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. The model yields a variety of testable predictions about the link between capital structure and attributes of firms’ investment opportunities, including the volatility and serial correlation of investment opportunity shocks, the marginal profitability of investment, and the nature of capital stock adjustment costs. Target capital structures reflect the value of the option to issue transitory debt, and the average outstanding amount of debt differs predictably from target because the optimal leverage path reflects time-varying (and state-contingent) transitory debt, whose usage is determined by the firm-specific properties of current and prospective shocks to investment opportunities. Slug-gish mean reversion in leverage reflects the opportunity cost of utilizing debt capacity, and not transactions costs of debt issuance, which are zero in our model.
1. Introduction

We estimate a dynamic capital structure model with endogenous investment in which firms have leverage targets, yet also issue transitory debt and deviate deliberately, but temporarily, from target. In this 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 model yields a rich set of comparative statics predictions that link average leverage (and other observable capital structure attributes) to variation in the volatility of shocks to investment policy, the serial correlation of such shocks, and the marginal profitability of investment, as well as to variation in the fixed (compared to convex) costs of adjusting the stock of physical capital. The model also generates the otherwise puzzling long-horizon average leverage paths documented by Lemmon, Roberts, and Zender (2008), clarifies the economically important distinction between average and target leverage, and explains why the two differ empirically.

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 perfectly 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. Our results and their underlying intuition hold both in our basic model in which firms have finite debt capacities, and in a model extension in which firms choose default endogenously and in which the interest rate on debt is an endogenous function of the amount of debt outstanding. In fact,
any cost of leverage that is increasing in the debt level implies that borrowing today entails an opportunity cost in terms of reduced future ability to borrow at terms the firm currently faces.

In our model, debt decisions reflect the opportunity cost of borrowing at each point in time—the foregone future ability to borrow at comparable terms—because firms face limits to (costs of) debt financing. Target capital structures are more conservative than implied by otherwise similar tax/distress cost trade-off 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, thus potentially forcing it to incur higher future costs of accessing capital to meet imperfectly anticipated funding needs. This valuable option radically changes the nature of leverage dynamics from those identified in extant trade-off models.

Although firms have leverage targets as in static trade-off models, managers sometimes choose to deviate from target, and subsequently seek to rebalance to target by reducing debt with a lag determined in part by the time path of investment opportunities and earnings realizations. Intuitively, a firm’s long-run target capital structure is the theoretically ideal debt level that, when viewed ex ante, optimally balances its corporate tax shield from debt against not only distress costs, but also against the opportunity cost of borrowing now rather than preserving the option to borrow later. More precisely, in our model a firm’s target capital structure is the 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 no shocks to its investment opportunities for many periods in a row. (In this case, the firm has ample resources to pay down any existing debt in excess of target, and also has no new profitable projects that it needs to fund.) 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.

We refer to the difference between actual and target debt levels as transitory debt,\(^1\) with

\(^1\)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
actual debt deviating from target because investment policy is endogenous. For example, with no tax or other permanent benefit from corporate debt, firms nevertheless find that issuing debt is sometimes the most efficient source of capital (in a sense made precise below), yet zero debt is the capital structure target. Paying down debt (issued to fund prior investment) frees up debt capacity, which reduces the expected future costs of capital access. Hence managers always have incentives to return their firms to zero debt in the absence of taxes. They may not be able to accomplish this objective quickly, however, since multiple sequential shocks may arrive, requiring additional funds and, perhaps, more borrowing.

The prediction that firms deliberately deviate from target leverage differentiates our analysis from static trade-off models and from the multi-period contingent claims generalizations thereof that assume exogenous investment and positive leverage rebalancing costs, e.g., Fischer, Heinkel, and Zechner (1989) and Goldstein, Ju, and Leland (2001). The latter models universally predict that all management-initiated changes in capital structure move firms toward target, although Welch (2004) and others show that this prediction is not borne out empirically. An important implication of our analysis is that, 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 their capital structures should differentiate between (i) pro-active decisions to incur transitory debt and deliberately, but temporarily, deviate from target leverage, and (ii) pro-active and passive capital structure changes that move firms back toward target.

Our model generates long-horizon leverage paths that conform closely to those reported by Lemmon, Roberts, and Zender (2008, figure 1), who analyze average leverage ratios over 20 years for four groups of firms sorted by initial (high versus low) leverage, and find that all groups converge slowly, but incompletely, toward moderate leverage. LRZ conclude that the majority of variation in leverage ratios is driven by an unobserved time-invariant effect, and that previously identified capital structure determinants cannot explain their findings. Our model yields qualitatively identical leverage paths, although it has no debt issuance costs that would slow mean reversion in leverage, so that transitory debt alone is responsible for

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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.
both the time-series pattern in average leverage and the persistent cross-sectional differences in average leverage. The model-generated average leverage ratios for each of LRZ’s groups stabilize over time, but not at values in the neighborhood of target leverage. Rather, the capital structure of the average firm (in each group) approaches its target debt level plus the amount of transitory debt expected to be outstanding at a randomly selected point in time. Since the latter value varies cross-sectionally and predictably with variation in the nature of investment opportunities, our analysis suggests 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.

Our model yields a variety of specific testable predictions that link firms’ investment attributes 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. (Average debt outstanding is 9.1% of total assets for high shock volatility firms versus 72.2% for low shock volatility firms.) 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, the model also predicts lower average debt ratios and greater reliance on cash balances for 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.

Endogeneity of investment policy is critical to our analysis, and variation in investment opportunity attributes is the main driver of our comparative statics predictions about the time-series and cross-sectional variation in leverage. The importance of endogenous investment is evident not only in our comparative statics analysis, but also in the results of a small but growing literature of dynamic models that explore the interactions of investment policy and capital
structure. For example, Tserlukevich (2008), Morellec and Schürhoff (2008), and Sundaresan and Wang (2008) study the leverage impact of real options. Similarly, 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.\(^2\) Our analysis complements that of these studies by focusing directly 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, the marginal profitability of investment, and the properties of capital stock adjustment costs. (Here and throughout, when we use the shorthand term “investment shock,” we mean a shock to investment opportunities, and not a stochastic shift in the level of investment outlays.)

