Capital Structure Dynamics and Transitory Debt

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Abstract

We estimate a dynamic capital structure model in which firms have permanent leverage targets, yet respond to shocks to investment opportunities by incurring transitory debt obligations that represent deliberate, but temporary, deviations from target. Target capital structures reflect the value of the option to issue transitory debt, and the average amount of debt outstanding differs predictably from target as a function of the attributes of investment opportunities. The model yields testable predictions about the link between capital structure and the volatility and serial correlation of investment opportunity shocks, the marginal profitability of investment, and the nature of capital stock adjustment costs. The leverage ratios implied by our estimated model parameters exhibit slow average speed of adjustment to target similar to the estimates in prior empirical studies. Sluggish adjustment reflects deliberate transitory deviations from target leverage and not costs of debt issuance.

1. Introduction

We estimate a dynamic capital structure model with endogenous investment in which firms have leverage targets but in which they sometimes issue transitory debt and deviate deliberately, but temporarily, from target. These deviations distinguish our model from prior target capital structure models and produce radically different leverage dynamics, with the model offering new insights on three important issues. First, it yields a rich set of testable predictions that link capital structure to variation in the volatility and serial correlation of shocks to investment policy and the marginal profitability of investment, as well as to variation in the fixed (versus convex) costs of adjusting the capital stock. Second, the model generates leverage ratios with average speeds of adjustment (SOA) to target that closely approximate the unusually slow SOA estimates reported in empirical rebalancing studies. However, because firms issue transitory debt, measures of the average SOA obscure the strength of firms' incentives to rebalance leverage, which manifest in our model as aggressive state-contingent (investment shock-dependent) decisions to adjust leverage toward target. Third, the model predicts that transitory debt is a substantial fraction of total outstanding debt, even in long-horizon leverage analyses of the type conducted by Lemmon, Roberts, and Zender (2008), and clarifies the economically important distinction between average and target leverage.

In our model, firms' use of transitory debt and their target capital structures are systematically related to the nature of their investment opportunities because (i) borrowing is a cost-efficient means of raising capital when a given shock to investment opportunities dictates a funding need, and (ii) the option to issue debt is a scarce resource whose optimal intertemporal utilization depends on both current and prospective shocks. The option to issue debt is valuable in our model because investment is endogenous and because of three assumptions that dictate that all sources of capital (external equity, corporate cash balances, and borrowing) are costly means of funding investment. First, equity issuance entails costs, an assumption intended to reflect the existence of adverse selection problems or security flotation expenses. Second, holding cash incurs costs, which can reflect corporate taxes, agency costs, or an interest rate differential on precautionary liquid asset holdings in the spirit of Keynes (1936). Finally, debt capacity is finite, an assumption that can reflect financial distress costs or asymmetric information problems that prevent creditors from gauging firms' ability to support debt. As a result, when a firm borrows today, the relevant "leverage-related cost" includes the opportunity cost of its consequent future inability to borrow.

Target capital structures are more conservative than in otherwise similar tax/distress cost tradeoff models because the cost of borrowing today includes the value lost when a firm fails to preserve the option to borrow later at comparable terms. 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. Analytically, in our model the target capital structure is the matching of debt and assets to which the firm would converge if it optimized its debt and assets decisions in the face of uncertainty, but then by chance happened to receive only neutral shocks to investment opportunities for many periods in a row. (In this case, the firm has ample resources to pay down any debt in excess of target and no projects that require outside funding.) In general, the target debt level is a function of the probability distribution of investment opportunities, taxes, financial distress costs, external equity financing costs, and the costs of holding cash balances. 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 firms have a range of target leverage ratios.

Our model yields a variety of specific testable predictions that link the attributes of firms' investment opportunities to their capital structure decisions. For example, average debt outstanding is inversely related to the volatility of unexpected shocks to investment opportunities, and the imposition of corporate taxes induces greater leverage for firms that face low as opposed to high shock volatility. Intuitively, firms that face high shock volatility find it especially valuable to preserve debt capacity to address substantial funding needs associated with future shocks to investment opportunities, 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 induce the former to rely more on (costly) cash balances to fund investment. For similar reasons, firms that face higher (i) serial correlation of shocks to investment opportunities, (ii) marginal profitability of investment, and (iii) fixed (compared to convex) costs of adjusting the stock of physical capital are all predicted to have lower average debt ratios and to place greater reliance on cash balances.

We refer to the difference between actual and target debt levels as transitory debt,[1] with actual debt deviating temporarily from target because investment policy is endogenous. For example, with no tax or other permanent benefit from corporate debt, firms find that issuing debt is sometimes the most efficient way to raise capital (in a sense made precise below), even though zero debt is the capital structure target. Paying down debt frees up debt capacity, which reduces the expected future costs of capital access. While 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 because, e.g., additional shocks arrive, requiring more funds and, perhaps, more borrowing.

The prediction that firms choose to deviate temporarily from target leverage differentiates our analysis from static trade-off models and the multi-period contingent claims generalizations thereof, both of which assume exogenous investment and positive leverage rebalancing costs (see, e.g., Fischer, Heinkel, and Zechner (1989) and Goldstein, Ju, and Leland (2001)). These models universally predict that all management-initiated changes in capital structure move firms toward target, although Welch (2004) and others find that this prediction is not borne out empirically. For example, Hovakimian (2004) finds that "... debt issues do not reduce the deviation from the target debt ratio. The pre-debt-issue deviation from the target is essentially zero. The issuance of debt increases rather than reduces the deviation from the target." In Hovakimian, Opler, and Titman's (2001, table 4) sample, the average long-term debt issue is 17.4% of total assets, and is undertaken when the firm's debt-to-assets ratio is 1.3% below the authors' estimate of target. Harford, Klasa, and Walford (2008) report that, in debt-financed acquisitions, bidding firms typically move away from their target capital structures, and then rebalance back toward target with a lag. Denis and McKeon (2009) document 2,513 cases (over 1971 to 1999) in which 2,272 firms substantially increase their total debt at a time when their debt ratios are at least 10% above estimated target leverage.

Another empirical shortcoming of extant tradeoff theories—and one that plausibly reflects the high empirical incidence of deliberate deviations from target—is the notably slow speeds of adjustment (SOA) to target estimated in leverage rebalancing studies. For example, Fama and French

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[1] Transitory debt is not synonymous with short-term debt. Indeed our model includes only perpetual debt, which managers issue and later retire or perhaps leave outstanding indefinitely 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. In other words, it is managerial intent (and behavior) that determines whether debt is transitory, and not the stated life or any other contractual feature of a given debt issue.

(2002) report speeds of adjustment to target leverage that are "suspiciously slow," and other studies find that firms adjust an average of somewhere between one-third and one-twelfth of the way toward target in a typical year (see, e.g., Flannery and Rangan (2006), Kayhan and Titman (2007), Lemmon, Roberts, and Zender (2008), and the other SOA papers surveyed by Parsons and Titman (2008)). These uniformly slow SOA estimates call into question the premise of extant trade-off theories that rebalancing to target is the sole motive for pro-active changes in capital structure.

The leverage ratios implied by our estimated model parameters exhibit slow average speeds of adjustment in the neighborhood of the estimates in prior empirical studies. Since our estimation procedure does not match model parameter values to real-world data based on speeds of adjustment, this finding provides additional empirical support for the model. Importantly, the slow speeds of adjustment in our model do not imply that firms' incentives to rebalance leverage are weak. Rather, the SOA measures used in earlier rebalancing studies understate the strength of firms' incentives to rebalance leverage because these studies' SOA estimates include financing decisions in which firms choose to move temporarily away from target, as our model predicts they will do from time to time. When we exclude such financing decisions from SOA measures, we find that firms in our model rebalance leverage aggressively toward target in some but not all states of the world, most notably when optimal investment outlays are low so that resources are best used to free up debt capacity for future use. In order to increase the power and accuracy of their statistical tests, future empirical studies that seek to gauge the strength of firms' incentives to rebalance leverage should control for deliberate deviations from target because their inclusion biases downward the estimated rate at which firms choose to adjust leverage toward target.

We analyze leverage over long horizons using an approach that parallels that of Lemmon, Roberts, and Zender (2008, LRZ), and find that cross-sectional average leverage paths generated by our model closely conform to those found empirically by LRZ. More importantly, this analysis indicates that transitory debt is predicted by our model to be an economically material fraction of total debt outstanding at a randomly selected point in time and that, when firms issue transitory debt, average leverage is not expected to converge to target even in the long run. Rather, over long horizons, model-generated average leverage incorporates both the average of firms' target debt levels plus the amount of transitory debt they are expected to have outstanding at a randomly selected point in time. Since the latter varies cross-sectionally with variation in investment opportunities, our analysis predicts that, empirically, cross-firm variation in average leverage reflects significant variation in transitory debt due, e.g., to differences in the volatility of shocks to investment opportunities.

Investment policy endogeneity is critical to our analysis, and variation in investment opportunity attributes is the main driver of our comparative statics predictions. Endogenous investment also characterizes a small but growing literature of dynamic models that explores the interactions of investment policy and capital structure. Brennan and Schwartz (1984), Hennessy and Whited (2005), Titman and Tsyplakov (2007), and Gamba and Triantis (2008) treat investment as endogenous while focusing respectively on debt covenants, taxes, agency issues, and cash holdings. Tserlukevich (2008), Morellec and Schürhoff (2008), and Sundaresan and Wang (2008) study the leverage impact of real options.[2] We focus on the capital structure impact of variation in investment attributes and, in particular, on the leverage impact of variation in the volatility and serial correlation of investment shocks, in the marginal profitability of investment, and in the properties of capital stock adjustment costs. (Here and throughout, when we use the term “investment shock,” we mean a shock to investment opportunities, not a stochastic shift in investment outlays.)

Our analysis moves beyond existing dynamic capital structure models in that it (i) develops the target capital structure and leverage dynamics implications of the opportunity cost of borrowing, (ii) demonstrates that this opportunity cost induces firms to use debt as a transitory financing vehicle, (iii) 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 target leverage, (iv) formally operationalizes the notion of—and demonstrates the existence of—capital structure targets in a dynamic model with endogenous investment, (v) yields new testable implications that link the time-series and cross-sectional variation in firms’ capital structures to variation in their investment opportunities, (vi) shows that when firms employ transitory debt, conventional measures of the speed of adjustment to target leverage materially understate the

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[2] Tserlukevich (2008, table 1) catalogs the assumptions of 10 dynamic capital structure models, and notes that five treat investment as exogenous (Kane, Marcus, and McDonald (1984), Fischer, Heinkel, and Zechner (1989), Goldstein, Ju, and Leland (2001), Strebulaev (2007), and Leary and Roberts (2005)) and five treat it as endogenous (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 Bolton, Chen, and Wang (2009) also treat investment as endogenous, as do Riddick and Whited (2008), who analyze cash balances (but not leverage decisions) in an analytical framework close in spirit to the one we employ.

strength of their rebalancing incentives, (vii) shows that transitory debt alone can fully explain the leverage paths documented by Lemmon, Roberts, and Zender (2008), and (viii) demonstrates that the types of physical capital stock adjustment costs that firms face affect predicted leverage dynamics and determine whether capital structure targets are unique.

While our model shares several features with Whited (1992) and Hennessy and Whited (2005), e.g., endogenous investment, there are a number of important differences. First, while Hennessy and Whited (2005, abstract) indicate that "there is no target leverage ratio" in their analysis, we recognize that a meaningful leverage target does in fact exist in dynamic models of the general type they employ. Second, our analysis considers a more realistic set of investment policy features, which both generate a richer set of leverage predictions and enable our model to do a markedly better job than Hennessy and Whited's model does in matching the empirical volatility of investment. More generally, our model is distinctive in its emphasis on the opportunity cost of issuing debt and the resultant implications for transitory debt, for the existence of (and cross-firm variation in) target capital structures, and for the systematic connections between the nature of investment opportunities and leverage comparative statics. We posit a simple dynamic model to sharply highlight the capital structure role of transitory debt, but as we show in section 7, our conclusions generalize to considerably more complex model settings. These extensions illustrate the general principle that any leverage cost that increases in the level of total debt implies that borrowing today entails the opportunity cost of a reduced future ability to borrow at currently available terms.

Section 2 describes the model and presents the estimation results. Sections 3 and 4 contain the comparative statics analysis that establishes the predicted connections between firms' leverage decisions and attributes of their investment opportunities. Section 5 describes our model's implications for the speed of adjustment to target leverage and the strength of rebalancing incentives, while section 6 reports its predictions about long-horizon average leverage paths. Section 7 demonstrates that our conclusions generalize to models that include collateral constraints, endogenous default, and the simultaneous holding of debt and cash balances. Section 8 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) equity or debt issuances, 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)), and/or a premium paid for precautionary liquid asset holdings (Keynes (1936)). We refer to these costs hereafter, for simplicity, as "agency costs" or "costs of maintaining cash balances."

2.1 Model setup

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 $\pi(k, z)$, in which k is capital and z is a shock observed by managers each period before making 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 and concave, with $\pi(0, z) = 0$, $\pi_z(k, z) > 0$, $\pi_k(k, z) > 0$, $\pi_{kk}(k, z) < 0$, and $\lim_{k \to \infty} \pi_k(k, z) = 0$. We use the standard functional form $\pi(k, z) = zk^{\theta}$, where θ 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 $[z, \bar{z}]$ 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,

$$\ln\left(z'\right) = \rho \ln(z) + v', \tag{1}$$

in which v' has a truncated normal distribution with mean 0 and variance σ_v^2.

