Collateral, Taxes, and Leverage*

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Abstract

We quantify the importance of collateral versus taxes for firms' capital structures. We estimate a dynamic contracting model in which a firm seeks financing and is subject to taxation. In the model, collateral constraints arise endogenously. Optimal firm leverage stays a safe distance from the constraint, balancing the tax benefit of debt with the cost of lost financial flexibility. Models with and without taxes fit the data equally well, and optimal leverage rarely responds to the tax rate. We estimate the value of preserving financial flexibility at 7.9% of firm assets, which is comparable to the estimated tax benefit.

1. Introduction

How important are taxes for corporate capital structures? The traditional discussion of this issue is based on the framework of Modigliani and Miller (1958) in which capital structure is irrelevant for firm value in the absence of taxes. Against this backdrop, taxes and the countervailing friction of the costs of financial distress then provide the tradeoff that determines an optimal amount of debt in a firm's capital structure. Yet this framework abstracts from two critical ingredients that influence corporate borrowing: lenders' desire to be repaid and the time-varying need for funds to implement new projects. In addition, many models that embody the traditional tradeoff between taxes and bankruptcy costs take external financial frictions as exogenous, so that firms' actions and characteristics never affect the terms of their financing.

We depart from this paradigm by quantifying the importance of contracting frictions in shaping corporate financial decisions. In particular, we compare the importance of endogenous collateral constraints that arise in a contracting environment with a more traditional friction that is central to most models of corporate capital structure: taxation. To this end, we estimate a version of the dynamic model of capital structure in Rampini and Viswanathan (2013), which is based on limited enforceability of contracts between lenders and firms. We extend this framework by including the taxation of income and a tax benefit of debt. Thus, in the model, optimal leverage balances the value of preserving debt capacity and financial flexibility with the traditional tax benefit.

The results from our model estimation are striking. The model both with and without taxation can be reconciled with average firm leverage, with only modest changes in model parameters across the two cases. Similarly, our counterfactuals show that changing the corporate tax rate has only a limited effect on optimal firm leverage. Our parameter estimates allow us to quantify the value to the firm of preserving debt capacity in the face of external financial frictions. We find that this value is a substantial 7.9% of firm assets, and it is comparable to our estimates of the tax benefit of debt, which range from 5.8% to 10% of firm assets. These last two results stand in sharp contrast to the horse and rabbit stew of Miller (1977) that has long characterized the tradeoff between the tax benefit and financial distress costs. Thus, by focusing on the immediate, everyday tradeoff between the tax benefit and financial flexibility, we end up with a stew of two similar-sized horses.

The intuition for these results lies in the structure of the model, in which an infinitely lived firm enters the market with a stock of capital that can generate taxable revenues. However, the firm has insufficient funds to scale the project to an optimal level and must obtain financing from a lender, which is more patient than the firm. There are no informational asymmetries: the lender can observe firm policies. However, financing is not frictionless because the firm can renege on the financing contract, abscond with the firm's capital, and start over, albeit after losing part of the firm's capital as collateral. An additional friction is the firm's limited liability, which prevents costless equity infusions. Finally, we assume that the firm receives a rebate from the tax authority based on the amount of financing it receives.

The optimal financing contract maximizes the firm's equity value, and because the lender commits to the contract, the only feasible contracts are self-enforcing, so that the firm never has an incentive to renege. The contract specifies optimal state-contingent financing, payout, and investment policies so that the firm's long-term benefits from adhering to the contract outweigh the benefits from repudiating it. Interestingly, the contract is sufficiently flexible that the firm can save in some states of the world. We show, as in Rampini and Viswanathan (2013) that the constraint that ensures contract enforcement is equivalent to a collateral constraint. Optimal leverage then balances the benefit of financial flexibility with the benefit of satisfying the firm's impatience. The value of financial flexibility in turn stems from the endogenous collateral constraint, and the impatience benefit stems in part from the lender's inherent patience relative to the firm and in part from the tax advantage of debt. This tradeoff leads the firm to conserve debt capacity, so that it seldom bumps up against the collateral constraint. This incentive to preserve financial flexibility is shaped by many forces, including the position of the collateral constraint, the firm's technology, and the amount of uncertainty the firm faces.

In this setting, taxes have little effect on the optimal borrowing contract. To understand this result, note that financial frictions are typically negligible for small amounts of outside financing. In our model, the relevant friction is a debt capacity preservation motive that arises in response to an endogenous financial constraint. More generally, these frictions could include traditional financial distress costs. Thus, at low levels of borrowing, borrowing is essentially a constant-returns technology for transferring funds through time. However, at some level of borrowing, financial frictions become important, and decreasing returns set in. That is, each extra dollar borrowed today incurs a higher marginal cost, which in our model takes the form of lost financial flexibility. After this point, the firm optimally chooses an interior financial policy that balances the costs arising from financial frictions with the tax and impatience benefits of debt.

Now consider two firms, one of which can raise a great deal of debt without encountering financial frictions and another that can only raise a small amount of debt before decreasing returns to scale set in. In this case, increasing the corporate tax rate from zero to a small positive rate will cause both firms to borrow up to the point where the costs from financing frictions equal the tax benefit. Because financing initially exhibits constant returns, lower levels of borrowing cannot be optimal. Put differently, at low levels of borrowing, flexibility costs are near zero, so even the smallest tax benefit will induce large amounts of borrowing. Next, increasing the interest tax deduction further by raising the tax rate will increase optimal borrowing, but this effect will be small relative to the large jump induced by the initial small tax. Thus, the cross-sectional distribution of firms depends more on the cross-sectional distribution of financial frictions, and less on the tax rate. Of course, this argument can also be extended to a single firm if the level of financial frictions evolves over time. In either case, taxes have a second-order effect on capital structure.

Although this intuition is qualitative, we show that it is quantitatively important because it comes from a model whose parameters we do not choose arbitrarily. Instead, we estimate them via simulated method of moments. The data therefore put tight restrictions on our model parameters and on predictions from the model. This feature of our approach is important because the relative magnitudes of the costs and benefits of leverage have been the center of much of the research agenda in capital structure.

We find largely reasonable estimates of our model parameters. Our estimates of the firm's technological characteristics, such as the variance of technology shocks and the extent of decreasing returns to scale are in line with many other structural estimation studies (e.g. Hennessy and Whited 2005, 2007). More importantly, we estimate a parameter that describes the firm's incentive to renege on the contract: the fraction of the firm's assets that are lost to creditors in default. We find that this collateral parameter is statistically different from zero and economically important. Finally, we find that the model, although highly stylized, can match important features of the data in large samples of heterogeneous firms and in smaller samples from several diverse industries. We conclude that an optimal contracting model can characterize broad features of the data, even though the form of real-world contracts deviates from the exact model predictions.

Our findings would have been hard to obtain by more conventional methods. Capital structure and firm investment are endogenous, and most tax changes are motivated by political economy considerations. Even when tax changes are plausibly exogenous, they affect so many firm decisions that it is hard to pinpoint a link between interest deductibility and specific capital structure effects. In addition, the main sources of the contracting frictions are unobservable, and proxies for these frictions are unavailable. Using a model helps solve these problems by putting enough structure on the data to identify the effects of interest. Finally, quantifying the benefit of financial flexibility requires calculating a counterfactual, which cannot be done absent a theoretical framework.

We provide two demonstrations of external model validity. First, we estimate our collateral parameter on data from 24 industries and then regress a conventional measure of industry-level asset tangibility on the collateral parameters. We find a significant coefficient of exactly 0.99. Second, using a natural experiment that affects creditors' ability to repossess collateral in bankruptcy, we find that the significant changes in leverage surrounding this experiment do indeed stem from movements in the position of the collateral constraint.

Our paper fits into several strands of the literature. The first is a set of theoretical papers that uses limited commitment models such as ours to study such subjects as international trade contracts (Thomas and Worrall 1994), financial constraints (Albuquerque and Hopenhayn 2004), macroeconomic dynamics (Cooley, Marimon, and Quadrini 2004; Jermann and Quadrini 2007, 2012), investment (Lorenzoni and Walentin 2007; Schmid 2011), risk management (Rampini and Viswanathan 2010), and capital structure (Rampini and Viswanathan 2013). Our model is most closely related to that in Rampini and Viswanathan (2013), but our paper is unique in this group because we use a limited commitment model as the basis of an explicitly *empirical* investigation, whereas the rest of these papers are theoretical.

Our paper is also related to dynamic contracting models based on moral hazard (e.g. DeMarzo and Sannikov 2006; Biais, Mariotti, Rochet, and Villeneuve 2010; DeMarzo, Fishman, He, and Wang 2012). In these models, leverage serves solely as a device to incentivize the entrepreneur from consuming private benefits. In contrast, in the limited enforcement model we consider, leverage is set so that the lender can guarantee repayment.

A further related strand of the literature is the structural estimation of dynamic models in corporate finance, such as Hennessy and Whited (2005, 2007) or Taylor (2010). Our paper departs from these predecessors in one important way. Instead of specifying financial constraints or agency concerns as exogenous parameters, we derive financial constraints from an optimal contracting framework, and then estimate the magnitudes of the underlying frictions. In this regard, our paper is similar only to Nikolov and Schmid (2012). However, their estimation is based on a dynamic moral hazard model, and their goal is to quantify private benefits. Our focus differs sharply in that we quantify the relative effects of taxation and contract enforcement on capital structure.

Finally, our work builds on previous attempts to measure the value of financial flexibility. DeAngelo, DeAngelo, and Whited (2011) explores the implications of financial flexibility for leverage dynamics in a related model. On the empirical side, several studies, such as Marchica and Mura (2010) and Denis and McKeon (2012), have shown that financial flexibility impacts corporate policies, but none of these studies have quantified the value of flexibility, as we do.[1] Finally, Gamba and Triantis (2008) assess the value of relaxing financing frictions in a dynamic model, but because their parameters are not estimated, their results are only qualitative.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 describes the data. Section 4 outlines the estimation methodology and identification strategy. Section 5 presents the estimation results. Section 6 describes our counterfactuals. Section 7 presents several model extensions, and Section 8 concludes. The Appendices contain proofs, describe our model solution procedure, provide estimation details, and present auxiliary estimation results.

2. The Model

In this section, we develop the model, which is a simple discrete-time, infinite-horizon, limited-enforcement contracting problem in the spirit of Albuquerque and Hopenhayn (2004) or Lorenzoni and Walentin (2007). Our model follows Rampini and Viswanathan (2013) most closely. We start

[1] Faulkender and Wang (2006) and several subsequent studies quantify the marginal value of cash, but cash is not equivalent to the broader concept of financial flexibility.

with a description of the firm's technology. We then move on to the incentive and contracting environment. Next, we characterize the optimal contract. Finally, we consider taxation.

2.1 Technology

We consider a model of a representative firm that starts business at time t with capital stock k_t and can start to use this capital. The firm uses the production technology $y_t = z_t k_t^{\alpha}$, in which k_t is a capital input, α is a parameter that governs returns to scale, and z_t is a firm-specific technology shock, which follows a Markov process with finite support $\mathbb{Z}$ and transition matrix Π. The law of motion for k_t is given by:

$$k_{t+1} = (1-\delta)k_t + i_t, \tag{1}$$

in which i_t is capital investment at time t and δ is the capital depreciation rate.

2.2 Contracting Environment

When the firm starts, it has no current profits to fund expansion, and it therefore obtains financing by entering a contractual relationship with a financial intermediary/bank/lender. Three important assumptions shape the financing contract. First, the firm has limited liability. Second, the lender commits to the long-run contract, while the firm can choose to default; that is, the long-run contract has one-sided commitment.

The third assumption is particularly important. The firm has a higher discount rate than the lender, as in Lorenzoni and Walentin (2007). Let β be the discount factor for the firm, and let β_C be the discount factor for the bank, with $\beta_C > \beta$ so that firms are less patient than lenders. As discussed below, when $\beta = \beta_C$, the firm can sometimes be completely unconstrained, so that financial structure is irrelevant. In order to estimate this model, we require a determinate financial structure, so we assume that $\beta_C > \beta$. A plausible real-world friction that might force a wedge between borrowers' and lenders' discount factors is the existence of insured deposits, which provide banks with a cheap source of capital and thus induces them to behave patiently. In addition, a natural way to motivate the difference in the discount rates of the lender and firm can be found in Ai, Kiku, and Li (2013). In their general equilibrium economy, both the lender and firm have the same rate of time preference, but the economy grows. In this setting, the discount rate of the firm exceeds that of the lender by expected consumption growth divided by the intertemporal elasticity of substitution. Thus, the lender is more patient than the firm in growth economies. As we show below, the difference between β_C and β is important for our results concerning the sensitivity of optimal financial policy with respect to the corporate tax rate. Therefore, we examine the implications of relaxing the assumption that $\beta_C > \beta$ below.

The timing of events is as follows. When the firm starts at time t, it has an initial capital stock k_t and receives a draw from the distribution of the productivity shock. It then signs a long-term contract with the lender that provides initial funding. Once the firm enters the contract, production takes place and the firm invests, pays out dividends, and makes payments to the lender as required in the contract. At the beginning of the next period, the firm can choose whether or not to renege on the contract after observing the productivity shock and earning current-period profits. If the firm does not renege, the plan defined by the contract continues.

We now define the specifics of the contract. Let z_t be the state at time t, and let $z^t = (z_0, z_1, \ldots, z_t)$ denote the history of states from time 0 to t. A contract between the entrant and the lender at time t is a triple $(i_{t+j}(z^{t+j}), d_{t+j}(z^{t+j}), p_{t+j}(z^{t+j}))_{j=0}^{\infty}$ of sequences specifying the investment, i_{t+j}, the dividend distribution, d_{t+j}, and the payment to the lender, p_{t+j}, as functions of the firm's current history. We allow p_{t+j} to be either positive or negative, with positive amounts corresponding to repayments to the lender and negative amounts corresponding to additional external financing. The contract is thus fully state-contingent.

Of course, real-world financial contracts do not literally specify policies in this manner. Nonetheless, real-world state-contingent financial contracts are ubiquitous. All loan and debt contracts contain covenants, and these covenants often specify limits on investment and dividend policies. In addition, some common debt instruments, such as credit lines, floating-rate debt, and loans with performance pricing grids, are by nature state-contingent.

We define a contract to be feasible if it meets the following two conditions:

$$z_{t+j} k_{t+j}^{\alpha} - i_{t+j}(z^{t+j}) \geq d_{t+j}(z^{t+j}) + p_{t+j}(z^{t+j}) \tag{2}$$

$$d_{t+j}(z^{t+j}) \geq 0 \tag{3}$$

for any z^{t+j}, $j \geq 0$. The constraint (2) is simply the budget constraint, which requires that net revenue be at least as large as payments to shareholders and the lender. The constraint (3) is the result of limited liability. It prevents the firm from obtaining costless external equity financing from shareholders. Without such a constraint, the contract would be unnecessary. In this detail, our model departs from dynamic investment-based capital structure models, such as Hennessy and Whited (2005), in which the firm can extract negative dividends from shareholders, but only after paying them a premium. As such, our model cannot capture the equity issuances we see in the data. However, given that firm initiated equity issuances are both tiny and rare (DeAngelo, DeAngelo, and Stulz 2010; McKeon 2013), we view this drawback of our model as minor. In addition, below we check the robustness of our results to adding equity issuance to the model.

We assume that the long-run contract is not fully enforceable. The firm has control of its capital and has the option to renege on the contract and default, leaving the lender with no further payments on the loan and thus setting its liability to zero. If the firm defaults, it can keep a fraction $(1-\theta)$ of the capital k_t, as well as all cash flow from time t production. At this point, the firm is not excluded from the market. Instead, it can reinvest the capital and sign a new financing contract. Thus, the form of punishment for the firm in default is only the loss of a fraction θ of its assets. This feature of the model captures Chapter 11 renegotiation, rather than Chapter 7 liquidation.