Our analysis moves beyond existing dynamic capital structure models in that our approach (i) explicitly recognizes and develops the capital structure implications of the opportunity cost of borrowing, (ii) demonstrates that this opportunity cost induces firms to use debt as a transitory financing vehicle, taking deliberate, but temporary deviations from their target capital structures, (iii) establishes that transitory debt implies radically different leverage dynamics from those of adjustment cost models in which all pro-active capital structure decisions move firms toward their leverage targets, (iv) formally operationalizes the notion of—and demonstrates the existence of—capital structure targets in a dynamic model with endogenous investment policy, (v) shows that transitory debt alone can fully explain the leverage paths documented by Lemmon, Roberts, and Zender (2008), (vi) 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, and (vii) yields new testable implications that link the time-series and cross-sectional variation in firms’ capital structure to variation in the nature of their investment opportunities.

While our model shares several features with Whited (1992) and Hennessy and Whited\(^2\) 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.
(2005), e.g., endogenous investment, there are a number of important differences. For example, 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. Our analysis is also differentiated by its consideration of a more realistic set of investment policy features, which both generate a richer set of predictions about leverage behavior 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 associated implications for transitory debt, the resultant implications for the existence of (and cross-firm variation in) target capital structures, and the systematic connections between the nature of investment opportunities and leverage comparative statics. We posit a simple dynamic model in order to sharply highlight the capital structure role of transitory debt, but as we show in section 6, our conclusions generalize to considerably more complex model settings.

We begin in section 2 by detailing the assumptions of the model and presenting the estimation results. Section 3 shows that the model generates long-horizon leverage paths that qualitatively conform to those documented by Lemmon, Roberts, and Zender (2008), and explains the empirically important distinction between long-run average leverage and target leverage. Sections 4 and 5 present comparative statics analysis of the model. Section 6 demonstrates that our conclusions generalize to allow for collateral constraints, endogenous default, and the simultaneous holding of debt and cash balances. Section 7 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 de-
terminating 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 model starts with a firm that uses capital, $k$, to produce output. The firm’s managers select investment and financing decisions to maximize the wealth of owners, which is determined by risk-neutral security pricing in the capital market. The firm’s per period profit function is given by $\pi(k, z)$, in which $z$ is a shock to the profit function, observed by managers each period before making the firm’s investment and financing decisions. For brevity, we often refer to $z$ as an “investment shock” to capture the idea that variation in $z$ alters the marginal productivity of capital and therefore the firm’s investment opportunities. The profit function $\pi(k, z)$ is continuous, with $\pi(0, z) = 0$, $\pi_z(k, z) > 0$, $\pi_k(k, z) > 0$, $\pi_{kk}(k, z) < 0$, and $\lim_{k \to \infty} \pi_k(k, z) = 0$. Concavity of $\pi(k, z)$ in $k$ results from decreasing returns in production, a downward sloping demand curve, or both. In what follows we use the functional form $\pi(k, z) = zk^\theta$, where $\theta$ is an index of the curvature of the profit function, with $0 < \theta < 1$, which satisfies concavity and the Inada condition.

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

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

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

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

$$\left(1 - \tau_c\right) \pi(\underline{k}, z) - \delta \underline{k} \equiv 0, \quad (2)$$
in which $\delta$ is the capital depreciation rate, $0 < \delta < 1$, and $\tau_c$ is the corporate income tax rate. Concavity of $\pi (k, z)$ in $k$ and $\lim_{k \to \infty} \pi_k (k, z) = 0$ ensure that $\pi$ is well-defined. Because $k > \bar{k}$ is not economically profitable, $k$ lies in the interval $[0, \bar{k}]$. Compactness of the state space and continuity of $\pi (k, z)$ ensure that $\pi (k, z)$ is bounded.

Investment, $I$, is defined as

$$I \equiv k' - (1 - \delta)k,$$  \hspace{1cm} (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

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

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

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

Debt takes the form of a riskless perpetual bond that incurs taxable interest at the after-corporate tax rate $r (1 - \tau_c)$, while cash earns the same after-tax rate of return (aside from the
incremental cost, \( s \), formalized below). For simplicity, we model the tax advantage of debt only via a corporate income tax. We abstract from the effects of 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:

\[
p \leq \bar{p}.
\]

The estimated value of the parameter \( \bar{p} \) leads to a solution for equity value that always exceeds zero so that the firm therefore never has an incentive to default. Although the assumption of riskless debt with an exogenously specified upper bound may appear excessively simple and restrictive, we show in section 6 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 by including a stochastic probability of default, as in Carlstrom and Fuerst (1997). The agency cost function is given by

\[
s (p) = sp\Phi_c,
\]

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

The final source of finance is external equity. In the model, equity issuance/distributions are determined simultaneously with investment, debt, and cash. These decision variables are connected by the familiar identity that stipulates the sources and uses of funds are equal in each period. To express this identity in the context of our model, we first define \( e(k, k', p, p', z) \) as gross equity issuance/distributions. If \( e(k, k', p, p', z) > 0 \), the firm is making distributions to shareholders, and if \( e(k, k', p, p', z) < 0 \), the firm is issuing equity. As in Hennessy and Whited (2005, 2007) and Riddick and Whited (2008) we model the cost of external equity finance in a reduced-form fashion that preserves tractability, which is necessary to estimate the model. The external equity-cost function is linear-quadratic and weakly convex:

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

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

\[
e(k, k', p, p', z) + \phi(e(k, k', p, p', z)) \equiv (1 - \tau_c) \pi(k, z) + p' - p(1 + r(1 - \tau_c)) + \delta k \tau_c - (1 - \delta) k - A(k, k') + s(p). \tag{7}
\]

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

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

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 \( e(k, k', p, p', z) + \phi(e(k, k', p, p', z)) \) is weakly concave in its first and third arguments. This requirement puts easily verified restrictions on \( \phi(\cdot) \) that are satisfied by the functional forms chosen above. The policy function is essentially a rule that states the best choice of \( k' \) and \( p' \) in the next period for any \( (k, p, z) \) triple in the current period. 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. To simplify the exposition of optimal policies, we assume in this subsection that \( V \) is once differentiable. This assumption 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