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

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

in which δ is the capital depreciation rate, $0 < \delta < 1$, and τ_c is the corporate income tax rate.

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

Investment, I, is defined as

$$I \equiv k' - (1-\delta)k, \tag{3}$$

in which a prime once again indicates a variable in the next period. The firm purchases and sells capital at a price of 1 and incurs capital stock adjustment costs that are given by

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

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 γ is a constant, and Φ_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.

The firm can finance via debt, internal cash, current profits, and external equity. Define 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 tax bill unchanged and reduce agency costs. It follows that $d=\max(p,0)$ and $c=\max(0,-p)$, and so we can parsimoniously represent the model with the variable p and then use the definitions of d and c to obtain 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 (aside from the incremental cost, s, formalized below). For simplicity, we model the tax advantage of debt only via a corporate income tax. We abstract from personal taxes and debt covenants, which are treated in Miller (1977), Hennessy and Whited (2005), Smith and Warner (1979), and Brennan and Schwartz (1984).

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:

$$p \leq \bar{p}. \tag{5}$$

The estimated value of the parameter $\bar{p}$ leads to a solution for equity value that always exceeds zero, which implies that the firm never defaults. Although the assumption of riskless debt with an exogenously specified upper bound may appear unduly simple and restrictive, we show in section 7 that relaxing this assumption has no material effect on our results.

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. Bounded savings are ensured by the corporate tax on interest earned on cash balances and by the assumption that firms face what we refer to as "agency costs," as in Eisfeldt and Rampini (2006). For simplicity, we do not bound cash holdings via a stochastic probability of default, as in Carlstrom and Fuerst (1997). The agency cost function is given by

$$s\left(p\right) = sp\Phi_c, \tag{6}$$

in which s is a constant and Φ_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, $\underline{p}$. This lower bound is imposed without loss of generality because of our taxation and agency cost assumptions. As in the case of an exogenously specified upper bound on debt, the assumption that cash equals negative debt has no qualitative effects on our results.

Equity issuance/distributions are determined simultaneously with investment, debt, and cash, and these decision variables are connected by the familiar identity that stipulates the sources and uses of funds are equal in each period. To express this identity in the context of our model, we first define $e\left(k, k', p, p', z\right)$ as gross equity issuance/distributions. If $e\left(\cdot\right) > 0$, the firm is making distributions to shareholders, and if $e(\cdot) < 0$, 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, which is necessary to estimate the model. The external equity-cost function is linear-quadratic and weakly convex:

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

in which $\lambda_1 > 0$ and $\lambda_2 \geq 0$. The indicator function Φ_e equals 1 if $e(\cdot) < 0$, and 0 otherwise. Convexity of $\phi(e(\cdot))$ is consistent with the evidence on underwriting fees in Altinkilic and Hansen (2000). Net equity issuance/distributions are then given by $e(\cdot) + \phi(e(\cdot))$. This quantity must be equal to the difference between the firm's sources of funds and uses of funds via the identity:

$$e(\cdot)+\phi(e(\cdot)) \equiv (1-\tau_c)\,\pi(k,z)+p'-p\,(1+r\,(1-\tau_c))+\delta k\tau_c-\big(k'-(1-\delta)k\big)-A\left(k,k'\right)+s\,(p)\,. \quad (7)$$

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

$$V\left(k,p,z\right)=\max_{k',\,p'}\left\{e\left(k,k',p,p',z\right)+\phi\big(e\left(k,k',p,p',z\right)\big)+\frac{1}{1+r}\int V\left(k',p',z'\right)dg\left(z',z\right)\right\}. \quad (8)$$

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 (8). Theorem 9.8 in Stokey and Lucas (1989) ensures a unique optimal policy function, $\{k',p'\} = u\,(k,p,z)$, if $e(\cdot)+\phi(e(\cdot))$ 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. Intuitively, it tells the firm how much to invest given the trade-off between the cost of investing and expectations about future productivity. It also positions the firm's capital structure optimally to balance current financing needs with the possible need to raise debt capital once again in response to future shocks that might materialize.

2.2 Optimal financial policy

This subsection develops the intuition behind the model by examining its optimality conditions. For simplicity of exposition, we assume in this subsection that V is once differentiable. This assumptions is not necessary for the existence of a solution to (8) or of an optimal policy function. The optimal interior financial policy, obtained by solving the optimization problem (8), satisfies

$$1+(\lambda_1-\lambda_2 e(\cdot))\,\Phi_e=-\frac{1}{1+r}\int V_2\big(k',p',z'\big)\,dg\big(z',z\big)\,. \tag{9}$$

The left side represents the marginal cost of equity finance. If the firm is issuing equity, this cost includes issuance costs. If the firm is not issuing equity then this cost is simply a dollar for dollar cost of cutting distributions to shareholders. The right side represents the expected marginal cost of debt next period. At an optimum the firm is indifferent between issuing equity, which incurs costs today, and issuing debt, which entails costs in the future.

To see precisely what these costs are, we use the envelope condition. Let μ be the Lagrange multiplier on the constraint (5). Then the envelope condition can be written as:

$$-V_2\,(k,p,z)=((1+(1-\tau_c)r)-s\Phi_c)\,(1+(\lambda_1-\frac{1}{2}\lambda_2 e\,(\cdot))\Phi_e)+\mu. \tag{10}$$

This condition clearly illustrates the marginal costs of having debt/cash on the balance sheet. The first term in parentheses represents interest payments (less the tax shield). In the case of cash balances this term represents the benefit of the interest on the cash (less taxes) minus the extra cost of carrying cash. The second term in parentheses captures the fact that this debt service is all the more costly if the firm has to issue external equity to make the payments. Finally, the third term is the shadow value of relaxing the constraint on debt issuance. This last term captures the intuitive point that a firm may want to preserve debt capacity today in order to avoid bumping up against its constraint in the next period. One clear implication of the value of preserving debt capacity is the intertwining of real and financial decisions. In particular, if a particular firm characteristic increases the probability that the firm will optimally want to make a large future investment, that characteristic also implies that the firm preserves debt capacity now.

2.3 Defining a target

Hennessy and Whited (2005) state that in this type of model there is no single optimal capital structure independent of the current state of the world. Indeed, in our model, capital structure choices are made each period and are state-contingent, exhibiting (local) path dependence. One of our main contributions is the observation that even in this type of setting, firms nonetheless have capital structure targets in a long-run sense. Consider the following thought experiment. What if the firm forms an optimal policy in the face of uncertainty but then happens by chance to face an arbitrarily long 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?[3] 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

$$\left[\liminf_{j\to\infty} u_1^j(k, p, 1), \limsup_{j\to\infty} u_1^j(k, p, 1)\right]. \tag{11}$$

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 is 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 use simulation to solve for the target and to determine its exact form. As we elaborate in section 4.3 below, 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 (11) is a single point depends strongly on the form of the physical adjustment cost function (4).

The target is a special case (i.e. limit) of the policy function. Therefore, like the state-contingent optimum defined by the policy function, the target also positions the firm optimally to raise capital

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[3] 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 4.3.

in the future, given the nature of the uncertainty it faces. In addition, the particular limit of the policy function that we use to define a target is economically relevant. It isolates the long-run tax and opportunity cost incentives for optimizing capital structure, while abstracting from optimal financing decisions that are at least in part due to the need to finance specific investment projects.

2.4 Model estimation

Because the solution of the model must be obtained numerically, the quantitative properties of the model can depend on the 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, θ; shock serial correlation, ρ; shock standard deviation, σ_v; smooth and fixed physical adjustment costs, a and γ; the agency cost parameter, s; the two external equity cost parameters, λ_1 and λ_2, and the ratio of the debt limit, $\bar{p}$, to the steady state capital stock, k^{ss}, that would prevail in the absence of financing or physical adjustment frictions.[4] We estimate this latter parameter to address concerns that average leverage from our model might be hard wired by an arbitrary choice of $\bar{p}$. Appendix A 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 and simulated moments with t-statistics for the difference between the two, and panel B reporting parameter point estimates. Most simulated moments in panel A match the corresponding data moments well. In particular, the simulated and actual variances of investment are economically and statistically indistinguishable. In contrast, the models in Hennessy and Whited (2005, 2007) fail to match this particular moment. We attribute this result to the presence of physical adjustment costs in our model and the absence of such costs in their models. Only one moment, average equity issuance, has a simulated value that differs significantly from its corresponding average value in the data. A more refined model would include a fixed cost that discourages small equity issuances, which would increase the average issuance size. We have not pursued that refinement here, given that the point

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[4] The steady state capital stock is $k^{ss} = \left(\theta\left(1-\tau_c\right)/\left(r+\delta\right)\right)^{1/(1-\theta)}$. It equates the marginal product of capital with the user cost: $r+\delta$. In our model k^{ss} is always close to the average simulated capital stock.

estimate of the absolute gap in average equity issuance size is not that large (about 1.8% of assets, per table 1), and the frequency of equity issues is empirically plausible (see section 4). Since our main concern is with leverage dynamics, it seems reasonable to leave such model refinements for future work that is focused on explaining SEOs and other equity issuance decisions.

The point estimates of the profit function curvature (θ) and of the serial correlation of profit shocks (ρ) in panel B of table 1 are qualitatively similar to those in Hennessy and Whited (2005, 2007). The estimates of the external equity cost parameters, λ_1 and λ_2, and the standard deviation of shocks (σ_v) are, however, much higher than the estimates from their models. The reason makes intuitive sense. Our upper limit on debt does not have as much of a dampening effect on leverage as does the modeling of financial distress in Hennessy and Whited's papers. Therefore, in order for simulated average leverage to be as low as actual average leverage, other parameters in our model need to adjust to hold simulated leverage down. As explained in detail below, both high external equity costs and high shock volatility work to lower optimal average leverage. Our estimates of the physical adjustment cost parameters, a and γ, are also comparable to those in previous studies. For example, they display a different, but understandable, pattern from the estimates in Cooper and Haltiwanger (2006). The estimate of our fixed cost parameter is smaller, while the estimate of our smooth cost parameter is higher. This result makes sense because we estimate these parameters with firm-level data, which is substantially smoother than the plant-level data that they use. 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. Finally, the estimate of $\bar{p}/k^{ss}$ is quite high at 0.71. This level is much higher than the model simulated average leverage, which is approximately 0.24. This large discrepancy indicates that our model predicts that firms set leverage conservatively relative to their debt capacities. This result is remarkable and instructive, given that the only force in the model keeping leverage down is the need to preserve debt capacity for future use.

3. Comparative statics: Illustrations and preliminary results

To clarify the general approach we use to obtain our comparative statics predictions and the intuition that underlies them, this section provides a highly simplified example to illustrate firms' incentives to issue and retire transitory debt (section 3.1), and presents our predictions regarding the impact of financing frictions on the average amount of debt employed by firms (section 3.2).

3.1 Predicted capital structure paths: A simple example

Consider a firm that faces baseline model parameter values (per section 2) and, for simplicity of illustration, assume temporarily that there is no corporate tax benefit to borrowing. Assume that the firm currently has no debt outstanding so that, given the absence of a tax incentive to borrow, it is at its target capital structure. Assume also that an economically material investment shock arrives with an associated large funding need that the firm cannot fully meet from internal sources, i.e., from 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.) Finally, assume for the moment that managers issue debt 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 purely transitory.

Intuitively, the ability to issue debt is valuable because borrowing is a low (zero in our model) transactions cost means of raising cash, and so a firm that borrows to meet today's funding need will subsequently seek to pay off debt to be able to borrow again if and when the need arises.

Figure 1 illustrates the important distinction between target leverage and average leverage in our model. The figure reports the histogram of leverage ratios from a simulation of a model parameterized according to section 2's SMM estimation results, but in which we remove the tax incentive to borrow, while preserving the same quantitative disincentive to accumulate cash balances.[5] In approximately 47% of sample observations, firms are at their long-run capital structure targets with no debt outstanding, while in the remaining 53% of the observations, firms have various amounts of transitory debt outstanding. Thus average debt outstanding is significantly positive even though all firms' target capital structures have zero debt. Although not evident from the frequency counts in Figure 1, the leverage of any given firm exhibits significant time-series volatility. To illustrate,

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[5] Specifically, firms continue to incur the same total cost of holding cash as in the section 2 model, which equals the sum of the marginal agency cost, s, and the tax penalty for holding cash, $\tau_c r$. We adopt this approach in this example because 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 cash. We employ the same approach to generate the example in Figure 2. We use this approach only in simplified examples to illustrate the intuition of the model, and not in our comparative statics analysis.

Figure 2 plots a realized leverage path for a firm that has no tax motive to borrow that experiences a sequence of investment shocks. 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. As a result, stability of cross-sectional average leverage (e.g., as in Lemmon, Roberts, and Zender (2008)) is by no means indicative of time-series stability of leverage for a given firm.

