PRELIMINARY AND INCOMPLETE!

Estimating the Effects of Contracting Frictions

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Abstract

We quantify the extent to which contracting frictions affect firms' real and financial decisions. To this end, we estimate a dynamic contracting model based on limited entrepreneurial commitment. In the model a firm seeks financing from an intermediary, but the firm can renege on the financing contract. The optimal contract is self-enforcing, so that financial constraints arise endogenously. The model uses relatively few parameters to reconcile many features of the data across young and old firms. Our counterfactual exercises show that endogenous financial constraints affect investment only when the financial constraint binds. These constraints always have an effect on firm leverage, and these effects are quantitatively important.

1 Introduction

It is safe to say that financial frictions affect firms' real economic decisions. Hundreds of studies have demonstrated that the cross-sectional and time-series patterns in investment, employment, and finance are nearly impossible to reconcile with a world in which external finance is easy to obtain. However, evidence concerning the specific mechanisms that link finance to real decisions is scarcer. Several studies have uncovered evidence concerning particular institutional frictions such as debt covenants (Chava and Roberts 2008) or government interventions in lending (Paravisini 2008). However, quantifying the effects of the fundamental agency or information problems behind financial frictions is more difficult because these abstract concepts are, by definition, unobservable.

We step into this picture by trying to understand empirically the extent to which contracting frictions affect financing arrangements and thus real economic activity. To this end, we formulate and estimate a model of capital structure based on limited enforceability of contracts between lenders and firms. The fundamental friction in the model is an agency issue that arises because of managers' option to renege on a contract and divert the firm's resources as a private benefit. Estimates of the parameters of the model reveal that this agency issue can reconcile differences in financing patterns between new and old firms, as well as across several industries. We find that the parameters describing this contracting friction statistically significant and quantitatively important. Lowering the manager's incentive to renege on a contract increases investment, but only for firms that are financially constrained. In contrast, changing the incentive to renege has a large impact on firm leverage. Interestingly, we find these substantial effects even though the model contains no taxes. This result indicates that the tradeoff between taxes benefits and bankruptcy costs cannot be the only important determinant of financing patterns.

In the model a firm with potential infinite lifespan enters the market with a valuable

investment opportunity but with insufficient funds to start it. The firm must therefore obtain financing from an intermediary. There are no informational asymmetries: the intermediary can observe firm policies. However, financing is not frictionless because the firm can renege on a financing contract, abscond with the firm's capital, and start over, albeit after paying a cost. In this setting, the only feasible contracts are self-enforcing, so that the firm never has an incentive to renege. In other words, the contract specifies 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. Specifically, the contract states the initial loan size, as well as future behavior, which is contingent on the history of observable shocks to the firm's profitability. This future behavior includes a repayment schedule and possible future financing. The contract is sufficiently flexible that the firm can save in some states of the world, instead of carrying a stock of debt. The contract also constrains the firm's investment and dividend policies, depending on the profitability history. Thus, borrowing constraints and investment policy emerge endogenously as a product of an optimal contract.

The state-contingent nature of the contract seems at first unnatural because debt contracts are typically thought of as being state-incontingent. However, Roberts (2012) documents that most loan contracts get renegotiated multiple times over their lifetime, and the mere existence of debt covenants implies that debt cannot, by definition, be completely state-incontingent.

We estimate the model parameters using simulated method of moments (SMM), which chooses parameters to minimize the distance between moments calculated from real data and the same moments calculated via simulation of the model. We obtain estimates of parameters describing the firm's technology, but more importantly, the size of the loan relative to the initial size of the firm, and two parameters that describe the firm's incentive to renege on the contract. The first of these is the fraction of the firm's assets that can be diverted in the event of default. The second is a start-up cost the firm must pay after it reneges but before

it can re-enter the loan market and start over.

We find largely reasonable parameter estimates. Our estimates of the firm's technological characteristics, such as the capital depreciation rate and the extent of decreasing returns to scale are in line with many other structural estimation studies (e.g. Hennessy and Whited 2005, 2007). Interestingly, we find that estimates of the firm's initial conditions are useful for understanding the difference between the investment and financing of young and old firms. Finally, as noted above, we find that the parameters describing the contracting frictions are statistically different from zero and economically important.

Structural estimation is a technique that is ideally suited to measuring the effects on financing and investment of a manager's ability to divert resources. Financing and investment are endogenous, and there are few obvious instruments. The main sources of the contracting frictions are unobservable. Quantifying their effects therefore requires a model, which puts enough structure on the data to tease out the effects of interest.