The parameter θ can be thought as the fraction of assets that can be collateralized and thus surrendered to the creditor in default. Further, as in Rampini and Viswanathan (2013), θ can be interpreted as the fraction of *tangible* assets that can be pledged to the lender. Thus, in our estimation, this parameter captures both the tangibility of the firm's assets and the pledgability of those tangible assets. The lender's seizure of assets in default does not alter the lender's incentives or the basic form of the problem, because the lender commits to the contract.

To understand the effect of limited enforcement on the form of the contract, it is useful to define the total value to the firm of repudiating an active contract. Let $\mathbb{E}(\cdot)$ be the expectation operator with respect to the transition function Π. Then this repudiation value at time τ is:

$$D(k_\tau, z_\tau) = \mathbb{E}_\tau \sum_{j=0}^{\infty} \beta^j \hat{d}_{\tau+j}(z_{\tau+j}), \tag{4}$$

in which $\{\hat{d}_{\tau+j}(z_{\tau+j})\}_{j=0}^{\infty}$ is the dividend stream the firm obtains at time τ, with a fraction $(1-\theta)$

of its capital stock, after it repudiates its original contract and then enters into a new contract. For simplicity, we assume that the firm repudiates after production. The diversion value in (4) is a primitive of the model and constitutes the equity value of reinvesting the diverted capital. Equivalently, this sum is the contract value for the shareholder with capital $(1-\theta)k_\tau$.

Because the lender commits to the contract, in order for the contract to be self-enforcing, the firm cannot have any incentive to deviate from its terms. Therefore, the discounted dividends from continuing the contract should be no less than the repudiation value. That is, the firm will not renege on the contract at time τ provided that:

$$D(k_\tau, z_\tau) \leq \mathbb{E}_\tau \sum_{j=0}^{\infty} \beta^j d_{\tau+j}. \tag{5}$$

The contract is then self-enforcing/enforceable if (5) is satisfied for all $\tau > t$.

2.3 Contracting Problem

The optimal contract maximizes the equity value of the firm subject to several constraints that define the contract. This problem for an entrant is defined as follows:

$$\max_{\{d_{t+j}, i_{t+j}, p_{t+j}\}_{j=0}^{\infty}} \quad \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j d_{t+j} \tag{6}$$

subject to:

$$d_{t+j} \geq 0, \tag{7}$$

$$z_{t+j} k_{t+j}^{\alpha} - i_{t+j} - p_{t+j} - d_{t+j} \geq 0, \tag{8}$$

$$\mathbb{E}_\tau \sum_{j=0}^{\infty} \beta^j d_{\tau+j} \geq D(k_\tau, z_\tau), \quad \forall \tau > t \tag{9}$$

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta_C^j p_{t+j} \geq 0. \tag{10}$$

Equations (7)–(9) are the dividend nonnegativity constraint, the budget constraint, and the enforcement constraint. Equation (10) is the initial participation constraint for the lender. Intuitively, the lender will only enter a financial contract with the firm if it expects the present value of its disbursements and repayments to be nonnegative. Note that the lender discounts these payments at a lower rate than the firm.

2.3.1. Collateral Constraint

Because of the presence of the future contract value in the enforcement constraint (9), the model given by (6)–(10) is difficult to solve. Therefore, as a first step, we follow Alvarez and Jermann (2000), Bai and Zhang (2010), and Rampini and Viswanathan (2013) by showing that the enforcement constraint is equivalent to an endogenous borrowing constraint. To start, we define

$$q_\tau \equiv \mathbb{E}_\tau \sum_{j=0}^{\infty} \beta_C^j p_{\tau+j},$$

which is the contract value for the lender at time τ. The collateral constraint is then defined as:

$$\theta k_\tau (1-\delta) \geq q_\tau(z_\tau), \quad \forall \tau > 0. \tag{11}$$

Next, we construct a transformed problem that maximizes (6) subject to (7), (8), (10), and (11). The following proposition shows that the solution to this transformed problem equals the solution to the original problem.

Proposition 1 *A sequence of* $\{k_{t+j+1}, \{q_{t+j+1}(z_{t+j+1})\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ *is optimal in the original problem given by given by (6)–(10) if and only if it is optimal in the transformed problem given by (6), (7), (8), (10), and (11).*

As stressed in Rampini and Viswanathan (2013), the constraint (11) can also be interpreted as a collateral constraint, so that θ represents the fraction of assets that can be pledged as collateral in default. The interpretation of (11) as a collateral constraint embodies many commonly observed borrowing practices. Most loans are drawn with the specific stated purpose of spending the proceeds on an asset, and some are secured by the asset. In addition, credit lines and term loans often have an upper limit that is contingent on what is called a borrowing base. The base consists of a set of pledgeable assets, usually current assets such as inventory or accounts receivable. The value of this base can vary over time (Taylor and Sansone 2006). Thus, this collateral constraint conforms to the types of actual financial contracts we observe in the real world.

2.4 Recursive Formulation

As in Spear and Srivastava (1987) and Abreu, Pearce, and Stacchetti (1990), we now rewrite the original problem with the enforcement constraint (9) recursively using q_τ as a state variable.

$$V(k,q,z) = \max_{k',q(z')} \quad zk^\alpha + k(1-\delta) - q - k' + \beta_C \mathbb{E}q(z') + \beta \mathbb{E}V(k', q'(z'), z') \tag{12}$$

subject to:

$$zk^\alpha + k(1-\delta) - q - k' + \beta_C \mathbb{E}q(z') \geq 0, \tag{13}$$

$$\theta k'(1-\delta) \geq q(z'), \quad \forall z' \in \mathbb{Z}, \tag{14}$$

in which a prime denotes the subsequent period, and no prime denotes the current period.

We now simplify the problem given by (12)–(14) by reducing the dimension of the state space. If we define net wealth as $w \equiv zk^\alpha + k(1-\delta) - q$, it is straightforward to show that the solution to (12)–(14) depends only on this variable and not on its individual components. To see this property of the solution, note that without the constraints (13) and (14), the solution to the unconstrained optimization (12) does not depend on both k and q because $\beta_C > \beta$ implies that the firm indefinitely postpones repaying the lender and always chooses the highest possible level of financing, $\bar{q}$. In this case, the total value of the firm is independent of the amount of borrowing. In the case of a constrained problem, k and q appear in the constraint (13) only to the extent that they define net wealth. Thus, the recursive problem in (12)–(14) can be rewritten as follows:

$$V(w,z) = \max_{k',q(z')} \quad w - k' + \beta_C \mathbb{E}q(z') + \beta \mathbb{E}V(w'(z'), z') \tag{15}$$

subject to:

$$w - k' + \beta_C \mathbb{E}q(z') \geq 0, \tag{16}$$

$$\theta k'(1-\delta) \geq q(z'), \quad \forall z' \in \mathbb{Z}, \tag{17}$$

$$w \equiv zk^\alpha + k(1-\delta) - q. \tag{18}$$

Next, we define the mapping T in the space of bounded functions as:

$$T(V)(w,z) = \max_{k',q(z')} \quad w - k' + \beta_C \mathbb{E}q(z') + \beta \mathbb{E}V(w'(z'), z') \tag{19}$$

subject to (16) and (17). Proposition 2 establishes the existence of a solution.

Proposition 2 *Let $C(X)$ be the space of bounded continuous functions. The operator T defined in (19), which maps $C(X)$ to itself, has a unique fixed point $V^* \in C(X)$; for all $v_0 \in C(X)$.*

This proposition is also useful because it implies that the solution to the model can then be obtained by iterating on (19).

2.5 Taxes

Thus far we have worked with a model with no taxation. We now consider an alternate model that is identical to our current setup, except in two regards. First, profits are taxed, so the profit function, zk^α, becomes $(1-\tau_c)zk^\alpha$, in which τ_c is the corporate tax rate. This feature of the model can be viewed purely as a technological constraint.

Next, motivated by the tax deductibility of interest payments, we assume that the tax authority gives the firm a rebate that is a function of the present value of payments to the lender, q. In this regard, our model departs from much of the financial contracting literature, which does not consider environments in which taxation affects securities. It is therefore important to observe that we are not allowing the lender and borrower to contract on the tax rebate. More importantly, we are not favoring any particular form of repayment with this rebate, which we assume takes the specific form $\tau_c q(1-\beta_C)$. This formulation has several useful features. First, it clearly represents a cash rebate and thus provides more funds to the firm. Second, as we show below, it effectively makes the firm more impatient than the lender. Third, this formulation closely captures the deductibility of interest. The term $(1-\beta_C)$ is of the same order of magnitude as an interest rate. Further, in our model with no optimal default, the market value of payments to the lender, q, is equivalent to the book value, which is the typical tax base.

It is worth noting that this taxation assumption maps back into a sequential problem of the form given by (6)–(10). All that is necessary is the replacement of the budget constraint (8) by:

$$(1-\tau_c)z_{t+j}k_{t+j}^{\alpha} - i_{t+j} - p_{t+j} - d_{t+j} + \tau_c(1-\beta_C)\mathbb{E}_{t+j}\sum_{m=0}^{\infty}(\beta_C)^m p_{t+j+m} \geq 0. \tag{20}$$

Thus, our taxation assumptions do not rely on the equivalence between the enforcement constraint (9) and the collateral constraint (11), the recursive reformulation of the contracting problem, or any particular implementation of the optimal contract.

Under this taxation assumption, we define net wealth as

$$w^* \equiv (1-\tau_c)zk^{\alpha} + k(1-\delta) - (1-\tau_c(1-\beta_C))q. \tag{21}$$

Now we can rewrite the recursive problem in (15)–(18) as:

$$V(w^*, z) = \max_{k', q(z')} \; w^* - k' + \beta_C \mathbb{E}q(z') + \beta \mathbb{E}V(w^{*\prime}, z') \tag{22}$$

subject to:

$$w^* - k' + \beta_C \mathbb{E}q(z') \geq 0, \tag{23}$$

$$\theta k'(1-\delta) \geq (1-\tau_c(1-\beta_C))q'(z'), \quad \forall z' \in \mathbb{Z}. \tag{24}$$

For this model, the proofs of Propositions 1 and 2 proceed with only minor modification.

2.6 Optimal Policies

To understand the properties of the model, it is useful to study the first-order conditions. To do so, we first assume that $V(w^*, z)$ is differentiable. Next, let μ be the Lagrange multiplier on the dividend nonnegativity constraint (23), and let $\beta\pi(z'|z)\lambda_{z'}$ be the Lagrange multiplier associated with the enforcement constraint (24) at state z', where $\pi(z'|z)$ is the transitional probability from state z to state z'. The first-order condition for k' is:

$$\beta \sum_{z'} \pi(z'|z)\left(V_{w^*}(w^{*\prime}, z')\frac{\partial w^{*\prime}}{\partial k'} + \lambda_{z'}\left(\theta(1-\delta)\right)\right) - \mu = 1, \tag{25}$$

where $\partial w^{*\prime}/\partial k' = (1-\tau_c)z'\alpha k'^{\alpha-1} + 1 - \delta$. The term in large parentheses in (25) is the constrained ratio of the marginal product of capital to the user cost. To interpret this term, suppose that the Lagrange multipliers μ and $\beta\pi(z'|z)\lambda_{z'}$ are zero (the unconstrained case). Because the envelope theorem implies that $V_{w^*}(w^*, z) = 1 + \mu$, (25) just states that the expected, after-tax marginal product of capital equals the user cost, as in a standard neoclassical investment model.

We now consider the constrained case. The next term in (25) is the marginal value of capital in relaxing the enforcement constraint. As long as $\theta > 0$, and as long the constraint binds in at least one state, this term is strictly positive. The last term is the shadow value of the dividend nonnegativity constraint. Thus, capital has value not only in the production of goods, but also in the relaxation of the enforcement and dividend nonnegativity constraints.

Next, we examine the optimality conditions with respect to the value of payments to the lender. The first-order condition for $q(z')$ for any given value of z' is:

$$1 + \mu + \frac{\beta}{\beta_C}\left(V_{w^*}\left(w^{*\prime}, z'\right)(1 - \tau_c(1-\beta_C))\frac{\partial w^{*\prime}}{\partial q'} - \lambda_{z'}\right) = 0, \quad \forall z' \in \mathbb{Z}. \tag{26}$$

Using the envelope theorem and the condition $\partial w^{*\prime}/\partial q' = -1$, we rewrite (26) as:

$$1 + \mu = \frac{\beta}{\beta_C}\left((1 + \mu(w^{*\prime}, z'))(1 - \tau_c(1-\beta_C)) + \lambda_{z'}\right), \quad \forall z' \in \mathbb{Z}. \tag{27}$$

The condition (27) simply equates the marginal value of funds across periods. To interpret (27), we first set $\tau_c = 0$. In this case, when $\mu = \mu(w^{*\prime}, z') = 0$, because $\beta < \beta_C$, the enforcement constraint binds. In other words, the assumption that the firm is less patient than the lender indicates even mature firms that pay dividends can be constrained because they always want to borrow more. However, if $\mu = 0$, but $\mu(w^{*\prime}, z') \neq 0$ for some $z' \in \mathbb{Z}$, the collateral constraint does not bind. This situation is likely to occur if the current state, z is low, but the future state, z', is high. In this case, the contract specifies that the firm conserve borrowing capacity because in these states the marginal value of capital is high relative to the marginal benefit of borrowing.

Taxation affects optimal financing via several different channels. The first is via the collateral constraint (24). Intuitively, for the firm to be indifferent between defaulting and continuing operations, the benefit from shedding q in default must equal the loss of revenue that follows from the destruction of capital in default. The tax rebate then loosens the constraint by rendering payments to the lender less onerous for the firm.

To see the effect of taxes on an unconstrained firm, we consider a special case of (27), in which we assume the firm is not constrained by collateral so that $\lambda_{z'} = 0, \forall z' \in \mathbb{Z}$, and for simplicity, we consider the case in which the current limited liability constraint does not bind, so that $\mu = 0$. With these assumptions, (27) can be rewritten as:

$$\frac{\beta_C}{\beta} \frac{1}{1-\tau_c(1-\beta_C)} = 1 + \mu\left(w^{*\prime}, z'\right), \quad \forall z' \in \mathbb{Z}. \tag{28}$$

The left-hand side of (28) represents the marginal benefit (MB) of financing. Intuitively, the firm desires external financing because it is less patient than the lender ($\beta_C > \beta$) or when a positive corporate tax rate renders the firm effectively more impatient. At an optimum, this impatience benefit is offset by the right-hand side of (28), which represents the marginal cost (MC). The cost of external financing derives from its effect on future financial flexibility, which is represented by $\mu\left(w^{*\prime}, z'\right)$, which is in turn simply the shadow value of future external funds.

To understand optimal financial policy of a firm that is not constrained by collateral, we plot (28) in Figure 1. In Panel A, we have set $\beta_C = \beta$, and in the bottom panel, we have set $\tau_c = 0$. In each panel, on the y-axis are the marginal benefit (MB) and marginal cost (MC) of financing. On the x-axis is optimal q'. In this figure, we have fixed the future state, and so we omit the dependence of future financing on the state from the notation. To analyze (28), we also fix optimal investment policy.

In Panel A, we have drawn three possible MB schedules, each corresponding to a different tax rate, $\tau_c^1 < \tau_c^2 < \tau_c^3$, with τ_c^1 near zero and with the higher MB schedules corresponding to higher tax rates. The MB schedule is clearly independent of q'. Because we are holding investment policy fixed, we have only drawn one MC schedule. Its shape depends on the relation between q' and the Lagrange multiplier, $\mu(w^{*\prime}, z')$. To show that $\mu(w^{*\prime}, z')$ is increasing in q', we apply the envelope theorem, which gives $1 + \mu(w^{*\prime}, z') = \partial V(w^{*\prime}, z')/\partial w^{*\prime}$. As shown in Rampini and Viswanathan (2013), $V(w^{*\prime}, z')$ is concave, so $\mu(w^{*\prime}, z')$ is decreasing in $w^{*\prime}$. Finally, from (21), $w^{*\prime}$ is a decreasing function of q', so $\mu(w^{*\prime}, z')$ is increasing in q'.