Our model recognizes that firms' financing decisions are considerably more complicated than in these simple examples. 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. Our model simulations indicate that firms generally do not follow pecking order behavior in selecting their financing decisions.[6] Specifically, if managers of a firm with unused debt capacity assess a sufficiently high probability that future funding needs would force them to incur higher equity issuance costs in a present value sense (because borrowing today leaves the firm with inadequate debt capacity), they forego borrowing and instead issue costly equity to meet an immediate funding need. In general, the rational financing response to any given investment shock depends not only on the volatility and serial correlation of those shocks, but also on firm profitability and the nature of the cost of adjusting the capital stock.

3.2 The capital structure impact of variation in financing frictions

We start with the baseline parameter values (from section 2's tax-inclusive SMM estimation) and analyze the model for a significant range of parameter values around each baseline value. For each set of parameter values, we run the model for 100,200 periods, with each firm receiving random investment shocks and responding to each by adjusting investment and financing decisions optimally. We discard the initial 200 periods of data and, from the remaining 100,000 observations, we record economically relevant, empirically quantifiable measures of a firm's capital structure

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[6] Myers' (1984, p. 590) notes that, once one moves beyond the single investment outlay decision modeled by Myers and Majluf (1984), firms may issue equity even when debt capacity is not exhausted. Viswanath (1993) and Chang and Dasgupta (2003) extend Myers and Majluf to include a second investment decision, and formally establish this result. Lemmon and Zender (2007) also note that firms may save debt capacity for future use in dynamic versions of Myers and Majluf. Our analysis moves beyond these studies by establishing two fundamental results. First, firms have leverage targets that incorporate an amount of unused debt capacity that reflects the optimal future (state-contingent) utilization of the option to borrow. Second, because unused debt capacity is a valuable asset, firms have the incentive to follow decisions to borrow and deviate from target by subsequently rebalancing toward target.

decisions, e.g., its average debt-to-assets ratio. We interpret the resultant large sample statistics as expected values implied by the specific model parameterization. We repeat the exercise for different parameter combinations. We generate testable predictions based on the change in the expected value of a given capital structure variable associated with the change in a specific parameter.

Table 2 reports expected leverage (panel A) and the standard deviation of leverage (panel B) as a function of the costs of issuing equity and of maintaining cash balances, with leverage measured as the debt-to-assets ratio (d/k). Each panel contains a 5x5 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 model specified with relatively high costs of accessing external equity coupled with relatively low costs of maintaining cash balances, while the south-west corner reports the expected value of d/k when equity access costs are low and the costs of maintaining cash balances are high.

Table 2 yields three main findings. First, average leverage is well above zero (never less than 19.3% of assets) under all cost specifications, as one would expect since firms in our model capture tax benefits from debt. Second, variation in the costs of maintaining cash balances has only a modest influence on the cross-firm variation in average leverage and in the volatility of leverage (scan each column in panels A and B). The intuitive explanation is that corporate taxes themselves provide strong incentives to maintain positive net debt, and so 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, average leverage is around 20% to 30% of assets for all cost specifications except when firms face low costs of accessing external equity, in which case the expected amount of debt is much higher at around 80% of total assets (panel A), and leverage volatility is around 50% (panel B).

The third finding indicates that a firm's ability to support high average amounts of debt increases when it has low cost access to equity capital to meet its *marginal* financing needs. Since the corporate tax subverts a firm's incentive to hold cash balances, "levering up" is all-the-more costly because it utilizes debt capacity that could have been preserved as a substitute source of capital. The opportunity cost of utilizing debt capacity loses much of its deterrent value to "levering up" today when it is cheap to tap equity markets. Hence, when firms have the safety-valve alternative of issuing equity at low cost, they have incentives to "lever up" and capture interest tax shields, even though doing so sacrifices their ability to tap the debt market in the future.[7]

4. Comparative statics: Leverage and investment opportunities

This section presents comparative statics results that predict how firms' leverage decisions vary with the nature of their investment opportunities. Section 4.1 examines the impact of variation in investment shock volatility on average leverage, leverage volatility, and a broad variety of other dimensions of capital structure. Section 4.2 analyzes how these leverage predictions differ for firms whose investment opportunities are characterized in turn by (i) high as opposed to low shock serial correlation, (ii) high rather than low marginal profitability, and (iii) lumpy versus smooth investment outlays attributable to differences in the fixed and convex costs of capital stock adjustment. Section 4.3 delineates the model's predictions regarding variation in target leverage as a function of differences in the nature of firms' investment opportunities.

4.1 The capital structure impact of variation in investment shock volatility

Table 3 summarizes the predicted capital structure impact of variation in the volatility of investment shocks. The rows of the table list capital structure attributes and the columns detail the predicted impact of various investment shock volatilities centered around the baseline values (per section 2), with standard deviations ranging from 15% to 50%. 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 a bit lower (row 3) for such firms. 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 facing low shock volatility have a debt-to-assets ratio of 0.722 on average, whereas firms facing high shock volatility have average leverage of only 0.091 (row 4). The former firms always carry some debt, whereas the latter have no debt outstanding almost 40% of

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[7] This point is conceptually distinct from the idea discussed by Myers (1984), Viswanath (1993), and others that firms (i) will time equity issuances for specific periods in which information asymmetries imply that equity issuance costs are *temporarily* low, and (ii) will obtain capital from debt issuances and cash balances in other periods in which equity issuance costs are high. Our point is that, in the presence of corporate taxes, firms will keep more debt outstanding on average when equity issuance costs are *consistently* low.

the time (row 10), reflecting their strong incentives to preserve debt capacity and to accumulate greater cash balances (row 8) to meet the potentially substantial funding needs that can arise with future investment shocks. The latter needs translate to higher volatility of investment (row 2) and somewhat higher average investment (row 1) for high as opposed to low shock volatility firms.

Table 3's most notable result is that, even in the face of corporate tax incentives to borrow, low leverage is the predicted norm for firms that face high investment shock volatility. Intuitively, high volatility implies a greater probability that large investment outlays will be optimal, and so the firm preserves debt capacity to address the commensurately large need for external finance.

Variation in firms' investment opportunities—and in particular their potential future funding needs—may therefore help resolve the "debt conservatism" puzzle that Graham (2000) poses, i.e., 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 trade-off models to predict unrealistically high leverage ratios, and in effect raising the question: what factors are missing from these trade-off 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 because it preserves the option to borrow to fund investment.

Table 3 further indicates that low shock volatility firms have higher leverage volatility than high shock volatility firms (row 5), which reflects the latter's tendency to hold large cash balances (rows 8, 12, and 6) as well as their higher volatility of cash balances and net debt (rows 9 and 7). Low shock volatility firms eschew large cash holdings (row 8) in part because these holdings trigger taxes, but also because, given the relatively high predictability of their funding needs (row 2), they can forego preserving large amounts of debt capacity to address such needs—hence low shock volatility firms find it attractive to have consistently high leverage and negligible cash balances.

For all shock volatility levels in table 3, current cash flow is by far the most important source of funding for investment (row 19). For high shock volatility firms, debt issuance and cash balances are of roughly equal importance in funding investment (row 20 and 21), with equity financing used to raise much smaller amounts (row 18). For low shock volatility firms, debt issuance is the second most important source of cash to fund investment (row 21), far outstripping equity sales and cash balance draw-downs (rows 22 and 20). For all levels of shock volatility, debt issuances occur more frequently than equity issuances (rows 13 and 17) and in larger amounts (rows 15 and 18). Debt reductions occur roughly as often as debt issuances (rows 13 and 14), reflecting firms' incentives to pay down debt today to free up debt capacity for future use, despite the loss of tax benefits.

Although in our model firms have positive debt and cash balances on average, they do not carry both 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 is easy to incorporate in our analytics and that does not change our transitory debt predictions. Gamba and Triantis (2008) note that, by accumulating cash while debt is outstanding, firms can reduce future debt issuance costs. We exclude direct costs of debt issuance from the model posited in section 2 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 by itself an impediment to borrowing. Section 7 shows that our qualitative conclusions remain unchanged when we add debt flotation costs to the model and allow firms to carry debt and cash balances simultaneously. In this case, firms are less aggressive in both borrowing and paying down debt, but they still treat debt capacity as a scarce resource and use debt as a transitory financing vehicle.

4.2 Serial correlation, profitability, and capital stock adjustment costs

Table 4 summarizes the capital structure impact of varying the serial correlation of investment shocks, the marginal profitability of investment, and the degree of smoothness in investment outlays. (Smooth investment is generated by no fixed costs of adjusting the capital stock coupled with high convex costs, while lumpy investment is induced by high fixed costs coupled with no variable adjustment costs.) For brevity, table 4 reports predicted capital structure values for "high" and "low" values of the first two parameters and contrasts smooth versus lumpy investment for the latter, with all other parameters held constant. The table indicates that firms that have high shock serial correlation, high marginal profitability, or lumpy optimal investment programs have relatively low average leverage ratios compared to those with the opposite attributes (row 4). Firms with the former investment characteristics typically forego large tax benefits of debt to preserve debt capacity that can be tapped to fund their more volatile prospective investment outlays (row 2).

The motives for a more conservative capital structure differ depending on the investment attribute. The higher the serial correlation of investment shocks, the more likely a current large shock will soon be followed by another, with an additional material need for funds. High serial correlation also implies that optimal investment outlays tend to be large because the profitability of these investments is expected to persist. Similarly, the higher a firm's marginal profitability of investment (i.e., the θ parameter), the larger is its optimal investment outlay in response to a given shock, and the possibility of a large funding need induces the firm to maintain conservative leverage on average. Finally, holding constant the fixed component of the cost of adjusting the capital stock, the greater the convex component of those costs, the less responsive is investment to new shock arrival, and the less variable is the resultant time profile of investment (Cooper and Haltiwanger, 2006). Accordingly, greater convexity in the costs of capital stock adjustment translates to greater predictability in funding needs, hence to less value from preserving debt capacity.

The same intuition explains the higher average cash balances and lower net debt of firms with high shock serial correlation, high marginal profitability, and lumpy investment outlays (rows 8 and 6). The volatility of cash balances and net debt are also markedly higher for these firms as opposed to those with the opposite investment attributes (rows 9 and 7). Such firms also exhibit higher volatility of cash balances than of leverage (compare the values in rows 9 and 5), which reflects their large build-up of cash balances in anticipation of future funding needs followed by large subsequent cash draw downs—coupled with incremental borrowing—when those needs do manifest.

In all cases in table 4, cash flow realizations are the main source of funds for new investment (compare row 19 with rows 20 to 22). The draw down of cash balances plays no funding role for firms with low shock serial correlation, low marginal profitability, or smooth investment outlays (row 20). The reason is that the corporate income tax coupled with predictable funding needs together induce such firms to maintain high debt loads and zero cash balances in order both to capture tax benefits and to avoid tax penalties on cash holdings. For firms with the opposite investment attributes, cash balances and debt issuances fund a substantial fraction of investment (rows 20 and

21), but cash flow is a markedly more important marginal funding source than both other sources. In all cases, equity issuance typically covers only a small fraction of investment outlays (row 22). The latter property conforms to real-world financing patterns and thereby provides something of an "out of sample" check on the model, given that our SMM estimation procedure does not match on any of these "source of funds" moments.

4.3 Target capital structures

In our model, firms' capital structures exhibit path dependence locally, but they are also globally self-correcting in the sense that, when managers find it optimal to borrow and deviate (or deviate further) from target leverage, they subsequently have incentives to return the firm to target by paying down debt as circumstances permit. Those incentives are traceable to 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, 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. In the absence of taxes, the model yields an analytically simple characterization of target capital structure—zero debt is the universal target for all firms—and 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 positive number yields a zero leverage ratio). With taxes, 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, and different firms have different leverage targets, which depend on the characteristics of their investment opportunities.

The capital structure target in our (tax-inclusive) model is either a fixed ratio of debt to total assets or a range[8] of such ratios, depending on the precise structure of the costs that a firm faces from 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,

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[8] 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 trade-off 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.

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 capital stock, but firms face variable costs of adjusting capital that are convex in the rate of investment (I/k). 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 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 investment constant at a rate that just allows for replacement of depreciated capital. The capital stock therefore remains constant at a level k^* (generally different from case #1). 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 of doing so. 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 3 plots target ratios of debt to total assets as a function of investment shock volatility and serial correlation for firms that respectively face (i) zero 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 3 reporting the upper bound of the target range and for simplicity omitting the lower bound, which is 0.0 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 that large investment outlays are optimal, which in turn provides incentives for firms to adopt capital structures with more conservative leverage, hence greater ability to borrow. Target leverage is also 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 the figure).

Figure 4 illustrates the existence of a leverage target and the convergence to target for a firm that faces convex capital stock adjustment costs but no fixed adjustment costs ($\alpha = 0.15$, $\gamma = 0.00$). Over dates $t = 0$ through $t = 52$, the firm's debt level fluctuates in response to the arrival of investment shocks and to its decision to pay down debt in periods in which cash flow realizations exceed contemporaneous funding needs. In some cases, the firm reduces debt below target because shock realizations—coupled with serial correlation of investment shocks—indicate that that large future investment outlays are likely to be optimal, and so the firm temporarily builds debt capacity in anticipation. At $t = 52$, 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 $t = 55$, it thereby attains its long-run leverage target where it remains as neutral shocks continue to arrive.

(Note that the target is not the leverage ratio at which the firm begins receiving neutral shocks, but rather is the leverage to which the firm moves in the limit if it were to experience repeated neutral shocks.) 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 leverage target. Rather, after $t = 52$, 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^*.