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

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 \( \mu \) be the Lagrange multiplier on the constraint (5). Then the envelope condition can be written as:

\[
-V_2(k, p, z) = ((1 + (1 - \tau_c) r) - s \Phi_e) \left( 1 + (\lambda_1 - \frac{1}{2} \lambda_2 e) \Phi_e \right) + \mu. \tag{10}
\]

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, as we illustrate in detail below via model simulations, 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 \(z = 1\),

\(^3\)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 5.3.
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

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

(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 will be exactly one optimal level of $p$ because the value function for this class of models is strictly concave (Hennessy and Whited (2005)). In intuitive terms, for any given $k$, there cannot be two values of $p$ that yield the same maximum valuation. Of course, because $u(k, p, z)$ has no closed-form solution, we use simulation to solve for the target and to determine its exact form. As we elaborate in section 5.3 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 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.4

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

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4 Another possible definition of a target is the solution to (8) using the steady state transition probabilities defined by $g(z, z')$. We have chosen our definition because of the clarity of the economic intuition behind the definition and because the alternate definition yields qualitatively similar results with much less transparent intuition.
method of moments (SMM), which chooses model parameters that set moments of artificial data simulated from the model as close as possible to corresponding real-data moments. We estimate the following parameters: profit function curvature, \( \theta \); shock serial correlation, \( \rho \); shock standard deviation, \( \sigma_v \); smooth and fixed physical adjustment costs, \( a \) and \( \gamma \); the agency cost parameter, \( s \); the two external equity cost parameters, \( \lambda_1 \) and \( \lambda_2 \), and the ratio of the debt limit, \( \bar{p} \), to the steady state capital stock, \( k^{**} \), that would prevail in the absence of financing or physical adjustment frictions.\(^5\) 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.

The point estimates of the profit function curvature (\( \theta \)) and of the serial correlation of profit shocks (\( \rho \)) 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, \( \lambda_1 \) and \( \lambda_2 \), and the standard deviation of shocks (\( \sigma_v \)) 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.

\(^5\) The steady state capital stock is given by \( k^{**} = (\theta (1 - \tau_c) / (r + \delta))^{1/(1 - \theta)} \). It is the level of the capital stock that equates the marginal product of capital with the user cost: \( r + \delta \). In our model \( k^{**} \) is always close to the average simulated capital stock.
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 $\gamma$, 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 $\bar{p}/k^{*s}$ 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. Transitory debt and long-horizon leverage paths

In this section we show that our model generates long-horizon leverage paths that closely conform to those documented by Lemmon, Roberts, and Zender (2008, LRZ). We obtain LRZ’s average leverage paths for a model parameterization based on our empirical estimates in which firms face heterogeneous investment shock volatilities and issue transitory debt to address the funding needs associated with shock arrival. Our focus on heterogeneous shock volatilities is for illustrative simplicity only, since heterogeneity in other investment characteristics also induces transitory debt usage that implies average leverage paths similar to LRZ’s.

Our model-generated average leverage ratios (for groups of firms formed as in LRZ) converge to stable values in the long run, but not to target leverage, as would occur under traditional static trade-off models in which firms always converge to target as quickly as adjustment costs allow. Rather, the average debt level for a given group approaches the sum of the transitory debt expected to be outstanding (given investment shock volatility) plus the average target
debt level for firms in that group. Moreover, our model-generated leverage ratios indicate that
transitory debt is a large percent—between 31.3% and 63.3%, depending on the specific LRZ
group—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, but it is also predicted
to be a large fraction of the leverage ratios that empirical studies seek to explain.

Consistent with another aspect of LRZ’s empirical findings, our model generates leverage
paths with less than instantaneous upward adjustment from low to long-run average leverage,
even though the model includes no debt issuance costs to impede “levering up.” This sluggish
mean reversion is the result of decisions to issue transitory debt when investment shocks arrive,
and inclusion of an empirically realistic 4% debt issuance cost has little effect on the average
leverage paths our model generates.

3.1 Leverage paths documented by LRZ versus those generated by the model

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

Figure 1B plots the long-horizon average leverage paths generated by our model, and a
comparison of figure 1B with figure 1A (LRZ’s results) indicates that our model-generated
paths are similar, both qualitatively and quantitatively, to those reported by LRZ. The average
leverage ratios of the four groups in figure 1B 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 and, in any case, it is not important for explaining the puzzling aspects of LRZ. What is important is that (i) convergence to stable leverage occurs in both figures 1A and 1B, and (ii) such convergence is incomplete in both figures, i.e., a gap in average leverage across groups remains after 20 years. Moreover, as we explain below, the leverage convergence for any one group in figure 1B is not to target leverage, even though the intuition of static capital structure models suggests that the long-run stability of average leverage represents convergence to a permanent capital structure objective.

Figure 1B’s leverage paths are generated for a sample of 1,000 model firms with baseline parameter values established by section 2’s SMM estimation. This sample is composed of 10 subsamples of 100 technologically identical firms, and the 10 subsamples differ only in the volatility of the investment shocks that firms in each subsample face (standard deviations from 15% to 50%). We introduce heterogeneity in shock volatility across subsamples because such heterogeneity induces variation in the usage of transitory debt, and our objective in this section is to establish that firms’ use of transitory debt generates LRZ’s stable long-horizon leverage paths. We show in sections 4 and 5 that differences in shock volatility imply variation in (i) the expected amount of transitory debt that firms employ, and in (ii) the target capital structures that optimally position firms to issue transitory debt to address prospective investment shocks. In sections 3.2 and 3.3, we explain how variation in both (i) and (ii) is reflected in the long-run average leverage paths generated by our model.