Next, economic intuition demonstrates that $\mu(w^{*\prime}, z')$ must be convex in q'. Ceteris paribus, for very low and possibly negative values of q', the future limited liability constraint cannot bind, so $\mu(w^{*\prime}, z') = 0$ for all q' below a certain threshold. However, as q' rises, $w^{*\prime}$ falls, and the constraint (23) eventually binds, so for sufficiently high q', $\mu(w^{*\prime}, z') > 0$. Thus, the MC schedule is convex. Here, it is important to note that absent the collateral constraint (24), the limited liability constraint would never bind, as the firm could borrow as much as it wanted.

Now we examine the implications for optimal financing from an increase in the tax rate. The main result that emerges from Figure 1 is that the convexity of the MC schedule implies a nonlinear response of optimal q' to a change in the tax rate. The optimal increase in q' is larger when the tax rate rises from near zero at τ_1 to τ_2 than from τ_2 to τ_3. To understand this result, note that external finance is essentially a means of transferring resources from one period to another, that is, a storage technology. When the amount of external financing is low, this storage technology is roughly constant returns, so the increase in the tax rate has a large effect on optimal borrowing. Put differently, if the costs associated with increased borrowing are negligible (i.e., constant returns), then optimal borrowing naturally rises a great deal when the benefit rises. Decreasing returns set in when q' is so high that the limited liability constraint binds in the future. In this region, the rise in the MB schedule from MB^2 to MB^3 has a dampened effect on borrowing because of the costs associated with losing financial flexibility in the future.

Panel B is identical to Panel A, except that we fix $\tau_c = 0$ and examine changes in lender patience relative to firm patience, β_C/β. As in Panel A, we consider three values for this ratio, with $(\beta_C/\beta)^1$ just barely above one, and $(\beta_C/\beta)^1 < (\beta_C/\beta)^2 < (\beta_C/\beta)^3$. Because taxes and firm impatience have identical effects on the MB schedule, we see similar effects. What is important in Panel B is the observation that if $\beta_C > \beta$, then further increases in the left-hand side of (28) from an increase in τ_c are likely to have small effects.

Of course, the model as it is written gives no guidance as to the exact shape of the MC schedule, and clearly the position and the curvature of this function are crucial for determining the optimal response of borrowing to the tax rate. Moreover, when the tax rate rises, optimal investment policy changes, so the MC schedule shifts left. However, the shape of the MC schedule and the magnitude of the shift in the MC schedule relative to the shift in the MB schedule are both quantitative questions. Thus, we now turn to estimating the model parameters to provide a data-relevant answer to the question of the effect of taxes on financing.

3. Data

3.1 Data sources

Our data are from the 2013 Compustat files. Following the literature, we remove all regulated utilities (SIC 4900-4999), financial firms (SIC 6000-6999), and quasi-governmental and non-profit firms (SIC 9000-9999). Observations with missing values for the SIC code, total assets, the gross capital stock, market value, debt, and cash are also excluded from the final sample. We also delete firms with fewer than three consecutive years of data. As a result of these selection criteria, we obtain a panel data set with 82,667 observations for the time period between 1965 and 2012 at an annual frequency.

3.2 Measurement

To estimate the model parameters, we need to find real-data counterparts to the model variables, q, k, i, and d. We start with the straightforward correspondences. We define total assets as Compustat variable AT, which we equate to the model variable k. Next, we define operating income, zk^{α} as item OIBDP, and we define d as the sum of equity repurchases (PRSTK) and common and preferred dividends (DVC and DVP). We define investment, i, as capital expenditures (CAPX) plus acquisitions (ACQ) minus sales of capital goods (SPPE).

Measuring the variable q is less straightforward because its definition as the present value of payments to the lender does not naturally imply that these payments necessarily represent the cash flows from any standard class of securities. However, in the model, the lender does not own the capital, and the borrower does. Thus, it is natural to exclude payments to equity from the definition of q. With this restriction, the present value of payments to the lender is, in principle, observable as non-equity liabilities, which we refer to hereafter simply as debt. This measurement assumption is necessary to estimate the model parameters and to interpret these results in terms of leverage. However, it does represent a departure from the strict model setting, which is agnostic about the specific securities used for repayment. Nonetheless, we view this assumption as natural, given the ownership structure in the model.

We define debt specifically as (DLTT + DLC) plus the capitalized value of operating leases, which can be substantial relative to traditional debt. For example, for many airlines, the value of leases is much larger than traditional debt.[2] To compute this present value, we discount reported lease payments due in years one through five (MRC1–MRC5) at the Baa bond rate. We similarly discount lease payments reported due in years beyond the fifth (MRCTA) by assuming that they are spread out evenly until year ten. Finally, to measure asset tangibility, we add this measure of capitalized lease payments to PPENT. We then express this sum as a fraction of total assets. Investment, debt, total payout (dividends plus repurchases), and operating profits are also expressed as fractions of total assets.

4. Estimation

This section provides a description of our estimation procedure and discusses the identification of our parameters.

4.1 Simulated Method of Moments

We estimate most of the structural parameters of the model using simulated method of moments (SMM). However, we estimate some of the model parameters separately. For example, we estimate β as $1/(1+r_f)$, where r_f is the average 3-month Treasury bill rate over our sample period. We also need to choose the number of years that we simulate. Here, instead of picking the average firm lifetime, which is unobservable, we use the average length of time a firm is in our sample, which we truncate to the nearest integer, 23. To remove the effect of the initial growth phase of the firm, we simulate the model for 73 years and drop the first 50. Finally, we set the time-zero capital stock, k_0, equal to 10% of the steady-state capital stock.[3] Because we simulate our model only in the steady state, this assumption has no effect on any of our results.

We then estimate the following parameters using SMM: the depreciation rate, δ; the production function curvature, α; the fraction of the capital stock that can be collateralized, θ; and the

[2] Broader measures of liabilities produce almost identical estimation results, but with slightly higher leverage ratios.

[3] The steady-state capital stock is defined as the capital stock that equates the expected marginal product of capital $\mathbb{E}(\alpha z'(k')^{\alpha-1})$ with the user cost, which is given by $\delta + 1/\beta - 1$.

difference between the lender's and the firm's discount factors, $\beta_C - \beta$. To estimate the transition matrix, Π, we approximate it as an $AR(1)$ process in logs, given by:

$$\ln z' = \rho \ln z + \varepsilon'. \tag{29}$$

Here, ε' is an *i.i.d.* truncated normal variable with mean 0 and standard deviation σ_z. With this assumption, we add two more parameters to our list: the standard deviation and serial correlation of the productivity shock, ρ and σ_z, respectively.

We define our simulated data variables as follows, where all are scaled by the current capital stock. Investment is $(k' - (1-\delta)k)/k$; leverage is q/k; profits are $zk^{\alpha-1}$, and dividends are d/k.

Simulated method of moments, although computationally cumbersome, is conceptually simple. First, we generate a panel of simulated data using the numerical solution to the model. In particular, we simulate a panel of 2,000 firms over 23 years. Next, we calculate interesting moments using both simulated data and actual data. The objective of SMM is then to pick the model parameters that make the actual and simulated moments as close to each other as possible.

4.2 Identification

The success of this procedure relies on model identification, which requires that we choose moments that are sensitive to variations in the structural parameters, such as the collateral parameter, θ. On the other hand, we do not "cherry-pick" moments. Instead, we examine moments of all of the observable policy variables contained in our model. Specifically, we match the means, standard deviations, and serial correlations of investment, the ratio of profits to assets, the leverage ratio, and the ratio of dividends to assets.

Although almost all of the moments depend in some way on every parameter, a few of the moment-parameter relations are strong and monotonic. Thus, these moments are particularly useful for identification of specific parameters. We start with the technological parameters, all of which are straightforward to identify. First, the mean rate of investment is the moment most useful for pinning down the depreciation rate, with higher rates of depreciation naturally leading to higher rates of contractual capital replacement. Next, the standard deviation and autocorrelation of profits are directly related to the parameters σ_z and ρ. Finally, the curvature of the production function, α, is most directly related to average profits. As α decreases, the firm faces more severe decreasing returns to scale, which, all else held constant, results in lower average profits.

The joint identification of θ and $\beta_C - \beta$ is tricky because both parameters are strictly increasing in the mean and variance of leverage, so leverage moments cannot be used to identify both parameters. However, these parameters play different roles in the model: θ sets the position of the collateral constraint, and $\beta_C - \beta$ is one of many parameters that helps determine the optimal distance the firm keeps from the constraint. Thus, leverage moments can be used to identify θ, while other moments can be used to identify $\beta_C - \beta$. In particular, when $\beta_C - \beta$ approaches zero, the firm is relatively more patient, so the benefits from borrowing are lower, and the firm keeps a great deal of distance from the collateral constraint. At the same time, this increased financial flexibility allows the firm to respond to productivity shocks more aggressively, so the variance of investment rises. Therefore, this moment can be used to pin down $\beta_C - \beta$. As will be seen below, this identifying mechanism works only under certain circumstances, which are instructive for understanding the quantitative implications of the model.

5. Results

Table 1 contains the results from our estimation. We consider two versions of the model: one in which we set the corporate tax rate to zero and one in which we set it to 20%. Panel A contains estimates of the real-data moments, the simulated moments, and the t-statistics for the differences between the two. Panel B contains the parameter estimates.

Two main results stand out in Panel A. First, both versions of the model fit the data reasonably well. Across the two estimations, only one quarter of the simulated moments are statistically significantly different from their real-data counterparts, and even fewer *economically* different. Both versions of the model do a good job of matching the means of leverage, investment, operating profit, and distributions to shareholders. Both models struggle more with standard deviations. We slightly underestimate the standard deviations of profits, but greatly overestimate the standard deviations of investment and distributions. This last result stems from the simplicity of the model, which omits capital adjustment costs, which in turn dampen the variability of investment. Similarly, the model struggles to match the relatively high serial correlation of investment observed in the data, again because of our omission of adjustment costs.[4] In contrast, the standard deviation of leverage is well-matched, and the model-implied serial correlation of leverage is only somewhat lower than the data estimate. In the end, by fitting a large number of moments, we have stress tested the model to determine whether and where it succeeds in matching important features of the data. For the purpose of studying leverage levels and dynamics, it does.

Our second main result is that adding taxes to the model does little to help reconcile the model with the data. In particular, average leverage is well matched (economically, if not statistically) in both models. We also find that when we conduct pairwise tests of the equality of the *simulated* moments across the models with and without taxes, we find that only one simulated moment, average investment, is significantly different (5%) across the two models. We discuss the intuition for this result below when we present the policy functions from the model.

Panel B in Table 1 shows that our estimates of fundamental contracting frictions are significantly different from zero. In both models, we estimate that 36% of the assets of an average firm can serve as collateral. This estimate is noticeably higher than our estimates of average leverage, and this result is important because it implies that firms do not always hug the collateral constraint. Our estimates of the technological parameters, δ, α, ρ, and σ_z, are comparable to those found in previous studies, such as Hennessy and Whited (2005, 2007). The only slight difference is a larger estimate for σ_z. Finally, we find a positive estimate for $\beta_C - \beta$, the difference between the discount factors of the lender and the firm. Interestingly, only the estimate in the no-tax model is significantly different from zero. Thus, because a large standard error indicates poor identification, the mechanism that identifies this parameter only appears to operate when the corporate tax rate is zero.

5.1 Policy Functions

To understand why estimating the models with and without taxes produces similar results, we examine the policy functions from two parameterizations of the model. The first uses the estimates from the no-tax model. The second uses the same parameterization, except that we set the tax rate to 0.2. This exercise is explicitly quantitative because we compute the model solution using estimated parameters.

[4]Below we examine the robustness of our basic results to the inclusion of adjustment costs.

Figure 2 contains the policy functions for the no-tax model. Here, we plot several optimal policies as a function of current net wealth, holding the current shock constant at its median value. The policy variables are capital (k'), dividends (d), and state-contingent debt ($q'(z')$), where we consider debt contingent on a low, a medium, and a high future state. Each of these variables is scaled by the before-tax steady-state capital stock.

Three patterns stand out in Figure 2. First, if the firm has low net wealth, the optimal choice of tomorrow's capital stock is increasing in today's net wealth. Because of the binding enforcement constraint, the firm can only pick a higher capital stock if it has sufficient internal resources. However, for high levels of net worth, the firm does not expand beyond the point where the marginal product of capital equals the user cost. Second, for low levels of net wealth, the firm does not pay dividends, because resources devoted to capital accumulation earn more than the user cost and because increasing capital helps relax the borrowing constraint. The firm only pays dividends at high levels of net worth when it has more than enough internal resources to fund optimal capital expenditures.

The third and most important feature of Figure 2 pertains to leverage. When the firm has low net wealth, the enforcement constraint always binds, as seen in the proportionality of debt to capital for all three state-contingent debt policies. At low levels of net worth, the constraint binds because the firm has not reached an optimal size and borrows as much as it can to grow out of its borrowing constraint. At higher levels of net worth, the enforcement constraint does not always bind when debt is contingent on the high or the medium shock. In these cases, the firm knows it will have good investment opportunities, which increase the value of unused debt capacity, which the firm then preserves accordingly. However, the collateral constraint always binds for debt contingent on the low state. In this case, the value of preserving debt capacity is not sufficient to offset the fact that the lender is more patient than the firm, and the firm ends up at a corner solution where the collateral constraint binds. It is worth noting that in this model, debt can take negative values, so that the model does indeed allow for positive cash holdings.

Figure 3 shows the same policy functions for a model parameterization in which all parameters are identical, except for the tax rate, which we set to 0.2. As in Figure 2, we scale all variables by the capital stock that sets the expected *before-tax* marginal product of capital equal to the user cost. Strikingly, Figures 2 and 3 appear almost identical, except that taxes lower the marginal product of capital, thereby causing the firm to operate on a much smaller scale, as can be seen in the scales of the x and y axes. Except for this difference in scale, the policies for a taxed firm are quantitatively almost identical to those for an untaxed firm.

To understand the striking similarity in optimal financial policies in Figures 2 and 3, we turn to Figure 1. In this latter figure, we see that both the corporate tax rate, τ_c, and the difference $\beta_C - \beta$ make the firm relatively more impatient and thus shift the marginal benefit of debt. Thus, our non-zero estimate of $\beta_C - \beta$ corresponds to a marginal benefit schedule such as MB^3 in Panel B, where taxes have a small impact on optimal financial policy. We explore this possibility below in our counterfactual exercises.

Finally, comparison of Figures 2 and 3 eliminates one explanation for the similarity between the estimates for the tax and no-tax models. Because we simulate the model only in the steady state, we eliminate the growth phase of the firm in which the collateral constraint always binds and in which taxes cannot, by definition, have any effect on optimal leverage.

5.2 Industry Estimation

We next put the model to a more strenuous test by ascertaining whether it fits data from 24 two-digit industries, which we choose using only the criterion that the industry have at least 1,000 firm-year observations. These industries are listed in Table A.1 in Appendix D, which also reports the parameter estimates. The results for matching the four mean moments are in Figure 4, where we plot actual versus simulated average leverage, investment, profits, and distributions.

Figure 4 shows that the model can match the wide variation across industries in leverage: 0.52 in Air Transportation to 0.18 in Metal Mining. The correlation between actual and simulated average leverage across industries is 0.98. Interestingly, the low-leverage industries have the lowest asset tangibility, as measured by the ratio of net property, plant, and equipment to total assets, and the highest leverage industry, Air Transportation, has the third highest measure of asset tangibility. Indeed, the correlation across industries between this measure of asset tangibility and our estimates of θ is 0.53, and the coefficient from regressing industry tangibility on θ is 0.99 with a standard error of 0.33. This piece of ancillary evidence is comforting in that one of the implications of our model is that collateral is one of the main determinants of leverage. It is also in accord with the reduced form evidence in Erickson, Jiang, and Whited (2014), who find that the coefficient on collateral in a standard leverage regression is near and insignificantly different from 1.