5. Speed of adjustment to target capital structure

Extant tradeoff models predict that, whenever leverage differs from target because of factors beyond managers' control, firms rebalance toward target as quickly as is economical, given the costs of security issuance. This prediction is the focus of much empirical analysis, with Fama and French (2002) casting doubt on the explanatory power of tradeoff models because the estimated speed of adjustment (SOA) to target is "suspiciously slow," and Welch (2004) finding little evidence of leverage rebalancing. Subsequent studies estimate that firms move on average between one-third and one-twelfth of the way toward target leverage in any given year (see, e.g., Flannery and Rangan (2006), Kayhan and Titman (2007), Lemmon, Roberts, and Zender (2008), and the other SOA papers surveyed by Parsons and Titman (2008)). Iliev and Welch (2009, p. 32-33) argue that these slow adjustment speeds cannot be explained by security issuance costs alone, since firms' pro-active issuance and repurchase decisions account for most leverage variation, with year-to-year leverage changes disproportionately reflecting debt refinancing activities, as found in Welch (2004).

Our estimated model parameters imply slow average speeds of adjustment to target leverage in the same neighborhood as the average SOA estimates reported in prior empirical studies. The slow SOA in our model reflect an ongoing shock-dependent sequence of both (i) debt issuances that raise funds needed for investment, but that also move firms temporarily away from target, and (ii) debt repayments in which firms rebalance toward target when investment needs slacken, in order to free up debt capacity for future borrowing. Extant tradeoff models treat investment as exogenous, and so they rule out the transitory deviations from target to fund investment which, in our model, slow the average SOA as it is measured in prior empirical studies. As a result, the SOA measures employed in prior studies understate the strength of the actual leverage rebalancing incentives firms face in our model because they inappropriately include leverage changes in which firms deliberately deviate from target to fund new investment. When we exclude the latter changes from our SOA measures, firms in our model move aggressively toward target leverage.

5.1 Speed of adjustment to target and investment policy

Table 5 presents our main SOA results, which are generated using the approach employed in prior sections to obtain our comparative statics results, with model parameters set at the estimated baseline values (per section 2). In rows 1 through 3, we report three different measures of the average rate at which firms move toward target leverage, with each model-generated SOA reported both (i) unconditional on current leverage and (ii) conditioned on whether current leverage is above/at or below target. The remaining rows (4 to 33) of table 5 document model-generated leverage changes and attributes of the related financing decisions that underlie our measured speeds of adjustment to target. Because investment plays an important role in the rate at which firms deviate from and rebalance to target, each variable in rows 4 to 33 is reported unconditional on investment, as well as conditional on low, moderate, and high levels of investment. While other attributes of firms' production technologies—notably, the serial correlation of investment shocks—also affect the expected SOA to target, we defer their discussion until later in this section.

In table 5, rows 1 and 2 report model-generated average SOA measures that are calculated, as done in prior empirical studies, to include both (i) rebalancing decisions, and (ii) financing decisions that deliberately move firms away from target, while row 3 reports the average SOA measured as our model indicates it should be, i.e., by (i) alone.[9] Since the model is estimated using yearly data, each SOA in table 5 represents an annual rate of movement toward target. Row 1's average SOA is 0.142, which indicates that in a randomly selected model year firms move about one-seventh of the way toward target on average—a figure that is close to the annual estimates in recent SOA studies. Row 2's average regression-based SOA is 0.378, which implies a movement of a little over

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[9] "Average SOA" in row 1 is the mean of (1) the change in leverage divided by (2) the distance from current leverage to target leverage. As discussed below, firms sometimes overshoot the leverage target, and inclusion of such overshooting biases upward the measured average rate at which firms adjust leverage toward target. We accordingly cap the ratio at 1.000 for any observation in which the leverage change exceeds the distance from target. "Average SOA toward target" in row 3 is calculated in the same fashion, but excludes observations that do not move leverage toward target. "Regression-based SOA" in row 2 is the SOA implied by a regression that uses model-generated leverage ratios and follows the general approach of extant SOA tests—i.e., current leverage is the left-hand side variable, while the explanatory variables are lagged leverage, firm value/assets, and cash flow/assets. The latter variables are included as proxies for the determinants of target leverage of the type posited in empirical SOA studies.

one-third of the way toward target in each randomly selected year—a figure that is again close to prior empirical estimates. In sharp contrast, row 3's average SOA, which excludes firms' pro-active decisions to deviate from target, is 0.605. This result indicates that firms whose current circumstances favor rebalancing do so aggressively, moving on average about 60% of the distance toward target in each period. Row 3 shows aggressive rebalancing to target, both for firms whose current leverage is above/at and below target leverage. All three SOA measures indicate that, when leverage exceeds target, firms typically move less aggressively in the direction of target, as is logical when equity issuance costs exceed debt issuance costs.

As expected when firms have target leverage ratios, firms are more likely to decrease leverage when it is currently above target (rows 8 and 9 of Table 5) and more likely to increase leverage when it is below target (rows 22 and 23), with the average leverage change negative in the former case and positive in the latter (-0.015 and 0.036 respectively, per rows 4 and 19). While these average changes are modest in absolute value, both include substantial increases and decreases (rows 5, 6, 20, and 21)—an indication that leverage changes often move firms significantly away from target. More precisely, the probability of a leverage increase is 0.372 when leverage is above target (row 7), while the probability of a leverage decrease is 0.347 when leverage is below target (row 23). Firms often take material (temporary) excursions away from target, and that is why conventional SOA measures indicate slow speeds of adjustment for model-generated leverage ratios. In short, conventional SOA measures obscure the consequences of our model's implication that firms aggressively rebalance leverage toward target in some but not all states of the world.

With endogenous investment, the specific attributes of a firm's investment opportunities dictate whether rebalancing toward or deviating further from target leverage is currently optimal. In our model firms find it costly to maintain a permanent large cash reserve. And, since firms are operating on a "tight leash" with respect to cash balances, external financing becomes necessary more often to meet the marginal funding needs associated with investment shocks. Moreover, because equity issuance is more costly than debt issuance, debt is an attractive source of marginal financing, with pro-active debt issuance decisions (to fund current investment) and repayment decisions (to replenish future borrowing capacity) reflecting the sequence of optimal investment outlays. Furthermore, because investment shocks are serially correlated, firms will sometimes respond to a specific favor-able shock by moving/remaining temporarily below target in order to obtain/preserve additional borrowing capacity (and perhaps to build cash balances) so as to be in a better position to fund the higher future investment outlays that are more likely given the recent shock realizations.

To clarify the link between investment outlays and movements relative to target, we first consider firms whose current leverage is above/at target. When such firms face high investment outlays, the probability of a debt issuance is 0.940 (row 10 of table 5), and the average issuance is 11.3% of total capital (row 13). When investment needs are low, the debt issuance probability falls to 0.124 (row 10), and new borrowing averages only 4.6% of capital (row 13). The situation is reversed for debt repayments, as firms with low investment outlays repay debt with a 0.875 probability, which far exceeds the 0.059 repayment probability in high investment states of the world (row 11). Moreover, in low investment states, the average debt reduction is four times that associated with high investment (9.9% versus 2.5% of capital, per row 14). Finally, while the average equity issuance is always small (1.8% of capital or less, per row 15), its likelihood nonetheless depends on investment—at 0.416 with high investment versus 0.083 with low investment (row 12). In sum, with high investment, firms that are currently above target leverage often issue substantial debt (and sometimes issue small amounts of equity), thereby deviating further from target, whereas with low investment, these firms typically pay down debt and thus replenish future borrowing capacity.

The attributes of firms' investment decisions also govern the leverage rebalancing decisions of firms whose current leverage is below target. With high investment, these firms' debt issuance probability is 0.930 (row 25), with an average issuance of 20.3% of capital (row 28). Such debt issuances represent aggressive movements toward target and, because the typical need for cash to fund investment is great, the (conditional) probability is 0.449 that the new leverage ratio overshoots the long-run leverage target (row 24). When investment is low, the debt issuance probability is far smaller (0.161, per row 25), as is the size of the average issuance (4.7% of capital, per row 28). However, the probability of overshooting target is nontrivial in all cases (row 24), indicating that when firms move toward target, they do so aggressively, motivated more by the need to fund investment than by the desirability of quickly returning to target leverage. Finally, when investment is low and leverage is below target, firms repay debt with probability 0.717 (row 26), a result that seems counter-intuitive because firms are reducing their debt when leverage is below target.

In general, why do firms sometimes choose to remain or move below target leverage when they could lever up at zero transactions costs by borrowing and immediately distributing the proceeds to stockholders? The answer is that investment shocks are serially correlated in our model, which implies that firms sometimes rationally build additional (temporary) debt capacity by moving below target when a given shock implies an increased likelihood of future shocks that will require additional resources to fund investment. While the influence of each such investment shock erodes over time, serially correlated shocks nonetheless encourage firms to remain below target for multiple periods, even when they could easily lever up. The same logic explains why firms with current leverage above target sometimes overshoot the target when reducing leverage (row 9). It also explains why we analytically define the long-run leverage target in terms of a limiting sequence of capital structures—since the influence on leverage of any given shock approaches zero over time, the firm's leverage converges to the long-run target in the limit as neutral shocks continue to arrive and any lingering influence of prior non-neutral shocks fades over time.

5.2 Predicted time away from target versus local SOA measures

The SOA estimates reported in most empirical studies—and the model-generated results in table 5—are both based on local SOA measures in the sense that both gauge the average per period rate at which firms move toward target. These local measures are potentially problematic when leverage changes are not intertemporally independent, which is the case in our model because serially correlated investment shocks govern the time path of leverage. The concern is that, with serially correlated shocks, extrapolation to a multiple-period leverage path from an average per period rate of adjustment may provide a distorted picture of the frequency with which firms' leverage ratios are expected to deviate from target over an extended time horizon.

We address concerns about such possible distortions by defining a "spell above target" as the number of consecutive model periods that a firm's leverage remains above target, and a "spell below target" as the number of consecutive periods it remains below. The average spell above target is 7.383 periods, while the average spell below target is 3.598 periods. Since the model is estimated using yearly data, these findings indicate that the average firm that has just moved above (below) target takes more than 7 years (3.5 years) to return to target. The cumulative frequency distributions in Figure 5 indicate that roughly 25% of the spells above target last at least 10 years, while about 16% of the spells below target last five or more years. Clearly, lengthy excursions away from target are far from atypical, and in fact are the norm when a firm's leverage exceeds its target. In sum, the sluggish rebalancing to target documented in prior studies is fully consistent with the leverage dynamics generated by our model.

6. Transitory debt and long-horizon leverage paths

This section analyzes model-generated leverage over long horizons using an approach that follows Lemmon, Roberts, and Zender (2008, LRZ). We find that transitory debt is a large percent—between 31.3% and 63.3%, depending on the characteristics of investment opportunities—of total debt expected to be outstanding at a randomly selected point in time. Hence transitory debt is not only a first-order determinant of leverage dynamics (per earlier sections), but it is also predicted to be a large fraction of the leverage ratios that empirical studies seek to explain. We also find that, although cross-sectional average leverage ratios (for groups of firms formed as in LRZ) converge to stable values in the long run, they do not converge to target leverage, as would occur under traditional static trade-off models. Rather, the average debt level approaches the sum of transitory debt expected to be outstanding plus the average long-run target debt level. The important carry-away is that future empirical work should control for transitory debt rather than focus solely on total debt when gauging the extent to which firms have stable capital structure targets.

6.1 With transitory debt, average leverage does not equal target leverage

LRZ's main findings appear in their 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 in the first year into four subsamples—very high, high, medium, and low values of leverage. Our Figure 6A plots the long-horizon average leverage paths generated by our model, and these paths are clearly similar to those in LRZ. The average leverage ratios of the four groups in Figure 6A start with a spread of 32.2% (versus 51.8% in LRZ) and converge to stable values that differ by 21.2% (versus 16.1% in LRZ). Convergence occurs more rapidly in our model and our average debt levels are lower than LRZ's by about 7%, but the latter difference is modest. In both cases, convergence to stable leverage occurs, and the convergence is incomplete, i.e., a gap in average leverage across groups remains after 20 years.

Figure 6A's leverage paths are generated for a sample of 1,000 model firms with baseline parameter values established by section 2's estimation. This sample is composed of 10 subsamples of 100 technologically identical firms, and the 10 subsamples differ only in the volatility of investment shocks (standard deviations from 15% to 50%). As shown in section 4, differences in shock volatility imply variation in the expected amount of transitory debt, and in target capital structures. We mimic LRZ's sampling procedure by allowing firm-specific shocks to arrive and capital structures to evolve in response to those shocks for 200 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 four groups, as in 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 shocks, 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. We allow new shocks to arrive and capital structures to continue to evolve for 20 periods, and we plot the resultant time series of average leverage ratios in Figure 6A.

