the profit function, with  $0 < \theta < 1$ , which satisfies concavity and the Inada condition.

The shock  $z$  takes values in the interval  $[\underline{z}, \bar{z}]$  and follows a first-order Markov process with transition probability  $g(z', z)$ , where a prime indicates a variable in the next period. The transition probability  $g(z', z)$  has the Feller property. A convenient parameterization is an  $AR(1)$  in logs,

$$\ln(z') = \rho \ln(z) + v', \quad (1)$$

in which  $v'$  has a truncated normal distribution with mean 0 and variance  $\sigma_v^2$ . In what follows we use the term “variance of investment shocks” to refer to  $\sigma_v^2$ .

Without loss of generality,  $k$  lies in a compact set. As in Gomes (2001), define  $\bar{k}$  as

$$(1 - \tau_c) \pi(\bar{k}, \bar{z}) - \delta \bar{k} \equiv 0, \quad (2)$$

in which  $\delta$  is the capital depreciation rate,  $0 < \delta < 1$ , and  $\tau_c$  is the corporate income tax rate. In some versions of the model we set this tax rate equal to zero. Concavity of  $\pi(k, z)$  and  $\lim_{k \rightarrow \infty} \pi_k(k, z) =$

0 ensure that  $\bar{k}$  is well-defined. Because  $k > \bar{k}$  is not economically profitable,  $k$  lies in the interval  $[0, \bar{k}]$ . Compactness of the state space and continuity of  $\pi(k, z)$  ensure that  $\pi(k, z)$  is bounded.

Investment,  $I$ , is defined as

$$I \equiv k' - (1 - \delta)k. \quad (3)$$

The firm purchases and sells capital at a price of 1 and incurs capital stock adjustment costs that are given by

$$A(k, k') = \gamma k \Phi_i + \frac{a}{2} \left( \frac{k' - (1 - \delta)k}{k} \right)^2 k. \quad (4)$$

The functional form of (4) is standard in the empirical investment literature, and it encompasses both fixed and smooth adjustment costs. See, for example, Cooper and Haltiwanger (2006). The first term captures the fixed component,  $\gamma k \Phi_i$ , in which  $\gamma$  is a constant, and  $\Phi_i$  equals 1 if investment is nonzero, and 0 otherwise. The fixed cost is proportional to the capital stock so that the firm has no incentive to grow out of the fixed cost. The smooth component is captured by the second term, in which  $a$  is a constant. Although curvature of the profit function acts to smooth investment over time in the same way that the quadratic component of (4) does, we include the quadratic component to isolate the effects of smooth adjustment costs, which turn out to have interesting effects on leverage dynamics.

We now discuss financing. The firm can finance via external debt, internal cash, and external equity. We start by defining the stock of net debt,  $p$ , as the difference between the stock of debt,  $d$ , and the stock of cash,  $c$ . Given no debt issuance costs and positive agency costs of holding cash, which are formalized below, a firm never simultaneously has positive values of both  $d$  and  $c$  because using the cash to pay off debt would leave the corporate tax bill unchanged and reduce agency costs. It follows that  $d = \max(p, 0)$  and  $c = \min(0, p)$ , and so we can parsimoniously represent the formal model with the variable  $p$  and then use the definitions of  $d$  and  $c$  to obtain the levels of debt and cash balances at each point in time.

Debt takes the form of a riskless perpetual bond that incurs taxable interest at the after-corporate tax rate  $r(1 - \tau_c)$ , while cash earns the same after-tax rate of return (aside from the incremental cost,  $s$ , formalized below). We motivate the modeling of a riskless bond from the literature that has focused on adverse selection as a mechanism for credit rationing. Jaffee and

Russell (1976) discuss the potential for the quality of the credit pool to decline as the amount borrowed increases, and Stiglitz and Weiss (1981) demonstrate that lenders, recognizing the existence of adverse selection and asset substitution problems, may ration credit rather than rely on higher promised interest rates as a device for allocating funds. Based on this consideration, we assume lenders allocate funds on the basis of a screening process that ensures the borrower can repay the loan in all states of the world. This assumption translates into an upper bound,  $\bar{p}$ , on the stock of net debt. As described in the Appendix, we set this bound so that equity value never falls below zero and so that the firm therefore never has an incentive to default. For simplicity, we model the tax advantage of debt only via a corporate income tax. We abstract from the effects of personal taxes, which are treated thoroughly in Hennessy and Whited (2005).

A value of  $p$  greater than zero indicates a positive net debt position, and a value less than zero indicates a positive net cash position. To ensure bounded savings, our model requires some penalty for holding cash. We have chosen to model what we refer to as “agency costs,” as in Eisfeldt and Rampini (2006). Other choices include a stochastic probability of default, as in Carlstrom and Fuerst (1997), or interest taxation, which is operative when we set  $\tau_c > 0$ . The agency cost function is given by

$$s(p) = sp\Phi_c, \tag{5}$$

in which  $s$  is a constant and  $\Phi_c$  is an indicator variable that takes a value of 1 if  $p < 0$ , and 0 otherwise. To make the choice set compact, we assume an arbitrary lower bound on liquid assets,  $p$ . This lower bound is imposed without loss of generality because of our taxation and agency cost assumptions.<sup>2</sup>

The final source of finance is external equity. In the model, gross equity issuance/distributions are determined simultaneously with investment, debt, and cash. These decision variables are connected by the familiar identity that stipulates the sources and uses of funds are equal in each period. Define  $e(k, k', p, p', z)$  as gross equity issuance/distributions and  $\phi(e(k, k', p, p', z))$  as the cost of

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<sup>2</sup>The assumptions that cash equals negative debt and of an upper bound on debt are innocuous for our purposes. What is important it that there be some type of cost or limitation to the use of debt, since otherwise debt will always dominate equity financing. In model simulations not reported, we have included financial distress costs as modeled by Hennessy and Whited (2005). We have also allowed for debt issuance costs and consequently separate cash and debt state variables, as in Gamba and Triantis (2008). Neither of these changes affects our basic conclusions.

issuing external equity. Then this identity can be written as:

$$e(k, k', p, p', z) \equiv (1 - \tau_c) \pi(k, z) + p' - p(1 + r(1 - \tau_c)) + \delta k \tau_c - (k' - (1 - \delta)k) - A(k, k') - s(p) - \phi(e(k, k', p, p', z)). \quad (6)$$

If  $e(k, k', p, p', z) > 0$ , the firm is making distributions to shareholders, and if  $e(k, k', p, p', z) < 0$ , the firm is issuing equity. As in Hennessy and Whited (2005, 2007) and Riddick and Whited (2008) we model the cost of external equity finance in a reduced-form fashion that preserves tractability.

The external equity-cost function is linear-quadratic and weakly convex:

$$\phi(e(k, k', p, p', z)) \equiv \Phi_e \left( \lambda_1 e(k, k', p, p', z) - \frac{1}{2} \lambda_2 e(k, k', p, p', z)^2 \right) \\ \lambda_i \geq 0, \quad i = 1, 2,$$

in which  $\Phi_e$  equals 1 if  $e(k, k', p, p', z) < 0$ , and 0 otherwise. Convexity of  $\phi(e(k, k', p, p', z))$  is consistent with the evidence on underwriting fees in Altinkilic and Hansen (2000).

The firm chooses  $(k', p')$  each period to maximize the value of expected future cash flows, discounting at the opportunity cost of funds,  $r$ . The Bellman equation for the problem is

$$V(k, p, z) = \max_{k', p'} \left\{ e(k, k', p, p', z) + \phi(e(k, k', p, p', z)) + \frac{1}{1+r} \int V(k', p', z') dg(z', z) \right\}. \quad (7)$$

The first two terms represent the current equity distribution net of equity infusions and issuance costs and the third term represents the continuation value of equity. The model satisfies the conditions for Theorem 9.6 in Stokey and Lucas (1989), which guarantees a solution for (7). Theorem 9.8 in Stokey and Lucas (1989) ensures a unique optimal policy function,  $\{k', p'\} = u(k, p, z)$ , if  $e(k, k', p, p', z) + \phi(e(k, k', p, p', z))$  is weakly concave in its first and third arguments. This requirement puts easily verified restrictions on  $\phi(\cdot)$  that are satisfied by the functional forms chosen above. The policy function is essentially a rule that states the best choice of  $k'$  and  $p'$  in the next period for any  $(k, p, z)$  triple in the current period.

Hennessy and Whited (2005) state that in this type of model there is no single optimal capital structure. Indeed, in our model, capital structure choices are made each period and are state-contingent, exhibiting (local) path dependence. Firms nonetheless have capital structure targets in a long-run sense, but specifying the analytical sense in which a target exists in this type of dynamic

model requires some care. To do so, we consider the following thought experiment. What if one subjected the firm to an infinite sequence of shocks, all of which are neutral ( $z = 1$ )? In this case no new funding requirements arrive randomly, and the firm eventually receives enough internally generated resources to enable it to reach its desired debt level without having to incur the costs of issuing equity. Would its optimal policy converge under this sequence of neutral shocks, and, if so, to a single  $\{k, p\}$  pair or to a range of  $\{k, p\}$  pairs?<sup>3</sup> To answer the first part of this question, we define  $u_1(k, p, 1)$  as the first element of the policy function, evaluated at  $z = 1$ , and we define  $u_1^j(k, p, 1)$  as the first element of the function that results from mapping  $u(k, p, 1)$  into itself  $j$  times. We then define the target capital stock as lying in the interval

$$\left[ \lim_{j \rightarrow \infty} \inf u_1^j(k, p, 1), \lim_{j \rightarrow \infty} \sup u_1^j(k, p, 1) \right]. \quad (8)$$

The existence of this interval is determined trivially by the compactness of the state space and the boundedness of  $u(k, p, z)$ . For each capital stock in this interval, there will be exactly one optimal level of  $p$  because the value function for this class of models is strictly concave (Hennessy and Whited (2005)). In intuitive terms, for any given  $k$ , there cannot be two values of  $p$  that yield the same maximum valuation. Of course, because  $u(k, p, z)$  has no closed-form solution, we must use simulation to solve for the target and to determine its exact form. Whether or not the firm has a unique leverage target depends on whether it has a unique capital stock target. Further, the issue of whether the target interval in (8) is a single point depends strongly on the form of the physical adjustment cost function (4), as we elaborate in section 5.3 below.

## 2.2 Model estimation

Although this model has a solution, the solution does not have a closed form. The solution must be obtained numerically, and the quantitative properties of the model can therefore depend on the

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<sup>3</sup>The intuition behind this definition of a long-run target capital structure is analogous to that which drives the notion of a target payout ratio in Lintner (1956). Consider a firm for which last period's dividend and this period's earnings give it an actual payout ratio below its long-run target payout ratio. Suppose the firm experiences a series of neutral earnings shocks, i.e., repeated realizations of this period's earnings. The firm will respond by increasing dividends over time so that its actual payout ratio converges to its long-run target. In the Lintner model, the firm virtually never has an actual payout ratio equal to target, but the existence of a long-run target payout ratio represents an economic force that governs the dynamics of dividend policy. In our model, the existence of a long-run target capital structure governs leverage dynamics in the same sense. An important difference is that Lintner assumes the existence of a target payout ratio, whereas we show that the existence of a target capital structure is an implication of our model. For more on target capital structures, see section 5.3.

parameters chosen. To address concerns about this dependency, we select parameters via structural estimation of the model. This procedure helps ensure that the parameters chosen produce results that are relevant given observed data. We use simulated method of moments (SMM), which chooses model parameters that set moments of artificial data simulated from the model as close as possible to corresponding real-data moments. We estimate the following parameters: profit function curvature,  $\theta$ ; shock serial correlation,  $\rho$ ; shock standard deviation,  $\sigma_v$ ; smooth and fixed physical adjustment costs,  $a$  and  $\gamma$ ; the agency cost parameter,  $s$ ; and the two external equity cost parameters,  $\lambda_1$  and  $\lambda_2$ . The Appendix contains details concerning the model’s numerical solution, the data, the choice of moments, and the estimation.

Table 1 presents the estimation results, with panel A reporting the actual moments and moments from the simulated model, and panel B reporting parameter point estimates. Most simulated moments in panel A match the corresponding data moments well, although the second moment of investment and the mean of net leverage are high. The high second moment of investment also shows up in a simulated sensitivity of investment to Tobin’s  $q$  that is markedly higher than the estimated sensitivity. A plausible explanation for the model’s unduly high debt prediction is that, by focusing on the role of debt as an efficient transitory financing vehicle, we ignore other factors that discourage managers from using debt financing, such as financial distress costs, debt covenant-induced loss of flexibility (Smith and Warner (1979), Roberts and Sufi (2008)), and debt issue costs (Gamba and Triantis (2008)). The reasons for the high predicted variability and sensitivity of investment are less clear. One factor may be our exclusion of these other impediments to debt financing. Without these extra model features, if investment variability were in line with the data, then leverage would be much too high, because uncertainty over future investment opportunities (coupled with a finite debt capacity) is the only aspect of the model that discourages debt financing. Despite the above discrepancies, when we use the  $\chi^2$  test from Hansen (1982) of the null hypothesis that the expected value of the vector of moment conditions equals zero, we fail to find a rejection (p-value of 0.357, see panel B).