Not only does the model match the wide variation in leverage, but it matches the wide variation in average distributions and profits. For these two moments, the correlations between the actual and simulated moments are 0.93 and 0.92 respectively. However, the model struggles more with matching average investment, with the correlation between actual and simulated moments falling to 0.69. Nonetheless, the model does capture most of the spread across the low-investment and high-investment industries.[5]

Although Table A.1 presents all of the parameter estimates accompanying Figure 4, we highlight the main result in this table in Figure 5. This figure shows average simulated leverage versus the collateral constraint, which is given by $\theta(1-\delta)$. We see that average leverage never hugs the collateral constraint, with just under 20% of debt capacity kept free on average. However, the amount of free debt capacity varies by industry. In some industries, such as Food Products (20) we find little free capacity, and others, such as Transportation Equipment (37) we find a great deal. To explore this variation, we examine the other parameter estimates. Those industries with high capacity preservation are those with highly variable profits and with less curvature in their production functions. This second feature is particularly important because it induces a highly variable optimal investment policy. Thus, in those industries where investment opportunities are highly variable and in which optimal investments themselves are optimally highly variable, debt capacity is naturally more valuable.

5.3 Natural Experiment

In this section, we reestimate the model using data surrounding a quasi-natural experiment involving the repossession of assets in bankruptcy, and thus the value of these assets as collateral. The purpose of this exercise is twofold. First, we wish to determine whether our model can detect this change in the value of collateral. Conversely, we want to use our model to ascertain whether other important determinants of leverage changed at the same time. Thus, we both use the nat-

[5] For brevity, we omit the analogous plots for the rest of our moments. The results largely mirror those in Table 1, with the well matched moments remaining well matched across industries and the poorly matched moments remaining poorly matched across industries.

ural experiment to test the model and allow the model to illuminate the results from the natural experiment.

The experiment we consider is the enactment of anti-recharacterization laws in seven states in the late 1990s and early 2000s.[6] These laws are relevant for any firm that uses a special purpose vehicle (SPV) to conduct secured borrowing. Instead of borrowing directly from the lender, the firm (the originator) first transfers collateral to an SPV, which has limited risk exposure and remains solvent even if the originator files for bankruptcy. The advantage of this transfer is that in bankruptcy, the secured lender is protected from the automatic stay because of the bankruptcy-remote status of the SPV. This status then enables the lender to seize the collateral without any delay. However, prior to the laws we consider, this strategy was not guaranteed to succeed because bankruptcy courts had the discretion to recharacterize the asset transfer to the SPV as a loan instead of a true sale. Once the recharacterization takes place, the lender becomes a secured creditor of the originator instead of the SPV. In addition, the collateral is protected by the automatic stay and goes back to the bankrupt firm. Recharacterization is likely to take place under Chapter 11 if the court believes that the collateral plays a key role in the originator's operation during the reorganization process. In this case, the lender cannot recover its claim until the originator is liquidated or emerges from the restructuring. The automatic stay delays the lender's seizure of the collateral and creates substantial uncertainty regarding the value of the collateral that is eventually recouped by the lenders.

The use of SPVs is widespread. For example, Feng, Gramlich, and Gupta (2009) look for evidence of the use of SPVs by searching a broad sample of firms' 10K filings from 1994 to 2004. They find that 42% of the firms are associated with at least one SPV, and nearly 30% of the firms have multiple SPVs.

The anti-recharacterization laws that we explore require collateral transfers to SPVs to be treated as true sales if they are labeled as such. These laws thus strengthen creditors' rights by enabling the swift seizure of collateral. These laws were officially introduced in Texas and Louisiana in 1997, followed by Alabama in 2001, Delaware in 2002, South Dakota in 2003, Virginia in 2004, and Nevada in 2005.

The passage of the state laws enhances the pledgability of assets for firms incorporated in

[6] For a similar identification strategy in the context of patents, see Mann (2014).

those states. At least as relevant for the repossession of assets that have been transferred to SPVs is the *Reaves Brokerage Company, Inc. v. Sunbelt Fruit & Vegetable Company, Inc.* case in 2003. In this case, the court recharacterized the debtor's transfer and prevented the creditor from seeking recovery after the debtor filed for bankruptcy. The importance of the case is that the court completely ignored the anti-recharacterization statute of Texas and used a federal standard to determine the nature of the sale. This specific court decision increases the likelihood that the federal law will preempt state-level property rights when the debtor goes bankrupt. Therefore, the effect of passing an anti-recharacterization law at the state level shortly before or after this case law should be limited. Indeed, in the 7 years following this court case, it served as a cited precedent in 62 other bankruptcy cases. Thus, the case created substantial uncertainty surrounding state-level safe harbors for secured lending.

This institutional setting allows us to construct a difference-in-difference specification as follows. We classify a firm as "treated" if it is incorporated in the three states that passed the law before 2002. Instead of examining a "before-after" temporal setting, we use an "on-off" approach in which the "on" period consists of those years after a state passed the law but before 2004.

Although the timing of the court case is plausibly exogenous to the firms we study, the enactment of the laws is likely to be influenced by lobbying activities. However, as discussed in Kettering (2008), these lobbying efforts were mainly concentrated among the banking and especially the securitization industries, rather than the industrial firms in our sample. Kettering (2008) describes the large role played by the securitization industry in forcing the legislative change, which elevated the popularity of asset-backed securities and provided a larger market for structured financial products. Similarly, Janger (2003) argues that lobbying activities by banks, bond lawyers, and rating agencies contributed significantly to the passage of state-level anti-recharacterization statutes. Interestingly, the impetus for this lobbying was not economic in nature, but legal. Specifically, in the LTV bankruptcy case in 1993, the bankruptcy court allowed the firm to pull back its collateralized assets and use them as working capital during the early part of its Chapter 11 process. In contrast, the industrial firms that act as originators and borrowers appear to have had a limited role in the law change. Indeed, Janger (2003) explains that they are likely to be the source of challenges to their own previous asset-transfer transactions when they ask the bankruptcy courts to recharacterize their sales of collateral to SPVs. In the end, although we cannot completely rule out political economy considerations in our difference-in-difference experiment, the background for the enactment of anti-recharacterization laws makes it difficult to believe that political economy considerations affect our experimental design.

As a first step in this investigation, we plot the data to determine whether there is an obvious visual change in leverage. In Figure 6, we see that there is. The x-axis contains the event year, which is defined as zero in 1997, unless the firm is incorporated in Alabama, in which case the base year is 2001. At event year zero, we see a sharp upward spike in average leverage in the treated group of firms. Approximately six to seven years later, at the time of the Texas court case, we see a sharp drop in average leverage in this group. The validity of any difference-in-difference experiment requires the assumption of parallel trends in the treated and control groups. Although this assumption, like all identifying assumptions, is inherently untestable, no obvious differential trends in leverage across the treated and control firms are apparent.

To ground the results in Figure 6 with more formal statistical analysis, we conduct a standard reduced-form difference-in-difference exercise by regressing leverage on a treatment dummy, an "on" dummy, and their interaction. We cluster the standard errors at the firm level. The results are in Table 2. We examine four specifications: with and without firm and time fixed effects, and with and without any other control variables. For the regression without any fixed effects or extra control variables, the difference-in-difference effect is 0.072. Including either fixed effects or extra controls results in a smaller coefficient of approximately 0.04. All of these effects are significant at the 5% level. This effect is economically quite large, and its statistical significance is notable, considering that we have fewer than 200 firm-year observations in the "treated-on" group. It is also unlikely that this result is driven by unobservable heterogeneity, given that it is robust to the inclusion of firm and year fixed effects, as well as to the inclusion of the standard control variables from Rajan and Zingales (1995): the log of sales, the market-to-book ratio, the ratio of operating income to assets, and the ratio of net property, plant, and equipment to assets.

We now use our model to ascertain the forces driving this change in leverage by estimating the model (with taxes) on the treated and control groups in the off and on periods. (The results from the model without taxes are nearly identical.) We estimate all model parameters in all four of these estimations in order to control for average firm characteristics that may have changed during the experiment.

Table 3 reports the moments and parameter estimates from these estimations. The main result in Table 3 is that our model is able to detect a plausibly exogenous change in the value of collateralized assets. First, note that in all four samples, leverage is well matched. The maximal difference between average and model-implied leverage is only 1.04%. Without this result, it would be hard to claim that our model could illuminate our reduced-form results. Second, the estimates of θ show that a change in the value of collateral is indeed behind the large difference-in-difference effect on leverage. If we compute the difference in differences of the collateral parameter, θ, we find that the experiment produces a difference-in-difference effect of 0.076 with a t-statistic of 3.6.

Digging deeper into the results in Table 3 reveals that the change in leverage surrounding the anti-recharacterization laws is a product of both changing collateral and changing debt capacity preservation. To see this result, we note first that in Panel B of Table 3, the value of collateral in the control group falls with treatment. This result is consistent with constant leverage in the control group because the estimate of the standard deviation of the productivity shock, z, falls with treatment. In the model, less uncertainty leads to less debt-capacity preservation, so for the control firms in the "on" period, the value of collateral falls, but the firms hug the collateral constraint somewhat more closely, with no change in leverage. This fall in the level of collateral in the control group implies that the 0.076 estimate likely overstates the true change in collateral. A sensible, informal lower bound on this effect is the simple difference between the θ parameters in the treated group with and without treatment, which is 0.052 and significant at the 5% level. This last result adds texture to our reduced-form difference-in-difference exercise, by using the model to measure the change in collateral, which we find is somewhat smaller than the change in leverage. Finally, this last result would have been impossible to uncover via reduced-form estimation alone.

6. Counterfactuals

In this section, we ask how taxes affect capital structure, and we quantify the value of preserving debt capacity. To answer the first question, we consider a two-dimensional counterfactual experiment. We start by parameterizing the model with the estimates from the no-tax model from Table

1. We then allow τ_c to take 20 evenly spaced values from 0 to 0.4 and $\beta_C - \beta$ to vary similarly from just above zero to 0.03. For each pair of τ_c and $\beta_C - \beta$, we solve the model, simulate it, and calculate average leverage. We then plot average leverage as a function of τ_c, for selected levels of $\beta_C - \beta$.

The results from this exercise are in Figure 7. In the top panel, we see that leverage responds strongly to changes in the corporate tax rate, but only when the difference between lender and borrower impatience is near zero. Even in this case, the response is much stronger when the tax rate is low than when the tax rate is high. As the difference in discount factors rises, this relation becomes flat. Interestingly, it only takes a small wedge of less than 0.015 in the difference between β_C and β to render leverage completely unresponsive to changes in the tax rate. This result implies that any force that makes borrowers effectively more impatient relative to lenders also sharply dampens the effect of taxes on leverage.

This result can be understood in terms of Figure 1, which depicts the first-order condition for optimal leverage. In this figure, taxes shift the marginal benefit of debt up, but the convexity of the marginal cost of debt implies that tax increases have a large effect on optimal leverage when the marginal benefit of debt is near one. This condition can, in turn, only hold when $\beta_C - \beta$ is near zero. If the marginal benefit of debt is sufficiently high, then taxes have only a small effect on optimal leverage.

One question that arises is whether the natural negative effect of corporate taxation on profitability and capital accumulation plays any role in the result that leverage is usually unresponsive to tax rate changes. To address this issue, we conduct a similar counterfactual, except we do not allow taxation to affect corporate profits. This experiment corresponds to a fixed marginal cost schedule in Figure 1. The results from this experiment are in the bottom panel of Figure 7. Here, we see that the results are almost identical to those in the top panel. This result implies that the presence of taxes affects the firm's budget constraint little. Profits fall, but so do optimal capital expenditures, and these two effects largely cancel one another out.

Taken together, these results show that taxes affect capital structure only under limited circumstances, when lenders are as patient as firms. As discussed above, the presence of deposit insurance and cheap deposits or the general equilibrium considerations in Ai et al. (2013) suggest that lenders behave as if they are much more patient than firms. Finally, it is important to note that these counterfactuals come from parameters that have been estimated, so they are not just a theoretical possibility. They demonstrate that the qualitative results in Figure 1 also hold quantitatively, and they are empirically relevant.

For our next counterfactual, we quantify the value of conserving financial flexibility. We start by computing the value of the firm in the model with the parameters from the baseline estimate with taxes. (The no-tax results are nearly identical.) We then recompute the model, but with the restriction that the collateral constraint is always required to bind. This second model represents a complete loss of financial flexibility. We then compute firm value and compare it with the value from the unrestricted model. We find that when the firm is constrained to hug the collateral constraint it loses value equal to 7.9% of firm assets. To determine whether this quantity is large or small, we compare it to a calculation of the tax benefit of debt. Here, we approximate the tax benefit with the textbook formula $\tau_c q$. For $\tau_c = 0.2$, as in our model, the tax benefit is 5.8% of firm assets. A higher statutory tax rate of 0.35 results in a tax benefit of 10% of firm assets. In both cases, the tax benefit is roughly the same magnitude as the cost of lost financial flexibility. This result represents a significant departure from nearly all models of taxes and distress costs in which the tax benefit is often several times larger than expected distress costs.[7]

7. Robustness

Our conclusions are based on a simple dynamic contracting model. There are no equity issuances or lumpy investment, and the tax code is much simpler than the tax codes observed in the real world. To allay concerns that our results concerning taxes are due to these simplifications, we add these features, one by one, to the our model. We modify the collateral-constraint version of the model instead of the original contracting problem, which has the value function in the constraints.

First, instead of requiring dividends to be positive, we allow them to be negative, but require the firm to pay a 5% equity issuance cost in this case. Second, investment in our model is not lumpy, as in the case of many real options models. To induce lumpiness in the model, we add a cost of adjustment equal to 0.5% of the current period capital stock. Because this cost is independent of

[7] See, for example, the review in Strebulaev and Whited (2012).

the amount of investment, it induces optimal lumpy behavior, where the firm is inactive for long spells before investing a great deal. Third, we add a convex tax schedule to the model, in which the tax rate is 0.1 when $zk^{\alpha} - q(1 - \tau_c(1 - \beta_C)) < 0.05$, and is 0.2 otherwise. This gradation approximates the convexity of the U.S. tax code. The real-world tax code results in approximately 25% of listed firms paying a substantially lower tax rate than the statutory rate. Given our two-tiered tax schedule, in our simulated panel, approximately 25% of the firms also pay the lower rate. Fourth, we allow dividends to be taxed at a rate of 10%. In all four cases, we find that changing the corporate tax rate has almost no effect on optimal leverage, as long as $\beta_C - \beta > 0.01$. The one difference is that in the model with lumpy investment, the firm preserves debt capacity to a greater extent. We conclude that our results concerning taxes are robust to these concerns.

One further concern is that taxes do not matter because the amount of debt capacity preservation in our model is too small. To address this concern, we reestimate the model, holding θ at 0.6 and forcing average leverage to be matched exactly by putting a large weight on that moment. Thus, the model is parameterized so that the firm keeps a large distance from the collateral constraint. We then conduct the same counterfactual experiments from Figure 7. We find nearly identical results. Taxes only matter for leverage when both the tax rate and $\beta_C - \beta$ are small.

Finally, we investigate whether our tax results are also present in more traditional models of corporate capital structure. First, we solve and simulate the collateral-constraint model from Strebulaev and Whited (2012), which is a simplified version of the model in Hennessy and Whited (2005). It consists of a dynamic investment model with costly equity issuance, debt financing, a collateral constraint, and straight, non-state-contingent debt. Again, we find strong effects of taxes on leverage only for very low tax rates. This robustness check is useful because it demonstrates that the state-contingency of the debt in our model is not driving our results.

Second, we solve and simulate the endogenous default model from Strebulaev and Whited (2012), which is a simplified version of the model in Hennessy and Whited (2007). This model is identical to the simple model described above, except that it does not contain a collateral constraint. Instead, the firm can borrow as much as it wishes, but when equity value is zero, it defaults. The interest rate is then set endogenously in a lender zero-profit condition. Yet again, we find strong effects of taxes on optimal capital structure only for very low tax rates.