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

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

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

Although it is perhaps instinctive to view a firm’s long-run average leverage as an unbiased estimate of its permanent leverage target, average leverage differs systematically from target in our model. The best way to see why average and target leverage differ is to consider how firms treat debt financing when there are no taxes. Absent taxes, managers have no incentive to keep debt outstanding permanently; in fact, they have an incentive to pay it off to free up debt capacity for future use—i.e., zero debt is the capital structure target for all firms. Firms nevertheless borrow periodically and deliberately deviate from target to meet funding needs associated with the arrival of investment shocks. They subsequently seek to rebalance to zero debt as soon as possible (depending on future cash flow realizations and the arrival of new investment shocks) so that they are once again optimally positioned to take on transitory debt to meet future funding needs. All debt is therefore transitory in the absence of taxes, but a given firm has debt obligations outstanding from time to time, and will sometimes carry substantial debt for significant periods of time because future cash flow realizations turn out
to be modest relative to the funding needs that arise due to additional investment shocks. In sum, even though there is no tax benefit or other motive to keep debt outstanding permanently, the amount of debt expected to be outstanding is positive and therefore exceeds the long-run target level of zero debt.

With taxes, which are a central feature of the model that generates Figure 1B, firms have positive debt targets, which reflect the incentive to maintain some debt outstanding on a permanent basis to capture interest tax shields. (Target capital structures are defined analytically and discussed in detail in sections 2 and 5.3.) Therefore, consistent with LRZ’s interpretation of their evidence, the capital structures generated by our model include permanent and transitory debt components. The permanent component is the target debt level toward which a firm will converge if it happens to receive only neutral investment shocks. The second is debt that a firm issues to address the funding needs associated with current and past investment shocks, and which it hopes to eventually pay off.

In the long run, leverage for a given firm—and average leverage for samples of firms, as in figure 1B’s model-generated results—does not converge to target leverage. As long as investment shocks continue to arrive, as they do in perpetuity in our model, 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 we observe in figure 1B is in part the result of a stationary investment shock-generating process. It also reflects the fact that we examine large sample averages, and the effects of time-series volatility in individual firms’ leverage ratios wash out in such averages. 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.

The law of large numbers similarly implies that the average debt level for a given group in figure 1B approaches the sum of the amount of transitory debt expected to be outstanding
plus the average target debt level for firms in that group. As we discuss in section 5.3, the target debt level depends on a variety of firm-specific technological parameters, including shock volatilities. As is evident in the first-order condition for optimal debt usage (9), the greater the chance of shocks that make large investment outlays optimal, the higher the value of having unused debt capacity available, and the lower the target debt level. Thus, variation in both components of the long-run leverage values in figure 1B—the expected amount of transitory debt and the long-run target debt level—is ultimately traceable to variation in firms’ use of transitory debt.

3.3 Why average leverage converges, but only incompletely, across leverage groups

In figure 1B, the cross-group differences in the initial average value of leverage reflect the sample selection approach, i.e., the fact that groups are formed by ranking firms on the basis of actual leverage ratios at an arbitrarily selected point in time, just as they are formed in LRZ. (Recall that in LRZ, the difference between the initial average leverage of the very high and low groups is 51.8%, whereas it is 32.2% for the model-generated results in figure 1B.) 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 of transitory debt. The transitory debt of the “very high” leverage group is accordingly expected to decline in future periods, and that of the “low” group is expected to increase—which explains the convergence of average leverage ratios in figure 1B, but not the 21.2% gap between the very high and low leverage groups that remains after 20 periods.

The incomplete convergence of the average leverage ratios in figure 1B reflects two factors. First, the four groups contain different proportions of firms that face different shock volatilities, and firms with different shock volatilities are expected to have different amounts of transitory debt outstanding, as we show in section 5 below. Second, the long-run differences across groups also reflect the fact that firms facing different shock volatilities have different incentives to employ debt permanently, i.e., their leverage targets differ.
Figure 2A plots the time path of model-generated net-of-target average leverage ratios—i.e., the typical amount of transitory debt outstanding—for each of the four leverage groups. At the final date, transitory debt (shown in figure 2A) as a percent of total debt (shown in figure 1B) 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 substantial fraction of total model-generated leverage and, in fact, all the remaining variation in figure 1B is indirectly attributable to transitory debt via its impact on cross-firm variation in target leverage. Since all model firms face identical tax benefits of debt and differ only in investment shock volatility, all variation in leverage targets reflects cross-firm differences in the value of preserving debt capacity to be able to issue transitory debt to meet funding needs associated with prospective investment shocks.

At first blush it seems counter-intuitive or even paradoxical that firms’ usage of transitory debt—a random variable characterized by potentially high time-series variability—could generate LRZ’s stable average leverage paths. However there is no paradox here because, in our dynamic model, a firm’s transitory debt level is both positive and stable in an expected value sense, which creates a statistical fixed effect of the type that drives LRZ’s findings of long-run stability in average leverage ratios. An important corollary is that average leverage is not generally indicative of a firm’s theoretically ideal capital structure and so, for example, there is every reason to expect that a firm that is currently at its (long-run) historical average debt ratio will rebalance away from that capital structure as future circumstances permit.

We would emphasize that firms face no transactions costs of issuing debt, and so the opportunity cost of issuing debt is the impediment to “levering up” in our model. This opportunity cost is the causal factor responsible for the slow mean reversion in leverage exhibited by the low leverage group in Figure 1B, and more generally for the time paths of average leverage for all groups in the figure. In Figure 2B, we show the result of adding to the model a debt issuance cost equal to 4% of the amount of new borrowing as a rough, but realistic, estimate of the transactions costs of raising debt capital faced by publicly held firms. A comparison of Figures 1B and 2B shows that introduction of debt issuance costs makes little difference in the
average leverage ratios generated by our model. For example, in every year, average leverage for the low group in Figure 1B is always within 1.1% of the average leverage for that group in Figure 2B, while the leverage ratios for the very high group in Figures 1B and 2B are always within 2.9% of each other.

We draw two conclusions from the fact that our model-generated average leverage paths differ only slightly when we include empirically plausible transactions costs of debt issuance. Most obviously, our analysis of LRZ’s long-run average leverage paths is robust to the inclusion of such costs. More generally, debt issuance costs are of second-order importance relative to the opportunity cost of using debt capacity, which is the underlying causal factor in our model that leads firms to employ transitory debt to meet funding needs associated with the arrival of shocks to investment opportunities.