The point estimates of the profit function curvature ( $\theta$ ) and of the serial correlation and residual standard deviation of profit shocks ( $\rho$  and  $\sigma_v$ ) in panel B of table 1 are qualitatively similar to those

in Hennessy and Whited (2005, 2007). The external equity cost parameters,  $\lambda_1$  and  $\lambda_2$ , are smaller than estimated by Hennessy and Whited (2007) because our model includes physical adjustment costs, while theirs does not. Intuitively, external equity costs not only create an incentive to rely on debt and cash balances to provide funding but can also, as Gomes (2001) and Moyen (2004) discuss, have a dampening effect on investment similar to that of physical adjustment costs. Because we include physical adjustment costs directly, our model’s equity cost parameters no longer must capture the investment-dampening effects of both physical adjustment costs and equity financing costs, thus our estimates of equity access costs are lower. Similarly, our estimates of the physical adjustment cost parameters are smaller than those of Cooper and Haltiwanger (2006) because their model excludes financing frictions, whereas ours includes them. Finally, our estimated agency costs are small and statistically insignificant because we operationalize this variable as the marginal cost of maintaining cash balances over and above the statutory tax penalty for holding cash.

### **3. Transitory debt and long-horizon leverage paths**

In this section we show that our model predicts long-horizon leverage paths that closely conform to those documented by Lemmon, Roberts, and Zender (2008, LRZ). Figure 1A reproduces LRZ’s figure 1a, which plots annual average leverage (defined as the book value of total debt divided by the book value of total assets) over 20 years for firms sorted into four subsamples—very high, high, medium, and low values of initial leverage. LRZ’s main finding is that, although the average leverage ratios for all four subsamples converge gradually toward one another, the firms with the highest initial leverage continue to have the highest average leverage two decades later and, in fact, the four subsamples’ relative leverage rankings remain unchanged throughout the 20 years of analysis. LRZ conclude that (i) the observation that “high (low) levered firms tend to remain as such for over two decades . . . is largely unexplained by previously identified determinants” of leverage, (ii) “variation in capital structures is primarily determined by factors that remain stable for long periods of time,” and (iii) “leverage ratios are characterized by both a transitory and permanent component that . . . have yet to be identified.”

Figure 1B plots the long-horizon average leverage paths generated by our section 2 model, which

we label the “with-tax” model to differentiate it from the simpler “no-tax” variant that we use later in this section to clarify how our model generates LRZ’s results. A comparison of figures 1A and 1B indicates that our model-generated leverage paths are similar, both qualitatively and quantitatively, to the paths that LRZ observe empirically. The average leverage ratios of the four groups in figure 1B start with a spread of 38.3% (versus 51.8% in LRZ) and converge to stable values that differ by 18.3% (versus 16.1% in LRZ). Convergence occurs more rapidly in our model and our average debt levels are lower than LRZ’s by 10% or so, but these differences are not important for explaining the puzzling aspects of LRZ. What is important is that (i) convergence to stable leverage occurs in both figures 1A and 1B, and (ii) such convergence is incomplete in both figures, i.e., a gap in average leverage across groups remains in the long run. As we show below, the incomplete convergence in figure 1B is entirely explained by two aspects of transitory debt—first, by the average amount of such debt outstanding each period and, second, by variation in target leverage which, in our model, is attributable entirely to differences in firms’ *ex ante* optimal positioning to enable themselves to issue transitory debt to meet future funding needs.

### 3.1 Leverage paths generated by the model

Figure 1B’s leverage paths are generated for a sample of 1,000 model firms with baseline parameter values established by section 2’s SMM estimation. This sample is composed of 125 subsamples of 8 technologically identical firms, and the 125 subsamples differ only in the volatility of the investment shocks that firms in each subsample face (standard deviations from 1% to 30%). We introduce heterogeneity in shock volatility across subsamples for two reasons. First, as we show in sections 4 and 5 below, such heterogeneity implies variation (i) in the expected amount of transitory debt that firms employ, and (ii) in the target capital structures that optimally position firms to issue transitory debt to address prospective investment shocks. Second, heterogeneity in shock volatility induces heterogeneity in firms’ usage of transitory debt, and our objective in this section is to establish that firms’ heterogeneous use of transitory debt generates LRZ’s stable long-horizon leverage paths.

We mimic LRZ’s sample selection procedure by first running the model and allowing firm-specific shocks to arrive and capital structures to evolve in response to those shocks. We halt the analysis

after 200 time periods, at which point we record the debt-to-assets ratio of each firm in the full sample, i.e., its “initial leverage ratio.” We then rank the 1,000 firms from highest to lowest initial leverage ratios, and divide them into the four groups analyzed by LRZ. The 250 firms with the highest leverage ratios are labeled “very high,” while the sets of 250 firms with successively lower leverage ratios are labeled “high,” “medium,” and “low.” Because initial leverage ratios reflect transitory debt issued in response to previous shock realizations, the groups vary in the extent to which they include firms with unusually high or low amounts of transitory debt at the time of sample formation. As discussed below, this property of the sample selection process indicates that mean reversion is expected for the extreme leverage groups, and it accordingly causes partial convergence over time of the four groups’ average leverage ratios.

Once we have formed the four leverage groups, we re-start the model, allowing new investment shocks to arrive and capital structures to continue to evolve for 20 model periods for each of the 1,000 firms, which began this stage of the analysis with their actual leverage ratios equal to those they had at the time we formed the four groups. Thus our analysis mimics in all important aspects the empirical investigation conducted by LRZ, who allocate firms to leverage groups based on initial leverage at a random point in time, and whose results are unaffected by whether or not the analysis is limited to firms that survive for the entire 20-year period.

Figure 2A documents the long-run average leverage paths generated by our no-tax specification of the model in section 2, under the same procedure we used to generate the leverage paths in figure 1B for our full model. In the no-tax model we remove the corporate income tax and the associated incentive to borrow to capture interest tax shields, but preserve the same quantitative disincentive to accumulate cash balances as implied by our SMM estimates of the with-tax model (see section 4 for details). While figure 2A bears a qualitative similarity to figure 1B, it falls short of replicating LRZ’s results in two respects—first, the long-run average levels of debt are too low and, second, the long-run leverage gap between the very high and low groups is too small. Our purpose in providing the no-tax results is not to offer this model as empirically superior to section 2’s with-tax formulation, because a simple comparison of figures 1B and 2A clearly indicates that the with-tax formulation generates leverage paths that conform much more closely to those documented by LRZ.

The no-tax results do, however, provide a superior illustration of the manner in which transitory debt affects the with-tax leverage paths in figure 1B, and to illustrate that mechanism is our sole purpose in providing them.

The illustrative advantage of the no-tax model is that its results are unclouded by firms' incentives to keep debt outstanding permanently in order to capture interest tax shields which not only raises average leverage but also, as we discuss in section 5.3, makes it more difficult to calibrate each firm's leverage target. Specifically, absent tax or other incentives to carry permanent leverage, all firms incur only transitory debt, thus all have target debt levels of zero. This intuitive prediction is supported by model simulations not only with the baseline parameterization from section 2, but also with parameterizations that vary widely, as described in section 4. The simplifying property of a zero target helps us greatly to clarify how our model generates the leverage paths documented by LRZ because, for example, it removes the cross-firm variability in target leverage that is one reason why a gap in average leverage ratios remains after 20 periods in figure 1B.

Inspection of figures 1B and 2A for our with- and no-tax models indicates that average leverage is markedly higher in the former, which is not surprising given firms' corporate tax-induced incentives to borrow. Two other attributes of our model-generated long-run leverage paths in figures 1B and 2A are more puzzling, and we next discuss these two issues in detail. First, why is average leverage always positive in figure 2A, when the no-tax model implies zero debt is the capital structure target for every model firm? Second, why do the model-generated average leverage ratios of the four groups converge incompletely in figures 1B and 2A, i.e., what explains the significant cross-group gap in average leverage that persists through the end of our analysis period? The answer to this second question helps us explain why our model generates long-run leverage paths that conform to those that LRZ document empirically. And the answers to both questions, as we next discuss in turn, reflect the role played by transitory debt in generating capital structure dynamics.

### **3.2 Why is average leverage positive in the absence of a tax incentive to borrow?**

In the no-tax model zero debt is the capital structure target for all firms because it provides maximum unused debt capacity, and no tax or other motive induces managers to keep debt outstanding permanently. Firms nevertheless borrow periodically to meet funding needs associated with the

arrival of investment shocks. They subsequently seek to rebalance to zero debt as soon as possible (depending on future cash flow realizations and the arrival of new investment shocks) so that they are once again optimally positioned to take on transitory debt to meet future funding needs. All debt is therefore transitory in the no-tax model, but a given firm has debt obligations outstanding from time to time, and will sometimes carry substantial debt for significant periods of time because future cash flow realizations turn out to be modest relative to the funding needs that arise due to additional investment shocks.

Accordingly, when one examines large sample averages subject to cross-sectionally independent investment shocks, as we do, it is virtually certain that at least one firm—and more realistically many firms—in the sample will have transitory debt outstanding at any given point in time. As a result, average leverage in figure 2A is always strictly positive, even though every firm with currently outstanding debt intends to fully repay that debt in future periods. Positive average debt can—and, in our model, does—mask substantial variation in leverage (due to transitory debt) within the cross section of firms contained in each subsample. Moreover, the fact that a large number of firms is included in each subsample accounts for the long-run stability in the average leverage ratios in figures 1B and 2A, despite the time-series volatility in the leverage of any one firm due to its use of transitory debt.

Figure 3, which presents the histogram of leverage ratios generated by the no-tax model for all 1,000 firms in our LRZ simulation, illustrates the important distinction between target leverage and average leverage. It shows that, in approximately 53% of sample observations, firms are at their long-run capital structure targets with no debt outstanding. In the remaining 47% of the observations, firms have various amounts of debt outstanding, which they incurred to meet funding needs associated with prior investment shocks. Thus average debt outstanding is significantly positive even though the theoretically ideal capital structure has zero debt. Although not evident from the frequency counts in figure 3, the leverage of any given firm exhibits significant time-series volatility, e.g., if a firm's leverage ratio plots at the average shown in figure 3 it will not remain there for long except by extreme coincidence. Rather, it will work its leverage back down to target or take on additional debt, depending on its future cash flow and investment shock realizations.

As a result, stability of cross-sectional average leverage is by no means indicative of time-series stability of leverage for a given firm.

### **3.3 Average leverage does not equal target leverage**

In the long run, leverage for a given firm—and average leverage for samples of firms, as portrayed in figures 1B and 2A—does not converge to target leverage in either the with-tax or no-tax model specifications. As long as investment shocks continue to arrive, as they do in perpetuity in our model, firms continue to incur transitory debt to meet imperfectly anticipated funding needs (and to pay off that debt as subsequent circumstances allow). In the no-tax model, zero debt is the target for all firms, but each firm is expected to have debt outstanding some portion of the time when investment shocks lead it to issue transitory debt to meet funding needs. In other words, the expected debt level, which consists entirely of transitory debt, is positive and strictly greater than target for the firms in figure 2A. Hence, that figure’s stable and positive long-run leverage ratios do not indicate that firms have positive target debt levels in the absence of taxes. They simply reflect firms’ usage of transitory debt.

If figure 2A’s leverage ratios reflect only transitory debt, then why are they so stable, since transitory debt is presumably characterized by non-trivial time-series volatility? The stability we observe in figure 2A is in part the result of an assumed stationary investment shock-generating process. It also reflects the fact that we examine large sample averages, and the effects of time-series volatility in individual firms’ leverage ratios wash out in such averages, since the shocks are not correlated across firms. The law of large numbers implies that, as new shocks arrive and firms respond to them and as old shocks fade in importance, the average amount of transitory debt outstanding in the no-tax model approaches the amount expected to be outstanding at a randomly selected point in time—a stable value for a fixed sample of firms facing stable shock-generating processes.

The law of large numbers similarly implies that, in the with-tax model, the average debt level for a given group in figure 1B approaches the sum of the amount of transitory debt expected to be outstanding plus the average target debt level for firms in that group. In the with-tax model, the target debt level depends on shock volatilities and other firm-specific technological parameters that

affect the likelihood that a firm will experience investment shocks with associated material funding needs. The greater the chance of such shocks, the higher the value of having unused debt capacity available to meet such funding needs, and the lower the target debt level. Thus, variation in both components of the long-run leverage values in figure 1B—the expected amount of transitory debt and the long-run target debt level—are ultimately traceable to variation in firms’ use of transitory debt to address funding needs associated with investment shocks.

### **3.4 Why does average leverage converge incompletely across leverage groups?**

In figures 1B and 2A, the cross-group differences in the initial average value of leverage reflect the sample selection approach, i.e., the fact that groups are formed by ranking firms on the basis of actual leverage ratios at an arbitrarily selected point in time, as in LRZ. [In LRZ, the difference between the initial average leverage of the very high and low groups is 51.8%, whereas it is 38.3% for the model generated results in figure 1B.] Since actual leverage includes transitory debt—and in our no-tax model that is all it includes—firms in the “very high” leverage group tend to have more than the expected amount of transitory debt outstanding at the time of group formation, and those in the “low” leverage group tend to have less than the expected amount of transitory debt. The transitory debt of the “very high” leverage group is accordingly expected to decline in future periods, and that of the “low” group is expected to increase—which explains the convergence of average leverage ratios in figures 1B and 2A, but not the 18.3% gap between the very high and low leverage groups that remains after 20 periods.

The incomplete convergence of the average leverage ratios in figures 1B and 2A reflects two factors. First, the four groups contain different proportions of firms that face different shock volatilities, and firms with different shock volatilities are expected to have different amounts of transitory debt outstanding, as we show in sections 4 and 5 below. Second, the long-run differences across groups also reflect the fact that firms facing different shock volatilities have different incentives to employ debt permanently. Specifically, firms have different debt targets that depend on investment opportunity attributes, including shock volatility, which determine the value of preserving debt capacity for future transitory borrowing (see section 5.3). The second factor is operative for our full model results in figure 1B, but not for the illustrative no-tax case in figure 2A, whereas the first factor is

operative in both cases.