8. Conclusion

We have sought to understand whether corporate taxes or collateral constraints that arise in the presence of agency problems are more important for capital structure. To this end, we estimate a dynamic contracting model in which financial constraints and capital structures arise endogenously as the result of contracting frictions. This approach departs from much of the structural estimation literature, in which researchers use models with financial constraints that are exogenous to firm actions and policies. We produce five main findings. First, a model without taxes fits the data as well as a model with taxes. Second, when we parameterize the model according to our estimation results, we find that counterfactually varying the corporate tax rate almost never has an appreciable effect on leverage. Third, our model can be used to reconcile model-generated leverage with actual leverage across a broad spectrum of industries, and the structurally estimated position of the collateral constraint is highly correlated with a traditional measure of asset tangibility. Fourth, we find that the significant changes in leverage surrounding a natural experiment concerning asset repossession stem from movements in the position of the collateral constraint. Finally, and most importantly, we quantify the cost of lost financial flexibility, and we find that it is approximately the same magnitude as the tax benefit of debt. Thus, our model with valuable financial flexibility but no equilibrium default solves the horse and rabbit stew problem of Miller (1977) much better than traditional tax-distress costs models that do have equilibrium default but ignore financial flexibility concerns.

Although our results are not in accord with Heider and Ljungqvist (2015) or Pérez-González, Panier, and Villanueva (2012), who find that taxation does affect capital structure, the results are in line with the vast majority of empirical studies surveyed in (Graham 2007), which report no effects of taxes on leverage. Our results are also in line with the recent evidence in Graham, Leary, and Roberts (2013), who find that the sharp tax increases of the 1940s were followed by only a gradual upward drift in leverage. Similarly, our results support the evidence in Bargeron, Denis, and Lehn (2013), who find that leverage during WWI responded much more to real investment demands than to sharp changes in tax incentives.

Estimating an optimal contracting model has given us a new perspective on the relative importance of taxes versus agency issues for capital structure. In a world where firms borrow only to fine-tune an optimal capital structure, taxes are clearly a first-order consideration. However, in a world where firms borrow to finance investment and in which lenders wish to be repaid, taxes are not nearly as important. We speculate that estimating optimal contracting models can be used as bases for deepening our understanding of a variety of corporate finance questions. One obvious candidate is executive compensation, but others include mergers, banking decisions, and managerial incentives in a conglomerate.

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Table 1: Simulated Moments Estimation

Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. The table contains estimates from two models: one without corporate taxation and one with both taxation of corporate income and an interest tax deduction. Panel A reports the simulated and actual moments and the clustered t-statistics for the differences between the corresponding moments. Panel B reports the estimated structural parameters, with clustered standard errors in parentheses. δ is the rate of capital depreciation. α is the curvature of the profit function. ρ_z and σ_z are the serial correlation and the standard deviation of the innovation to the profitability shock. θ is the fraction of the capital stock lost when a contract is repudiated. $\beta_C - \beta$ is the difference in discount factors between lenders and borrowers.

A. Moments

		No Taxes		Taxes	
	Actual	Sim.	t-stat.	Sim.	t-stat.
Average debt	0.291	0.304	−2.374	0.313	−3.084
Standard deviation of debt	0.107	0.107	0.042	0.106	1.835
Serial correlation of debt	0.861	0.587	0.858	0.575	0.878
Average investment	0.100	0.127	−4.360	0.097	0.156
Standard deviation of investment	0.141	0.292	−1.834	0.271	−1.289
Serial correlation of investment	0.683	−0.058	0.899	0.021	0.829
Average profits	0.140	0.141	−0.226	0.140	−0.045
Standard deviation of profits	0.074	0.052	1.820	0.049	2.071
Serial correlation of profits	0.700	0.403	1.341	0.484	0.931
Average distributions	0.028	0.034	−1.661	0.033	−1.251
Standard deviation of distributions	0.032	0.088	−9.022	0.085	−4.821
Serial correlation of distributions	0.253	−0.005	0.802	0.026	0.453

B. Parameter estimates

	δ	α	ρ_z	σ_z	θ	$\beta_C - \beta$
No Taxes						
	0.081	0.782	0.631	0.418	0.365	0.032
	(0.005)	(0.034)	(0.027)	(0.019)	(0.007)	(0.016)
Taxes						
	0.057	0.758	0.803	0.414	0.362	0.039
	(0.010)	(0.013)	(0.036)	(0.045)	(0.008)	(0.080)

Table 2: Difference-in-Difference Estimation of the Collateral Experiment

Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The dependent variable in all regressions is book leverage. "On" is defined as after the passage of an anti-recharacterization law but before 2004. "Treated" is defined as incorporation in Texas, Louisiana, or Alabama. Interaction denotes the interaction of these two variables. Profitability is operating income divided by assets. Tangibility is net property, plant, and equipment divided by book assets. Large firms are defined as those with book assets greater than the median in the sample, and small firms are defined as those with book assets less than the median. All other variables are self-explanatory. Standard errors clustered by firm are in paretheses under the coefficient estimates.

Interaction	0.072	0.040	0.044	0.037
	(0.020)	(0.019)	(0.017)	(0.017)
On	−0.008		0.018	
	(0.004)		(0.003)	
Treated	0.014		−0.028	
	(0.008)		(0.018)	
Log(sales)			0.068	0.044
			(0.010)	(0.015)
Profitability			−0.164	−0.134
			(0.015)	(0.018)
Tobin's q			−0.010	−0.010
			(0.002)	(0.002)
Tangibility			0.272	0.234
			(0.015)	(0.021)
R^2	0.0007	0.004	0.151	0.156
Fixed firm effects	NO	YES	NO	YES
Fixed time effects	NO	YES	NO	YES

Table 3: Difference-in-Difference Simulated Moments Estimation

Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. Panel A reports the simulated and actual moments and the clustered t-statistics for the differences between the corresponding moments. Panel B reports the estimated structural parameters, with clustered standard errors in parentheses. δ is the rate of capital depreciation. α is the curvature of the profit function. ρ_z and σ_z are the serial correlation and the standard deviation of the innovation to the profitability shock. θ is the fraction of the capital stock lost when a contract is repudiated. $\beta_C - \beta$ is the difference in discount factors between lenders and borrowers. After is defined as after the passage of an anti-recharacterization law but before 2004. Treated is defined as incorporation in Texas, Louisiana, or Alabama.

A. Moments

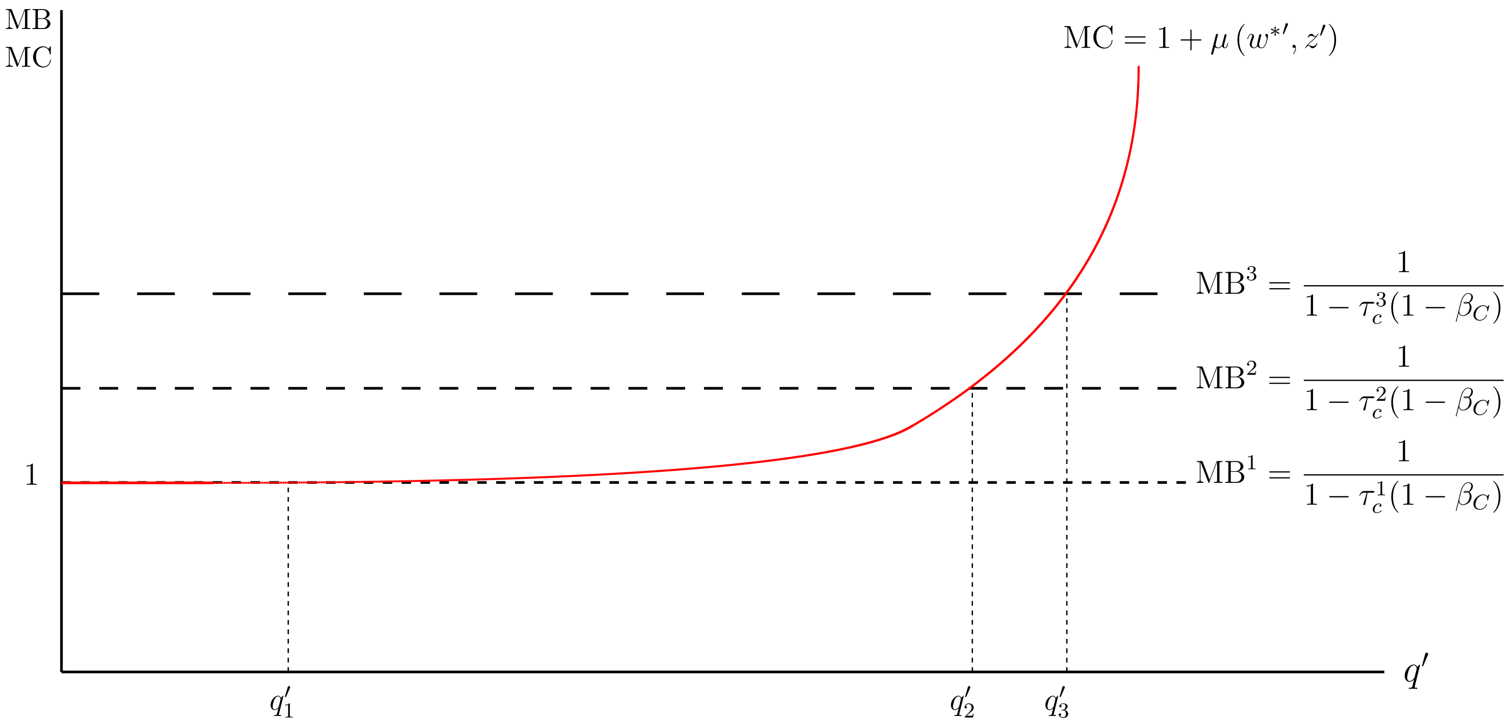
	Control Off			Control On			Treated Off			Treated On		
	Actual	Sim.	t-stat.	Actual	Sim.	t-stat.	Actual	Sim.	t-stat.	Actual	Sim.	t-stat.
Average debt	0.294	0.308	−1.358	0.292	0.306	−2.100	0.323	0.310	0.283	0.392	0.384	0.329
Standard deviation of debt	0.112	0.112	−0.020	0.073	0.070	1.935	0.121	0.115	0.741	0.099	0.088	0.686
Serial correlation of debt	0.870	0.673	1.789	0.746	0.571	1.743	0.711	0.211	0.256	0.821	0.461	0.199
Average investment	0.097	0.091	0.441	0.098	0.089	0.653	0.150	0.102	1.925	0.131	0.097	0.253
Standard deviation of investment	0.145	0.271	−1.167	0.134	0.170	−0.614	0.156	0.183	−0.784	0.146	0.128	0.087
Serial correlation of investment	0.714	0.003	0.781	0.644	−0.001	2.160	0.806	−0.060	0.643	0.449	0.069	0.582
Average profits	0.139	0.137	0.204	0.133	0.129	0.188	0.158	0.149	0.189	0.101	0.115	−0.169
Standard deviation of profits	0.075	0.045	1.873	0.059	0.020	1.977	0.089	0.037	0.684	0.085	0.023	0.507
Serial correlation of profits	0.736	0.514	0.860	0.580	0.617	−0.115	0.679	0.690	−0.012	0.761	0.699	0.100
Average distributions	0.029	0.035	−2.749	0.028	0.025	1.942	0.024	0.029	−0.533	0.011	0.013	−0.262
Standard deviation of distributions	0.033	0.084	−5.460	0.028	0.064	−9.093	0.031	0.040	−0.093	0.021	0.027	−0.102
Serial correlation of distributions	0.235	0.051	0.376	0.217	0.051	0.423	0.242	0.448	−0.145	0.015	0.448	−0.295

B. Parameter estimates

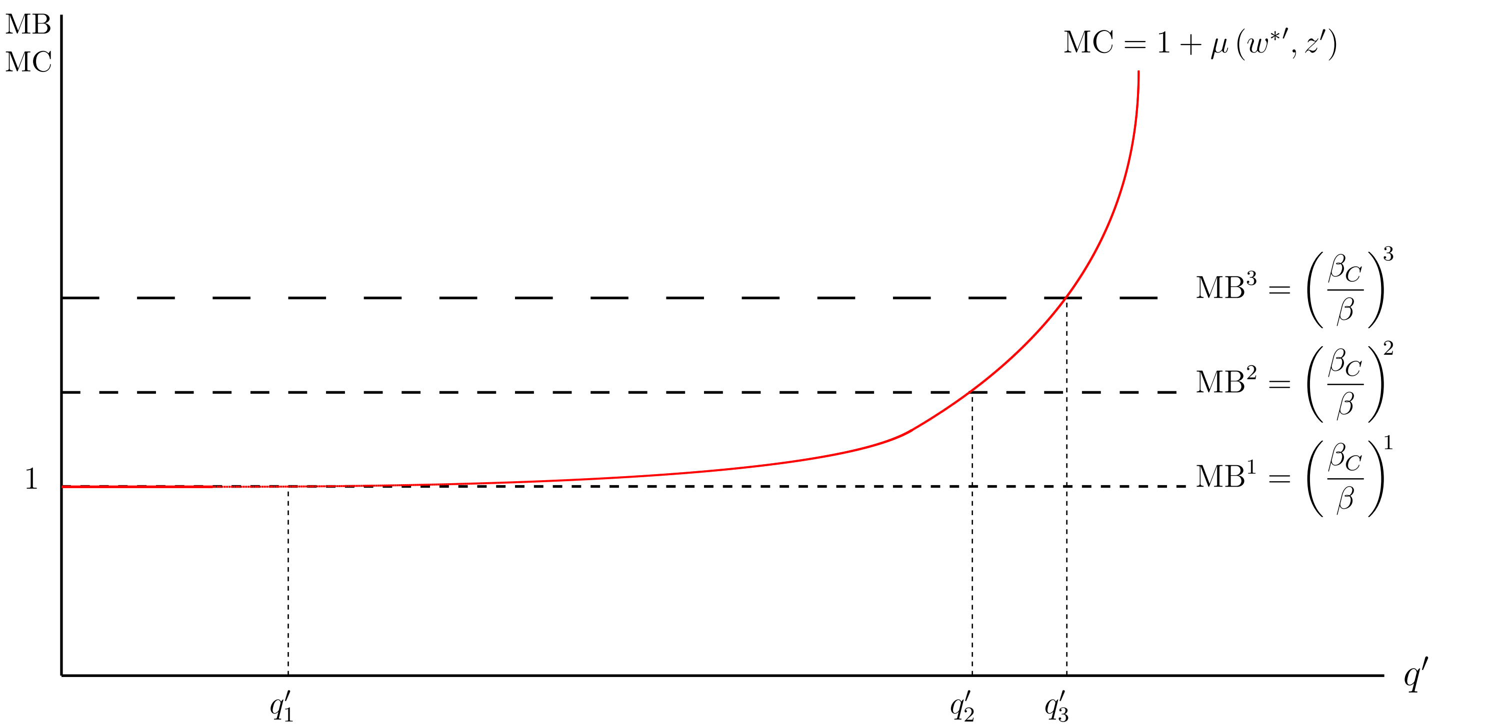
	δ	α	ρ_z	σ_z	θ	$\beta_C - \beta$
Control Off						
	0.053	0.745	0.884	0.408	0.356	0.038
	(0.004)	(0.041)	(0.103)	(0.025)	(0.009)	(0.005)
Control On						
	0.060	0.883	0.900	0.180	0.339	0.038
	(0.005)	(0.055)	(0.112)	(0.022)	(0.011)	(0.031)
Treated Off						
	0.056	0.900	0.687	0.220	0.388	0.015
	(0.037)	(0.415)	(0.404)	(0.108)	(0.016)	(0.022)
Treated On						
	0.041	0.914	0.730	0.176	0.440	0.021
	(0.003)	(0.081)	(0.179)	(0.087)	(0.021)	(0.002)