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

The second literature is the structural estimation of dynamic models in corporate finance, such as Hennessy and Whited (2005, 2007), DeAngelo, DeAngelo, and Whited (2011), and Morellec, Nikolov, and Schürhoff (2012). These papers examine such issues as capital structure, financial constraints, and agency problems. Our paper departs from these predecessors in one important dimension. Instead of specifying financial constraints or agency concerns as

an exogenous parameter, we derive financial constraints from an optimal contracting framework. Expressing finance constraints exogenously has the advantage that one can model a richer set of financial decisions. Unfortunately, this approach has the drawback that the counterfactuals are not meaningful because the parameters that describe financial constraints are not likely to be invariant to firms' actions. In contrast, estimating an actual contracting model allows one to examine counterfactual questions with respect to deeper parameters.

Our paper is most closely related to Nikolov and Schmid (2012), which also estimates a dynamic contracting model. However, our paper examines a different question. While we focus on the effects of finance constraints, their work examines the effects of agency frictions on capital structure. In addition, they work with a different class of contracting models (e.g. DeMarzo and Sannikov 2006; DeMarzo, Fishman, He, and Wang 2012). In that class of models the implementation of the contracts in terms of capital structures is not unique, so it is impossible to know which implementation corresponds to the actual capital structures we observe in the data.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 describes the data. Section 4 explains the estimation methodology and identification strategy. Section 5 presents the estimation results. Section 6 describes several counterfactual exercises, and Section 7 concludes.

2   The Model

This section develops the model, which is a simple limited-enforcement contracting problem in the spirit of Albuquerque and Hopenhayn (2004), Rampini and Viswanathan (2010, 2012), or Lorenzoni and Walentin (2007). We start with a description of the firm's technology. We then move on to describing the incentive and contracting environment. Finally, we characterize the optimal contract.

2.1 Technology

We consider an industry that consists of a continuum of firms, each of which produces a homogeneous product. Firms can enter and exit the industry. At time t, an entrant with capital stock k_0 can start to use this capital after paying a fixed initial investment $I_0 \geq 0$. Incumbents become unproductive and exit the industry with probability ϕ. We assume the mass of firms is fixed and normalize it to be one. Therefore, the mass of entrants each period is also ϕ.

Both incumbents and entrants use the production technology $y_t = z_t k_t^\alpha$, in which k_t is a capital input, and z_t is a firm-specific technology shock, which follows a Markov process with finite support $\mathbb{Z}$ and transition matrix Π. The entrant also takes its initial productivity draw from the same shock process. The law of motion for k_t is given by

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

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

2.2 Contracting Environment

We assume that the entrant does not have sufficient funds for the initial setup cost I_0, and therefore obtains financing by entering a contractual relationship with a financial intermediary/bank/lender. We also assume that firms have a higher discount factor than do banks, as in Lorenzoni and Walentin (2007). Let β be the discount factor for the firms, and let β_C be the discount factor for the banks, with $\beta_C > \beta$ so that firms are less patient than lenders. We make two further assumptions that shape the contract. First, the entrepreneur has limited liability. Second, the lender commits to the long-run contract, while the firms can choose to default; that is, the long-run contract has one-sided commitment.

The timing of events is as follows. When a new firm is born at time t, it receives a draw from the invariant distribution of the productivity shock and an initial capital stock

k_t. The firm then signs a long-term contract with the lender that provides the initial setup investment I_0. 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 next period, the firm first faces an exogenous exit shock. If it survives, the firm can choose whether to renege on the contract after observing the productivity shock. If the firm does not renege, the plan defined by the contract continues to be implemented.

We now define the specifics of the contract. Let z_t be the state at time t, and let $z^t = (z_1, z_2, \ldots, z_t)$ denote the history of states from times 1 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 to be either positive or negative, with positive amounts corresponding to repayments to the intermediary and negative amounts corresponding to additional external financing. The contract is thus fully state contingent.

A contract is feasible if

$$d_{t+j}(z^{t+j}) \geq 0 \tag{2}$$

$$z_{t+j}k_{t+j}^{\alpha} - i_{t+j}(z^{t+j}) \geq d_{t+j}(z^{t+j}) + p_{t+j}(z^{t+j}) \tag{3}$$

for any z^{t+j}, $j \geq 0$. The constraint (2) 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. The constraint (3) is simply the budget constraint, which requires that net revenue be at least as large as payments to shareholders and the lender.

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 divert a fraction $(1 - \theta)$ of the capital k_t, at which point its liability is set to zero.

At this point the firm is not excluded from the market. Instead, it can reinvest the diverted capital and signs a new contract. Thus, one form of punishment for the defaulting firm is the loss of a fraction θ of the firm's assets.[1] This feature of the model captures Chapter 11 renegotiation, rather than Chapter 7 liquidation. We also assume that the firm incurs a second diversion cost, κ/k_τ, when it repudiates the original contract at time τ. This cost, which is inversely proportional to the capital stock at the time of default, can be interpreted either as a fee for repudiating the contract or as a start-up cost when the firm signs a new contract. In the second interpretation, the inverse proportionality feature captures the idea that larger firms need fewer additional assets to start over than do small firms.[2]

The total value to the firm of repudiating an active contract at time τ is then:

$$D(k_\tau, z_\tau) = \mathbb{E}_\tau \sum_{j=0}^{\infty} (\beta(1-\phi))^j \hat{d}_{\tau+j} - \frac{\kappa}{k_\tau}, \tag{4}$$

in which for brevity we have omitted the dependence of d_t on the shock history, and in which $\mathbb{E}(\cdot)$ is the expectation operator with respect to the transition function Π.