In figure 1B, the model generated long-run gap between the average leverage ratios of the very high and low leverage groups is 18.3%, which is close to the 16.1% long-run gap reported by LRZ. Of the 18.3% permanent leverage gap predicted by our model, 4.2% (or 23.0% of the total) reflects outstanding transitory debt, and the remainder reflects target leverage differences across the groups, which also reflect transitory debt, as we explain immediately below in our discussion of figure 2B. We obtain the 4.2% transitory debt amount—the “net-of-target” leverage ratio—by subtracting each firm’s model-generated average leverage target from its model generated leverage ratio at each date in figure 1B. [We subtract the average leverage target for each firm because, as section 5.3 explains, fixed costs of adjusting the physical stock of capital imply a non-constant leverage target.]

Figure 2B plots the time path of net-of-target average leverage ratios—i.e., the typical amount of transitory debt outstanding—for each of the four leverage groups, and 4.2% is the gap that remains at the end of 20 periods. The fact that the leverage paths in figure 2B are very similar to those for the no-tax model in figure 2A reflects the fact that both figures plot the average leverage effects of purely transitory variation in capital structures. At the final date, transitory debt in the with-tax model (shown in figure 2B) as a percent of total debt (shown in figure 1B) is 46.7%, 33.4%, 29.0%, and 32.1% for the low, medium, high and very high leverage groups respectively. Transitory debt thus directly constitutes a substantial fraction of total model-generated leverage and, in fact, all the remaining variation in figure 1B is indirectly attributable to transitory debt via its impact on cross-firm variation in target leverage. Since all model firms face identical tax benefits of debt and differ only in investment shock volatility, all variation in leverage targets reflects cross-firm differences in the value of preserving debt capacity to be able to issue transitory debt to meet funding needs associated with prospective investment shocks.

At first blush it seems counter-intuitive or even paradoxical that firms’ usage of transitory debt—a random variable characterized by potentially high time-series variability—could generate LRZ’s stable average leverage paths. However there is no paradox here because, in our dynamic model, a firm’s transitory debt level is both positive and stable in an expected value sense, which creates a statistical fixed effect of the type that drives LRZ’s findings of long-run stability in average

leverage ratios. An important corollary is that average leverage is not generally indicative of a firm's theoretically ideal capital structure and so, for example, there is every reason to expect that a firm that is currently at its (long-run) historical average debt ratio will rebalance away from that capital structure as future circumstances permit.

#### 4. Comparative statics predictions of the no-tax model

When firms face an ongoing sequence of potential investment shocks over an infinite horizon, the set of possible capital structure paths is infinite, and the resultant model complexity poses a challenge to the derivation of empirically refutable predictions about the evolution of firms' leverage ratios. Our model nonetheless yields a broad range of testable predictions about capital structure. In order to explain the general approach we use to obtain these predictions and to clarify the intuition that underlies them, we develop the comparative statics implications of the no-tax model in the current section. Because corporate taxes are incontrovertibly an important determinant of capital structure decisions, we do not advance the no-tax analysis as a stand-alone model of capital structure.<sup>4</sup> Rather, we analyze the no-tax case to set the foundation for our more general discussion in section 5 of the comparative statics implications of the complete (with-tax) model.

In formulating the no-tax model, we remove the corporate tax and the associated incentive to borrow, but assume that firms continue to incur the same total cost of maintaining cash balances as in the with-tax model, which equals the sum of the marginal agency cost,  $s$ , and the tax penalty for holding cash,  $\tau_c r$ . The reason is that our SMM procedure estimates the total cost of cash balances, and we define the marginal agency cost as that total cost minus  $\tau_c r$ , an algorithm that assigns maximal weight to taxes. Since  $\tau_c r$  is the largest possible tax penalty and since many real-world firms have no taxable earnings, this allocation likely under-estimates the non-tax costs of holding

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<sup>4</sup>Most dynamic capital structure models assume a corporate tax incentive to borrow, and we believe that this assumption, coupled with the inherent complexity of these models, has obscured the important capital structure role of transitory debt. Tserlukevich (2008, table 1) catalogs the assumptions of 10 dynamic capital structure models, and indicates that all assume positive corporate taxes, with investment endogenous in five. Investment policy is exogenous in Kane, Marcus, and McDonald (1984), Fischer, Heinkel, and Zechner (1989), Goldstein, Ju, and Leland (2001), Strebulaev (2007), and Leary and Roberts (2005), while it is endogenous in Brennan and Schwartz (1984), Mauer and Triantis (1994), Titman and Tsyplakov (2007), Hennessy and Whited (2005), and Tserlukevich (2008). Hennessy and Whited (2007), Gamba and Triantis (2008), and Morellec and Schürhoff (2008) also assume positive taxes and endogenous investment, as do Riddick and Whited (2008), who analyze cash balances but not leverage decisions in an analytical framework close in spirit to the one employed here. Endogeneity of investment is critical to our analysis, but our main conclusions about transitory debt obtain in the absence of taxes.

cash. If we instead take the residual,  $s$ , as the cost of holding cash, the average leverage ratios reported in panel A of table 2 range from 0.022 to 0.028 rather than from 0.023 and 0.067, i.e., the average amount of transitory debt is a bit lower.

#### 4.1 Predicted capital structure paths: A simple example

We start with a highly simplified heuristic example designed to illustrate firms' incentives to issue and retire transitory debt. Consider a firm that faces baseline model parameter values (per section 2) and that currently has no debt outstanding so that, in the absence of taxes, it is at its long-run target capital structure. Assume that an economically material investment shock arrives with an associated large funding need that the firm cannot fully meet from internal sources (cash balances and current period cash flow). [In our model, firms use internal sources of capital before borrowing because of the costs of maintaining cash balances.] Let's assume that managers issue debt, but not equity, to raise the remaining funds they need because equity issuance entails direct costs, whereas debt issuance does not. [As discussed below, in our model managers sometimes issue equity even when debt capacity is available.] If managers do issue debt today, they will treat that debt as transitory and use subsequent cash flow realizations to pay it down as soon as they can to free up debt capacity to address (currently unknown) capital needs from future investment shocks.<sup>5</sup>

Our model recognizes that firms' financing decisions are considerably more complicated than in this simple example. In general, managers must decide whether to issue debt to meet an immediate cash need generated by today's investment shock given that future shocks may soon arrive, rendering debt capacity even more scarce, while also considering the likelihood that future cash flow realizations may be inadequate to retire debt anytime soon. Managers of firms with unused debt capacity will forego issuing debt and instead issue costly equity to meet an immediate funding need if they assess a sufficiently high likelihood that future funding needs would force them to incur even higher equity issuance costs (because borrowing today leaves the firm with inadequate debt capacity). As a result, pecking order behavior is not generally characteristic of our model. In

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<sup>5</sup>Some real-world investments fit this simple pattern—acquisitions come to mind—and the evidence of Harford, Klasa, and Walcott (2008)) indicates that bidders do borrow and deliberately deviate from their capital structure targets to fund acquisitions, and then subsequently rebalance back to target with a lag. This pattern of acquisition financing cannot be explained by extant tradeoff models, which predict that all pro-active financing decisions move firms toward, not away from their target capital structures.

general, potential investment shocks—and associated funding needs—differ in their volatility and serial correlation, and the rational financing response to any given shock also depends on other aspects of the firm’s investment opportunities, e.g., the nature of any costs associated with adjusting the stock of physical capital.

The actual time paths of leverage can and generally will be highly complex, reflecting as they do the precise sequence of (i) shock realizations over an infinite horizon, (ii) managers’ sequential responses to those shock realizations, and (iii) any intervening leverage rebalancing actions that they undertake. To illustrate, figure 4 plots a realized leverage path for a firm in the no-tax model with baseline parameter values (per section 2’s SMM estimation) that experiences a sequence of investment shocks. The figure shows that transitory debt increases as the firm borrows to meet shock-induced funding needs, then recedes with a lag as the firm pays down debt, but full payoff of the debt can take multiple periods because of the arrival of multiple investment shocks, each with its own funding need. A different path, also potentially complex, would result for a second firm that faces different technological conditions. For example, a firm that faces higher serial correlation of shocks will be less aggressive in its use of debt to meet the funding need associated with a given shock because of the greater likelihood that today’s economically material funding need will soon be followed by another one.

The potential complexity and scope of variation in leverage paths does not imply that a firm’s debt fluctuates purely at random, since debt issuances result from investment shocks that require funding, and debt reductions occur as they are made possible by future cash flow and shock realizations. While rationality thus governs the leverage paths that unfold over time, complexity in the evolution of capital structure is the norm because of the infinite number of sequences of investment shocks that could possibly arrive. Complexity notwithstanding, the model yields testable predictions that link observable features of expected debt dynamics to the nature of prospective investment shocks, as well as to the costs of raising external equity and of maintaining cash balances.

## **4.2 The capital structure impact of variation in financing frictions**

We generate comparative statics predictions from large sample simulations of the model. We start with the baseline parameter values (from section 2’s SMM estimation) and analyze the model for a

significant range of parameter values around each baseline value. For each set of specific parameter values, we run the model for 10,200 periods, with each firm receiving random investment shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data and, from the remaining 10,000 observations, we record economically relevant, empirically quantifiable measures of a firm’s capital structure decisions, e.g., its average debt-to-assets ratio. We interpret the resultant large sample statistics as expected values implied by the specific parameterization of the model. We repeat the exercise for different combinations of model parameters. We then generate testable predictions based on the difference in the expected value of a given capital structure variable associated with an underlying difference in the model’s parameter values.

For both the no-tax (panels A and C) and the with-tax variants of our model, (panels B and D), table 2 reports expected leverage and the volatility (standard deviation) of leverage as a function of the costs of issuing equity and of maintaining cash balances. We measure leverage as the debt-to-assets ratio ( $d/k$ ). Each panel contains a  $5 \times 5$  matrix whose elements are the model’s predicted (leverage or leverage volatility) values as a function of different costs of accessing external equity (columns) and of maintaining cash balances (rows). For example, the north-east corner of the matrix in panel A reports the expected  $d/k$  ratio for the no-tax model specified with high costs of accessing external equity coupled with low costs of maintaining cash balances, while the south-west corner reports the expected value of  $d/k$  for that model when equity access costs are low and the costs of maintaining cash balances are high.

Table 2 yields four main findings. First, and consistent with all prior capital structure models, the addition of corporate taxes induces a large increase in expected leverage (compare any cell in panel A to the corresponding cell in panel B). Second, variation in the costs of maintaining cash balances has only a modest influence on the cross-firm variation in average leverage in both the no-tax and with-tax models (compare all cells in any given column in panels A and B), but the effect is larger in the no-tax model. [Corporate taxes already provide strong incentives to maintain positive net debt and so, in the with-tax model, an increase in the cost of holding cash does little on the margin to induce firms to rely more on debt and less on cash balances.] Third, in the

with-tax model average leverage ratios are markedly lower when firms face high rather than low equity issuance costs (compare the values in any given row of panel B). Firms that face high equity issuance costs have capital structures that, on average, have higher equity proportions because such capital structures better enable them to use debt as a marginal financing vehicle, thus to avoid equity issuance costs. Finally, while variation in equity issuance costs has a non-trivial effect on average leverage, section 5 documents that variation in investment shock volatility and other attributes of investment opportunities have a markedly larger impact.

### 4.3 The capital structure impact of variation in investment shock volatility

For the no-tax model, table 3 summarizes the predicted capital structure impact of variation in the volatility of investment shocks. [We present analogous results for the with-tax model in table 4 (section 5), and highlight the important differences in the implications of the no-tax and with-tax models in our discussion of the latter table.] The rows of table 3 list capital structure attributes and the columns detail the predicted impact of various investment shock volatilities centered around the baseline, with standard deviations ranging from 1% to 30%. The model predicts that average investment as a percent of assets ( $I/k$ ) is somewhat higher for firms subject to high shock volatility (row 1), while the standard deviation of  $I/k$  is markedly higher (row 2), and the frequency of investment is roughly the same (row 3). For brevity here and throughout, shock volatility refers to the standard deviation of the error term in the investment shock generating process (1), and leverage volatility refers to the time-series standard deviation of the debt-to-assets ratio.

Table 3 indicates that firms that face low shock volatilities are expected to carry more debt (rows 4 and 11) and lower cash balances (rows 8 and 12) than firms that face high shock volatilities. For low shock volatility firms, periodic modest amounts of borrowing are preferable to the alternative of incurring the ongoing costs of maintaining cash balances because these firms' future funding needs are reasonably predictable and rarely extremely large. Low shock volatility firms are better positioned to follow this strategy than are high shock volatility firms because the former firms' low likelihood of a large funding need makes them less likely to incur high equity issuance costs, despite their low (nearly zero) average cash balances and higher average debt outstanding. In the no-tax model, low shock volatility firms have higher leverage volatility than high shock volatility

firms (row 5), which reflects the latter firms' strong tendency to hold large cash balances (rows 8, 12, and 6), which results in substantially higher volatility of cash balances and net debt (rows 9 and 7).

In the no-tax model, the transitory role of debt is evident from the fact that, regardless of their investment shock volatilities, firms do not keep debt outstanding all the time (row 10). The transitory element is especially obvious at high shock volatility firms, which have debt outstanding only about two-fifths of the time. And so, roughly three-fifths of the time, high shock volatility firms operate at their target debt level of zero—keeping their entire debt capacities available in case a substantial investment shock arrives—and they also carry large cash balances on average (rows 8 and 12) to help them meet possibly substantial future funding needs. When especially large funding needs materialize, high shock volatility firms fully draw down their cash balances, and rely mostly on these funds plus cash flow realizations to finance new investment (rows 19 and 20). They issue transitory debt with reasonable frequency (row 13) and in non-trivial amounts (row 15 and 21), while they issue equity quite often (row 17) but in modest amounts (rows 18 and 22).