Figure 1: First-order Conditions for Optimal Financing

Panel A

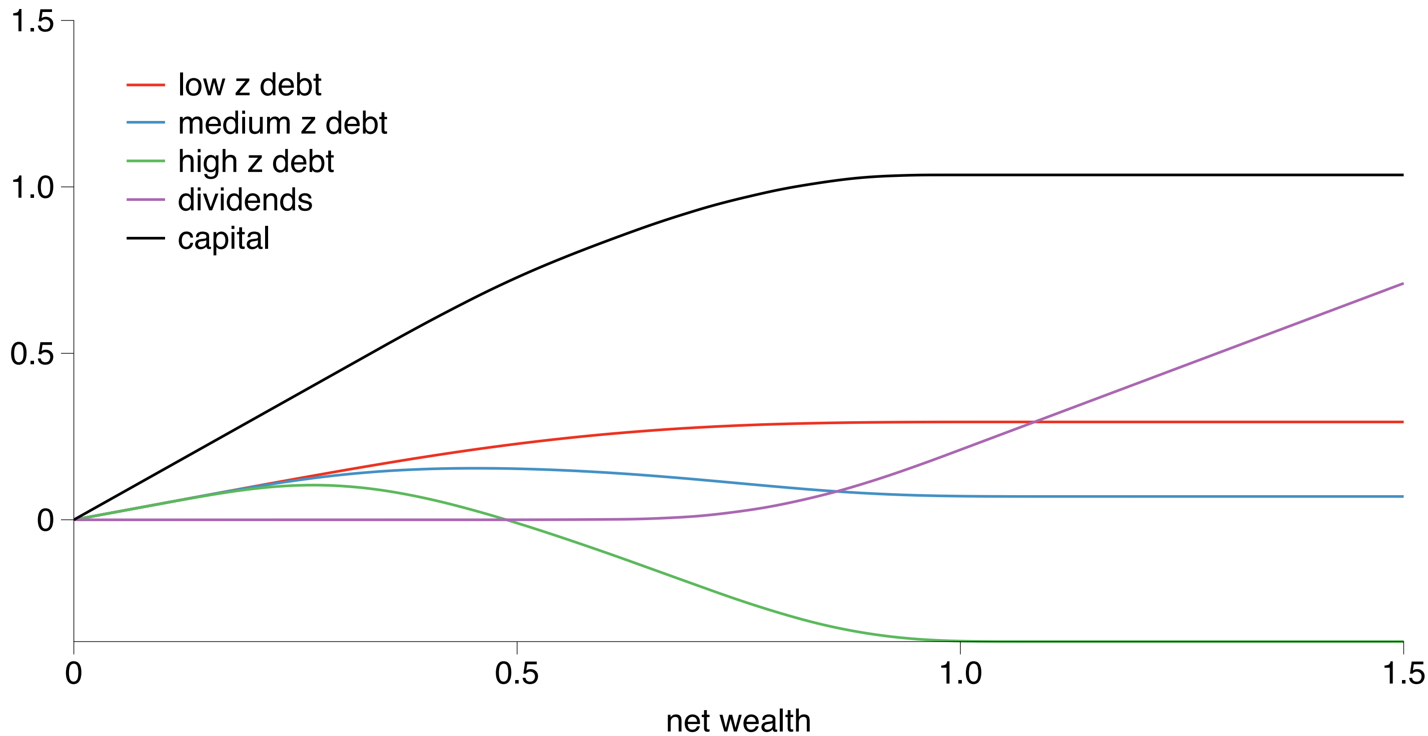


Panel B



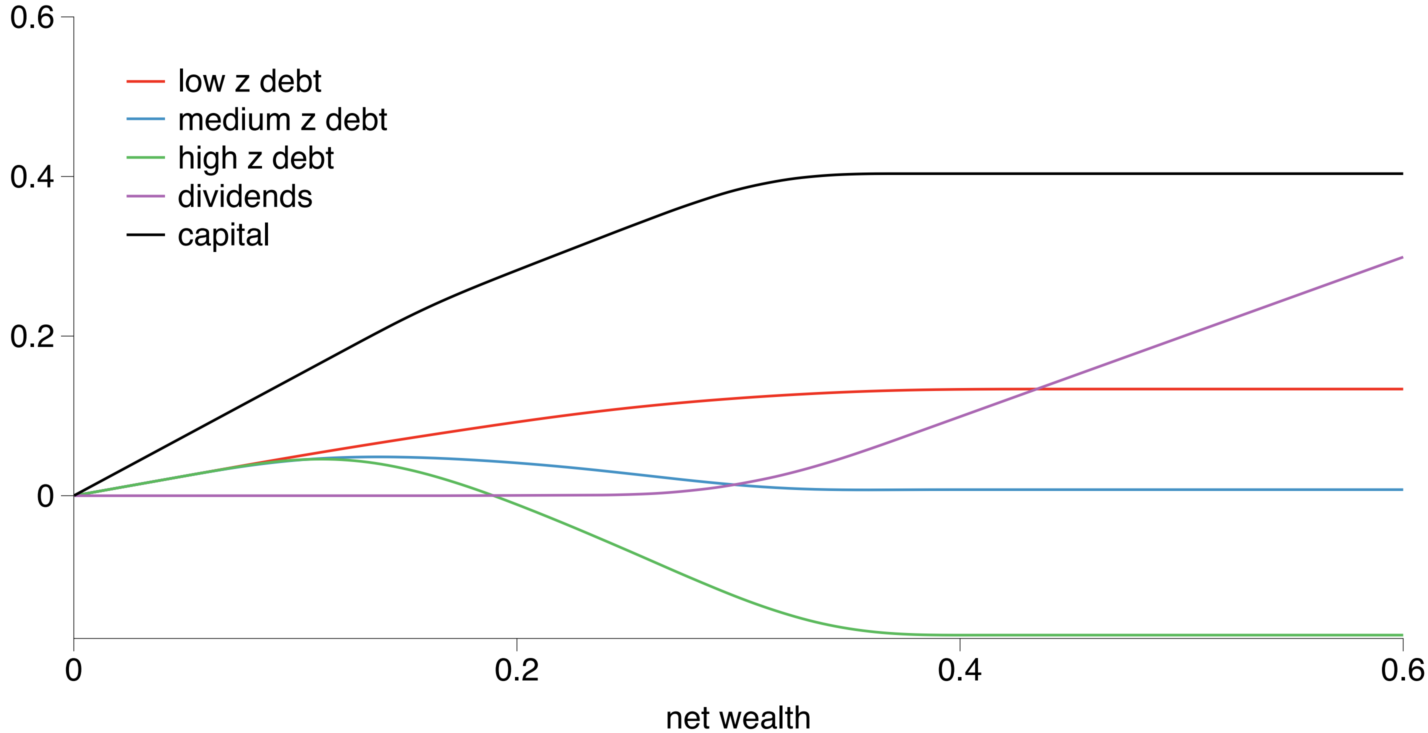
This figure depicts a simplified version of the first-order condition (27) for optimal debt policy. MC and MB represent the marginal cost and marginal benefit of an extra unit of financing, q' is optimal next-period borrowing, β_C is the lender's discount factor, β is the firm's discount factor, τ_c is the corporate tax rate, $\mu(w^{*\prime}, z')$ is the Lagrange multiplier on next period's limited liability constraint. Panel A is drawn holding $\beta_C = \beta$, and Panel B is drawn holding $\tau_c = 0$.

Figure 2: Policy Functions: No Tax Model



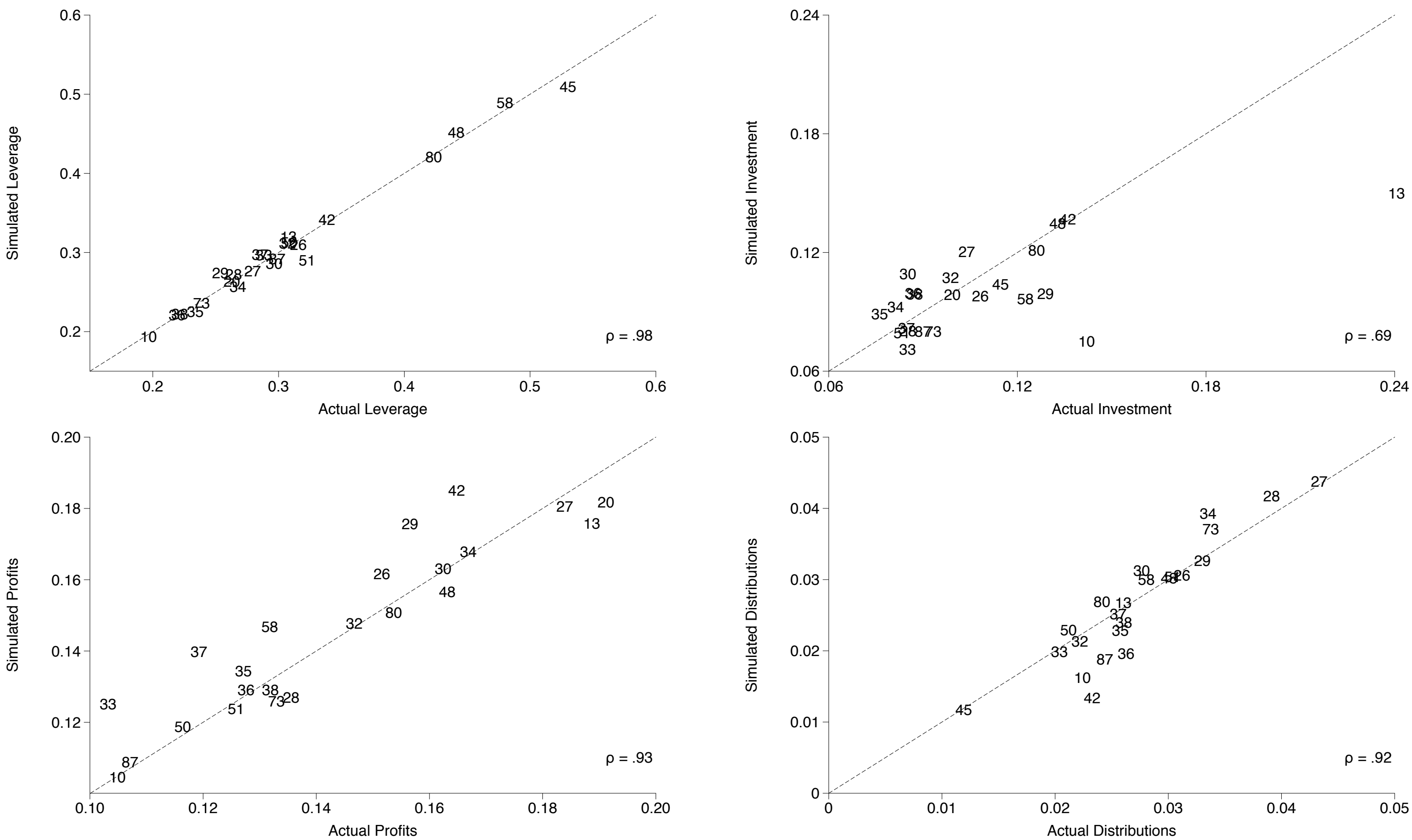
This figure depicts the policy functions for the model of Section 2, with the corporate tax rate set to zero and with all other parameters from the estimation of the no-tax model on the full sample. All of the variables are scaled by the unconstrained steady-state capital stock. The x-axis contains net wealth. On the y-axis are the capital stock, dividends, and debt contingent on a low future state, a medium future state, and a high future state. The figure is drawn fixing the current state at its median value and thus represents a two-dimensional slice of the policy function.

Figure 3: Policy Functions: Tax Model



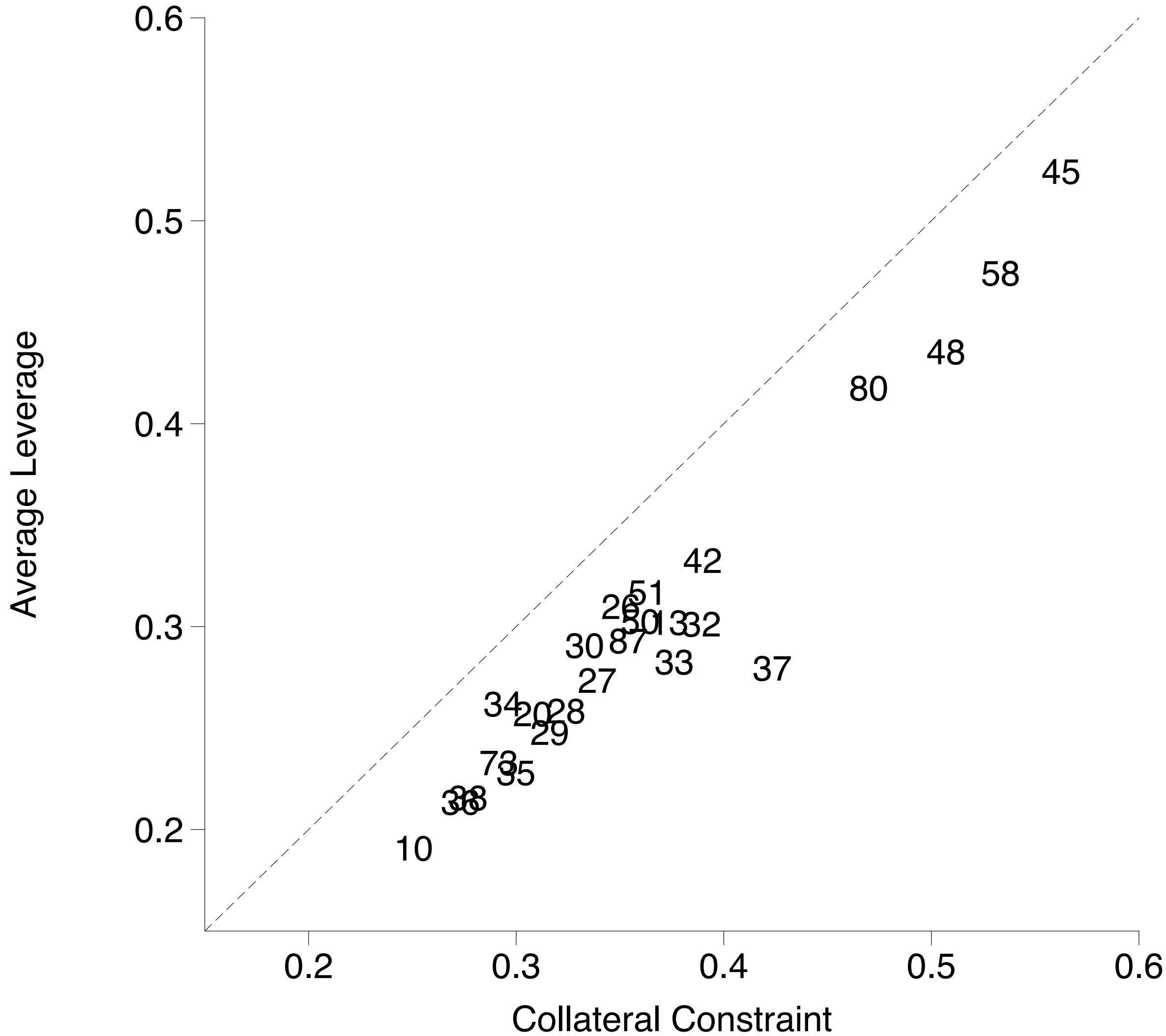
This figure depicts the policy functions for the model of Section 2, with the corporate tax rate set to 0.2 and with all other parameters from the estimation of the *no-tax* model on the full sample. We use the no-tax model parameters for comparability with Figure 2. All of the variables are scaled by the unconstrained steady-state capital stock. The x-axis contains net wealth. On the y-axis are the capital stock, dividends, and debt contingent on a low future state, a medium future state, and a high future state. The figure is drawn fixing the current state at its median value and thus represents a two-dimensional slice of the policy function.