4. 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 heuristic example designed to illustrate firms’ incentives to issue and retire transitory debt (section 4.1), and presents our predictions regarding the impact of financing frictions on the average amount of debt employed by firms (section 4.2). Section 5 presents our main comparative statics results, which predict the manner in which firms’ use of debt varies with (time-series changes and cross-sectional differences in) the nature of their investment opportunities.

4.1 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 to meet transitory funding needs, 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 future funding needs arise. Some real-world investments fit this simple pattern—acquisitions come to mind—and the evidence of Harford, Klasa, and Walcott (2008) indicates that bidders do borrow and deliberately deviate from their capital structure targets to fund acquisitions, and then subsequently rebalance back to target with a lag.

Figure 3 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. 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 3, the leverage of any given firm exhibits significant time-series volatility. To illustrate, figure 4 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

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6 Specifically, firms continue to incur the same total cost of maintaining cash balances as in the section 2 model, which equals the sum of the marginal agency cost, s, and the tax penalty for holding cash, τcτ. 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 τcτ, an algorithm that assigns maximal weight to taxes. Since τcτ 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 4. We use this approach only in simplified examples to illustrate the intuition of the model, and not in our comparative statics analysis.
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 illustrations. 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. 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 issuing debt and instead issue costly equity now 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 any costs of adjusting the stock of physical capital.

4.2 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 specific parameter values, we run the model for 100,200 periods, with each firm receiving random investment shocks and responding to each by adjusting its 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 decisions, e.g., its average debt-to-assets ratio. We interpret the resultant large sample statistics as expected values implied by the specific parameterization of the model. We repeat the exercise for different combinations of model parameters. We then generate testable predictions based on the difference in the expected value of a given capital structure variable associated with an underlying difference in the model’s parameter values.
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 total assets) under all cost specifications, as one would expect since firms in our model capture corporate 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 down 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 the volatility of leverage is around 50% (panel B).

The third finding is novel to the capital structure literature and especially interesting. Specifically, a firm’s ability to support high average amounts of debt in its capital structure increases when it has low cost access to equity capital to meet its marginal financing needs. Since the corporate income tax subverts a firm’s incentive to hold cash balances that it could tap to meet future funding needs, “levering up” is all-the-more costly because it utilizes debt capacity that could have been preserved as a substitute means of meeting future funding needs. The opportunity cost of utilizing debt capacity loses much of its deterrent value to “levering up” today when it is cheap for firms to tap equity markets. Hence firms 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, when they have the safety-valve alternative of issuing equity at low cost in order to meet the marginal financing needs that actually materialize in future periods.

5. Comparative statics predictions; Leverage and the nature of investment opportunities

This section presents comparative statics results that predict how firms’ leverage decisions vary with the nature of their investment opportunities. Section 5.1 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 5.2 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 5.3 provides an analytical definition of target leverage and delineates the model’s predictions regarding variation in target leverage as a function of differences in the nature of firms’ investment opportunities.

5.1 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 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 outlays (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 issue transitory debt 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 firms’ strong 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 future funding needs (row 2), they can forego preserving large amounts of untapped borrowing 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 marginal investment outlays (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 dollar 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 in order to free up debt capacity for future use, even though a cost of doing so is the loss of corporate tax benefits.

Although in our model firms have positive debt and cash balances on average, they do not have both outstanding simultaneously. With or without corporate taxes, firms with positive cash balances and debt are always better off if they use the cash to retire debt and thereby avoid the costs of maintaining cash balances, while freeing up debt capacity. Of course, real-world firms do simultaneously borrow and hold cash, most obviously because they require some cash to operate the business, a motive that 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 balances while debt is outstanding, firms can economize on 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. We show in section 6 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.

**5.2 Serial correlation, marginal profitability of investment, 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 attributable to differences in the costs of varying the physical stock of capital. (Smooth investment is generated by no fixed costs coupled with high convex costs of adjusting the capital stock, 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 model 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 investment opportunity attributes (row 4). Firms with the former investment characteristics typically forego large tax benefits of debt in order to preserve debt capacity that can be tapped to help fund their more volatile prospective investment outlays (row 2).

The specific reasons for the attraction of a more conservative capital structure differ depending on the investment attribute. The higher the serial correlation of investment shocks that a firm faces, the more likely a current large shock will soon be followed by another shock, 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 $\theta$ 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, and therefore to less value from preserving debt capacity.

The same intuition explains the higher average cash balances and lower net debt that the model predicts for 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.

5.3 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\(^7\) 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, in this case, it is easy to demonstrate that the optimal capital stock at any point in time is the level that equates the price of capital goods with the shadow value of capital. Because the value function is strictly convex, a neutral shock \((z = 1)\) corresponds to a uniquely optimal level of the capital stock, \(k^*\), which remains constant in the face of a repeated sequence of neutral shocks. Strict convexity of the value function then implies a unique target level of net debt, \(p^*\), and therefore a unique target level of debt, \(d^* = \max(p^*, 0)\), and an associated fixed target leverage ratio, \(d^*/k^*\).

In case #2, there are no fixed costs of adjusting the physical capital stock, but firms face variable costs of adjusting that stock that are convex in the 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

---

\(^7\)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.
(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 its investment constant at a rate that just allows for the replacement of depreciated capital. The capital stock therefore remains constant at a level \( k^* \) (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 5 plots target ratios of debt to total assets as a function of investment shock volatility.
and serial correlation for firms that respectively face (i) 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 5 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 6 illustrates the existence of a target leverage ratio and the convergence to that target for a firm that faces convex capital stock adjustment costs but no fixed costs of adjustment ($\alpha = 0.15, \gamma = 0.00$). 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 a large future investment outlay is 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 capital structure 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 target
leverage ratio. 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 $k^*$.

6. 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, $\lambda_1$, the serial correlation of productivity shocks, $\rho$, the standard deviation of productivity shocks, $\sigma_v$, and the curvature of the production function, $\theta$. We also perform an additional experiment in which we simultaneously increase the fixed cost of adjusting the capital stock, $\gamma$, 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, $\lambda_1$, for the baseline model estimates from Table 1, as well as for the four model variants described above. We allow $\lambda_1$ 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, which depict the relations between leverage and the serial correlation of productivity shocks, $\rho$, and the standard deviation of productivity shocks, $\sigma_v$. We allow $\rho$ to vary from 0.1 to 0.9 and $\sigma_v$ to vary from 0.15 to 0.5. In all five models leverage decreases with both $\rho$ and $\sigma_v$, 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, $\theta$, in which we let $\theta$ 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.