The diversion value in (4) is a primitive of the model and has two parts. The first term is the equity value of reinvesting the diverted capital. Note that this sum is the contract value for the shareholder with capital $(1-\theta)k_\tau$ and no set-up cost, that is, $I_0 = 0$. The assumption of no set-up cost is innocuous in that set-up costs can be subsumed in second part of (4).

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

$$D(k_\tau, z_\tau) \leq \mathbb{E}_\tau \sum_{j=0}^{\infty} (\beta(1-\phi))^j d_{\tau+j}. \tag{5}$$

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[1] The form of diversion is adopted from Lorenzoni and Walentin (2007).

[2] This features of the model also ensures that the model has a solution for all states k_t and z_t.

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

2.3 The Optimal Financial Contract

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

$$\max_{\{d_{t+j}, i_{t+j}, p_{t+j}\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} (\beta(1-\phi))^j d_{t+j} \tag{6}$$

subject to

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

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

$$\mathbb{E}_{\tau} \sum_{j=0}^{\infty} (\beta(1-\phi))^j d_{\tau+j} \geq D(k_{\tau}, z_{\tau}), \quad \forall \tau > t \tag{9}$$

$$\mathbb{E}_t \sum_{j=0}^{\infty} (\beta_C(1-\phi))^j p_{t+j} \geq I_0 \tag{10}$$

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 the contract with the firm if it expects the present value of its repayments to be at least as large as its initial investment in the firm. Note that the lender discounts these payments at a lower rate than does the firm.

2.4 Recursive formulation

To facilitate a feasible solution, this section reformulates the contracting problem recursively, with the solution characterized as the Pareto frontier between the value entitlements of the firm and the lender, given by (6) and (10), respectively. Define

$$q_{\tau} \equiv \mathbb{E}_{\tau} \sum_{j=0}^{\infty} (\beta_C(1-\phi))^j p_{\tau+j},$$

which is the contract value for debt owners, or the promised debt at time τ. Following Spear and Srivastava (1987) and Abreu, Pearce, and Stacchetti (1990), the contractual problem can be stated recursively using q_τ as a state variable.

Let a prime denote a variable in the subsequent period, and let no prime denote a variable in the current period. Then the Bellman equation for the problem can be expressed as:

$$V(k, q, z) = \max_{k', q(z')} zk^\alpha + k(1-\delta) - q - k' + \beta_C(1-\phi)\mathbb{E}q(z') + \beta(1-\phi)\mathbb{E}V(k', q'(z'), z') \quad (11)$$

subject to

$$zk^\alpha + k(1-\delta) - q - k' + \beta_C(1-\phi)\mathbb{E}q(z') \geq 0 \quad (12)$$

$$V(k', q'(z'), z') \geq D(k', z'), \quad \forall z' \in \mathbb{Z}, \quad (13)$$

where $D(k', z') = V((1-\theta)k', 0, z') - \kappa/k'$.

We now simplify the problem by reducing the dimension of the state space. Define the net wealth $w \equiv zk^\alpha + k(1-\delta) - q$. It is straightforward to show that the solution to the above problem depends only on this variable and not on its individual components. To see this property of the solution, note that without the constraints (12) and (13), the solution to the unconstrained optimization (11) does not depend on both k and q because the Modigliani-Miller theorem holds. In this case the total value of the firm does not depend on how much of it is financed with debt. In the case of a constrained problem, k and q appear in the constraint (12) only to the extent that they define net wealth. Thus, the recursive problem can be rewritten as follows:

$$V(w, z) = \max_{k', q(z')} w - k' + \beta_C(1-\phi)\mathbb{E}q(z') + \beta(1-\phi)\mathbb{E}V(w'(z'), z') \quad (14)$$

subject to

$$w - k' + \beta_C(1-\phi)\mathbb{E}q(z') \geq 0 \quad (15)$$

$$V(w'(z'), z') \geq D(k', z'), \quad \forall z' \in \mathbb{Z}, \quad (16)$$

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where $D(k', z') = V(w_1(z'), z') - (\kappa/k')$ and $w_1(z') = z'(k'(1-\theta))^\alpha + k'(1-\theta)(1-\delta)$.

Solving this problem is difficult for two reasons. First, in contrast to a standard dynamic programming problem, the value function appears in the constraints. Second, for some sets of model parameters, the constraint set is empty. We therefore compute the model under feasible parameterizations and then evaluate/estimate the model based on these parameter sets.