Figure 4: Moments from Industry Estimations



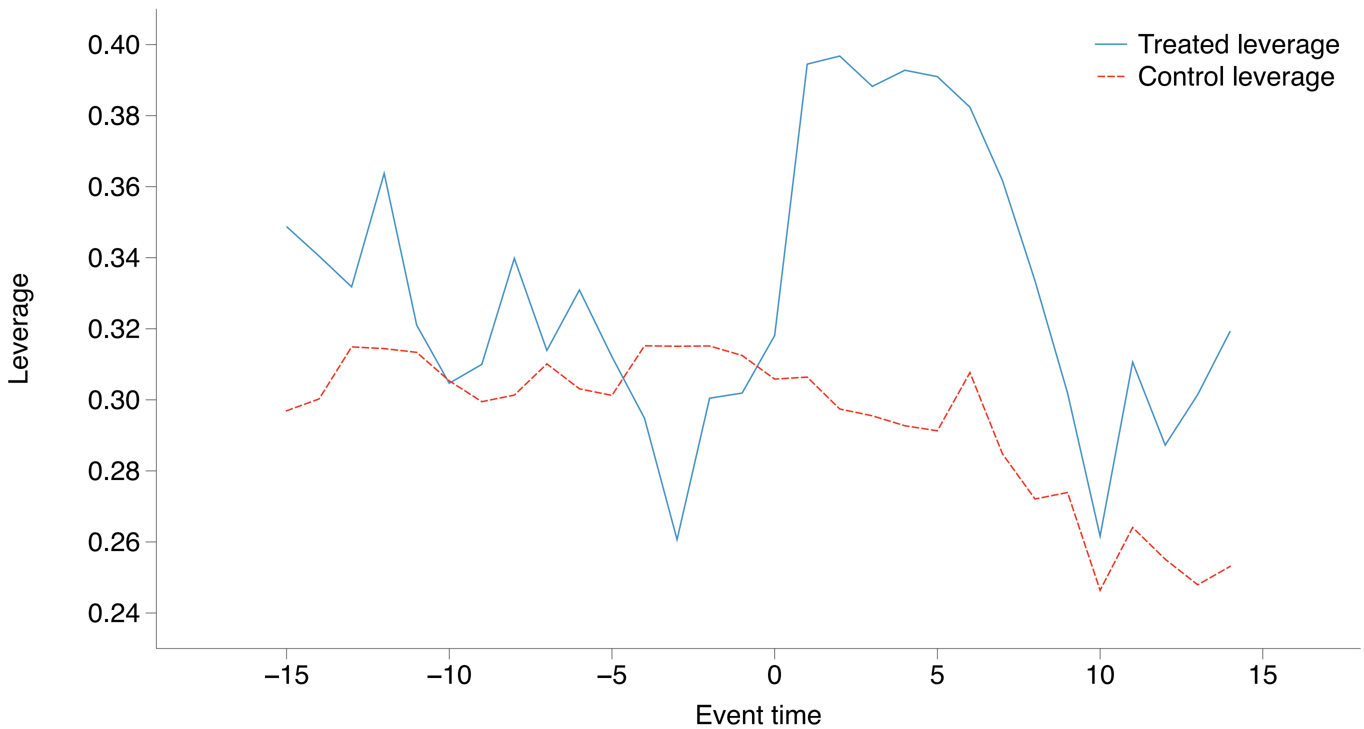
Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The sample is split into 24 industries, listed in Table A.1. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. This figure shows data averages versus simulated averages for four variables: leverage, the rate of investment, operating profits, and distributions, where the latter three are deflated by total book assets.

Figure 5: Industry Collateral Constraints versus Leverage



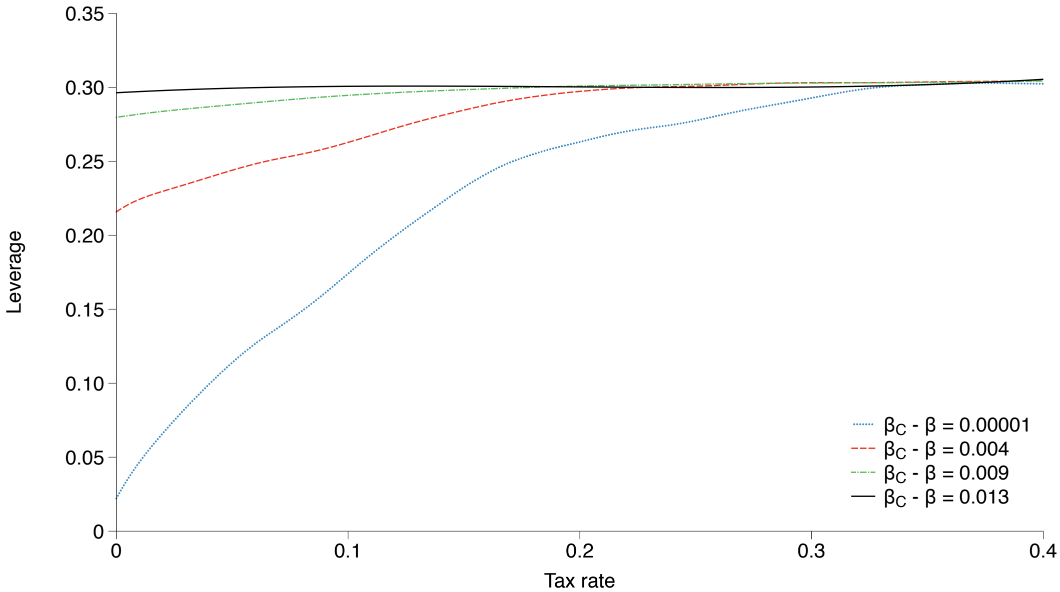
Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The sample is split into 24 industries, listed in Table A.1. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. This figure shows the estimated level of the collateral parameter, θ, versus average leverage for each industry.

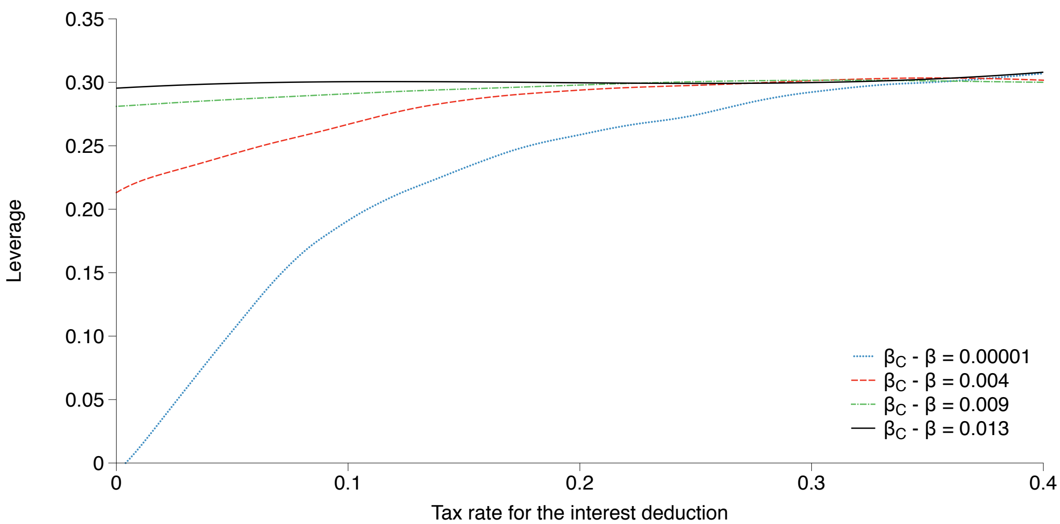
Figure 6: Leverage Surrounding Antirecharacterization Laws and Cases



Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1982 to 2012. This figure plots book leverage for two groups of firms. Treated is defined as incorporation in Texas, Louisiana, or Alabama, and Control is all other firms. Event time zero corresponds to the passage of state antirecharacterization laws. It is 1997, except for those firms incorporated in Alabama, in which case, it is 2001. The *Reaves Brokerage Company, Inc. v. Sunbelt Fruit & Vegetable Company, Inc.*, which set a precedent against state antirecharacterization laws, occurs in event year seven.

Figure 7: Counterfactuals: Leverage and Taxes





The top panel of this figure is constructed as follows. We pick grids for τ_c, the corporate tax rate, and $\beta_C - \beta$, the difference in the discount factors between borrowers and lenders. We then solve the model for each combination of $(\tau_c, \beta_C - \beta)$, simulate the model for 50 time periods, and then plot average leverage. We use the parameterization from the estimates of the no-tax model from Table 1. Each line in the figure is drawn for a specific value of $\beta_C - \beta$. The bottom panel is constructed in an identical manner, except we allow τ_c to affect only the tax benefit and not the profits.

Appendix A: Proofs

In Appendix A, we prove propositions 2 and 1.

Preliminaries

To streamline the proofs, we use a simplified characterization of the problem given by (6)–(10). Let $x = \{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ denote a sequence of capital stocks and state-contingent debt holdings. To simplify notation, we assume the contract starts at $t = 0$ so that the initial state is $x_0 = (k_0, q_0, z_0)$. First, we show that the budget constraint (8) and participation constraint (10) are both binding.

Lemma 1 *The budget constraint (8) and the participation constraint (10) hold with strict equality at any solution of (6)-(10).*

Proof. The proof proceeds by contradiction.

1. Budget constraint: Let $\{d_j^*, i_j^*, p_j^*\}_{j=0}^{\infty}$ be a solution with strict inequality of (8) for some period τ. Pick $d_\tau = d_\tau^* + \epsilon$. ϵ is a small positive number such that $z_\tau(k_\tau^*)^\alpha - i_\tau^* - p_\tau^* - d_\tau \geq 0$. Thus, we can construct a feasible plan equal to $\{d_j^*, i_j^*, p_j^*\}_{j=0}^{\infty}$ with $d_\tau = d_\tau^* + \epsilon$, which achieves a higher contract value.
2. Participation constraint: Let $\{d_j^*, i_j^*, p_j^*\}_{j=0}^{\infty}$ be a solution with strict inequality of (10). Pick $\epsilon > 0$, $p_0 = p_0^* - \epsilon$ such that $p_0 + \mathbb{E}_1 \sum_{j=0}^{\infty} \beta_C^j p_{j+1}^* \geq 0$. Let $d_0 = d_0^* + \epsilon$ so that the budget constraint does not change and the rest of constraints are satisfied. Thus, we can construct a feasible plan equal to $\{d_j^*, i_j^*, p_j^*\}_{j=0}^{\infty}$ with $p_0 < p_0^*$ and $d_0 = d_0^* + \epsilon$, which is associated with a higher contract value.

■

The original problem of an entrant is then stated as follows:

$$\max_x U(x) = \mathbb{E}_0 \sum_{j=0}^{\infty} \{(\beta)^j (z_j k_j^\alpha + k_j(1-\delta) - k_{j+1} - q_j + \beta_C \mathbb{E}_{j+1} q_{j+1}(z_{j+1})\}, \tag{A.1}$$

subject to:

$$z_j k_j^\alpha + k_j(1-\delta) - k_{j+1} - q_j + \beta_C \mathbb{E}_{j+1} q_{j+1}(z_{j+1}) \geq 0 \tag{A.2}$$

$$U(x; z^\tau) \geq D(k_j; z^\tau), \quad \forall z^\tau, \tau > 0 \tag{A.3}$$

$$\text{given} \quad k_0, z_0, \quad \text{and} \quad q_0 = 0, \tag{A.4}$$

where $U(x; z^\tau)$ describes the continuation value with allocation x and history z^τ and $D(k_j; z^\tau)$ represents the diversion value with capital stock k_j and history z^τ.

Proof of Proposition 1

First, we show that the solution of the original problem $\{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ is feasible in the transformed problem. As the constraints (A.2) and (A.4) are the same in the two problems, we focus on the feasibility of the collateral constraint (11). We prove feasibility by contradiction. Suppose (11) is violated for some τ: $q_\tau > \theta k_\tau(1-\delta)$. Let $\{k_{j+1}^D, \{q_{j+1}^D(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$

denote a sequence of allocations associated with contract repudiation at time τ, with $q^D_\tau = 0$. Let $\{k^D_{j+1}, \{q^D_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$=$\{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$. Thus, dividend policies are the same except in period τ. At period τ, $d_\tau = z_\tau k_\tau^\alpha + k_\tau(1-\delta) - k_{\tau+1} - q_\tau + \beta_C \mathbb{E}(q_{\tau+1})$, while $d^D_\tau = z_\tau k_\tau^\alpha + k_\tau(1-\theta)(1-\delta) - k_{\tau+1} + \beta_C \mathbb{E}(q_{\tau+1})$. Because $q_\tau > \theta k_\tau(1-\delta)$, we have $d^D_\tau > d_\tau \geq 0$. Thus, the newly constructed sequence is a feasible solution of the firm's problem after repudiation, and $\mathbb{E}_\tau \sum_{j=0}^{\infty} d^D_{\tau+j} > \mathbb{E}_\tau \sum_{j=0}^{\infty} d_{\tau+j}$. Then the diversion value $\mathbb{E}_\tau \sum_{j=0}^{\infty} \hat{d}_{\tau+j} \geq \mathbb{E}_\tau \sum_{j=0}^{\infty} d^D_{\tau+j} > \mathbb{E}_\tau \sum_{j=0}^{\infty} d_{\tau+j}$. This inequality then violates the assumption that $\{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ is optimal in the original problem.

Next, we show that the solution of the transformed problem $\{\tilde{k}_{j+1}, \{\tilde{q}_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ is feasible in the original problem. Suppose the enforcement constraint at time τ is violated: $\mathbb{E}_\tau \sum_{j=0}^{\infty} \tilde{d}_{\tau+j} < \mathbb{E}_\tau \sum_{j=0}^{\infty} \hat{d}_{\tau+j}$. We construct a sequence $\{k^N_{j+1}, \{q^N_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$ equal to the optimal policies of repudiating at τ, $\{\hat{k}_{j+1}, \{\hat{q}_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$. Then $d^N_{j+1} = \hat{d}_{j+1}, \forall j \geq \tau$. Let $k^N_\tau = \tilde{k}_\tau$ and $q^N_\tau = \tilde{q}_\tau$. Accordingly, $d^N_\tau = z_\tau \tilde{k}_\tau^\alpha + \tilde{k}_\tau(1-\delta) - \hat{k}_{\tau+1} - \tilde{q}_\tau + \beta_C \mathbb{E}(\hat{q}_{\tau+1})$. As $\hat{q}_\tau = 0$, $\hat{d}_\tau = z_\tau \tilde{k}_\tau^\alpha + \tilde{k}_\tau(1-\theta)(1-\delta) - \hat{k}_{\tau+1} + \beta_C \mathbb{E}(\hat{q}_{\tau+1})$. According to the collateral constraint, $d^N_\tau \geq \hat{d}_\tau$. Thus, $\mathbb{E}_\tau \sum_{j=0}^{\infty} d^N_{\tau+j} \geq \mathbb{E}_\tau \sum_{j=0}^{\infty} \hat{d}_{\tau+j}$, which combined with the violation of enforcement constraint, implies that $\mathbb{E}_\tau \sum_{j=0}^{\infty} d^N_{\tau+j} > \mathbb{E}_\tau \sum_{j=0}^{\infty} \tilde{d}_{\tau+j}$. Because the sequence $\{k^N_{j+1}, \{q^N_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau}^{\infty}$ is feasible in the original problem, it is also feasible in the corresponding transformed problem. Thus, the sequence $\{k^N_{j+1}, \{q^N_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=\tau-1}^{\infty}$ is a feasible solution in the transformed problem. Then $\mathbb{E}_\tau \sum_{j=0}^{\infty} d^N_{\tau+j} > \mathbb{E}_\tau \sum_{j=0}^{\infty} \tilde{d}_{\tau+j}$ indicates $\{\tilde{k}_{j+1}, \{\tilde{q}_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ is not optimal in the transformed problem.

Finally, we show the solution of the original problem $\{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ is also optimal in the transformed problem. Suppose not. Then there exists a new sequence that achieves a higher value because the solution of the transformed problem is also feasible in the original problem. This new sequence then generates a higher value in the original problem, which violates the condition that $\{k_{j+1}, \{q_{j+1}(z)\}_{z\in\mathbb{Z}}\}_{j=0}^{\infty}$ be optimal in the original problem. Similarly, we can prove that the solution of the transformed problem is also a solution of the original problem. ■

Proof of Proposition 2

We apply Theorem 9.6 in Stokey, Lucas, and Prescott (1989) as their Assumptions 9.4-9.7 hold. The only nontrivial of these assumptions is that the constraint set is non-empty, compact-valued, and continuous. We now establish this.