Table 3 illustrates a strong point of differentiation between the leverage dynamics predicted by our model and those of existing tradeoff models of capital structure. In our no-tax model, when firms borrow, they deliberately move away from their zero-debt targets, and when they pay down debt they rebalance toward target. Holding shock volatility constant, the frequency with which firms deliberately deviate from target (row 13) in most cases roughly equals the frequency that they move toward the zero-debt target (row 14). The magnitudes of leverage increases and decreases are both substantial, but the deliberate deviations from target (row 15) are notably larger than the leverage reductions, which constitute rebalancing (row 16). In existing tradeoff theories, all pro-active financing decisions are predicted to move the firm toward its theoretically ideal capital structure. Ample evidence from existing tests for capital structure rebalancing strongly refutes this prediction. The explanation offered by our model is that transitory debt is an important component of leverage dynamics, with the *ex ante* optimum capital structure determined by the capacity it provides to issue debt *ex post* and thereby deviate deliberately, but not permanently from the optimum.

## 5. Comparative statics predictions of the with-tax model

The main advantage of presenting a no-tax variant of our model is that it isolates and clarifies the role of transitory debt *per se*, unclouded by the variation in capital structure targets that occurs in the with-tax model. A second benefit is that the no-tax model provides the foundation with which to gauge the magnitude of the leverage increase expected due to corporate taxes and, more interestingly, how that increase varies with attributes of firms' investment opportunities. The current section's comparative statics analysis of the with-tax model establishes that the magnitude of the predicted tax-induced leverage increase varies markedly, depending on technological factors that determine firms' abilities to meet funding needs associated with investment shocks. For example, we show that firms that face high shock volatility find it especially valuable to preserve debt capacity to meet the substantial funding needs associated with future investment shocks, and this benefit looms large relative to the interest tax shields they lose by maintaining low average debt ratios. Similarly, the model predicts lower average leverage ratios for firms that face high as opposed to low (i) serial correlation of investment shocks, (ii) marginal profitability of investment, and (iii) fixed costs of adjusting the physical capital stock, and for (iv) firms that face low as opposed to high convex costs of capital stock adjustment.

### 5.1 The capital structure impact of variation in investment shock volatility

Table 4 presents the with-tax version of table 3's comparative statics exercise that relates capital structure attributes to differences in investment shock volatilities. Firms facing low shock volatility have a debt-to-assets ratio of 0.384 on average (row 4), which represents a substantial absolute leverage increase of 0.272 from their 0.112 average leverage in the no-tax model. In sharp contrast, firms facing high shock volatility have average leverage of only 0.062, a considerably more modest absolute increase of 0.017 over their 0.045 no-tax leverage. The former firms always carry some debt, but the latter have no debt outstanding more than half the time (row 10), reflecting their strong incentives to preserve debt capacity and accumulate cash balances to meet the potentially substantial cash needs that can arise with future investment shocks.

Table 4 thus indicates that, even in the face of corporate tax incentives to borrow, low leverage is

the norm for firms that face high investment shock volatility (row 4). Such firms have conservative leverage on average because substantial unused debt capacity gives them greater ability to access debt financing (and thereby economize on equity issuance costs) to address the significant funding needs that arise more often in their volatile investment environment. Variation in firms' investment opportunities may thus help resolve Graham's (2000) "debt conservatism" puzzle, which indicates that it is difficult to explain why some firms maintain low leverage despite strong tax incentives to borrow. Such variation may also help resolve Miller's (1977) closely related "horse and rabbit stew" criticism that the corporate tax benefit of borrowing swamps expected bankruptcy costs, leading traditional tradeoff models to predict unrealistically high leverage ratios, and in effect raising the question: what factors are missing from these models? The answer offered by the static models of Miller (1977) and DeAngelo and Masulis (1980), among others, is that attributes of the personal and corporate tax codes reduce firms' incentives to borrow. The answer offered by our dynamic model is that, with high investment shock volatility, low leverage is desirable despite the foregone corporate tax benefits, since firms that consistently preserve debt capacity have greater ability to borrow to meet imperfectly anticipated funding needs.

High shock volatility firms have about the same leverage volatility as low shock volatility firms (table 4, row 5), but they have far higher volatility of net debt and cash balances (rows 7 and 9), reflecting these firms' strong tendency to maintain costly cash balances (rows 8 and 12) to meet the substantial funding needs associated with their high volatility investments (row 2). Low shock volatility firms eschew cash balances (rows 8 and 12) and rely primarily on cash flow and secondarily on debt issuance to fund investment (rows 19 and 21), while their equity issues are rare (row 17) and small (rows 18 and 22). High shock volatility firms issue equity often (row 17), but in more modest amounts than they issue debt (rows 18 and 22). Cash flow is their main source of funds for investment (row 19), with cash balances providing larger amounts and debt issues smaller amounts than for low shock volatility firms (rows 20 and 21).

Although in our model firms have positive debt and cash balances on average, they do not have both outstanding simultaneously. With or without corporate taxes, firms with positive cash balances and debt are always better off if they use the cash to retire debt and thereby avoid the

costs of maintaining cash balances, while freeing up debt capacity. Of course, real-world firms do simultaneously borrow and hold cash, most obviously because they require some cash to operate the business, a motive that would be easy to incorporate in our analytics without changing our transitory debt predictions. Gamba and Triantis (2008) note that, by accumulating cash balances while debt is outstanding, firms can economize on future debt issuance costs. We exclude direct costs of debt issuance from our model to highlight our point that the opportunity cost of issuing debt today (i.e., the debt capacity that is no longer available for borrowing tomorrow) is itself an impediment to borrowing. In model simulations in which we both allow firms to simultaneously have debt and cash balances, and add debt flotation costs, the model’s qualitative conclusions are identical. Firms are less aggressive in both borrowing and paying down debt, but retain incentives to treat debt capacity as a scarce resource and to use transitory debt to address imperfectly anticipated funding needs.

## **5.2 Serial correlation, marginal profitability of investment, and capital stock adjustment costs**

In this subsection, we consider the capital structure impact of varying four other parameters that determine investment opportunities—the serial correlation of investment shocks, the marginal profitability of investment, the degree of convexity in the variable costs of adjusting the physical stock of capital, and the magnitude of fixed costs of capital stock adjustment. For each parameter, the testable implications that we obtain are similar in substance to those reported in table 4 for variation in investment shock volatility. For brevity, rather than describe the full spectrum of predicted values as we did in table 4 for shock volatility, we simply report in table 5 the predicted capital structure values for “high” and “low” values of each one of the four parameters, with all other model parameters held constant.

Table 5’s most notable finding is that firms that have high shock serial correlation, high marginal profitability, low convex capital stock adjustment costs, or high fixed adjustment costs have relatively low average leverage ratios, which range from 6.7% to 16.2% of total assets, or less than half the leverage of firms that have the opposite serial correlation, profitability, or adjustment cost characteristics (row 4). Firms with any of these four investment attributes typically forego large tax

benefits of debt in order to preserve debt capacity that can be tapped to help fund their especially volatile prospective investment outlays (row 2).

The specific reasons for the attraction of a more conservative capital structure differ depending on which of the four investment attributes we analyze. The higher the serial correlation, the more likely a current large shock will soon be followed by another shock, with an additional material need for funds. In addition, high serial correlation implies that investment outlays tend to be large because the profitability of these investments is expected to persist. Similarly, the higher the marginal profitability of investment (i.e., the  $\theta$  parameter), the larger is the optimal investment outlay undertaken in response to a given shock, and the possibility of a large funding need induces the firm to maintain conservative leverage on average. The less convex are capital stock adjustment costs, the more responsive is investment to new shock arrival, and the more variable is the resultant time profile of investment (Cooper and Haltiwanger (2006)). With greater fixed costs of capital stock adjustment, firms rationally wait longer in between investments (row 3) but invest larger amounts (row 1), thus they maintain greater debt capacity to borrow to meet those larger funding needs.

Higher leverage volatility characterizes firms with (i) high (versus low) marginal investment profitability, (ii) low (versus high) convexity of capital stock adjustment costs, and (iii) high (versus low) fixed adjustment costs (row 5), consistent with their greater investment volatility (row 2). Firms whose investment shocks exhibit high serial correlation have essentially the same leverage volatility as firms with low serial correlation (row 5), a finding that reflects the former's tendency to maintain high cash balances (row 8) and negative net debt (row 6), with very high volatility of both cash balances and net debt (rows 9 and 7). High serial correlation firms bear the agency and tax costs of maintaining large cash balances to meet the large, temporally clustered funding needs that are more likely for them than for low serial correlation firms. Firms with high fixed physical adjustment costs similarly accumulate substantial cash balances (row 8) and have large negative net debt on average (row 6), with substantial volatility in both cash and net debt (rows 9 and 7). In fact, firms with high serial correlation or high fixed adjustment cost carry zero debt more than half the time (row 10), as they accumulate large cash balances in anticipation of large

future funding needs (row 12).

In all cases in table 5, cash flow realizations are the main source of funds for new investment (row 19), with borrowing providing a substantial minority of funds, ranging from 10.1% to 26.5% (row 21). Firms whose investment shocks exhibit high serial correlation issue equity 43.4% of the time (row 17), a high incidence that reflects their often temporally clustered needs to raise outside funds. However, the amount of equity that these firms raise remains modest (row 18 and 22), since they also typically maintain debt levels that leave substantial latitude for future borrowing. Similar equity issuance behavior characterizes firms with high marginal profitability of investment (rows 17, 18, and 22). These firms' greater reliance on debt rather than equity to fund investment (compare rows 21 and 22) is attributable to substantial equity issuance costs, coupled with their generally conservative leverage ratios that leave substantial untapped debt capacity. For all capital stock adjustment cost scenarios in table 5, debt is markedly more important than equity as a marginal financing vehicle (compare rows 21 and 22), although firms also issue equity a substantial portion of the time (row 17).

### **5.3 Target debt levels in the presence of corporate taxes**

The essence of a capital structure target is that firms face economic forces—i.e., pressures to increase firm value—which act as a self-corrective mechanism that encourages them to alter their current financial structure when that structure is dysfunctional or would, if allowed to persist, become so. In our model, firms' capital structures exhibit path dependence (hysteresis) locally. Although locally path dependent, capital structures are globally self-correcting in the sense that, when a firm finds it optimal to borrow and deviate (or deviate further) from target, it subsequently faces economic pressures to return to target by paying down debt as soon as its circumstances permit. Those pressures reflect the fact that the option to borrow is valuable because it enables the firm to avoid more costly forms of financing in future periods, and reducing debt is attractive because it restores that option.

Analytically, in both the no-tax and with-tax models a given firm's target capital structure is the optimal matching of debt and assets to which that firm would converge if it optimized its debt and assets decisions in the face of uncertainty but then were to receive only neutral

investment shocks ( $z = 1$ ) for many periods in a row. The no-tax model yields an analytically simple characterization of target capital structure—zero debt is the universal target for all firms—and in that model we can equally well characterize firms as having a zero-debt target level or a zero target leverage ratio (since zero debt divided by any number yields a zero leverage ratio). In the more complex with-tax model, a given firm’s target capital structure almost always contains a positive amount of debt, which enables it to capture interest tax shields on a permanent basis. With taxes, moreover, different firms have different leverage targets, which depend on the characteristics of their investment opportunities.

The capital structure target in the with-tax model is either a fixed ratio of debt to total assets or a range<sup>6</sup> of such ratios, depending on the precise structure of the costs that a firm faces of adjusting its stock of physical capital. We consider three cases, each characterized by a different specification of capital stock adjustment costs. In case #1, firms face no such costs and, in this case, it is easy to demonstrate that the optimal capital stock at any point in time is the level that equates the price of capital goods with the shadow value of capital. Because the value function is strictly convex, a neutral shock ( $z = 1$ ) corresponds to a uniquely optimal level of the capital stock,  $k^*$ , which remains constant in the face of a repeated sequence of neutral shocks. Strict convexity of the value function then implies a unique target level of net debt,  $p^*$ , and therefore a unique target level of debt,  $d^* = \max(p^*, 0)$ , and an associated fixed target leverage ratio,  $d^*/k^*$ .

In case #2, there are no fixed costs of adjusting the physical capital stock, but firms face variable costs of adjusting that stock that are convex in the level of investment. In this case, if a firm receives a long series of neutral shocks, it also converges to a unique capital stock, although this level generally differs from that which obtains in the zero adjustment cost case (case #1 above) because the expected future marginal product of capital incorporates potential future adjustment costs, as discussed by Cooper and Willis (2004). The reasoning is as follows. Because the adjustment cost function is convex in the rate of investment, Jensen’s inequality implies that the firm’s optimal

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<sup>6</sup>Many capital structure models are characterized by a range of target leverage ratios rather than by a unique target ratio independent of the scale of the firm. For example, in static tradeoff models such as Robichek and Myers (1966), Kraus and Litzenberger (1973), and DeAngelo and Masulis (1980), there is no single fixed ratio of debt to assets (or debt to market value) that is optimal independent of scale, unless one imposes restrictive assumptions on the functional forms of investment opportunities and bankruptcy/agency costs.

policy in the face of uncertainty is to avoid changing its rate of investment, except in response to a shock. If the firm receives a long series of neutral ( $z = 1$ ) shocks, the firm keeps its investment constant at a rate that just allows for the replacement of depreciated capital. The capital stock therefore remains constant at a level  $k^*$ . This rate equates the marginal adjustment and purchasing costs with the shadow value of capital. As in case #1, in case #2 a unique target capital stock,  $k^*$ , implies a unique target level of debt,  $d^*$ , and a unique target leverage ratio,  $d^*/k^*$ .