To implement a solution algorithm, we assume that under some parameterizations, the constraint set is not empty. The computation algorithm follows the approach pioneered in Abreu, Pearce, and Stacchetti (1990), in which the iteration begins with an initial guess that strictly dominates the solution, in the sense that both the lender and the firm are better off. In particular, we use the Pareto frontier of the first-best problem as the initial guess, as in Thomas and Worrall (1994). Here the first best problem is for the shareholders to maximize the total gain from the project in the absence of enforcement problems, the Pareto frontier is then defined as follows:

$$W(w, z) = \max_{k', q'} \quad w - k' + \beta_C(1-\phi)q' + \beta(1-\phi)\mathbb{E}W(w', z') \tag{17}$$

where $w = zk^\alpha + k(1-\delta) - q$. Note that here w' does not depend on the future state z', whereas w' does depend on z' in the constrained optimization problem. The reason is that in the constrained problem, w' depends on the state contingent payments to the lender, whereas in the first-best problem, any such payments are undefined.

Define the mapping T in the space of bounded functions.

$$T(V)(w, z) = \max_{k', q(z')} \quad w - k' + \beta_C(1-\phi)\mathbb{E}q(z') + \beta(1-\phi)\mathbb{E}V(w'(z'), z') \tag{18}$$

subject to (15) and(16). The following lemma is useful for computation.

Lemma 1 *When the constraint set is not empty, or the constrained problem has a solution, $T^n(W)$ converges pointwise to V as $n \to \infty$.*

The solution to the model can then be obtained by iterating on (18).

2.5   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 (15), and let $\beta(1 - \phi)\pi(z'|z)\lambda_{z'}$ be the Lagrange multiplier associated with the enforcement constraint (16) at state z'. $\pi_{z'|z}$ is the transitional probability from state z to state z'. The first order condition for k' is:

$$- (1 + \mu) + \beta(1 - \phi) \sum_{z'} \pi_{z'|z}(1 + \lambda_{z'})V_w(w', z')\frac{\partial w'}{\partial k'} - \beta(1 - \phi) \sum_{z'} \pi_{z'|z}\lambda_{z'}\frac{\partial D'}{\partial k'} = 0. \quad (19)$$

where $\frac{\partial w'}{\partial k'} = z'\alpha k'^{\alpha-1} + 1 - \delta$.

To understand (19), note that when $\mu = 0$, $\lambda_{z'} = 0$; that is, when the firm is paying dividends, the enforcement constraint cannot be binding. In this case, (19) reduces to a condition that the expected marginal product of capital equals the user cost; that is, the optimal capital stock is the same as it is in the unconstrained case. On the other hand, if the enforcement constraint is expected to bind in any state, then the constrained capital stock can be either higher or lower than it is in the first best case. To see this result, we rewrite (19) as

$$\beta(1 - \phi) \sum_{z'} \pi_{z'|z}V_w(w', z')\frac{\partial w'}{\partial k'} + \beta(1 - \phi) \sum_{z'} \pi_{z'|z}\lambda_{z'} \left(V_w(w', z')\frac{\partial w'}{\partial k'} - \frac{\partial D'}{\partial k'} \right) - \mu = 1.$$

The first term is the constrained ratio of the marginal product of capital to the user cost. This term does not equal the equivalent ratio in the unconstrained case because the shadow value of net wealth V_w is different in the constrained and unconstrained cases. The next term is the expected difference between the marginal product of capital and the marginal contribution of capital to the diversion value, where this difference is weighted by the shadow value of the enforcement constraint. The final term is the shadow value of the enforcement

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constraint. Depending on the relative magnitudes of these three terms, the constrained firm can invest either more or less than its unconstrained counterpart.

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

$$1 + \mu + \frac{\beta}{\beta_C}(1 + \lambda_{z'})V_w(w', z')\frac{\partial w'}{\partial q'} = 0, \tag{20}$$

where $\frac{\partial w'}{\partial q'} = -1$.

According to the envelope theorem, $V_w(w, z) = 1 + \mu$. Therefore, (20) shows that if $\beta = \beta_C$, the firm will not pay out dividends when the enforcement constraint binds, that is, when the firm is financially constrained. Since $\lambda_{z'} > 0$, μ must be positive because $V_w(w', z') \geq 0$. However, when $\beta_C > \beta$, there is no such relation between a binding enforcement constraint and dividend payments. Even if the firm begins to distribute dividends, the enforcement constraint could still bind, that is, $\lambda_{z'} > 0$ even when $\mu = \mu' = 0$. In other words, the assumption that the firm is less patient than the lender indicates that financing policy matters in the long run, even for old firms. From equation (20), we know that the firm will never be completely unconstrained, since the equation does not hold when $\lambda_{z'} = \mu = \mu' = 0$.

2.6 Policy Functions

3 Data

Our data are from the 2012 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. As a result of these selection criteria, we obtain a panel data set with 100,149 observations for the time period between 1964 and 2011 at an annual frequency.