Assume that $z \in \mathbb{Z}$, which is a Borel set in $\mathbb{R}$, and that the transition function has the Feller property. For simplicity and without loss of generality, we assume $k' \in [0, \bar{k}]$ and $q'(z) \in [\underline{q}, \bar{q}]$. Here the upper bound for the capital stock, $\bar{k}$, can be derived from $\bar{k} = z_h \bar{k}^\alpha + \bar{k}(1-\delta)$ because if the capital stock is larger than $\bar{k}$, profit is negative. The upper bound for q can then be derived from the collateral constraint. The lower bound for q is also well defined. First, the limited liability constraint implies that p_j has an upper bound $\forall j$. Second, the initial participation constraint then implies that the lower bound of p_j is well-defined $\forall j$. Therefore the lower bound of q, $\underline{q}$, must also be well defined. Let $\bar{w}$ and $\underline{w}$ be the corresponding boundaries for net wealth. Define the domain $\mathbb{X} = \mathbb{Z} \times [\underline{w}, \bar{w}]$. $\mathbb{Y} = [0, \bar{k}] \times [\underline{q}, \bar{q}]$. Define $\Gamma(w, z)$ as follows.

$$\Gamma(w,z) = \{(k', \{q'(z')\}_{z'\in\mathbb{Z}}) | w - k' + \beta_C \mathbb{E} q'(z') \geq 0;\ \theta k'(1-\delta) \geq q'(z'), \forall z' \in \mathbb{Z}\}.$$

Lemma 2 $\Gamma : \mathbb{X} \to \mathbb{Y}$ *is non-empty, compact-valued, and continuous.*

Proof. Pick $(w, z) \in \mathbb{X}$.

1. $k' = 0$ and $\{q'(z')\}_{z' \in \mathbb{Z}} = 0$ belongs to $\Gamma(w, z)$. Thus, the constraint set is non-empty.

2. $\Gamma(w, z)$ is bounded as a subset of Y. Pick $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \in \Gamma(w, z)$ and $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \to (k', \{q'(z')\}_{z' \in \mathbb{Z}})$. Because of the continuity of the constraints, $(k', \{q'(z')\}_{z' \in \mathbb{Z}}) \in \Gamma(w, z)$. Thus, $\Gamma(w, z)$ is closed and compact-valued.

3. Lower hemi-continuity: Pick $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \in \Gamma(w, z)$ and $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \to (k', \{q'(z')\}_{z' \in \mathbb{Z}})$. $\exists M_1$ such that $|k'_n - k'| < \delta_1$, $|q'_n(z') - q'(z')| < \delta_2, \forall z'$, and $w - k'_n + \beta(1-\delta)\mathbb{E}q'_n(z') > 0$. Pick $w_n \to w$ and $z_n \to z$, $\exists M_2$ such that $|w_n - w| < \delta_3$, $|z_n - z| < \delta_4$, and $w_n - k'_n + \beta(1-\delta)\mathbb{E}(q'_n(z')|z_n) \geq 0$. Let $N = \max(M_1, M_2)$. Then $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \in \Gamma(w_n, z_n)$. Thus, $\forall (k', \{q'(z')\}_{z' \in \mathbb{Z}}) \in \Gamma(w, z)$, $\forall (w_n, z_n) \to (w, z)$, we can find an N such that $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\}_N^\infty \to (k', \{q'(z')\}_{z' \in \mathbb{Z}})$, $\{k'_n, \{q'_n(z')\}_{z' \in \mathbb{Z}}\} \in \Gamma(w_n, z_n)$. The upper hemi-continuity can be proved by applying Theorem 3.4 in Stokey et al. (1989). As (w, z) is chosen arbitrarily, the arguments apply to all $(w, z) \in \mathbb{X}$.

■

Appendix B: Numerical Model Solution

In Appendix B, we summarize the numerical methods used to solve the model in the main text. The basic procedure follows Proposition 2 by using value function iteration. We use the enumeration method to search for a set of feasible boundaries of net wealth w, the capital stock k, and debt q. In particular, the upper bound of k, $\bar{k}$, can be derived from the first-best solution. By fixing the lower bound of q, $\underline{q}$, the upper bound of w ,$\bar{w}$, can be derived using $\bar{k}$ from the definition of the wealth. The upper bound of debt, $\bar{q}$, can be also be derived from $\underline{w}$ and $\underline{k}$. Thus, we only need to search for the feasible values of $\underline{w}$ and $\underline{k}$ in addition to $\underline{q}$. The details of this computational method are as follows:

(a) We first define the sets of possible values of $\underline{w}$ and $\underline{k}$. As w and k are both strictly positive[8], we set the lower bounds of $\underline{w}$ and $\underline{k}$ to be small positive numbers. The upper bounds of $\underline{w}$ and $\underline{k}$ can be derived from the first-best solution. Then, the possible values of $\underline{w}$ and $\underline{k}$ are divided into two vectors, each with 30 equal-spaced grid points. As a starting point, we let $\underline{q} = 0$.

(b) Next we search over the two vectors for $\underline{w}$ and $\underline{k}$ in an ascending order. Give one set of boundaries, the state space of w has 128 log-spaced grid points. The control space of k has 100 equally-spaced grid points. The control space of $q(z')$ has 80 equally-spaced grid points. We then re-compute the first-best case as an initial guess. The $AR(1)$ process of the idiosyncratic shock is discretized using using the algorithm in Tauchen and Hussey (1991) with the number grid points equal to 3.

(c) We then iterate the value function four times. The value function iteration method is described in detail below. During this process, if at least one of the policy functions hits the lower bound of k or the upper bound of $q(z')$ the search process will go back to step (b) and repeat this process for the next set of boundaries. If the iteration survives after four iterations, we proceed to step (d).

[8] See Lemma 6 in Rampini and Viswanathan (2013).

(d) If steps (b) through (c) produce one feasible pair of $\underline{w}$ and $\underline{k}$ but the lower bound of q is hit by the policy function for optimal debt, $\underline{q}$ needs to be updated and the procedure goes back to step (a). Otherwise, we say the procedure finds a feasible set of boundaries.

If the above procedure does find a set of feasible boundaries, we then keep solving the Bellman equation using the value function iteration method and accelerating the process with McQueen Porteus bounds. At each grid point of the state space, the maximum is achieved by searching the control spaces of k and $\{q(z')\}$ plus two extra sets of possible control variables. One set of control variables is associated with all the binding enforcement constraints where k' belongs to the grids of the control space. The other set of control variables is associated with all the binding enforcement constraints and the binding non-negative dividend constraint. In the later case, the binding non-negative dividend constraint is transformed into one equation with one unknown k'. We then use the bisection method to solve for the zero root. The off-grid value of w is interpolated using a cubic spline with a "not-a-knot" condition, as stated in Khan and Thomas (2008).

Appendix C

In Appendix C, we give a brief outline of the estimation procedure, which draws from Ingram and Lee (1991) Duffie and Singleton (1993), but which is adapted to our panel setting. Suppose we have J variables contained in the data vector x_{it}, $i = 1, \ldots, n$; $t = 1, \ldots, T$. We assume that the $J \times T$ matrix x_i is *i.i.d.*, but we allow for possible dependence among the elements of x_i. Let $y_{itk}(b)$ be a data vector from simulation k, $i = 1, \ldots, n$, $t = 1, \ldots, T$, and $k = 1, \ldots, K$. Here, K is the number of times the model is simulated, i.e., the simulated sample size divided by the actual sample size.

The simulated data, $y_{itk}(b)$, depend on a vector of structural parameters, b. In our application $b \equiv$ $(\delta, \alpha, \rho, \sigma_z, \phi, \theta, k_0, \beta_C - \beta)$. The goal is to estimate b by matching a set of simulated moments, denoted as $h(y_{itk}(b))$, with the corresponding set of actual data moments, denoted as $h(x_{it})$. Our moments are listed in the text, and we denote the number of moments as H. Define the sample moment vector:

$$g(x_{it}, b) = (nT)^{-1} \sum_{i=1}^{n} \sum_{t=1}^{T} \left[h(x_{it}) - K^{-1} \sum_{k=1}^{K} h(y_{itk}(b)) \right].$$

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

$$\hat{b} = \arg\min_{b} g(x, b)' \hat{W} g(x, b),$$

in which $\hat{W}$ is a positive definite matrix that converges in probability to a deterministic positive definite matrix W.

Our weight matrix, $\hat{W}$, differs from that given in Ingram and Lee (1991). First, we calculate it using the influence function approach in Erickson and Whited (2002). Second, it is not the optimal weight matrix, and we justify this choice as follows. First, because our model is of an individual firm, we want the influence functions to reflect within-firm variation. Because our data contain a great deal of heterogeneity, we therefore demean each of our variables at the firm level and then calculate the influence functions for each moment using the demeaned data. We then covary the influence functions (summing over both i and t) to obtain an estimate of the covariance matrix of the moments. The estimated weight matrix, $\hat{W}$, is the inverse of this covariance matrix. Note that the weight matrix does not depend on the parameter vector, b.

Two details regarding this issue are important. First, neither the influence functions for the autocorrelation coefficients nor the coefficients themselves are calculated using demeaned data because we obtain them using the double-differencing estimator in Han and Phillips (2010). Thus, we remove heterogeneity by differencing rather than by demeaning. Second, although we cannot use firm-demeaned data to calculate the means in the moment vector, we do use demeaned data to calculate the influence functions for these moments. Otherwise, the influence functions for the means would reflect primarily cross sectional variation, whereas the influence functions for the rest of the moments would reflect within-firm variation. In this case, the estimation would put the least weight on the mean moments, which does not appear to be a sensible economic objective.

The above described weight matrix does achieve our goal of reflecting within-firm variation. However, it does not account for any temporal dependence in the data. We therefore calculate our standard errors using the optimal weight matrix, which is the inverse of a clustered moment covariance matrix. We calculate the estimate of this covariance matrix, denoted $\hat{\Omega}$, as follows. Let ϕ_{it} be the influence function of the moment vector $g(x_{it}, b)$ for firm i at time t. ϕ_{it} then has dimension H. Note that this influence function is of the actual moment vector $g(x_{it}, b)$, which implies that we do not use demeaned data to calculate the influence functions for the means or autocorrelation coefficients, but that we do use demeaned data to calculate the rest of the moments. The estimate of Ω is:

$$\frac{1}{nT}\sum_{i=1}^{n}\left(\sum_{t=1}^{T}\phi_{it}\right)\left(\sum_{t=1}^{T}\phi_{it}\right)'.$$

Note that this estimate does not depend on b. Note also that if we were to use demeaned data, the elements corresponding to the mean moments would be zero.

The standard errors are then given by the usual GMM formula, adjusted for simulation error. Letting $G \equiv \partial g(x_{it}, b)/\partial b$, the asymptotic distribution of b is:

$$\text{avar}(\hat{b}) \equiv \left(1+\frac{1}{K}\right)\left[GWG'\right]^{-1}\left[GW\Omega WG'\right]\left[GWG'\right]^{-1}.$$

Appendix D

Table A.1: Industry Parameter Estimates

Calculations are based on a sample of nonfinancial firms from the annual 2013 Compustat industrial files. The sample period is from 1965 to 2012. The estimation is done with SMM, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments from the data. The table contains the parameter estimates from estimations done on 24 industries. We estimate the model with taxes. δ is the rate of capital depreciation. α is the curvature of the profit function. ρ_z and σ_z are the serial correlation and the standard deviation of the innovation to the profitability shock. θ is fraction of the capital stock lost when a contract is repudiated. $\beta_C - \beta$ is the difference in discount factors between lenders and borrowers. Clustered standard errors are in parentheses.

	δ	α	ρ_z	σ_z	θ	$\beta_C - \beta$
Metal Mining (10)						
	0.027	0.888	0.559	0.219	0.230	0.030
	(0.020)	(0.149)	(0.276)	(0.133)	(0.009)	(0.028)
Oil and Gas (13)						
	0.092	0.815	0.633	0.464	0.383	0.037
	(0.009)	(0.201)	(0.161)	(0.210)	(0.028)	(0.018)
Food (20)						
	0.074	0.734	0.904	0.151	0.304	0.010
	(0.031)	(0.101)	(0.262)	(0.049)	(0.056)	(0.068)
Paper (26)						
	0.075	0.890	0.899	0.135	0.350	0.036
	(0.032)	(0.125)	(0.199)	(0.056)	(0.020)	(0.030)
Printing (27)						
	0.072	0.744	0.630	0.382	0.337	0.010
	(0.032)	(0.131)	(0.213)	(0.159)	(0.080)	(0.005)
Chemicals (28)						
	0.044	0.693	0.906	0.397	0.341	0.040
	(0.016)	(0.085)	(0.176)	(0.083)	(0.023)	(0.048)
Oil Refining (29)						
	0.076	0.878	0.899	0.137	0.314	0.036
	(0.034)	(0.164)	(0.147)	(0.071)	(0.064)	(0.078)
Rubber and Plastics (30)						
	0.081	0.869	0.900	0.179	0.334	0.040
	(0.037)	(0.118)	(0.207)	(0.061)	(0.073)	(0.107)
Stone, Clay, Glass, Concrete (32)						
	0.057	0.909	0.787	0.230	0.385	0.014
	(0.024)	(0.136)	(0.110)	(0.117)	(0.001)	(0.001)
Primary Metal (33)						
	0.025	0.896	0.630	0.208	0.358	0.011
	(0.017)	(0.203)	(0.116)	(0.101)	(0.040)	(0.002)
Fabricated Metal (34)						
	0.078	0.877	0.901	0.069	0.290	0.010
	(0.041)	(0.073)	(0.409)	(0.072)	(0.063)	(0.007)

	δ	α	ρ_z	σ_z	θ	$\beta_C - \beta$
Machinery (35)						
	0.042	0.888	0.630	0.281	0.285	0.021
	(0.015)	(0.126)	(0.256)	(0.063)	(0.001)	(0.020)
Electronics (36)						
	0.054	0.860	0.630	0.402	0.281	0.030
	(0.018)	(0.105)	(0.234)	(0.130)	(0.030)	(0.005)
Transportation Equipment (37)						
	0.034	0.890	0.680	0.260	0.370	0.018
	(0.028)	(0.246)	(0.352)	(0.123)	(0.007)	(0.012)
Instrumentation (38)						
	0.058	0.844	0.630	0.398	0.286	0.032
	(0.021)	(0.209)	(0.254)	(0.120)	(0.040)	(0.061)
Trucking (42)						
	0.085	0.920	0.772	0.142	0.397	0.034
	(0.035)	(0.246)	(0.240)	(0.047)	(0.003)	(0.002)
Air Transportation (45)						
	0.035	0.890	0.847	0.284	0.575	0.034
	(0.036)	(0.186)	(0.373)	(0.145)	(0.008)	(0.019)
Communications (48)						
	0.079	0.797	0.888	0.400	0.522	0.038
	(0.017)	(0.163)	(0.369)	(0.102)	(0.044)	(0.022)
Wholesale Durable (50)						
	0.045	0.850	0.900	0.278	0.349	0.040
	(0.025)	(0.127)	(0.365)	(0.082)	(0.034)	(0.144)
Wholesale Nondurable (51)						
	0.039	0.908	0.721	0.199	0.350	0.025
	(0.018)	(0.135)	(0.275)	(0.110)	(0.026)	(0.016)
Restaurants (58)						
	0.050	0.898	0.712	0.240	0.533	0.035
	(0.022)	(0.162)	(0.344)	(0.107)	(0.010)	(0.028)
Business Services (73)						
	0.044	0.762	0.630	0.408	0.297	0.012
	(0.017)	(0.061)	(0.238)	(0.181)	(0.030)	(0.001)
Health Services (80)						
	0.074	0.815	0.851	0.401	0.499	0.040
	(0.039)	(0.179)	(0.237)	(0.135)	(0.061)	(0.045)
Engineering, Accounting, Research (87)						
	0.031	0.909	0.640	0.159	0.338	0.031
	(0.017)	(0.151)	(0.292)	(0.042)	(0.008)	(0.025)