In case #3, firms face only fixed costs of capital stock adjustment. In this case, a firm's optimal investment policy (in the limit after a series of neutral shocks) is not to maintain a constant capital stock, but to allow that stock to depreciate from an upper to a lower bound, at which point it invests to restore the depreciated capital. [See Caballero and Leahy (1996), Caballero (1999), and Whited (2006).] The upper bound is the optimal level of the capital stock at which the shadow value of capital equals the price of capital goods, a level that in general differs from those for both cases #1 and #2. In case #3, the firm does not immediately return to this level when capital depreciates, rather it waits until its capital stock reaches the lower bound, at which point the marginal benefit from returning to the optimal level just covers the fixed cost. Under the baseline model parameterization, at this lower bound the firm faces a funding need that exceeds its internal resources, which it satisfies by borrowing. As the capital stock depreciates from the upper to the lower bound, the firm uses its cash flow first to pay down debt and then to increase cash balances in anticipation of the approaching large funding need. This behavior dictates a fixed range for the optimal levels of physical capital and debt (and of net debt). Hence, in case #3, the firm has a range of target leverage ratios that is determined by its levels of debt and capital as physical capital depreciates from the upper to the lower bound described above.

Figure 5 plots target ratios of debt to total assets as a function of investment shock volatility and serial correlation for firms that respectively face (i) no costs of adjusting the physical capital stock, (ii) high convex costs of adjustment, and (iii) high fixed costs of adjustment, i.e., for variants of cases #1-3 discussed above. Target leverage is unique for capital stock adjustment cost scenarios (i) and (ii), but takes a range of values for scenario (iii), with figure 5 reporting the upper bound of the target range and for simplicity omitting the lower bound, which is 0.00 in all cases. The

figure indicates that lower target leverage is associated with higher levels of shock volatility and of shock serial correlation (panels A and B respectively). The intuitive explanation is that a higher value of each parameter implies a higher probability of significant funding needs, which in turn provides incentives for firms to adopt *ex ante* capital structures with more conservative leverage, leaving them with greater latitude to borrow in response to the funding needs that manifest. Target leverage is negatively related to the marginal profitability of investment, but the relation is not as strongly negative as it is for shock volatility and serial correlation (details not shown in figure).

Figure 6 illustrates the existence of a target leverage ratio and the convergence to that target for a firm that faces convex capital stock adjustment costs but no fixed costs of adjustment ( $\alpha = 0.015$ ,  $\gamma = 0.00$ ). From dates  $t = 0$  through  $t = 39$ , the firm carries debt whose level fluctuates in response to the arrival of investment shocks and to the firm's decision to pay down debt when cash flow realizations exceed funding needs. In some cases, the firm reduces debt below target because shock realizations—coupled with serial correlation of investment shocks—indicate that a large future funding need is likely, and so the firm temporarily builds debt capacity in anticipation of that need. At  $t = 40$ , the firm experiences a neutral investment shock, and such shocks continue to arrive. The firm uses its cash flow realizations to pay down debt and, at  $t = 41$ , it thereby attains its long-run leverage target where it remains as neutral shocks continue to arrive. If non-neutral shocks were to resume, leverage would once again follow a volatile path. If instead the firm faced fixed costs of adjusting its capital stock, it would not have a constant target leverage ratio. Rather, after  $t = 40$ , the firm's target  $d^*/k^*$  ratio would fluctuate as the optimal capital stock,  $k^*$ , depreciates and the firm delays replenishment, while the debt level,  $d^*$ , is adjusted downward in response, but generally not in strict proportion, to the reduction in  $k^*$ .

## 6. Summary and conclusions

We develop a dynamic capital structure model in the spirit of Hennessy and Whited (2005) in which debt serves as a transitory financing vehicle that enables firms to meet funding needs associated with imperfectly anticipated investment shocks, while allowing them to economize on the costs of issuing equity and of maintaining cash balances. Firms that issue debt incur no flotation or other

direct issuance costs, but because debt capacity is finite in our model they nonetheless face an economically important opportunity cost of borrowing, namely that a decision to issue debt in a given period reduces the debt capacity available to meet future funding needs that may arise. The firm's *ex ante* optimum debt level reflects the value of the option to use debt capacity to borrow *ex post* and deliberately, but temporarily, move away from target to meet imperfectly anticipated funding needs. The opportunity cost of borrowing—and the resultant transitory role of debt in corporate capital structures—radically alters the nature of predicted leverage dynamics from those of extant trade-off models in which firms issue debt to capture permanent tax benefits and all pro-active financing decisions move firms toward their target debt levels.

Sufi (2005) provides evidence that one form of transitory debt—borrowing under pre-established lines of credit—plays a significant role in shaping real-world leverage dynamics. He reports that “when firms adjust their levels of debt upward or downward, they use lines of credit more than any other type of financing” and that credit lines are generally the largest source of firms’ capital structure adjustments, including both upward and downward adjustments and even when the sample is restricted to large adjustments. In Sufi’s sample, the average unused credit line constitutes 11.4% of total assets, while total debt outstanding averages 20.8% of total assets. Used lines of credit represent 5.5% of assets, or more than 25% of total debt outstanding on average. While transitory debt is obviously not limited to utilized lines of credit, Sufi’s evidence leaves little doubt that such debt is a significant fraction of most firms’ outstanding debt obligations, and that firms do in fact routinely arrange their capital structures in advance to provide unused debt capacity that they can tap to meet future funding needs.

Our analysis moves beyond existing dynamic capital structure models in that our approach (i) explicitly recognizes and develops the capital structure implications of the opportunity cost of borrowing, (ii) demonstrates that this opportunity cost induces firms to use debt as a transitory financing vehicle, taking deliberate, but temporary deviations from their target capital structures, (iii) shows that transitory debt can fully explain the leverage paths documented by Lemmon, Roberts, and Zender (2008), (iv) establishes that transitory debt implies radically different leverage dynamics from those of adjustment cost models in which all pro-active capital structure decisions move

firms toward their leverage targets, (v) formally operationalizes the notion of—and demonstrates the existence of—capital structure targets in a dynamic model with endogenous investment policy, (vi) shows that the types of physical capital stock adjustment costs that firms face affect predicted leverage dynamics and determine whether capital structure targets are unique, and (vii) yields new testable implications linking time-series and cross-sectional variation in capital structure to variation in the nature of firms’ investment opportunities.

Overall, our analysis implies that investment policy is the primary determinant of capital structure, with financing frictions of but secondary importance. Our underlying premise is that all sources of capital—external equity, cash balances, and debt—are costly, and that the specific costs of accessing capital shape the dynamic capital structure paths generated as random investment shocks arrive and firms make their financing decisions to meet each new resultant funding need. At the same time, we distinguish between the existence of capital access costs, which clearly make financing decisions relevant, and the ability of variation in those financing frictions to explain variation in capital structure decisions. Our model indicates that the capital structure impact of variation in capital access costs is second order relative to the influence of variation in the characteristics of investment opportunities, e.g., in the volatility and serial correlation of investment shocks. Thus, while capital structure matters in the presence of financing frictions, predictable variation in capital structure depends primarily on the attributes of firms’ investment opportunities, with the linkage between investment attributes and leverage dynamics reflecting firms’ usage of transitory debt.

## Appendix

This appendix discusses the numerical solution procedure, the data, and the estimation procedure.

### Model Solution

To find a numerical solution, we need to specify a finite state space for the three state variables.

We let the capital stock lie on the points

$$\left[ \bar{k}(1-\delta)^{35}, \dots, \bar{k}(1-\delta)^{1/2}, \bar{k} \right].$$

We let the productivity shock  $z$  have 19 points of support, transforming (1) into a discrete-state Markov chain on the interval  $[-4\sigma_v, 4\sigma_v]$  using the method in Tauchen (1986). We let  $p$  have 29 equally spaced points in the interval  $[-\bar{p}, \bar{p}]$ , in which  $\bar{p}$  is set to  $k^*/2$  and in which  $k^*$  is the steady-state capital stock from a model with only costless external equity financing. The optimal choice of  $p$  never hits the lower endpoint, although it occasionally hits the upper endpoint when the firm finds it optimal to exhaust its debt capacity.

We choose the upper bound,  $\bar{p}$ , as follows. First, we pick an initial model parameterization in which we set  $s = 0$  and in which the rest of the parameters are from Riddick and Whited (2008). Then we set the upper bound equal to  $2k^*$  and solve the model. If the model solution produces regions of the state space in which  $V < 0$ , we decrease the bound. We repeat this process until  $V$  is positive over its entire range.<sup>7</sup> After the SMM estimation produces a new estimated parameterization, we check whether  $V > 0$ . We find that this condition holds.

We solve the model via iteration on the Bellman equation, which produces the value function  $V(k, p, z)$  and the policy function  $\{k', p'\} = u(k, p, z)$ . In the subsequent model simulation, the space for  $z$  is expanded to include 152 points, with interpolation used to find corresponding values of  $V$ ,  $k$ , and  $p$ . The model simulation proceeds by taking a random draw from the distribution of  $z'$  (conditional on  $z$ ), and then computing  $V(k, p, z)$  and  $u(k, p, z)$ . We use these computations to generate an artificial panel of firms.

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<sup>7</sup>This procedure requires monotonicity of  $V(k, p, z)$  in  $p$ . This condition can be established by the usual envelope condition and the fact that  $e(k, k', p, p')$ , as defined in (6), is monotonic in  $p$ .

## Data

We obtain data on U.S. nonfinancial firms from the 2007 Standard and Poor’s Compustat industrial files. These data constitute an unbalanced panel that covers 1988 to 2001. As in Hennessy and Whited (2005), we choose this sample period because the tax code during this period contains no large structural breaks. To select the sample, we delete firm-year observations with missing data and for which total assets, the gross capital stock, or sales are either zero or negative. Then for each firm we select the longest consecutive times series of data and exclude firms with only one observation. Finally, we omit all firms whose primary SIC code is between 4900 and 4999, between 6000 and 6999, or greater than 9000, because our model is inappropriate for regulated, financial, or quasi-public firms. We end up with between 3,066 and 5,036 observations per year, for a total of 53,677 firm-year observations.

## Estimation

We now give a brief outline of the estimation procedure, which closely follows Lee and Ingram (1991). Let  $x_i$  be an *i.i.d.* data vector,  $i = 1, \dots, n$ , and let  $y_{ik}(b)$  be an *i.i.d.* simulated vector from simulation  $k$ ,  $i = 1, \dots, n$ , and  $k = 1, \dots, K$ . Here,  $n$  is the length of the simulated sample, and  $K$  is the number of times the model is simulated. We pick  $n = 53,677$  and  $K = 10$ , following Michalides and Ng (2000), who find that good finite-sample performance of a simulation estimator requires a simulated sample that is approximately ten times as large as the actual data sample.

The simulated data vector,  $y_{ik}(b)$ , depends on a vector of structural parameters,  $b$ . In our application  $b \equiv (\theta, \rho, \sigma_v, a, \gamma, s, \lambda_1, \lambda_2)$ . Three parameters we do not estimate are the rate of economic depreciation,  $\delta$ , the real interest rate,  $r$ , and the effective corporate tax rate,  $\tau_c$ . We set  $\delta$  at 0.15, which is approximately equal to the average in our data set of the ratio of depreciation to the capital stock. We set the real interest rate equal to 0.015, which is approximately equal to the average of the realized real interest rate over the twentieth century. We set  $\tau_c$  at the statutory rate of 0.35.

The goal is to estimate  $b$  by matching a set of *simulated moments*, denoted as  $h(y_{ik}(b))$ , with the corresponding set of actual *data moments*, denoted as  $h(x_i)$ . The candidates for the moments to be

matched include simple summary statistics, OLS regression coefficients, and coefficient estimates from non-linear reduced-form models. Define

$$g_n(b) = n^{-1} \sum_{i=1}^n \left[ h(x_i) - \sum_{k=1}^K h(y_{ik}(b)) \right].$$

The simulated moments estimator of  $b$  is then defined as the solution to the minimization of

$$\hat{b} = \arg \min_b g_n(b)' \hat{W}_n g_n(b),$$

in which  $\hat{W}_n$  is a positive definite matrix that converges in probability to a deterministic positive definite matrix  $W$ . In our application, we use the identity matrix. This choice stems from a desire to equate directly data and simulated moments, which is an economically interesting exercise and reflects an implicit judgment that all moments are equally important. Using other weight matrices would set unequally weighted linear combinations of data and simulated moments equal to zero, making it more difficult to interpret the economics of the estimated model.

The simulated moments estimator is asymptotically normal for fixed  $K$ . The asymptotic distribution of  $\hat{b}$  is given by

$$\sqrt{n}(\hat{b} - b) \xrightarrow{d} \mathcal{N}(0, \text{avar}(\hat{b}))$$

in which

$$\text{avar}(\hat{b}) \equiv \left(1 + \frac{1}{K}\right) \left[ \frac{\partial g_n(b)}{\partial b} W \frac{\partial g_n(b)}{\partial b'} \right]^{-1} \left[ \frac{\partial g_n(b)}{\partial b} \Omega \frac{\partial g_n(b)}{\partial b'} \right] \left[ \frac{\partial g_n(b)}{\partial b} W \frac{\partial g_n(b)}{\partial b'} \right]^{-1} \quad (9)$$

in which  $W$  is the probability limit of  $\hat{W}_n$  as  $n \rightarrow \infty$ , and in which  $\Omega$  is the probability limit of a consistent estimator of the covariance matrix of  $h(x_i)$ .

The success of this procedure relies on picking moments  $h$  that can identify the structural parameters  $b$ . In other words, the model must be identified. 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. Although our model does not yield such a closed form mapping, we take care in choosing appropriate moments to match, and we use a minimization algorithm, simulated annealing, that avoids local minima.