We define total assets as Compustat variable AT, the capital stock as PPEGT, investment

as capital expenditures (CAPX) minus sales of capital goods (SPPE), cash and equivalents as CHE, operating income as OIBDP, equity repurchases as PRSTK, dividends as the sum of common and preferred dividends (DVC + DVP), debt as (DLTT + DLC), depreciation as DP, current assets as AC, and Tobin's q as the ratio of (AT + PRCC_F × CSHO − TXDB − CEQ − AC) to PPEGT. Investment is expressed as a fraction of the capital stock, but net leverage (DLTT+DLC − CHE), total payout (dividends plus repurchases), and operating profit are expressed as fractions of total assets.

4   Estimation

This section provides an intuitive description of our estimation procedure and discusses the identification of our parameters. The appendix contains the technical details.

4.1   Simulated Method of Moments

We estimate most of the structural parameters of the model using simulated method of moments. 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 real 3-month Treasury bill rate over our sample period. We then estimate the following parameters using simulated method of moments: the depreciation rate, δ; the production function curvature, α; σ_z and ρ; the probability of exit, ϕ, the fraction of the capital stock that can be diverted, θ, the extra cost of diverting, κ; the time-zero capital stock, k_0; the initial investment, I_0, and the difference between the creditors' discount rate and the firms' discount rate, $\beta_C - \beta$. To estimate the transition matrix, Π, we approximate it as an $AR(1)$ process in logs, given by

$$\ln z_{t+1} = \rho \ln z_t + \varepsilon_{t+1}. \tag{21}$$

Here, ε_t 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.

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. Next, we calculate interesting moments using both these 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.

The next issue in SMM is whether to match moments using an identity matrix or a weight matrix based on the moment covariances. Using an identity matrix implicitly puts the most weight on the moment that is the largest in absolute value. Because the size of a moment rarely corresponds to a relevant economic or statistical objective, we match moments using the inverse of the covariance matrix of the moments. Roughly speaking, this scheme puts the most weight on the most precisely estimated moments, which is a sensible statistical objective. See the Appendix for details.

One final issue is unobserved heterogeneity in our data from Compustat. These firms differ along a variety of dimensions, such as industry and age. In contrast, although our simulations do generate substantial heterogeneity in terms of financial constraints, the amount of heterogeneity in the real data dwarfs that in the simulated data. Therefore, in order to render our simulated data comparable to our actual data, we use fixed firm effects in the estimation of variances and covariances. We calculate autocorrelation coefficients using the method in Han and Phillips (2010), which controls for heterogeneity at the firm level.

4.2 Identification

The success of this procedure relies on model identification. Global identification of a simulated moments estimator obtains when the expected value of the difference between the simulated moments and the data moments equal zero if and only if the structural parameters equal their true values. A sufficient condition for identification is a one-to-one mapping

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between the structural parameters and a subset of the data moments of the same dimension. Because our model does not yield such a closed-form mapping, we take care to choose moments that are sensitive to variations in the structural parameters such as the diversion parameter, θ. On the other hand, we do not "cherry-pick" moments. Instead, we examine the mean, variance, and serial correlation of all of the variables we can compute from our model: investment, profits, payout, net leverage, and Tobin's q. We also use several correlations between these variables that are particularly useful for identifying specific parameters.

We now describe and rationalize the 18 moments that we match. The first 15 are the means, variances, and first-order autocorrelation coefficients for the rate of investment, the ratio of profits to assets, the leverage ratio, Tobin's q, and the ratio of distributions to assets. We include all of these moments to "stress test" the model to ascertain whether it can capture broad features of the data. In this list several of 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 variance 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 profits and Tobin's q. As α decreases, the firm faces more severe decreasing returns to scale, which, all else held constant, results in lower average profits, and thus Tobin's q.

The identification of the rest of the parameters is slightly more nuanced and requires three additional moments: the correlations between profits and Tobin's q, between leverage and Tobin's q, and between leverage and distributions. The two identification argument that follow can be thought of a finding a non-zero Jacobian for an exactly identified system of linear equations. First, we consider the four parameters, ϕ, θ, κ, and $\beta_C - \beta$. Leverage is strongly increasing in each one, so although leverage is informative about these four param-

eters, this one moment cannot identify them all. However, only one of these parameters, ϕ, the probability of exiting the industry, induces changes in the correlation between profits and q. The reason is simple: as ϕ rises, the discount rate rises. This change in the discount rate in turn decouples current profits from the expected present future distributions, which is roughly the numerator of Tobin's q. Next, although the variance of leverage is increasing in ϕ, κ, and $\beta_C - \beta$, it is invariant to θ. Finally, the variance of profits rises with $\beta_C - \beta$ because the variance of the capital stock rises with this parameters. However, the variance of profits is unaffected by θ and κ. Thus, we have four relationships between moments and parameters, with enough "zeros" in these four relationships to be able to identify each of the parameters.