7. 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 imperfectly anticipated investment outlays. 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 capital structure targets, but all pro-active financing decisions move firms toward target.

Sufi (2005) provides evidence that one form of transitory debt—borrowing under pre-established lines of credit—plays a significant role in shaping real-world leverage dynamics. He reports that “when firms adjust their levels of debt upward or downward, they use lines of credit more than any other type of financing” and that credit lines are generally the largest source of firms’ capital structure adjustments, including both upward and downward adjustments and even when the sample is restricted to large adjustments. 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 do in fact routinely arrange their capital structures in advance to provide unused debt capacity that they can tap to meet future funding needs. Consistent with this interpretation, Harford, Klasa, and Walcott (2008) find that bidders borrow and deliberately deviate from their capital structure targets to fund acquisitions, and then rebalance back to target with a lag. These observed leverage dynamics cannot be explained by extant trade-off models which predict that all pro-active leverage changes move a firm in the direction of target, but they fully conform to the dynamics predicted by our model.

Our emphasis is squarely on the role of transitory debt, a concept that plays no role in extant trade-off theories in which firms have leverage targets because those theories ignore the interplay among target leverage, leverage dynamics, and firms’ desire to raise capital to meet the intertemporal sequence of funding needs that arise from investment shocks. Because in our
model firms issue transitory debt to finance investment outlays, the time path of 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 the firm’s stochastic investment opportunity set. Our approach yields a variety of new testable predictions that link capital structure decisions to variation in the volatility and serial correlation of investment shocks, the marginal profitability of investment, and properties of capital stock adjustment costs.

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 markedly 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 capital structure 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

\[
[\bar{k} (1 - \delta)^{35}, \ldots, \bar{k} (1 - \delta)^{1/2}, \bar{k}] .
\]  

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 rate of economic depreciation, \( \delta \), the real interest rate, \( r \), and the effective corporate tax rate, \( \tau_c \). We set \( \delta \) at 0.15, which is approximately equal to the average in our data set of the ratio of depreciation to the capital stock. We set the real interest rate equal to 0.015, which is approximately equal to the average of the realized real interest rate over the twentieth century. We set \( \tau_c \) at the statutory rate of 0.35.

The goal is to estimate \( b \) by matching a set of \textit{simulated moments}, denoted as \( h(y_{ik}(b)) \), with the corresponding set of actual \textit{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

\[
\hat{b} = \arg\min_b g_n(b)' \hat{W}_ng_n(b),
\]

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 \( \hat{b} \) is given by

\[
\sqrt{n}(\hat{b} - b) \xrightarrow{d} \mathcal{N}(0, \operatorname{avar}(\hat{b}))
\]

in which

\[
\operatorname{avar}(\hat{b}) \equiv \left(1 + \frac{1}{K} \right) \left[ \frac{\partial g_n(b)}{\partial b} W \frac{\partial g_n(b)}{\partial b'} \right]^{-1} \left[ \frac{\partial g_n(b)}{\partial b} \Omega \frac{\partial g_n(b)}{\partial b'} \right] \left[ \frac{\partial g_n(b)}{\partial b} W \frac{\partial g_n(b)}{\partial b'} \right]^{-1}
\] (13)
in which $W$ is the probability limit of $\hat{W}_n$ as $n \to \infty$, and in which $\Omega$ is the probability limit of a consistent estimator of the covariance matrix of $h(x_i)$.

The success of this procedure relies on picking moments $h$ that can identify the structural parameters $b$. In other words, the model must be identified. Global identification of a simulated moments estimator obtains when the expected value of the difference between the simulated moments and the data moments equal zero if and only if the structural parameters equal their true values. A sufficient condition for identification is a one-to-one mapping between the structural parameters and a subset of the data moments of the same dimension. Although our model does not yield such a closed-form mapping, we take care in choosing appropriate moments to match, and we use a minimization algorithm, simulated annealing, that avoids local minima.

We pick the following 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 7.8 Average investment helps identify the adjustment cost parameters, $a$ and $\gamma$, 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, $\theta$, and the adjustment cost parameters. Lower $\theta$, higher $a$, and lower $\gamma$ produce less volatile investment. The next moment is the skewness of the rate of investment, which helps identify the fixed adjustment cost parameter, $\gamma$. Higher values of this parameter lead to more intermittent, and thus more skewed investment. 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 $zk^\theta/k$: the higher $\theta$, the higher average operating income. Our next two moments capture the important features

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8 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).
of the driving process for \( z \). Here, we estimate 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, \( \lambda_1 \) and \( \lambda_2 \). Our final moment is the ratio of cash to assets. In our simulations it is defined as \( c/k \), conditional on \( c > 0 \), and in Compustat it is defined as the ratio of item 1 to item 6. This moment helps identify the agency cost parameter.

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

One final issue is unobserved heterogeneity in our data from Compustat. Recall that our simulations produce \( i.i.d. \) firms. Therefore, in order to render our simulated data comparable to our actual data we can either add heterogeneity to the simulations, or remove the heterogeneity from the actual data. We opt for the latter approach, using fixed firm and year effects in the estimation of our regression-based data moments 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 $V(k, p, z) = 0$. 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, $\xi$, 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

$$R(k', z') = (1 - \xi) (1 - \delta) (k' - k) + (1 - \tau_c) (z' \pi(k') - \delta k') - A(k', k) + (1 - \xi) (1 - \delta) k$$

(14)

$$= (1 - \xi) (1 - \delta) k' + (1 - \tau_c) (z' \pi(k') - \delta k') - A(k', k)$$

(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 $Z_d(k', p', z)$ be the set of states in which the firm defaults, as a function of $k'$, $p'$, and the current state $z$. Similarly, let $Z_s(k', p', z)$ be the set of states in which the firm remains solvent. The interest rate, $r_d(k', p', z)$, is then defined by:

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

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.
References


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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. \( \lambda_1 \) and \( \lambda_2 \) are the linear and quadratic costs of equity issuance. \( \sigma_v \) is the standard deviation of the innovation to \( \ln(z) \), in which \( z \) is the shock to the revenue function. \( \rho \) is the serial correlation of \( \ln(z) \). \( \theta \) is the curvature of the revenue function, \( zk^\theta \). \( \gamma \) and \( a \) are the fixed and convex adjustment cost parameters, and \( s \) is the agency cost parameter. \( \bar{p}/k^{ss} \) is the debt ceiling expressed as a fraction of the steady state capital stock, \( k^{ss} \).