We pick the following 11 moments to match. Because the firm’s real and financial decisions are intertwined, all of the model parameters affect all of these moments in some way. We can, nonetheless, categorize the moments roughly as representing the real or financial side of the firm’s decision-making problem. The first of the non-financial or “real” moments is the second moment of the rate of investment, defined in the simulation as  $I/k$ , and defined in Compustat as item 128 divided by item 7. This moment helps identify both the curvature of the profit function,  $\theta$ , and the smooth adjustment cost parameter,  $a$ . Lower  $\theta$  and higher  $a$  produce less volatile investment. The next moment is the skewness of the rate of investment, which helps identify the fixed adjustment cost parameter,  $\gamma$ . Higher values of this parameter lead to more intermittent, and thus more skewed investment. Our next two moments capture the important features of the driving process for  $z$ . Here, we estimate a first-order panel autoregression of operating income on lagged operating income. Simulated operating income is defined as  $zk^\theta/k$ , and actual operating income is defined as the ratio of items 13 and 6. The two moments that we match from this exercise are the autoregressive coefficient and the shock variance. Our next two moments are the mean of Tobin’s  $q$  and the slope coefficient from the regression of the rate of investment on Tobin’s  $q$ . Simulated Tobin’s  $q$  is constructed as  $(V + p)/k$  and actual Tobin’s  $q$  is constructed following Erickson and Whited (2000). All model parameters affect the first of these last two moments, the mean of  $q$ . The slope coefficient is informative about the smooth adjustment costs parameter,  $a$ , because in a neoclassical investment model with quadratic adjustment costs, this coefficient is the reciprocal of this parameter.

The remaining moments pertain to the firm’s financing decisions. The first two are the mean and second moment of the ratio of net debt to assets. In our simulation net debt is defined as  $p/k$ , and in Compustat this variable is defined as items 9 plus 34 minus 1, all divided by item 6. All of the parameters in the model affect these two moments. The next two moments are average equity issuance and the incidence of equity issuance. In the model, equity issuance is defined as  $e/k$  and in Compustat it is defined as the ratio of items 108 and 6. These two moments help identify the two equity adjustment cost parameters,  $\lambda_1$  and  $\lambda_2$ . Our final moment is the ratio of cash to assets. In our simulations it is defined as  $c/k$ , conditional on  $c > 0$ , and in Compustat it is defined as the

ratio of item 1 to item 6. This moment helps identify the agency cost parameter.

Because our moment vector consists of first through third moments, as well as regression coefficients, we use the influence-function approach in Erickson and Whited (2000) to calculate the covariance matrix of the moment vector. Specifically, we stack the influence functions for each of our moments and then form the covariance matrix by taking the inner product of this stack.

One final issue is unobserved heterogeneity in our data from Compustat. Recall that our simulations produce *i.i.d.* firms. 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.

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**Table 1**

**Simulated moments estimation**

Calculations are based on a sample of nonfinancial, unregulated firms from the annual 2007 COMPUSTAT industrial files. The sample period is 1988 to 2001. 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 estimated moments. All moments are self-explanatory, except the serial correlation and innovation to income. These moments are the slope coefficient and error variance from a first order autoregression of the ratio of income to assets. The second panel reports the estimated structural parameters, with standard errors in parentheses.  $\lambda_1$  and  $\lambda_2$  are the linear and quadratic costs of equity issuance.  $\sigma_v$  is the standard deviation of the innovation to  $\ln(z)$ , in which  $z$  is the shock to the revenue function.  $\rho$  is the serial correlation of  $\ln(z)$ .  $\theta$  is the curvature of the revenue function,  $zk^\theta$ .  $\gamma$  and  $a$  are the fixed and convex adjustment cost parameters, and  $s$  is the agency cost parameter.  $\chi^2$  is a chi-squared statistic for the test of the equality of the moments, with its  $p$ -value in parentheses.

**A. Moments**

	Simulated moments	Actual moments
Second moment of investment ( $I/k$ )	0.078	0.020
Second moment of net leverage ( $p/k$ )	0.032	0.104
Average net leverage ( $p/k$ )	0.189	0.099
Average equity issuance ( $e/k$ )	0.031	0.041
Frequency of equity issuance ( $e/k$ )	0.246	0.222
Average Tobin's $q$ ( $(V + p)/k$ )	4.036	3.671
Third moment of investment ( $I/k$ )	0.061	0.068
Sensitivity of investment to Tobin's $q$	0.028	0.004
Serial correlation of income ( $zk^\theta/k$ )	0.477	0.791
Variance of the innovation to income ( $zk^\theta/k$ )	0.002	0.002
Average cash balances ( $c/k$ ), conditional on $c > 0$	0.179	0.140

**B. Parameter estimates**

$\lambda_1$	$\lambda_2$	$\sigma_v$	$\rho$	$\theta$	$\gamma$	$a$	$s$	$\chi^2$
0.037	0.0002	0.178	0.650	0.759	0.007	0.008	0.0001	3.233
(0.005)	(0.0007)	(0.040)	(0.057)	(0.067)	(0.001)	(0.019)	(0.0002)	(0.357)

**Table 2**

**Average and standard deviation of the debt-to-assets ratio**

The average and standard deviation of the debt-to-assets ratio,  $d/k$ , are expressed as a function of equity access costs and of agency costs of cash balances. Panels A and B report average leverage for the no-tax and with-tax models respectively, while panels C and D report the standard deviation of leverage for those models. We start with the baseline model (per section 2's SMM estimation results) and consider a significant range of parameter values around each baseline parameter value. Here, we consider variation in (i) the linear cost of accessing outside equity,  $\lambda_1$  (which varies from 0.001 to 0.075 across the columns of the table) and (ii) the total cost of maintaining cash balances, which equals the sum of the marginal agency cost,  $s$ , and the tax cost,  $\tau_c r$ . We allow  $s$  to vary from 0.0001 to 0.00075, and hold  $\tau_c r$  constant at 0.00525, so that the total cost of maintaining cash balances ranges from 0.00535 to 0.0060 down the rows. For each combination of parameter values, we run the model for 10,200 periods, with the firm receiving random productivity shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data, and record and report the average of the debt-to-assets ratio,  $d/k$ , and the standard deviation of  $d/k$  for the remaining 10,000 observations.

**A. Average debt-to-assets ratio ( $d/k$ ): no-tax model**

Cost of maintaining cash balances:	Cost of accessing external equity:				
	Low				High
Low	0.023	0.025	0.025	0.026	0.027
	0.028	0.030	0.031	0.031	0.030
	0.043	0.039	0.039	0.039	0.037
	0.056	0.053	0.047	0.044	0.044
High	0.067	0.063	0.060	0.059	0.056

**B. Average debt-to-assets ratio ( $d/k$ ): with-tax model**

Low	0.283	0.226	0.196	0.171	0.158
	0.286	0.229	0.200	0.177	0.159
	0.287	0.229	0.197	0.180	0.164
	0.287	0.229	0.199	0.184	0.171
High	0.286	0.231	0.201	0.185	0.169

**C. Standard deviation of  $d/k$ : no-tax model**

Low	0.069	0.070	0.072	0.072	0.072
	0.071	0.074	0.074	0.074	0.072
	0.081	0.079	0.080	0.081	0.077
	0.087	0.086	0.084	0.082	0.081
High	0.091	0.090	0.088	0.087	0.084

**D. Standard deviation of  $d/k$ : with-tax model**

Low	0.115	0.109	0.104	0.105	0.102
	0.117	0.109	0.104	0.105	0.103
	0.117	0.108	0.104	0.105	0.102
	0.116	0.109	0.105	0.105	0.102
High	0.116	0.110	0.104	0.104	0.103

**Table 3**

**Capital structure and investment shock volatility in the no-tax model**

This table reports a variety of summary statistics from simulations of the baseline model in which the tax advantage of debt has been removed. We simulate the model for 10,200 periods, with the firm receiving random productivity shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data. Each column reports statistics for a different model simulation, each of which corresponds to a different standard deviation of the productivity shock. We let this standard deviation range from 0.01 to 0.3.

		Standard deviation of investment shocks:									
		Low			Moderate				High		
1.	Average investment ( $I/k$ )	0.177	0.178	0.178	0.178	0.181	0.190	0.198	0.209	0.223	0.231
2.	Standard deviation of investment ( $I/k$ )	0.255	0.258	0.264	0.260	0.277	0.319	0.348	0.379	0.425	0.446
3.	Frequency of investment	0.628	0.637	0.625	0.633	0.624	0.600	0.612	0.604	0.614	0.631
4.	Average debt-to-assets ratio ( $d/k$ )	0.112	0.105	0.094	0.075	0.056	0.051	0.045	0.040	0.042	0.045
5.	Standard deviation of leverage ( $d/k$ )	0.101	0.102	0.101	0.093	0.087	0.086	0.079	0.077	0.075	0.074
6.	Average net debt ( $(d - c)/k$ )	0.105	0.104	0.087	0.053	0.006	-0.052	-0.108	-0.161	-0.201	-0.191
7.	Standard deviation of net debt	0.115	0.111	0.117	0.129	0.157	0.225	0.285	0.329	0.383	0.392
8.	Average cash balances to assets ( $c/k$ )	0.000	0.000	0.002	0.009	0.029	0.073	0.117	0.159	0.194	0.186
9.	Standard deviation of ( $c/k$ )	0.002	0.021	0.078	0.096	0.145	0.220	0.290	0.335	0.393	0.412
10.	Frequency of positive debt outstanding	0.781	0.690	0.629	0.538	0.419	0.389	0.354	0.352	0.344	0.388
11.	Average of positive leverage values	0.144	0.153	0.149	0.140	0.134	0.130	0.127	0.115	0.121	0.115
12.	Average of positive cash balance values	0.002	0.016	0.073	0.075	0.118	0.191	0.278	0.326	0.401	0.416
13.	Debt issuance frequency	0.370	0.409	0.379	0.349	0.288	0.258	0.255	0.239	0.241	0.257
14.	Debt reduction frequency	0.625	0.496	0.454	0.397	0.330	0.300	0.275	0.270	0.272	0.295
15.	Average debt issuance/assets	0.289	0.253	0.244	0.223	0.216	0.220	0.205	0.198	0.212	0.205
16.	Average debt reduction/assets	-0.128	-0.150	-0.141	-0.133	-0.122	-0.114	-0.112	-0.098	-0.099	-0.094
17.	Equity issuance frequency	0.045	0.225	0.254	0.227	0.264	0.268	0.278	0.311	0.332	0.370
18.	Average equity issuance/assets	0.013	0.019	0.021	0.020	0.021	0.024	0.026	0.032	0.040	0.044
Average fraction of investment funded from:											
19.	Current cash flow	0.679	0.713	0.731	0.750	0.765	0.753	0.740	0.718	0.701	0.707
20.	Cash balances	0.016	0.002	0.012	0.035	0.064	0.098	0.121	0.158	0.173	0.165
21.	Debt issuance	0.304	0.279	0.247	0.207	0.159	0.134	0.121	0.100	0.099	0.096
22.	Equity issuance	0.001	0.006	0.010	0.008	0.012	0.014	0.016	0.021	0.024	0.029

Table 4

Capital structure and investment shock volatility in the with-tax model

This table reports a variety of summary statistics from simulations of the baseline model. We simulate the model for 10,200 periods, with the firm receiving random productivity shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data. Each column reports statistics for a different model simulation, each of which corresponds to a different standard deviation of the productivity shock. We let this standard deviation range from 0.01 to 0.3.

		Standard deviation of investment shocks:									
		Low		Moderate						High	
1.	Average investment ( $I/k$ )	0.178	0.177	0.177	0.177	0.179	0.182	0.188	0.198	0.214	0.223
2.	Standard deviation of investment ( $I/k$ )	0.251	0.253	0.255	0.254	0.268	0.285	0.314	0.349	0.413	0.437
3.	Frequency of investment	0.836	0.710	0.680	0.679	0.661	0.633	0.617	0.601	0.596	0.601
4.	Average debt-to-assets ratio ( $d/k$ )	0.384	0.353	0.305	0.286	0.245	0.196	0.141	0.110	0.077	0.062
5.	Standard deviation of leverage ( $d/k$ )	0.075	0.088	0.098	0.104	0.103	0.106	0.099	0.093	0.082	0.077
6.	Average net debt ( $(d-c)/k$ )	0.384	0.353	0.305	0.286	0.243	0.185	0.100	0.020	-0.126	-0.180
7.	Standard deviation of net debt	0.075	0.088	0.098	0.106	0.119	0.145	0.202	0.287	0.427	0.452
8.	Average cash balances to assets ( $c/k$ )	0.000	0.000	0.000	0.000	0.001	0.005	0.024	0.063	0.161	0.195
9.	Standard deviation of ( $c/k$ )	0.000	0.000	0.000	0.025	0.104	0.157	0.242	0.367	0.488	0.501
10.	Frequency of positive debt outstanding	1.000	1.000	0.999	0.995	0.966	0.911	0.763	0.666	0.512	0.452
11.	Average of positive leverage values	0.384	0.353	0.305	0.287	0.254	0.215	0.185	0.166	0.151	0.138
12.	Average of positive cash balance values	0.000	0.000	0.000	0.056	0.093	0.140	0.214	0.316	0.453	0.496
13.	Debt issuance frequency	0.333	0.347	0.376	0.403	0.400	0.392	0.366	0.339	0.283	0.271
14.	Debt reduction frequency	0.667	0.648	0.621	0.593	0.584	0.571	0.516	0.460	0.361	0.334
15.	Average debt issuance/assets	0.349	0.312	0.262	0.235	0.231	0.237	0.236	0.228	0.223	0.223
16.	Average debt reduction/assets	-0.139	-0.132	-0.122	-0.123	-0.119	-0.119	-0.115	-0.111	-0.103	-0.102
17.	Equity issuance frequency	0.005	0.106	0.259	0.327	0.331	0.351	0.364	0.383	0.418	0.419
18.	Average equity issuance/assets	0.014	0.024	0.028	0.028	0.031	0.029	0.031	0.034	0.036	0.037
Average fraction of investment funded from:											
19.	Current cash flow	0.740	0.717	0.732	0.747	0.755	0.751	0.737	0.719	0.712	0.691
20.	Cash balances	0.000	0.000	0.000	0.000	0.004	0.015	0.042	0.080	0.129	0.157
21.	Debt issuance	0.260	0.279	0.253	0.233	0.220	0.213	0.194	0.170	0.126	0.119
22.	Equity issuance	0.000	0.004	0.014	0.019	0.021	0.022	0.026	0.030	0.032	0.032