Finally, we need to identify k_0 and I_0. Here, we use the correlations between leverage and Tobin's q and between leverage and distributions. Both parameters induce sharp monotonic movements in the second correlation, but only I_0 induces substantial movement in the first. Thus, we have enough moments to identify all of our parameters. The extra moments then serve to provide overidenfitying information, which can be used for specification testing.

5   Results

Table 1 contains the results from our estimation. We have divided the sample into two groups: observations on firms in the first five years since their IPO and observations preceded by at least a 20 year history after the IPO. Panel A contains estimates of the real-data moments, the simulated moments, and the t-statistics for the difference between the two. Panel B contains the parameter estimates.

Panel A shows that the model fits the data reasonably well. Across the two estimations just over half of the simulated moments are statistically significantly different from their real-data counterparts, but only a few are *economically* different. This good fit is remarkable, given that we have used almost twice as many moments as parameters in the estimation.

The model does a particularly good job in matching the mean of net leverage and several of the serial correlation coefficients. The model does a fair job of matching such moments as the means of investment, Tobin's q, and profits. The model struggles with several features of the data. The variance of Tobin's q is much too small in the simulated data relative to its real-data counterpart. This result is shared by many asset pricing models, which cannot reconcile the observed high volatility of asset prices. In addition, simulated distributions to shareholders are much larger and more volatile than their real-data counterparts. This failure to reconcile dividends observed smoothing is shared by all but a handful (e.g. Lambrecht and Myers 2012) of dynamic investment and financing models. 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. Our conclusion is that the model is indeed useful for understanding several important regularities in our data.

Panel B shows that our estimates of fundamental contracting frictions are significantly different from zero. We estimate that the young firms lose about 17% of their assets as a deadweight cost when they repudiate a contract. The figure for old firms is somewhat smaller at 14%, but the two estimates are not statistically different from one another. In contrast, the estimates of the costs of market reentry after repudiation do differ across the two groups. The estimate for the young firms is nearly twice as small as that for old firms, so that their contracting frictions are *higher*. In other words, because young firms find it easier to repudiate a contract than old firms, they are more likely to be financially constrained by their contracts. In Section 6 below, we quantify these estimates in terms of their implications for investment and financing.

Our estimates of the starting conditions for the firms are also of interest in that they do not differ significantly across the two groups. Thus, differences in financing and investment patterns across the two groups are more likely a product of their entire histories than of their starting points.

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Our estimates of the technological parameters, δ, α, ρ, and σ_z are all in line with those found in previous studies such as Hennessy and Whited (2005, 2007). With respect to these technological characteristics, the two groups of firms differ in the rate at which capital depreciates, which is higher for the young firms. This result makes sense because the depreciation rate is identified off of the average rate of investment, which is higher for the young firms. They also differ in the persistence of their cash flows, with the older firms having more persistent and, therefore, predictable cash flows.

The only parameter estimate that appears unreasonable is the exogenous rate of exit, which is estimated to be tiny and insignificantly different from zero. In reality, we do see substantial turnover in the Compustat database, so this result indicates that our model is not useful for understanding this feature of the data.

6   Counterfactuals

We now examine what would happen to observed firm financing and investment patterns if firms had different fundamental characteristics than those implied by the parameter estimates from Table 1. To this end, we consider a baseline simulated firm whose parameters are the average of the estimates from the young and old firms. We then investigate results of changing two key parameters: θ and κ, which are the proportion of the capital stock if the firm repudiates a contract and the fixed cost of reentering the market after repudiation.

The results from these exercises are in Figures 1 and 2. To constrict each of these figures, we pick a grid for the parameter in question. We then solve the model for each of the different parameter values, simulate the model for 200 firms over 50 time periods, and then plot average leverage, investment, Tobin's q, and dividends as functions of either θ or κ. We also consider two groups of *simulated* firm-year observations. "Constrained" firms are those for whom the enforcement constraint binds, and "unconstrained" firms are those for whom the enforcement constraint doesn't bind.

Figure 1 contains the results from varying θ. The first striking result is the difference between constrained and unconstrained firms. The constrained firms pay no dividends, have much higher values of Tobin's q, and invest at a substantially higher rate. Interestingly, both the constrained and unconstrained firms have the same level of leverage, regardless of the level of θ. Clearly, constrained firms are financing their rapid growth primarily with internal funds. Unconstrained firms, in contrast, are only investing enough to replace depreciated capital and paying the rest of their cash flow out to shareholders. These last two results represent an external validity check on the model. The life-cycle of simulated firms appears close to that of real-world firms.