The capital structures in Figure 6A include permanent and transitory debt components. The permanent debt level, i.e., the long-run target for each firm, is positive because maintaining some debt outstanding generates ongoing interest tax shields. The transitory debt level is borrowing undertaken to address the funding needs associated with current and past investment shocks, and which each firm hopes to pay off as circumstances permit. In the long run, leverage for a given firm—and average leverage for samples of firms, as in Figure 6A—does not converge to target. As long as investment shocks continue to arrive—as they do in perpetuity in our model and in real-world samples—firms continue to incur transitory debt. Thus, if we observe firms at any randomly selected date, the expected level of outstanding debt equals the sum of the target debt level plus the amount of transitory debt expected to be outstanding.

The leverage stability in Figure 6A reflects the fact that we examine large sample cross-sectional averages in which the effects of time-series volatility in individual firms' leverage ratios wash out. 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 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. Therefore, the average debt level for a given group in Figure 6A approaches the sum of the amount of transitory debt expected to be outstanding plus the average target debt level for firms in that group.

The cross-group differences in the initial average value of leverage in Figure 6A reflect the fact that groups are formed by ranking firms on the basis of actual leverage ratios at an arbitrarily selected point in time. Since actual leverage includes transitory debt, 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. 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 Figure 6A, but not the 21.2% gap between the very high and low leverage groups that remains after 20 periods. The incomplete convergence reflects two factors. First, the 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. Second, firms facing different shock volatilities have different incentives to employ debt permanently, i.e., their leverage targets differ.

6.2 Transitory debt as a fraction of total debt

Figure 6B plots the net-of-target average leverage ratios—i.e., the typical amount of transitory debt outstanding—for each of the four groups. At the final date, transitory debt (shown in Figure 6B) as a percent of total debt (shown in Figure 6A) is 63.3%, 58.9%, 46.5%, and 31.3% for the low, medium, high and very high leverage groups respectively. Transitory debt thus directly constitutes a large fraction of total leverage and, in fact, all remaining variation in Figure 6A 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.

An empirically important corollary of Figures 6A and 6B 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.

Because firms face no transactions costs of issuing debt, the opportunity cost of issuing debt is the impediment to "levering up" in our model. This opportunity cost induces the slow mean reversion in leverage exhibited by the low leverage group in Figure 6A, and more generally is responsible for the time paths of average leverage for all groups in the figure. Average leverage ratios change very little when we re-run the analysis underlying Figure 6A by adding a debt issuance cost equal to 4% of the amount of new borrowing as a rough, and deliberately upward-biased, estimate of the transactions costs of issuing debt. For example, in every year, average leverage for the low group remains within 1.1% of the average leverage for that group in Figure 6A, while the average leverage for the very high group remains within 2.9% of its corresponding number in Figure 6A. In short, our analysis of long-horizon leverage paths is robust to the inclusion of debt issuance costs. More generally, debt issuance costs are of second-order import relative to the opportunity cost of using debt capacity, which leads firms to use debt as a transitory financing vehicle in our model.

7. Model robustness

The model is intentionally sparse to highlight the intuition surrounding the preservation of debt capacity. To assuage concerns that our results are artifacts of the model's simplicity, in this section we add several more realistic features to the model to examine whether leverage responds to our model parameters in a qualitatively similar way. We examine four extensions to the model, one at a time. First, we add debt issuance costs of 4%. Second, we add an extra state variable that allows the firm to hold cash and debt at the same time. This model contains a small issuance costs of 10 basis points to ensure that optimal behavior entails the simultaneous holding of cash and debt. Third, following exactly Hennessy and Whited (2005), we add a collateral constraint on debt financing and financial distress in the form of a fire sale discount of 40% on capital that must be sold when profits are insufficient to pay off debt. Fourth, we allow for endogenous default and deadweight costs of default. This model is described in Appendix B. For each of these four cases we examine how leverage responds to changes in the linear cost of issuing equity, λ_1, the serial correlation of productivity shocks, ρ, the standard deviation of productivity shocks, σ_v, and the curvature of the production function, θ. We also perform an additional experiment in which we simultaneously increase the fixed cost of adjusting the capital stock, γ, and decrease the convex cost of adjusting the capital stock, a.

The results from these comparative statics exercises appear in Figure 7. In the first panel we plot the relation between average leverage and linear equity issuance costs, λ_1, for the baseline model estimates from Table 1, as well as for the four model variants described above. We allow λ_1 to vary from near 0.0 to 0.3, which is approximately double its baseline estimate of 0.1615. For all four model variants we find the same negative relation between equity issuance costs and leverage that we find in the baseline model. Although the patterns from the model with separate cash holding and with debt issuance costs are almost identical to the pattern from the baseline model, the negative relation between equity issuance costs and leverage is attenuated in the two models that incorporate financial distress. The reason is simple: both equity issuance costs and financial distress work in this model to depress leverage. Therefore, the introduction of distress costs into the model diminishes the role for equity issuance costs.

This same general pattern appears in the second and third panels of Figure 7, which depict the relations between leverage and the serial correlation of productivity shocks, ρ, and the standard deviation of productivity shocks, σ_v. We allow ρ to vary from 0.1 to 0.9 and σ_v to vary from 0.15 to 0.5. In all five models leverage decreases with both ρ and σ_v, and the models with a collateral constraint and endogenous default generate slightly weaker relations. The fourth panel shows the relation between leverage and profit function curvature, θ, in which we let θ range from 0.5 to 0.9. In this case leverage falls sharply with profitability in all five models. Finally, the fifth panel shows the relation between leverage and the nature of physical adjustment costs. To generate this plot we allow the fixed cost of adjustment to vary from 0.0 to 0.04, while the convex cost varies from 0.3 to 0.0. Once again, leverage falls in all five models as adjustment costs become more fixed in nature and investment therefore optimally becomes more lumpy.

In sum, our original simple model with a fixed ceiling on corporate debt generates qualitatively the same comparative statics as do more complicated models. The advantage of the simple model is its ability to highlight the role of preserving debt capacity in a dynamic setting. In contrast, the additional features, such as financial distress, in these more complicated models sometimes muddy but never erase the trade-off between utilizing debt capacity today and preserving it for future usage. We therefore view the results from our original simple model as broadly representative of the results from a much broader class of dynamic models.

8. Summary and conclusions

We develop and estimate a dynamic capital structure model 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 nonetheless face an economically meaningful opportunity cost of borrowing, since a firm's decision to issue debt in a given period reduces the debt capacity available to meet its future funding needs or, more generally, reduces the firm's future ability to borrow at the terms it currently faces. The firm's ex ante optimum debt level reflects the value of the option to use its debt capacity to borrow ex post and deliberately, but temporarily, move away from target to fund investment. The opportunity cost of borrowing—and the resultant transitory role of debt in capital structures—radically alters the nature of predicted leverage dynamics from those of other trade-off models in which firms have leverage targets, but all pro-active financing decisions move firms toward target.

Sufi (2005) finds 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. While transitory debt is clearly not limited to utilized lines of credit, Sufi's evidence leaves little doubt that transitory debt is a significant fraction of most firms' outstanding debt, and that firms routinely arrange their capital structures to provide unused debt capacity that they can tap to meet future funding needs.

Our emphasis is squarely on the role of transitory debt, a concept that plays no role in extant target leverage models because those models ignore the interplay among firms' long-run target capital structures, the evolution of leverage, and the desire to raise capital to meet the intertemporal sequence of funding needs that arise from investment shocks. Since firms in our model issue transitory debt to finance investment outlays, the time path of their deviations from and rebalancing to target is shaped both by the nature of prospective investment opportunities and by the precise sequence of shock realizations from their stochastic investment opportunity sets.

Our approach yields a variety of new testable predictions that link firms' leverage decisions to variation in the attributes of their investment opportunities, and offers plausible explanations for a number of puzzling aspects of observed capital structure decisions. First, the slow estimated speeds of adjustment reported in virtually all leverage rebalancing studies raise significant doubts about the empirical validity of extant target leverage models in which rebalancing is the sole motive underlying pro-active capital structure changes. Our analysis offers hope that the concept of target leverage has considerably more explanatory power than prior empirical studies suggest because it implies that conventional SOA measures are biased downward and therefore understate the strength of firms' incentives to rebalance leverage toward target. Our analysis also highlights the distinction between average and target leverage when firms issue transitory debt, and establishes that the long-horizon average leverage paths in Lemmon, Roberts, and Zender (2008) need not indicate convergence to a time-invariant leverage optimum, but rather will, in a world in which firms issue transitory debt, represent convergence to the sum of the target debt level plus the amount of transitory debt expected to be outstanding at a randomly selected point in time. The important implication—for studies of the SOA to target and of long-horizon leverage paths—is the need to control empirically for transitory debt issuances.

A promising area for future research is to incorporate uncertainty about the "unknown unknowns" of investment decision making rather than simply assuming, as we do here, that capital structure decisions are driven by (the parameters of and realizations from) known stochastic investment opportunity sets. For example, intuition suggests that conservative financial policies are more attractive in the face of uncertainty regarding both the nature of investment opportunities and the pricing and other contractual terms associated with access to capital—including, but not limited to, so-called Black Swan events such as the recent financial crisis. The robust decision-making approach advanced by Hansen and Sargent (2007) provides a potentially productive approach with which to generalize our analysis to incorporate the influence of unknown unknowns, both on the leverage targets that firms adopt and on the process through which their use of transitory debt evolves over time with changes in the investment environments that they face.

Appendix A

This appendix discusses the numerical 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

$$\left[\overline{k}\,(1-\delta)^{35},\ldots,\overline{k}\,(1-\delta)^{1/2},\overline{k}\right]. \tag{12}$$

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 $[-\overline{p}/2, \overline{p}]$, in which $\overline{p}$ is a parameter to be estimated. 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. For our estimated value of $\overline{p}$, equity value, V, is always strictly positive in all states of the world.

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.

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, $i = 1, \ldots, n$, and let $y_{ik}(b)$ be an *i.i.d.* simulated vector from simulation k, $i = 1, \ldots, n$, and $k = 1, \ldots, K$. 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 Michealides 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 depreciation rate, δ, the real interest rate, r, and the effective corporate tax rate, τ_c. We set δ 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 τ_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

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

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 inverse of the sample covariance matrix of the moments, which we calculate using the influence function approach in Erickson and Whited (2000).

The simulated moments estimator is asymptotically normal for fixed K. The asymptotic distribution of b is given by

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

in which

$$\text{avar}(\hat{b}) \equiv \left(1+\frac{1}{K}\right)\left[\frac{\partial g_n(b)}{\partial b}W\frac{\partial g_n(b)}{\partial b'}\right]^{-1}\left[\frac{\partial g_n(b)}{\partial b}\Omega\frac{\partial g_n(b)}{\partial b'}\right]\left[\frac{\partial g_n(b)}{\partial b}W\frac{\partial g_n(b)}{\partial b'}\right]^{-1} \tag{13}$$

in which W is the probability limit of $\hat{W}_n$ as $n \to \infty$, and in which Ω 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 12 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 are the first and seconds moment of the rate of investment, defined in the simulation as I/k, and defined in Compustat as the sum of items 128 and 129 divided by item 7.[10] Average investment helps identify the adjustment cost parameters, a and γ, because smooth investment tends to be less skewed than lumpy investment. Therefore, the mean is lower because it tends to lie nearer the median than the upper percentiles of the distribution of investment. The variance helps identify both the curvature of the profit function, θ, and the adjustment cost parameters. Lower θ, higher a, and lower γ produce less volatile investment. The next moment is the skewness of the rate of investment, which helps identify the fixed adjustment cost parameter, γ. Higher values of this parameter lead to more intermittent, and thus more skewed investment. The next moment, average operating income, is primarily affected by the curvature of the profit function. This relation can be seen by the definition of simulated operating income as zk^{θ}/k: the higher θ, the higher average operating income. Our next two moments capture the important features of the driving process for z. Here, we estimate

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[10] We define investment this way because our model allows for the optimality of lumpy investment. Therefore, we can allow for a much more general definition of investment than that in Hennessy and Whited (2005, 2007).

a first-order panel autoregression of operating income on lagged operating income, in which 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 moment is the mean of 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 mean of q.

The remaining moments pertain to the firm's financing decisions. The first two are the mean and second moment of the ratio of debt to assets. In our simulation debt is defined as d/k, and in Compustat this variable is defined as items 9 plus 34, 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 variance 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, λ_1 and λ_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 separately estimated regression coefficients and first through third moments, 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 moment 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 and our estimates of variance and skewness.

Appendix B

The model that includes endogenous default replaces the upper bound on leverage, $\bar{p}$, with the following mechanism, which is similar to that in Hennessy and Whited (2007) and Cooley and Quadrini (2001), except that physical adjustment costs prevent the firm from costlessly transforming capital into liquid assets. The presence of physical adjustment costs complicates slightly what happens to the firm when it defaults, that is, when equity value reaches zero. The endogenous default schedule is then defined implicitly by the equation $V\left(k,p,z\right)=0$. In the event of default, debtholders seize the firm's profits and almost all of its capital stock, less any applicable adjustment costs and less a fraction, ξ, of the capital stock that can be thought of as deadweight default costs. Because physical adjustment costs are a function of the rate of investment, they are not well defined for a firm with a zero capital stock. We therefore leave the firm with the smallest capital stock in the discrete grid described by (12), k, and require the firm to pay the amount $(1-\xi)\,(1-\delta)k$ in cash to the debtholders.