Table 5

Capital structure comparative statics

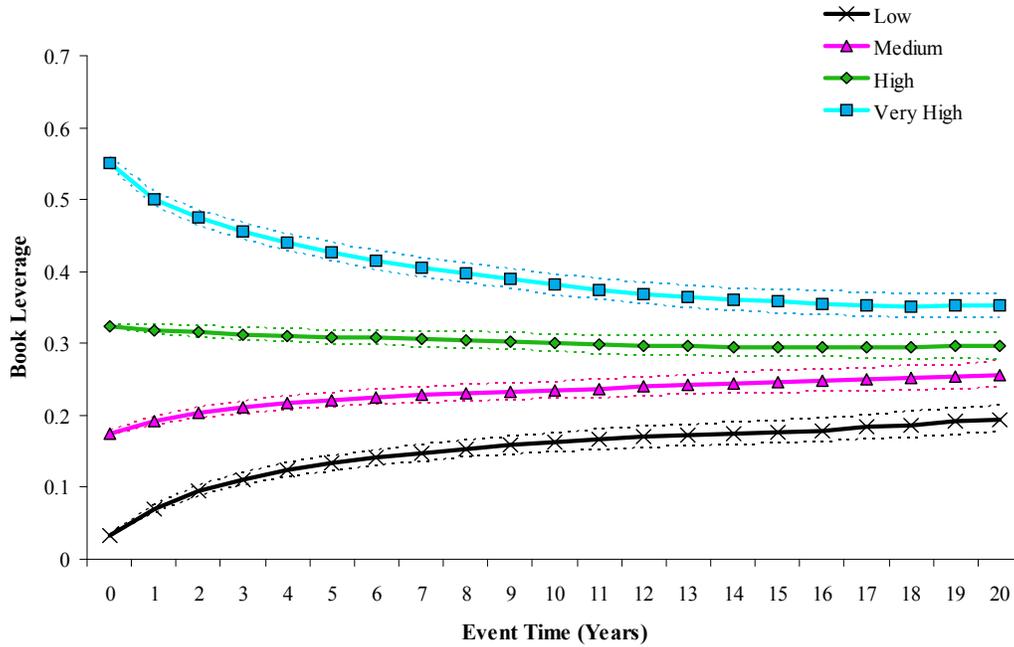
This table reports a variety of summary statistics from simulations of the baseline model. We simulate the model for 10,200 periods, with the firm receiving random productivity shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data. Each column reports statistics for a different model simulation. The first two are for low and high shock serial correlation, set at 0.25 and 0.85. The next two are for low and high  $\theta$ , the parameter governing the marginal profitability of capital, set at 0.4 and 0.8. The next two are for low and high convex costs of adjusting the physical stock of capital, set at 0 and 0.1. The final two are for low and high fixed adjustment costs, set at 0 and 0.1.

		Shock serial correlation		Marginal profitability		Capital stock adjustment costs			
		Low	High	Low	High	Convex		Fixed	
						Low	High	Low	High
1.	Average investment ( $I/k$ )	0.177	0.207	0.171	0.186	0.196	0.162	0.183	0.269
2.	Standard deviation of investment ( $I/k$ )	0.252	0.380	0.220	0.308	0.364	0.159	0.257	0.739
3.	Frequency of investment	0.697	0.644	0.735	0.619	0.589	0.784	0.759	0.386
4.	Average debt-to-assets ratio ( $d/k$ )	0.340	0.067	0.349	0.150	0.162	0.377	0.240	0.104
5.	Standard deviation of leverage ( $d/k$ )	0.098	0.099	0.068	0.103	0.104	0.066	0.081	0.130
6.	Average net debt ( $(d-c)/k$ )	0.340	-0.139	0.349	0.108	0.117	0.377	0.230	-0.319
7.	Standard deviation of net debt	0.098	0.401	0.068	0.209	0.226	0.066	0.137	0.600
8.	Average cash balances to assets ( $c/k$ )	0.000	0.173	0.000	0.025	0.024	0.000	0.005	0.320
9.	Standard deviation of ( $c/k$ )	0.000	0.430	0.000	0.256	0.256	0.000	0.226	0.441
10.	Frequency of positive debt outstanding	0.999	0.459	1.000	0.797	0.800	1.000	0.934	0.381
11.	Average of positive leverage values	0.340	0.146	0.349	0.188	0.202	0.377	0.257	0.274
12.	Average of positive cash balance values	0.000	0.430	0.000	0.233	0.231	0.000	0.214	0.633
13.	Debt issuance frequency	0.351	0.270	0.420	0.361	0.342	0.516	0.470	0.140
14.	Debt reduction frequency	0.633	0.324	0.533	0.529	0.547	0.472	0.501	0.306
15.	Average debt issuance/assets	0.290	0.215	0.134	0.243	0.282	0.091	0.142	0.692
16.	Average debt reduction/assets	-0.128	-0.100	-0.086	-0.116	-0.117	-0.084	-0.090	-0.138
17.	Equity issuance frequency	0.213	0.434	0.095	0.364	0.337	0.296	0.437	0.379
18.	Average equity issuance/assets	0.022	0.055	0.039	0.025	0.031	0.028	0.032	0.052
Average fraction of investment funded from:									
19.	Current cash flow	0.728	0.723	0.869	0.731	0.726	0.827	0.763	0.676
20.	Cash balances	0.000	0.112	0.000	0.040	0.038	0.000	0.016	0.204
21.	Debt issuance	0.265	0.113	0.122	0.210	0.213	0.148	0.179	0.101
22.	Equity issuance	0.007	0.050	0.009	0.019	0.023	0.025	0.042	0.017

Figure 1

Long-run average leverage ratios of firms sorted by initial leverage:  
 Lemmon, Roberts, and Zender's (2008) leverage paths versus model-generated paths

1A. Lemmon, Roberts, and Zender's (2008) long-run leverage paths



1B. Long-run average leverage generated by the with-tax model

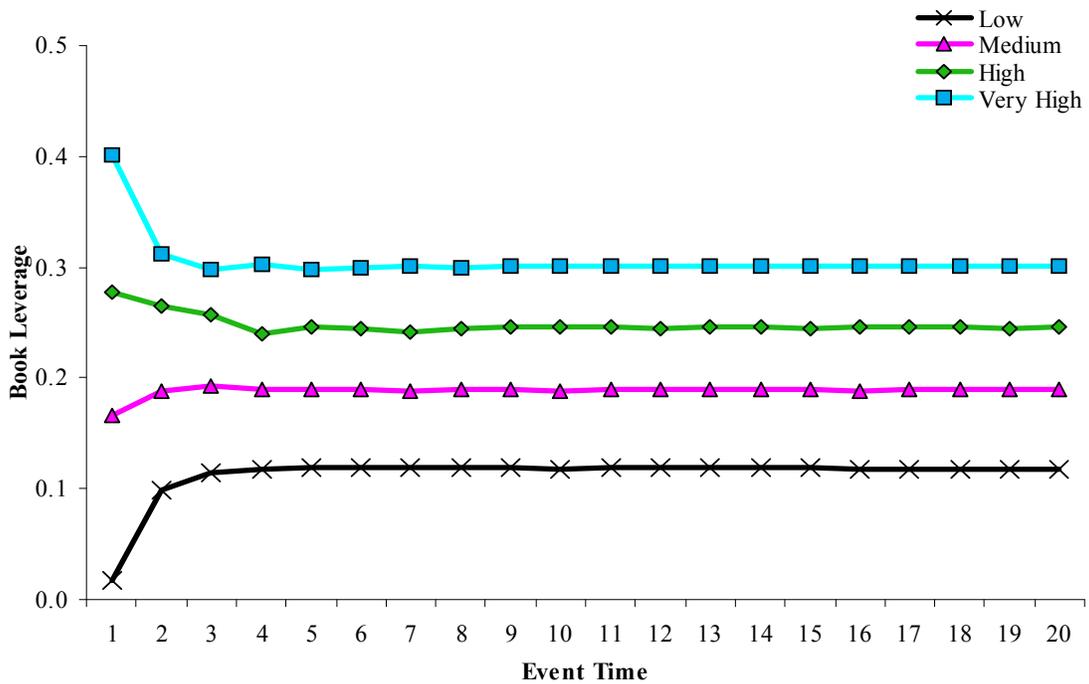
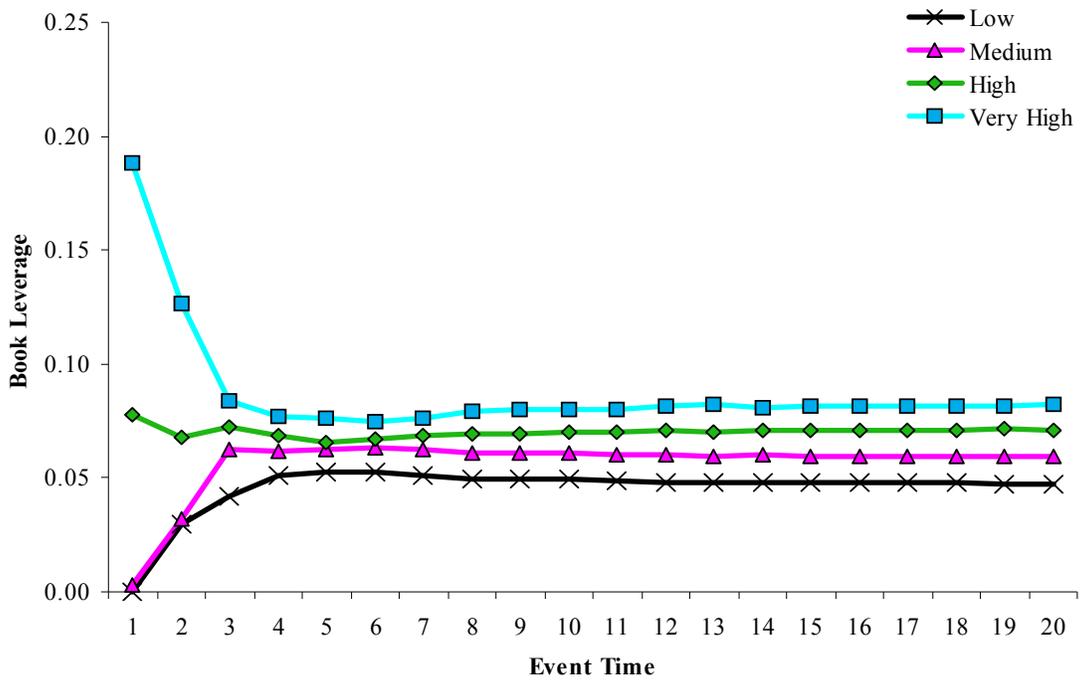


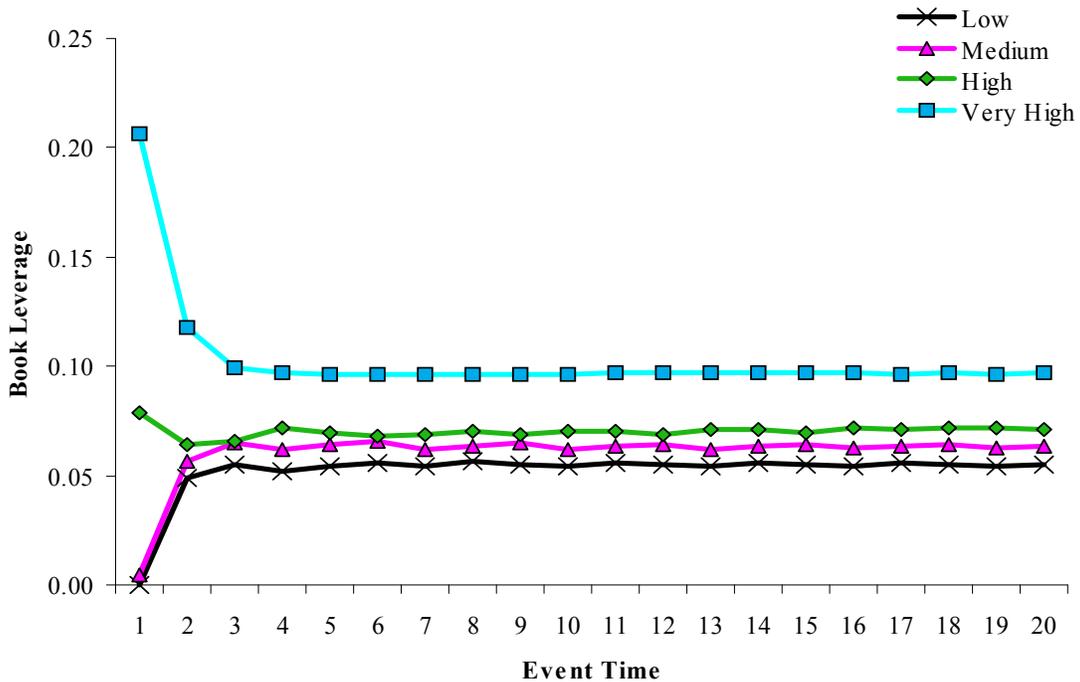
Figure 2

Long-run average leverage in the no-tax model versus net-of-target leverage in the with-tax model

2A. Long-run average leverage generated by the no-tax model



2B. Net-of-target long-run average leverage generated by the with-tax model



**Figure 3**

**Histogram of debt-to-assets ratios generated by the no-tax model for the full sample of 1,000 firms in the simulated replication of Lemmon, Roberts, and Zender (2008)**

In the no-tax model, zero debt is the capital structure target for all firms. The figure shows that sample firms are at their debt targets in about 53% of the periods in our no-tax model's simulation of the empirical analysis of Lemmon, Roberts, and Zender (2008). The histogram indicates that firms have transitory debt outstanding around 47% of the time, and so the average outstanding amount of debt is positive, even though the target amount is zero in this model specification.