Two further results are of interest in Figure 1. First, a firm's incentive to renege on a contract has a noticeable effect on its investment, but only when the firm is constrained. Relative to a "baseline" firm with a value of 0.08 for θ, a firm with $\theta = 0$ (with a larger incentive to repudiate) invests approximately 11% less. In contrast, an unconstrained firm just replaces depreciated capital no matter what incentive it has to repudiate a contract. Thus, endogenous financial constraints affect only constrained firms, who are not getting enough debt financing and would use more debt and invest more if contracting frictions did not limit their access to credit. Second, changing θ has a profound effect on leverage. When $\theta = 0$ for either the constrained or unconstrained firms, leverage is near zero, that is, intermediaries grant them little external financing. Leverage rises monotonically as θ increases from 0 to 0.16, for both the constrained and the unconstrained firms. As the firm's incentive to repudiate the contract falls, the contract allows for more debt financing. For the constrained firms, the debt serves to finance investment, but for the unconstrained firms the debt serves to increase payout to shareholders. Figure 2 tells approximately the same story as Figure 1, which is reassuring, given that both θ and κ quantify the value to the firm of repudiating the contract.

7 Conclusion

We have sought to estimate the underlying economic frictions behind the contracts that lead to financial constraints. This goal departs from much of the structural estimation literature, which models financial constraints as exogenous parameters that cannot be changed. Our model departs from this framework by endogenizing financial constraints as the outcome of an optimal contracting model. We can therefore answer more questions than can the previous literature, such as Whited (1992) or Hennessy and Whited (2007). Although these studies provide useful measures of the extent to which firms are financially constrained, they are less useful for answering counterfactual questions regarding what would happen if financial constraints were tightened or loosened. Our work overcomes this issue by estimating firms' fundamental incentives to renege on financial contracts.

We estimate that these contracting frictions are statistically significant, both for young and old firms. We find that these incentives have an important effect on capital structure, whether or not firms are financially constrained. In either case, reducing a firm's incentive to renege on a contract leads to a sharp increase in its use of outside financing. In contrast, endogenous financial constraints only affect the investment of constrained firms.

We speculate that optimal contracting models can be used as bases for estimating the effects of contracting frictions on a variety of corporate finance questions. One obvious candidate is executive compensation, but others include managerial incentives in a conglomerate, mergers, and banking decisions.

Appendix

We now 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 $b \equiv (\delta, \alpha, \rho, \sigma_z, \phi, \theta, \kappa, k_0, I_0, \beta_C - \beta)$. 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

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

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Table 1: SIMULATED MOMENTS ESTIMATION

Calculations are based on a sample of nonfinancial firms from the annual 2012 COMPUSTAT industrial files. The sample period is from 1964 to 2011. The sample is split into two groups: observations on firms in the first ten years after their IPO, and observations on firms twenty years after their IPO—young and old. 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. ϕ is the exogenous exit rate. θ and κ are the fraction of the capital stock lost when a contract is repudiated and the cost of reentering the market after repudiating a contract. k_0 and I_0 are the initial capital stock and the initial investment cost. $\beta_C - \beta$ is the difference in discount factors between lenders and borrowers.
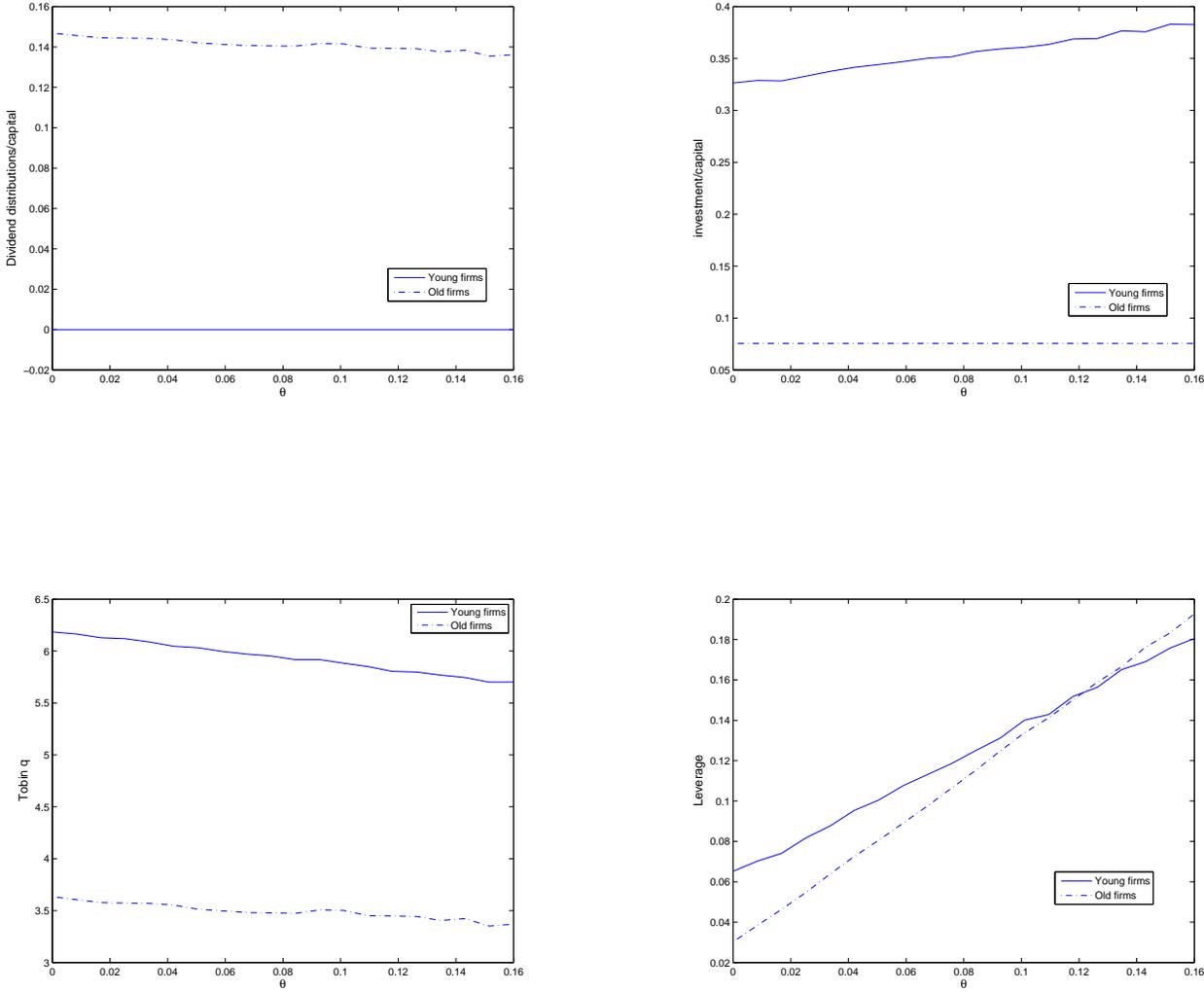
A. Moments