A. Moments

<table>
<thead>
<tr>
<th>Actual moments</th>
<th>Simulated moments</th>
<th>T-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance of investment ( (I/k) )</td>
<td>0.0385</td>
<td>0.0329</td>
</tr>
<tr>
<td>Variance of leverage ( (d/k) )</td>
<td>0.0118</td>
<td>0.0165</td>
</tr>
<tr>
<td>Average leverage ( (d/k) )</td>
<td>0.2393</td>
<td>0.2423</td>
</tr>
<tr>
<td>Average equity issuance ( (e/k) )</td>
<td>0.0407</td>
<td>0.0231</td>
</tr>
<tr>
<td>Average Tobin’s ( q ) ( (V + p)/k )</td>
<td>3.6707</td>
<td>3.9549</td>
</tr>
<tr>
<td>Third central moment of investment ( (I/k) )</td>
<td>0.0534</td>
<td>0.0363</td>
</tr>
<tr>
<td>Average operating income ( (zk^\theta/k) )</td>
<td>0.1915</td>
<td>0.1903</td>
</tr>
<tr>
<td>Serial correlation of income ( (zk^\theta/k) )</td>
<td>0.6635</td>
<td>0.6488</td>
</tr>
<tr>
<td>Variance of the innovation to income ( (zk^\theta/k) )</td>
<td>0.0048</td>
<td>0.0015</td>
</tr>
<tr>
<td>Average cash balances ( (c/k) ), conditional on ( c &gt; 0 )</td>
<td>0.1399</td>
<td>0.1350</td>
</tr>
<tr>
<td>Variance of equity issuance ( (e/k) )</td>
<td>0.0079</td>
<td>0.0051</td>
</tr>
<tr>
<td>Average investment ( (I/k) )</td>
<td>0.1868</td>
<td>0.1657</td>
</tr>
</tbody>
</table>

B. Parameter estimates

<table>
<thead>
<tr>
<th>( \lambda_1 )</th>
<th>( \lambda_2 )</th>
<th>( \sigma_v )</th>
<th>( \rho )</th>
<th>( \theta )</th>
<th>( \gamma )</th>
<th>( a )</th>
<th>( s )</th>
<th>( \bar{p}/k^{ss} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1615</td>
<td>0.0041</td>
<td>0.2843</td>
<td>0.7280</td>
<td>0.7880</td>
<td>0.0034</td>
<td>0.1519</td>
<td>0.0077</td>
<td>0.7196</td>
</tr>
<tr>
<td>(0.0164)</td>
<td>(0.4662)</td>
<td>(0.0479)</td>
<td>(0.1790)</td>
<td>(0.0673)</td>
<td>(0.0016)</td>
<td>(0.0092)</td>
<td>(0.0157)</td>
<td>(0.0143)</td>
</tr>
</tbody>
</table>
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, $\lambda_1$ (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, $\lambda_2$, 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 ($d/k$)

<table>
<thead>
<tr>
<th>Cost of maintaining cash balances:</th>
<th>Linear cost of accessing external equity:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>0.803</td>
<td>0.313</td>
<td>0.232</td>
</tr>
<tr>
<td></td>
<td>0.806</td>
<td>0.324</td>
<td>0.266</td>
<td>0.246</td>
</tr>
<tr>
<td></td>
<td>0.801</td>
<td>0.326</td>
<td>0.271</td>
<td>0.253</td>
</tr>
<tr>
<td></td>
<td>0.806</td>
<td>0.328</td>
<td>0.272</td>
<td>0.258</td>
</tr>
<tr>
<td>High</td>
<td>0.794</td>
<td>0.328</td>
<td>0.275</td>
<td>0.265</td>
</tr>
</tbody>
</table>

### B. Standard deviation of $d/k$

<table>
<thead>
<tr>
<th>Low</th>
<th>0.498</th>
<th>0.099</th>
<th>0.093</th>
<th>0.095</th>
<th>0.093</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.497</td>
<td>0.103</td>
<td>0.098</td>
<td>0.100</td>
<td>0.101</td>
</tr>
<tr>
<td></td>
<td>0.499</td>
<td>0.104</td>
<td>0.099</td>
<td>0.100</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>0.498</td>
<td>0.102</td>
<td>0.102</td>
<td>0.102</td>
<td>0.105</td>
</tr>
<tr>
<td>High</td>
<td>0.495</td>
<td>0.103</td>
<td>0.101</td>
<td>0.102</td>
<td>0.105</td>
</tr>
</tbody>
</table>
**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.