The debtholders' recovery in default (R) is equal to

$$R(k',z') = (1-\xi)\,(1-\delta)\left(k'-k\right) + (1-\tau_c)\left(z'\pi(k')-\delta k'\right) - A\left(k',k\right) + (1-\xi)\,(1-\delta)\,k \tag{14}$$

$$= (1-\xi)\,(1-\delta)\,k' + (1-\tau_c)\left(z'\pi(k')-\delta k'\right) - A\left(k',k\right) \tag{15}$$

As an approximation to the U.S. tax code, this formulation of the debtholders' recovery assumes that in the event of default, interest deductions on the debt obligation are disallowed.

The interest rate on debt, r_d, is determined endogenously via a zero-profit condition for the debtholders. Let $Z_d\left(k',p',z\right)$ be the set of states in which the firm defaults, as a function of k', p', and the current state z. Similarly, let $Z_s\left(k',p',z\right)$ be the set of states in which the firm remains solvent. The interest rate, $r_d\left(k',p',z\right)$, is then defined by:

$$\int_{Z_d(k',p',z)} R(k',z')dg\big(z',z\big) + \big(1+r_d\left(k',p',z\right)\big)\,p' \int_{Z_s(k',p',z)} dg\big(z',z\big) = (1+r)\,p'.$$

In words, debtholders expect over all states to earn the risk-free rate. For a proof of the existence of a solution to this class of models, see Hennessy and Whited (2007).

In this model debt does not have an arbitrary upper bound, but the higher interest rate charged by debtholders limits the optimal amount of debt chosen by the firm.

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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 and the t-statistics for the differences between the corresponding 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. λ_1 and λ_2 are the linear and quadratic costs of equity issuance. σ_v is the standard deviation of the innovation to $\ln(z)$, in which z is the shock to the revenue function. ρ is the serial correlation of $\ln(z)$. θ is the curvature of the revenue function, zk^{θ}. γ and a are the fixed and convex adjustment cost parameters, and s is the agency cost parameter. $\bar{p}/k^{ss}$ is the debt ceiling expressed as a fraction of the steady state capital stock, k^{ss}.

A. Moments

	Actual moments	Simulated moments	T-statistics
Variance of investment (I/k)	0.0385	0.0329	-0.4150
Variance of leverage (d/k)	0.0118	0.0165	1.8220
Average leverage (d/k)	0.2393	0.2423	0.3347
Average equity issuance (e/k)	0.0407	0.0231	-2.0196
Average Tobin's q $((V+p)/k)$	3.6707	3.9549	0.4181
Third central moment of investment (I/k)	0.0534	0.0363	-0.5629
Average operating income (zk^{θ}/k)	0.1915	0.1903	-0.0352
Serial correlation of income (zk^{θ}/k)	0.6635	0.6488	-0.2360
Variance of the innovation to income (zk^{θ}/k)	0.0048	0.0015	-0.2974
Average cash balances (c/k), conditional on $c > 0$	0.1399	0.1350	-0.3395
Variance of equity issuance (e/k)	0.0079	0.0051	-1.1062
Average investment (I/k)	0.1868	0.1657	-1.1146

B. Parameter estimates

λ_1	λ_2	σ_v	ρ	θ	γ	a	s	$\bar{p}/k^{ss}$
0.1615	0.0041	0.2843	0.7280	0.7880	0.0034	0.1519	0.0077	0.7196
(0.0164)	(0.4662)	(0.0479)	(0.1790)	(0.0673)	(0.0016)	(0.0092)	(0.0157)	(0.0143)

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. Panel A reports average leverage, and panel B reports the standard deviation of leverage. 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, λ_1 (which varies from 0.001 to 0.3 across the columns of the table) and (ii) the marginal agency cost, s, which varies from 0 to 0.05 down the rows. For these experiments, the quadratic cost of equity, λ_2 is set to zero. For each combination of parameter values, we run the model for 100,200 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 100,000 observations.

A. Average debt-to-assets ratio (d/k)

Cost of maintaining cash balances:	**Linear cost of accessing external equity:**				
	Low				**High**
Low	0.803	0.313	0.232	0.210	0.193
	0.806	0.324	0.266	0.246	0.234
	0.801	0.326	0.271	0.253	0.240
	0.806	0.328	0.272	0.258	0.243
High	0.794	0.328	0.275	0.265	0.254

B. Standard deviation of d/k

Low	0.498	0.099	0.093	0.095	0.093
	0.497	0.103	0.098	0.100	0.101
	0.499	0.104	0.099	0.100	0.104
	0.498	0.102	0.102	0.102	0.105
High	0.495	0.103	0.101	0.102	0.105

Table 3

Capital structure and investment shock volatility

This table reports a variety of summary statistics from simulations of the baseline model. We simulate the model for 100,200 periods, with the firm receiving random investment 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 investment shock. We let this standard deviation range from 0.15 to 0.5.

		Standard deviation of investment shocks:							
		Low			Moderate				High
1.	Average investment (I/k)	0.158	0.160	0.163	0.167	0.169	0.171	0.172	0.171
2.	Standard deviation of investment (I/k)	0.129	0.145	0.166	0.187	0.197	0.211	0.214	0.213
3.	Frequency of investment	0.852	0.833	0.791	0.775	0.763	0.754	0.767	0.772
4.	Average debt-to-assets ratio (d/k)	0.722	0.508	0.336	0.203	0.133	0.104	0.091	0.091
5.	Standard deviation of leverage (d/k)	0.110	0.089	0.101	0.096	0.087	0.077	0.072	0.069
6.	Average net debt $((d-c)/k)$	0.722	0.508	0.333	0.190	0.081	0.011	-0.010	-0.007
7.	Standard deviation of net debt	0.110	0.089	0.127	0.145	0.227	0.272	0.261	0.248
8.	Average cash balances to assets (c/k)	0.000	0.000	0.002	0.010	0.046	0.085	0.091	0.088
9.	Standard deviation of (c/k)	0.000	0.000	0.083	0.153	0.303	0.306	0.269	0.236
10.	Frequency of positive debt outstanding	1.000	1.000	0.965	0.908	0.779	0.672	0.639	0.627
11.	Average of positive leverage values	0.722	0.508	0.348	0.223	0.171	0.155	0.142	0.146
12.	Average of positive cash balance values	0.000	0.000	0.091	0.165	0.283	0.334	0.322	0.302
13.	Debt issuance frequency	0.468	0.463	0.451	0.438	0.393	0.341	0.330	0.328
14.	Debt repayment frequency	0.521	0.534	0.528	0.499	0.436	0.390	0.367	0.356
15.	Average debt issuance/assets	0.088	0.092	0.106	0.114	0.106	0.111	0.106	0.104
16.	Average debt repayment/assets	-0.069	-0.070	-0.076	-0.075	-0.069	-0.067	-0.064	-0.064
17.	Equity issuance frequency	0.255	0.257	0.261	0.255	0.245	0.237	0.239	0.236
18.	Average equity issuance/assets	0.028	0.024	0.022	0.018	0.019	0.018	0.018	0.017
Average fraction of investment funded from:									
19.	Current cash flow	0.840	0.847	0.832	0.823	0.816	0.802	0.807	0.810
20.	Cash balances	0.000	0.000	0.004	0.017	0.047	0.076	0.083	0.086
21.	Debt issuance	0.143	0.135	0.148	0.148	0.125	0.112	0.098	0.093
22.	Equity issuance	0.017	0.018	0.016	0.012	0.012	0.009	0.011	0.011

Table 4

Capital structure comparative statics

This table reports a variety of summary statistics from simulations of the baseline model. We simulate the model for 100,200 periods, with the firm receiving random investment 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 0.1 and 0.9. The next two are for low and high θ, the parameter governing the marginal profitability of capital, set at 0.4 and 0.9. The last two are for smooth and lumpy investment. For smooth investment we set the convex adjustment cost parameter at 0.3 and the fixed adjustment cost parameter at 0.0. For lumpy investment we set the convex cost parameter to 0.0 and the fixed cost parameter to 0.04.

		Shock serial correlation		Marginal profitability		Optimal Investment	
		Low	High	Low	High	Smooth	Lumpy
1.	Average investment (I/k)	0.151	0.178	0.161	0.164	0.158	0.251
2.	Standard deviation of investment (I/k)	0.051	0.244	0.150	0.171	0.129	0.742
3.	Frequency of investment	0.998	0.816	0.828	0.772	0.872	0.426
4.	Average debt-to-assets ratio (d/k)	0.889	0.085	0.711	0.094	0.400	0.088
5.	Standard deviation of leverage (d/k)	0.038	0.084	0.192	0.083	0.087	0.134
6.	Average net debt ($(d-c)/k$)	0.889	-0.453	0.711	-0.004	0.399	-0.184
7.	Standard deviation of net debt	0.038	1.413	0.192	0.258	0.089	0.669
8.	Average cash balances to assets (c/k)	0.000	0.530	0.000	0.090	0.000	0.207
9.	Standard deviation of (c/k)	0.000	1.894	0.000	0.252	0.023	0.811
10.	Frequency of positive debt outstanding	1.000	0.527	1.000	0.644	0.998	0.456
11.	Average of positive leverage values	0.889	0.161	0.711	0.146	0.400	0.194
12.	Average of positive cash balance values	0.000	1.256	0.000	0.318	0.083	0.528
13.	Debt issuance frequency	0.024	0.263	0.420	0.331	0.489	0.217
14.	Debt repayment frequency	0.017	0.272	0.437	0.385	0.503	0.390
15.	Average debt issuance/assets	0.027	0.100	0.030	0.101	0.060	0.564
16.	Average debt repayment/assets	-0.034	-0.059	-0.028	-0.065	-0.052	-0.138
17.	Equity issuance frequency	0.165	0.293	0.061	0.253	0.248	0.248
18.	Average equity issuance/assets	0.016	0.039	0.020	0.015	0.020	0.032
Average fraction of investment funded from:							
19.	Current cash flow	0.987	0.809	0.975	0.786	0.899	0.671
20.	Cash balances	0.000	0.092	0.000	0.090	0.000	0.126
21.	Debt issuance	0.002	0.067	0.022	0.114	0.089	0.198
22.	Equity issuance	0.011	0.028	0.003	0.009	0.011	0.005

Table 5
Speed of adjustment to target

This table reports speeds of adjustment to target in a simulation of the baseline model. We simulate the model for 100,200 periods, with the firm receiving random investment shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data. "Average SOA" in row 1 is the mean of (1) the change in leverage divided by (2) the distance from current leverage to target leverage. "Average SOA toward target" in row 3 is calculated in the same fashion, but excludes observations that do not move leverage toward target. "Regression-based SOA" in row 2 is the SOA implied by a regression that uses model-generated leverage ratios and follows the general approach of extant SOA tests—i.e., current leverage is the left-hand side variable, while the explanatory variables are lagged leverage, firm value/assets, and cash flow/assets. All statistics are reported for the entire simulated sample, as well as for the first through third terciles of the ratio of investment to capital.

A. Alternative SOA measures			Current leverage:	
		Unconditional	at or above target	below target
1.	Average SOA	0.142	0.115	0.204
2.	Regression based SOA	0.378	0.332	0.593
3.	Average SOA towards target	0.605	0.543	0.769

B. Leverage changes and investment				Investment:	
		Unconditional	Low	Moderate	High
Leverage above or at target					
4.	Average change in leverage	-0.015	-0.021	-0.017	-0.007
5.	Average increase in leverage	0.057	0.057	0.052	0.063
6.	Average decrease in leverage	-0.058	-0.061	-0.056	-0.057
7.	Probability of leverage increase	0.372	0.344	0.366	0.414
8.	Probability of leverage decrease	0.627	0.655	0.634	0.585
9.	Probability of overshooting target	0.280	0.293	0.253	0.293
10.	Probability of debt issuance	0.406	0.124	0.238	0.940
11.	Probability of debt repayment	0.592	0.875	0.760	0.059
12.	Probability of equity issuance	0.244	0.083	0.263	0.416
13.	Size of debt issuance	0.089	0.046	0.031	0.113
14.	Size of debt repayment	-0.079	-0.099	-0.059	-0.025
15.	Size of equity issuance	0.015	0.018	0.015	0.015
16.	Average shock	0.061	-0.292	0.113	0.429
17.	Probability of a positive shock	0.561	0.139	0.671	0.949
18.	Fraction of observations	0.702	0.254	0.238	0.210
Leverage below target					
19.	Average change in leverage	0.036	0.021	0.024	0.055
20.	Average increase in leverage	0.099	0.083	0.088	0.115
21.	Average decrease in leverage	-0.053	-0.053	-0.054	-0.053
22.	Probability of leverage increase	0.554	0.524	0.514	0.604
23.	Probability of leverage decrease	0.347	0.410	0.389	0.273
24.	Probability of overshooting target	0.464	0.521	0.434	0.449
25.	Probability of debt issuance	0.547	0.161	0.378	0.930
26.	Probability of debt repayment	0.352	0.717	0.493	0.005
27.	Probability of equity issuance	0.293	0.113	0.293	0.410
28.	Size of debt issuance	0.154	0.047	0.039	0.203
29.	Size of debt repayment	-0.061	-0.073	-0.047	-0.022
30.	Size of equity issuance	0.029	0.028	0.026	0.031
31.	Average shock	-0.150	-0.459	-0.189	0.080
32.	Probability of a positive shock	0.348	0.145	0.222	0.577
33.	Fraction of observations	0.298	0.080	0.095	0.123

Figure 1

Histogram of leverage generated by a model with no tax incentive to borrow

This histogram is from data generated by a version of our estimated model in which the tax incentive to borrow has been set to zero. As such, zero debt is the capital structure target for all firms. The figure shows that sample firms are at their debt targets about 47% of the time. The histogram indicates that firms have transitory debt outstanding around 53% of the time, and so the average outstanding amount of debt is positive, even though the target amount is zero in this model specification.