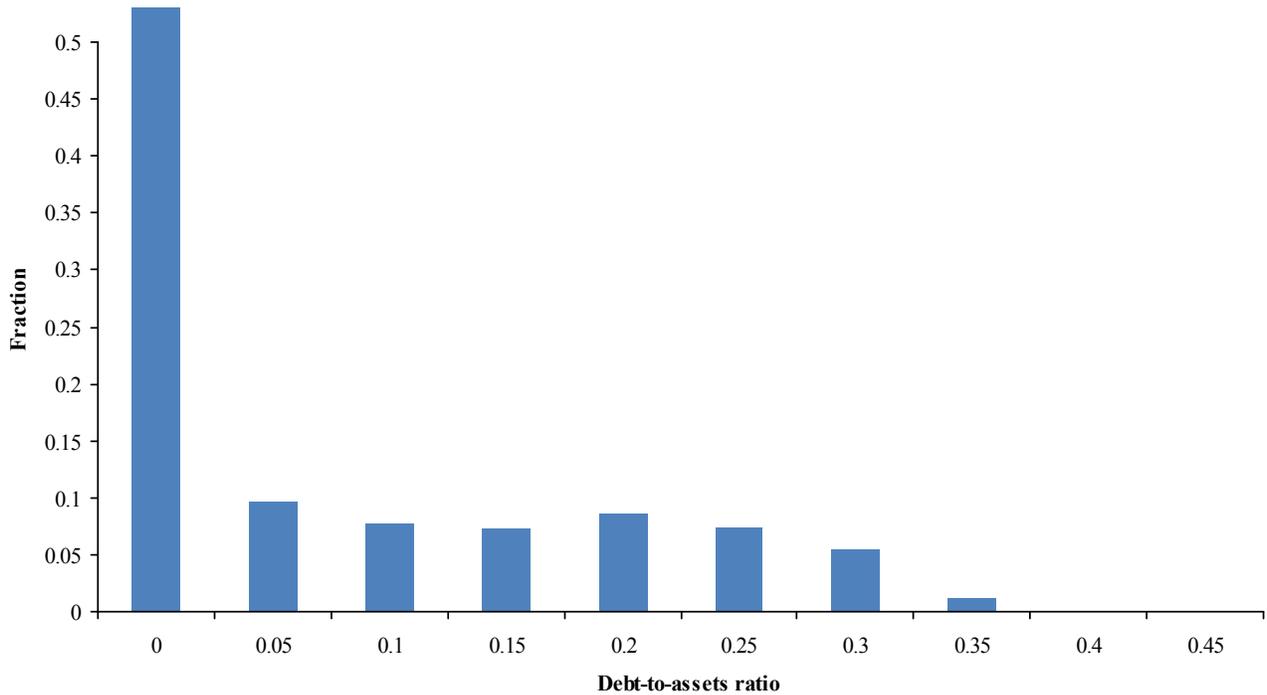


Figure 4

Illustrative time path of leverage and debt issuance/retirement in no-tax model

In the no-tax model, zero debt is the long-run capital structure target.

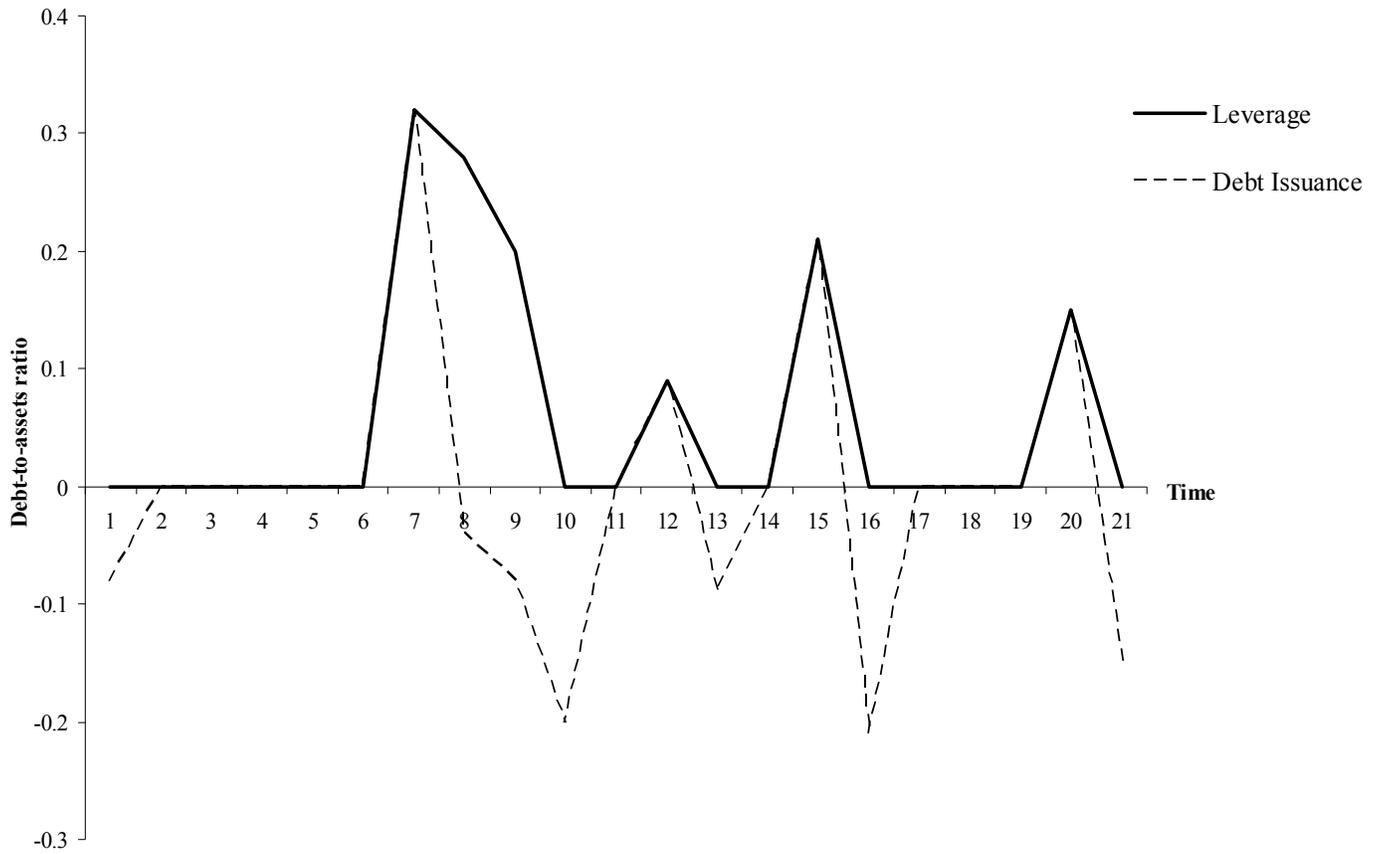
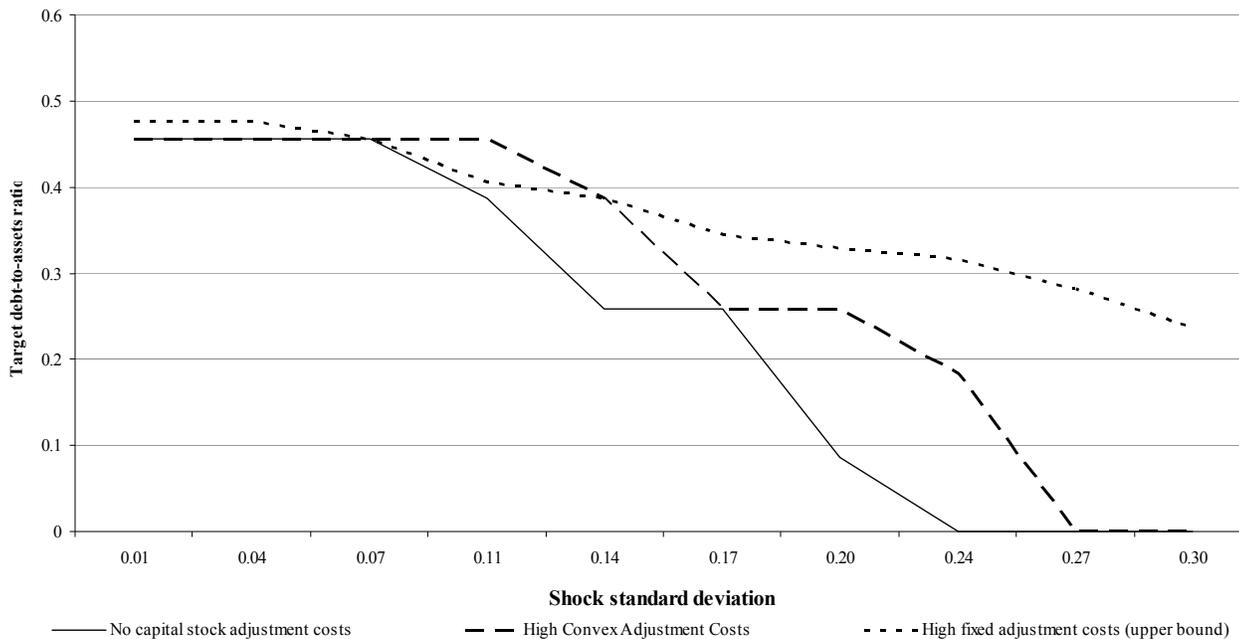


Figure 5

Target capital structure as a function of the attributes of investment opportunities

Leverage is measured as the ratio of debt to total assets. Shock volatility ( $\sigma_v$ ) and serial correlation ( $\rho$ ) parameters are centered around the estimates from the SMM estimation in Section 2. Target leverage is unique for the no capital stock adjustment cost and high convex adjustment cost cases, but not for the high fixed cost case. Both panels plot the upper bound on target leverage for the latter case, with the lower bound always equal to 0.00.

A. Target capital structure and investment shock standard deviation



B. Target capital structure and investment shock serial correlation

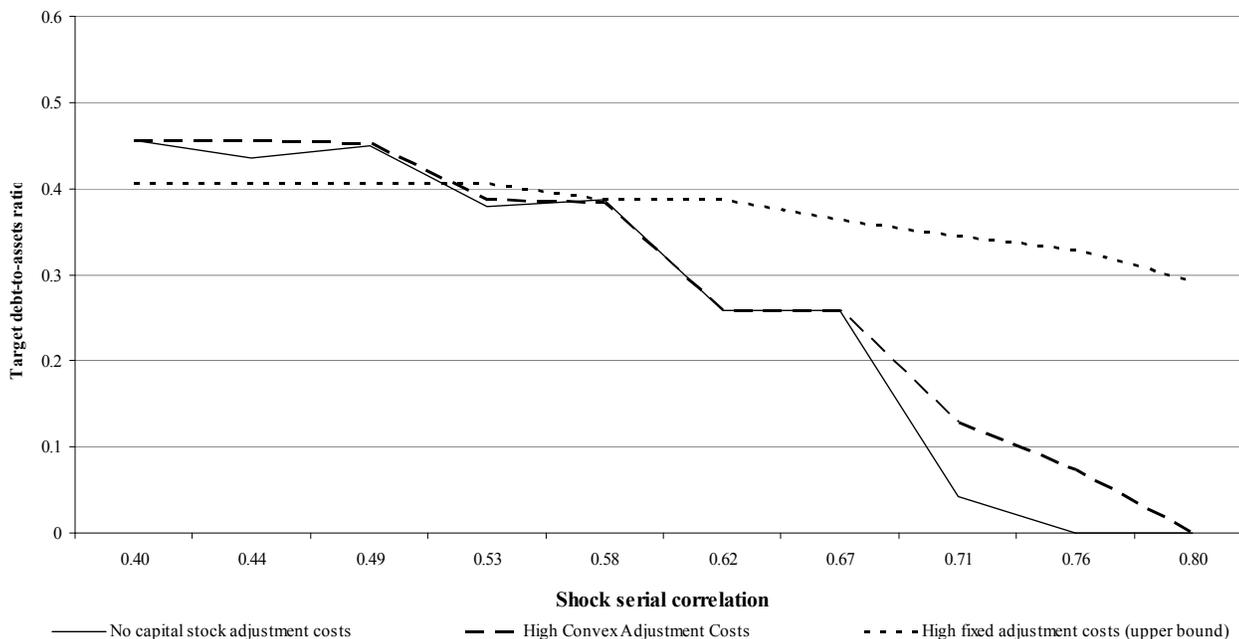


Figure 6

**Illustrative convergence to target leverage in the with-tax model**

The firm experiences random investment shocks until date  $t = 39$ , at which point it begins to receive a series of neutral investment shocks. It converges to target at  $t = 41$  and remains there as neutral shocks continue to arrive. This illustrative firm faces convex capital stock adjustment costs, but no fixed costs of adjustment, and so it has a constant long-run target leverage ratio.