<table>
<thead>
<tr>
<th>Standard deviation of investment shocks:</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average investment ((I/k))</td>
<td>0.158</td>
<td>0.160</td>
<td>0.169</td>
</tr>
<tr>
<td>2. Standard deviation of investment ((I/k))</td>
<td>0.129</td>
<td>0.145</td>
<td>0.187</td>
</tr>
<tr>
<td>3. Frequency of investment</td>
<td>0.852</td>
<td>0.833</td>
<td>0.775</td>
</tr>
<tr>
<td>4. Average debt-to-assets ratio ((d/k))</td>
<td>0.722</td>
<td>0.508</td>
<td>0.336</td>
</tr>
<tr>
<td>5. Standard deviation of leverage ((d/k))</td>
<td>0.110</td>
<td>0.101</td>
<td>0.096</td>
</tr>
<tr>
<td>6. Average net debt ((d - c)/k)</td>
<td>0.722</td>
<td>0.333</td>
<td>0.190</td>
</tr>
<tr>
<td>7. Standard deviation of net debt</td>
<td>0.110</td>
<td>0.127</td>
<td>0.145</td>
</tr>
<tr>
<td>8. Average cash balances to assets ((c/k))</td>
<td>0.000</td>
<td>0.002</td>
<td>0.010</td>
</tr>
<tr>
<td>9. Standard deviation of ((c/k))</td>
<td>0.000</td>
<td>0.083</td>
<td>0.153</td>
</tr>
<tr>
<td>10. Frequency of positive debt outstanding</td>
<td>1.000</td>
<td>0.965</td>
<td>0.908</td>
</tr>
<tr>
<td>11. Average of positive leverage values</td>
<td>0.722</td>
<td>0.348</td>
<td>0.223</td>
</tr>
<tr>
<td>12. Average of positive cash balance values</td>
<td>0.000</td>
<td>0.091</td>
<td>0.165</td>
</tr>
<tr>
<td>13. Debt issuance frequency</td>
<td>0.468</td>
<td>0.451</td>
<td>0.438</td>
</tr>
<tr>
<td>14. Debt reduction frequency</td>
<td>0.521</td>
<td>0.528</td>
<td>0.499</td>
</tr>
<tr>
<td>15. Average debt issuance/assets</td>
<td>0.088</td>
<td>0.106</td>
<td>0.114</td>
</tr>
<tr>
<td>16. Average debt reduction/assets</td>
<td>-0.069</td>
<td>-0.076</td>
<td>-0.075</td>
</tr>
<tr>
<td>17. Equity issuance frequency</td>
<td>0.255</td>
<td>0.261</td>
<td>0.255</td>
</tr>
<tr>
<td>18. Average equity issuance/assets</td>
<td>0.028</td>
<td>0.022</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Average fraction of investment funded from:

| Current cash flow                        | 0.840| 0.847    | 0.832|
| Cash balances                            | 0.000| 0.004    | 0.017|
| Debt issuance                            | 0.143| 0.148    | 0.148|
| Equity issuance                          | 0.017| 0.018    | 0.016|
### 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.

<table>
<thead>
<tr>
<th></th>
<th>Shock serial correlation</th>
<th>Marginal profitability</th>
<th>Optimal Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>1. Average investment ($I/k$)</td>
<td>0.151</td>
<td>0.178</td>
<td>0.161</td>
</tr>
<tr>
<td>2. Standard deviation of investment ($I/k$)</td>
<td>0.051</td>
<td>0.244</td>
<td>0.150</td>
</tr>
<tr>
<td>3. Frequency of investment</td>
<td>0.998</td>
<td>0.816</td>
<td>0.828</td>
</tr>
<tr>
<td>4. Average debt-to-assets ratio ($d/k$)</td>
<td>0.889</td>
<td>0.085</td>
<td>0.711</td>
</tr>
<tr>
<td>5. Standard deviation of leverage ($d/k$)</td>
<td>0.038</td>
<td>0.192</td>
<td>0.083</td>
</tr>
<tr>
<td>6. Average net debt (($d - c)/k$)</td>
<td>0.889</td>
<td>-0.453</td>
<td>0.711</td>
</tr>
<tr>
<td>7. Standard deviation of net debt</td>
<td>0.038</td>
<td>1.413</td>
<td>0.192</td>
</tr>
<tr>
<td>8. Average cash balances to assets ($c/k$)</td>
<td>0.000</td>
<td>0.530</td>
<td>0.000</td>
</tr>
<tr>
<td>9. Standard deviation of ($c/k$)</td>
<td>0.000</td>
<td>1.894</td>
<td>0.000</td>
</tr>
<tr>
<td>10. Frequency of positive debt outstanding</td>
<td>1.000</td>
<td>0.527</td>
<td>1.000</td>
</tr>
<tr>
<td>11. Average of positive leverage values</td>
<td>0.889</td>
<td>0.161</td>
<td>0.711</td>
</tr>
<tr>
<td>12. Average of positive cash balance values</td>
<td>0.000</td>
<td>1.256</td>
<td>0.000</td>
</tr>
<tr>
<td>13. Debt issuance frequency</td>
<td>0.024</td>
<td>0.263</td>
<td>0.420</td>
</tr>
<tr>
<td>14. Debt reduction frequency</td>
<td>0.017</td>
<td>0.272</td>
<td>0.437</td>
</tr>
<tr>
<td>15. Average debt issuance/assets</td>
<td>0.027</td>
<td>0.100</td>
<td>0.030</td>
</tr>
<tr>
<td>16. Average debt reduction/assets</td>
<td>-0.034</td>
<td>-0.059</td>
<td>-0.028</td>
</tr>
<tr>
<td>17. Equity issuance frequency</td>
<td>0.165</td>
<td>0.293</td>
<td>0.061</td>
</tr>
<tr>
<td>18. Average equity issuance/assets</td>
<td>0.016</td>
<td>0.039</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Average fraction of investment funded from:

<table>
<thead>
<tr>
<th></th>
<th>Current cash flow</th>
<th>Cash balances</th>
<th>Debt issuance</th>
<th>Equity issuance</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.</td>
<td>0.987</td>
<td>0.000</td>
<td>0.002</td>
<td>0.011</td>
</tr>
<tr>
<td>20.</td>
<td>0.000</td>
<td>0.092</td>
<td>0.067</td>
<td>0.028</td>
</tr>
<tr>
<td>21.</td>
<td>0.000</td>
<td>0.000</td>
<td>0.222</td>
<td>0.000</td>
</tr>
<tr>
<td>22.</td>
<td>0.000</td>
<td>0.090</td>
<td>0.011</td>
<td>0.009</td>
</tr>
</tbody>
</table>

49
This figure plots the long-run leverage paths from Lemmon, Roberts, and Zender (2008) in panel A versus the long-run 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. Lemmon, Roberts, and Zender’s (2008) long-run leverage paths

B. Model generated long-run average leverage
Long-run average leverage paths: net-of-target and in a model with debt issuance costs

This figure plots the long-run net-of-target leverage paths from our estimated model in panel A and the long-run leverage paths from a model with debt issuance costs 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 net-of-target long-run average leverage

B. Model generated long-run average leverage in the model with debt issuance costs
Figure 3

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 4

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

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