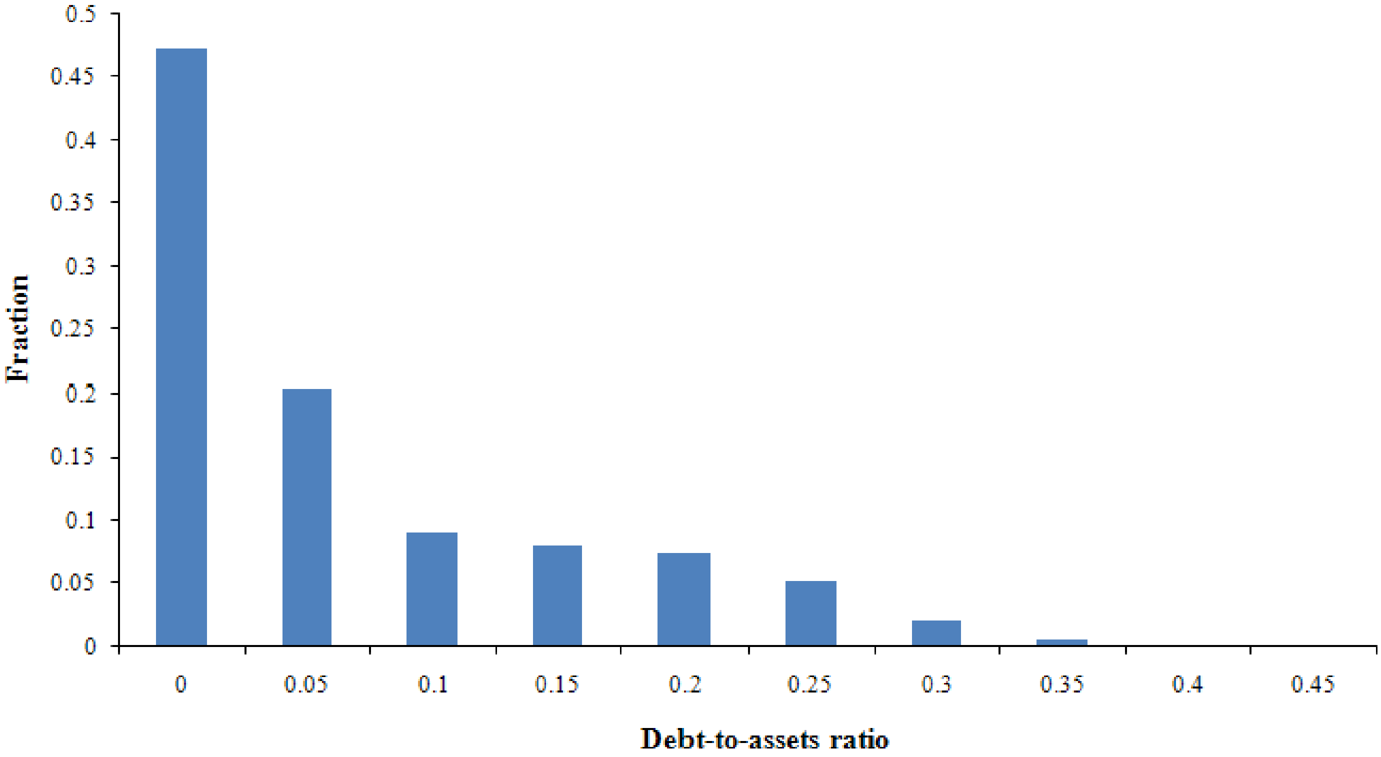


Figure 2

Illustrative time path of leverage and debt issuance/retirement with no tax incentive to borrow

The time path is generated from the estimated model in which the tax incentive to borrow has been set to zero. As such, zero debt is the long-run capital structure target.

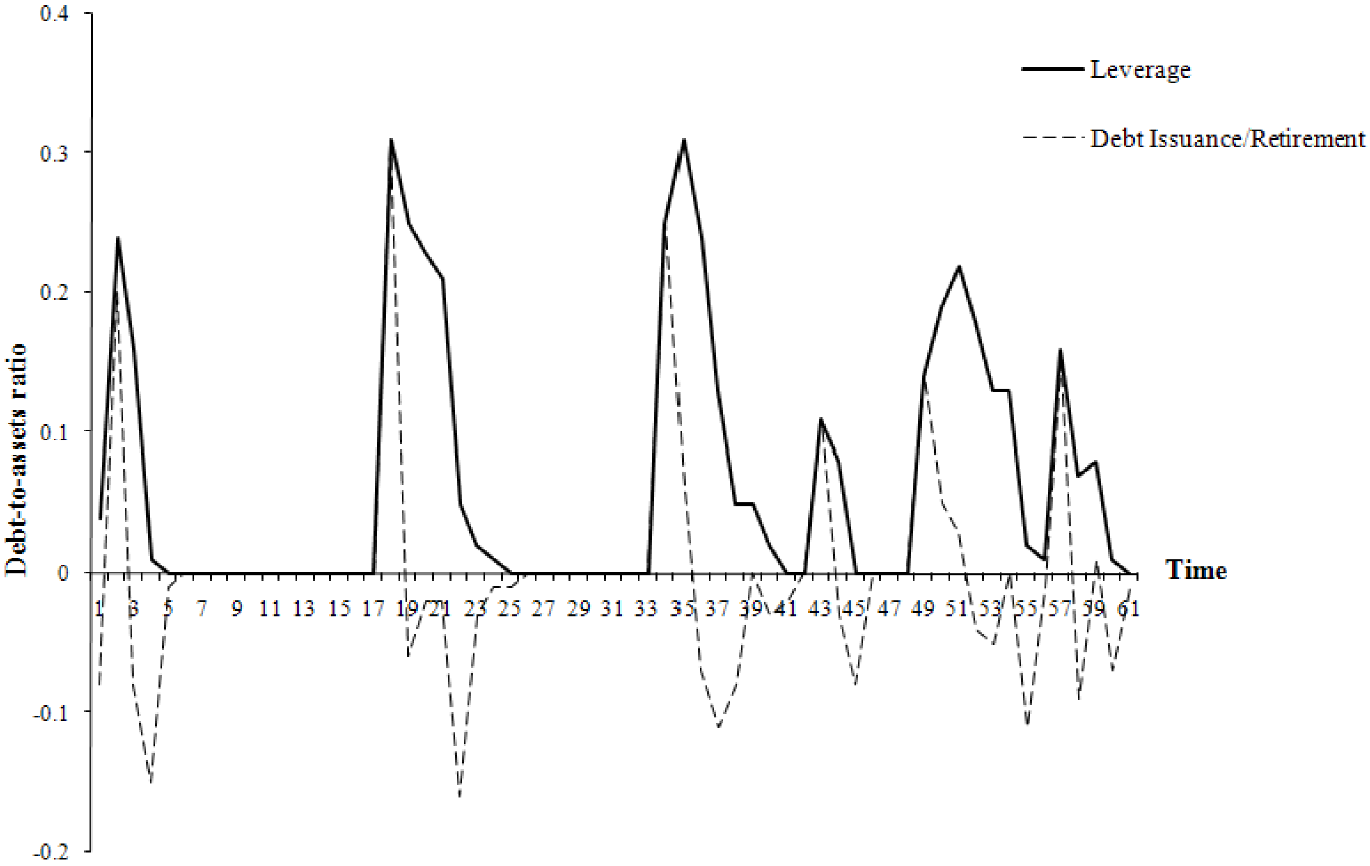


Figure 3

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 (σ_v) and serial correlation (ρ) 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.

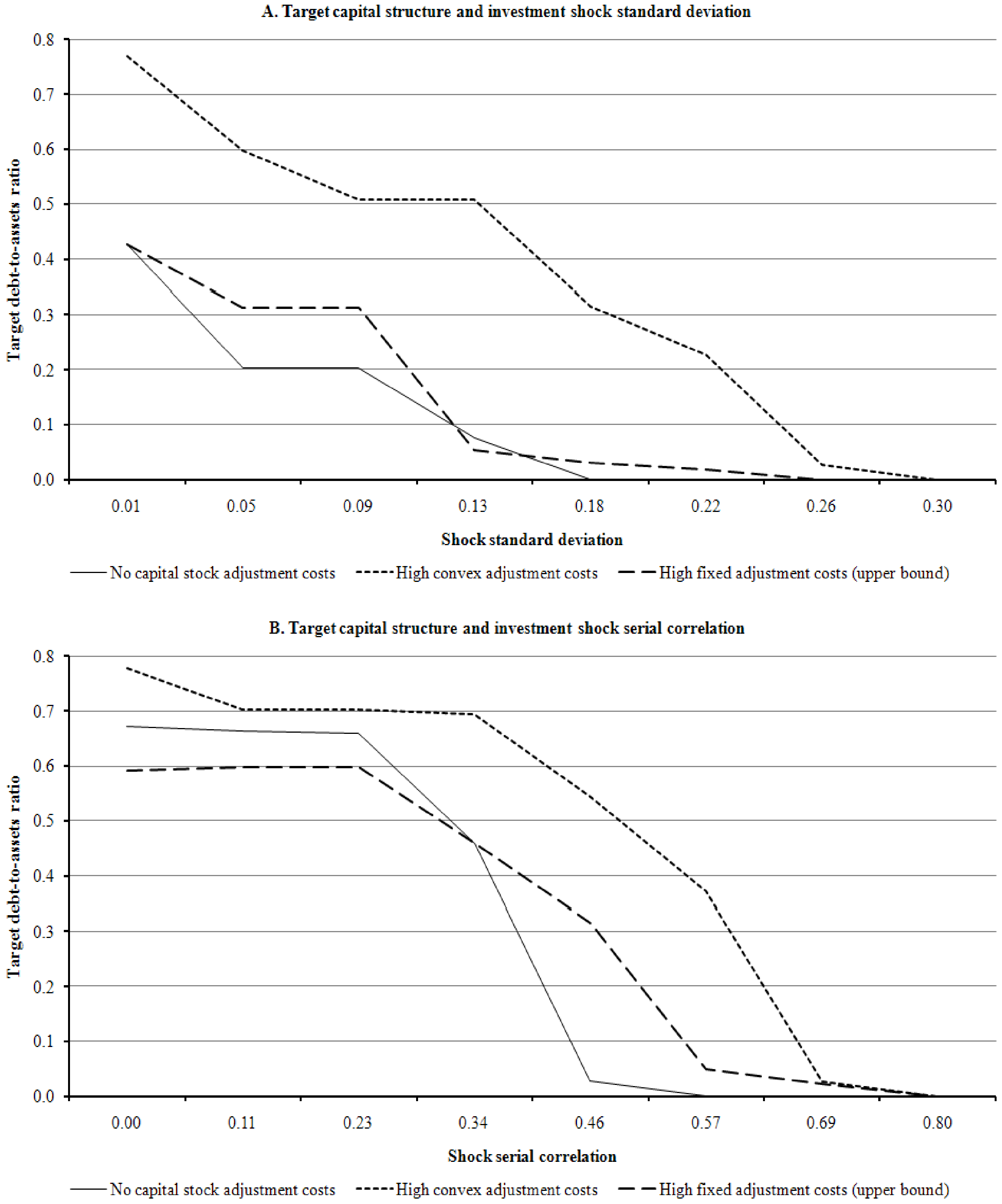


Figure 4

Illustrative convergence to target leverage in the estimated model

The firm experiences random investment shocks until date $t = 52$, at which point it begins to receive a series of neutral investment shocks. It converges to target at $t = 55$ 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 unique long-run target leverage ratio.

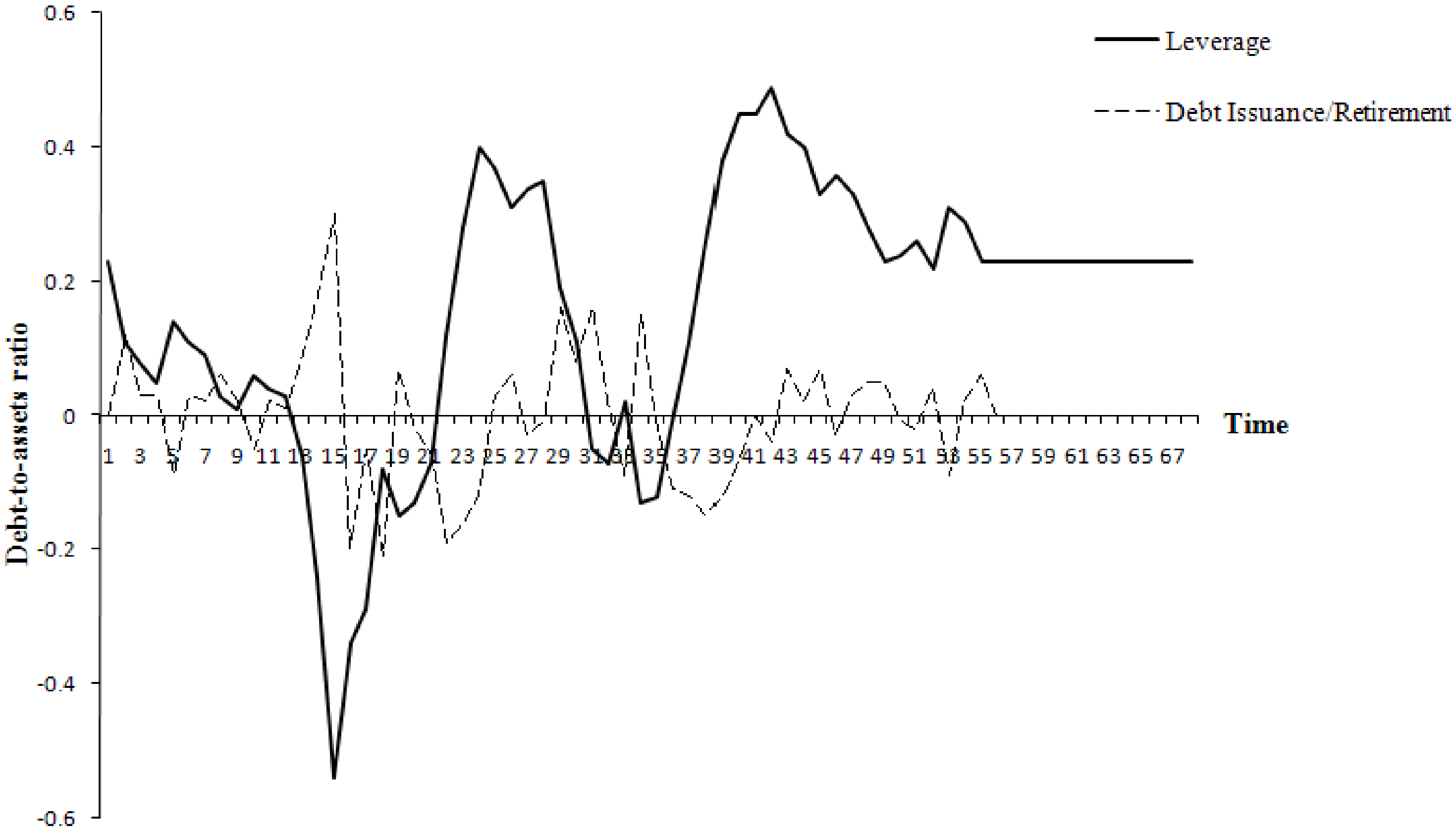


Figure 5

Cumulative frequency distributions of spells above and below target leverage

This figure reports the cumulative distribution of spells of time leverage spends above and below target in a simulation of the baseline model. We simulate the model for 100,200 periods, with the firm receiving random investment shocks and responding to each by adjusting its investment and financing decisions. We discard the initial 200 periods of data. A spell above (below) target is the number of consecutive periods that actual leverage exceeds (is less than) target leverage. The solid line depicts the fraction of spells above target of a length that is less than or equal to the number of specified years, and the dashed line depicts a similar statistic for spells below target. Since the model is estimated with annual data, each model period corresponds to one year.

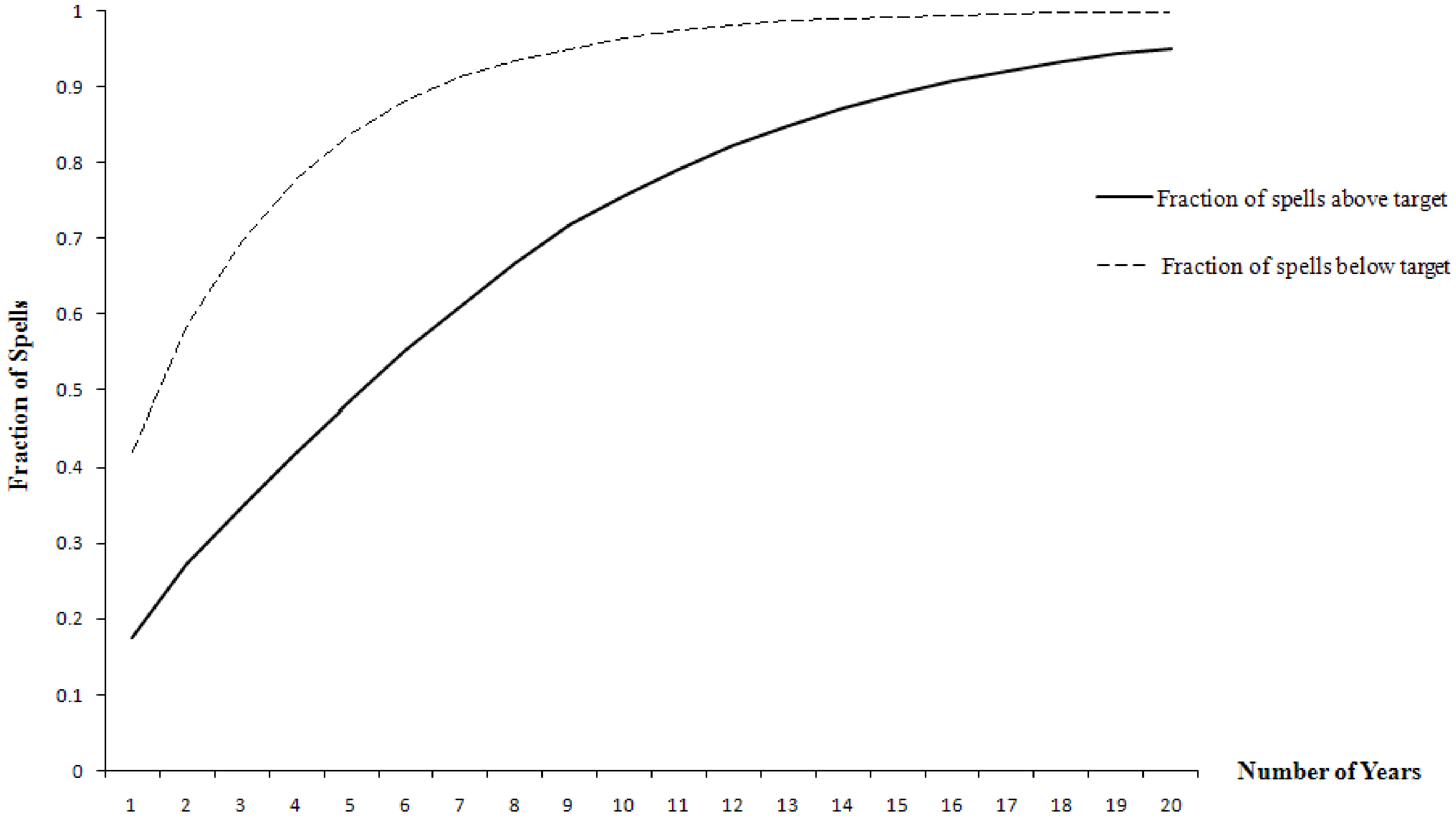
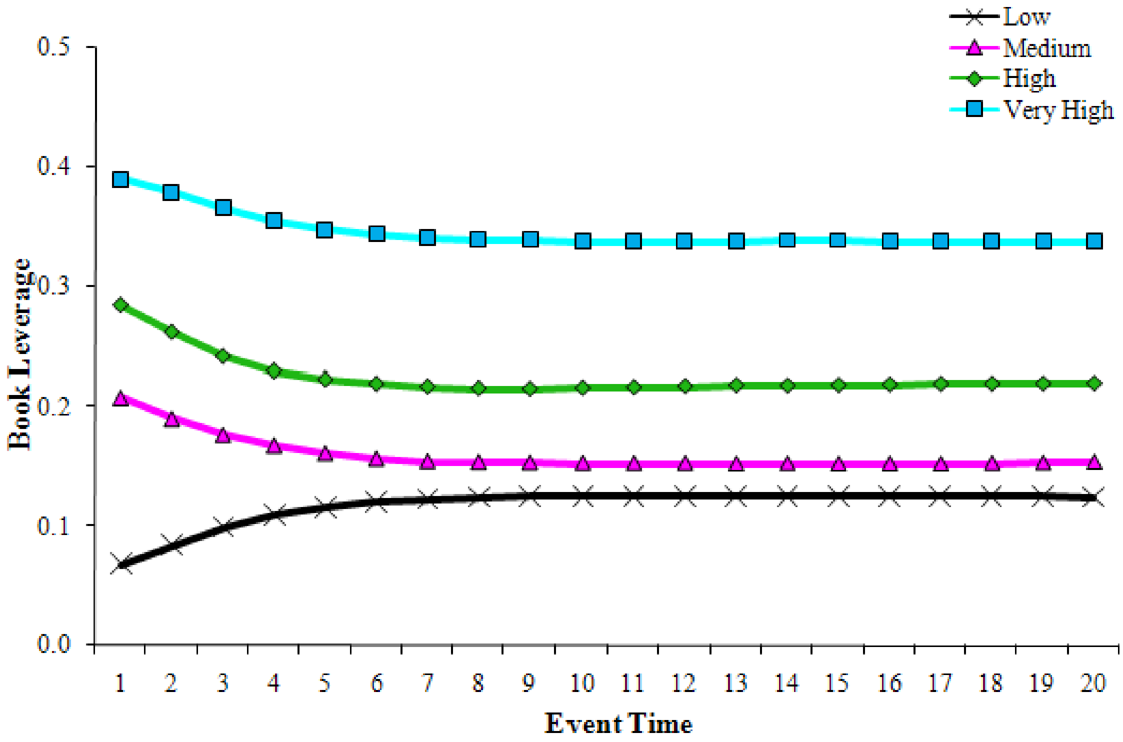


Figure 6

Long-run average leverage paths

This figure plots the long-run leverage paths from our estimated model in panel A and the long-run net-of-target leverage paths from our estimated model in panel B. At date zero the sample is sorted into four groups. Average leverage is then tracked for the next 20 years. Each line represents the long-run averages for each group.

A. Model generated long-run average leverage



B. Model generated net-of-target long-run average leverage

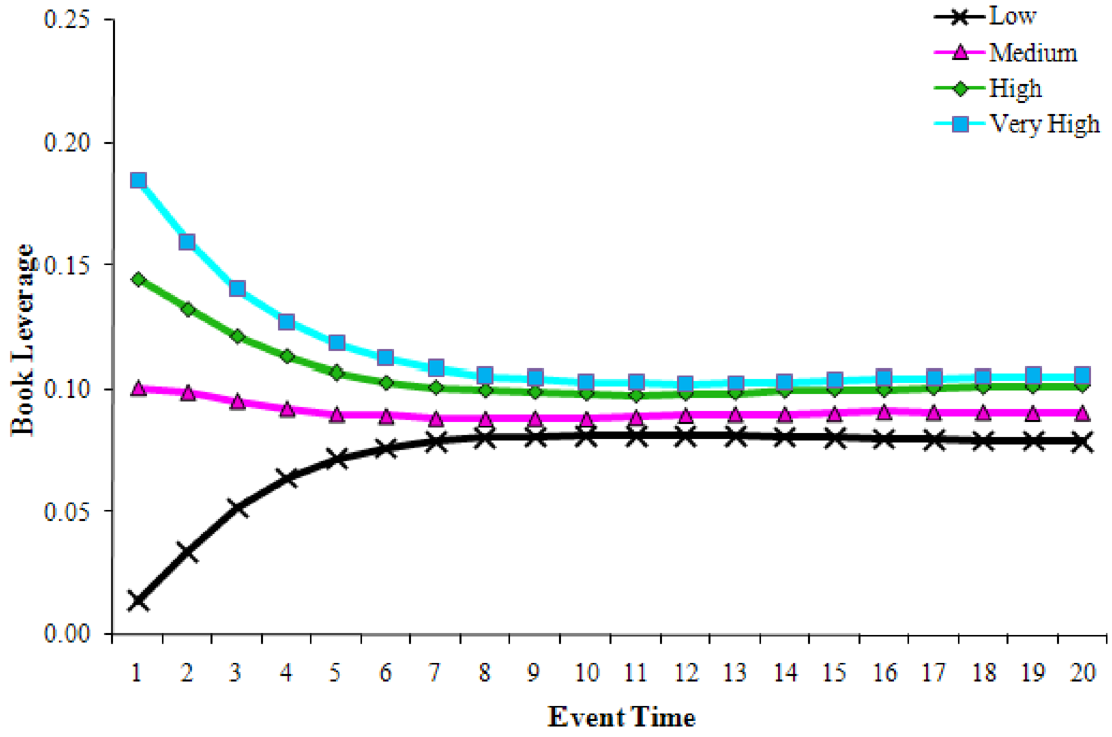


Figure 7

Comparative statics in models with issuance costs, simultaneous debt and cash balances, collateral constraints, and endogenous default

Each panel depicts leverage as a function of one of the model parameters: linear equity issuance costs, shock standard deviation, shock serial correlation, profit function curvature, and the the convexity of capital stock adjustment costs. Each line in a panel depicts the relation from a particular version of the baseline model: one with issuance costs, one with simultaneous positive amounts of debt outstanding and cash balances (labeled "extra state variable"), one with a collateral constraint, and one with endogenous default.