|	Young			Old		
	Simulated	Actual	T-Statistic	Simulated	Actual	T-Statistic
Average net debt	0.101	0.121	1.983	0.153	0.148	-1.178
Variance of net debt	0.001	0.007	3.000	0.006	0.018	3.011
Serial correlation net debt	0.818	0.825	0.941	0.776	0.806	0.798
Average investment	0.128	0.176	3.101	0.086	0.106	3.078
Variance of investment	0.005	0.007	0.297	0.008	0.004	-2.015
Serial correlation investment	0.331	0.639	1.148	0.403	0.511	0.697
Average profits	0.221	0.145	-5.523	0.181	0.144	-3.170
Variance of profits	0.000	0.003	3.021	0.007	0.004	-2.035
Serial correlation profits	0.358	0.786	1.677	0.385	0.621	3.758
Average Tobin's q	3.171	3.444	1.886	3.043	2.336	-5.793
Variance of Tobin's q	0.014	3.762	5.999	0.017	3.150	6.277
Serial correlation Tobin's q	0.414	0.829	2.318	0.615	0.816	0.738
Average distributions	0.127	0.018	-7.913	0.122	0.035	-9.174
Variance of distributions	0.004	0.000	-4.457	0.006	0.001	-4.068
Serial correlation of distributions	-0.019	0.162	0.787	0.100	0.231	1.016
Correlation between profits and Tobin's q	0.297	0.140	-2.565	0.546	0.173	-2.010
Correlation between leverage and Tobin's q	0.036	-0.143	-2.446	0.008	-0.049	-1.018
Correlation between leverage and distributions	-0.122	-0.149	0.064	0.012	-0.242	4.554

B. Parameter estimates

	δ	α	ρ_z	σ_z	ϕ	θ	κ	k_0	I_0	$\beta_C - \beta$
Young										
	0.118	0.579	0.576	0.002	0.0002	0.171	16.314	9.751	0.135	0.007
	(0.009)	(0.076)	(0.077)	(0.0004)	(0.001)	(0.070)	(6.036)	(5.002)	(0.074)	(0.002)
Old										
	0.092	0.516	0.786	0.004	0.0001	0.142	31.582	9.908	0.050	0.018
	(0.005)	(0.050)	(0.081)	(0.0005)	(0.011)	(0.011)	(10.008)	(7.015)	(0.029)	(0.008)

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Figure 1: Counterfactuals: Proportional Cost of Repudiation

This figure is constructed as follows. We pick a grid for θ, the fraction of the capital stock lost to the firm when it repudiates a contract. We then solve the model for each of the different parameter values, simulate the model for 50 time periods, and then plot average leverage, investment, Tobin's q, and dividends. We use a parameterization that is the average of the parameter estimates from Table 1. "Young" firms are those in the first 10 periods of life, and "old" firms are those in periods 11 to 50.

Figure 2: Counterfactuals: Fixed Cost of Market Re-Entry
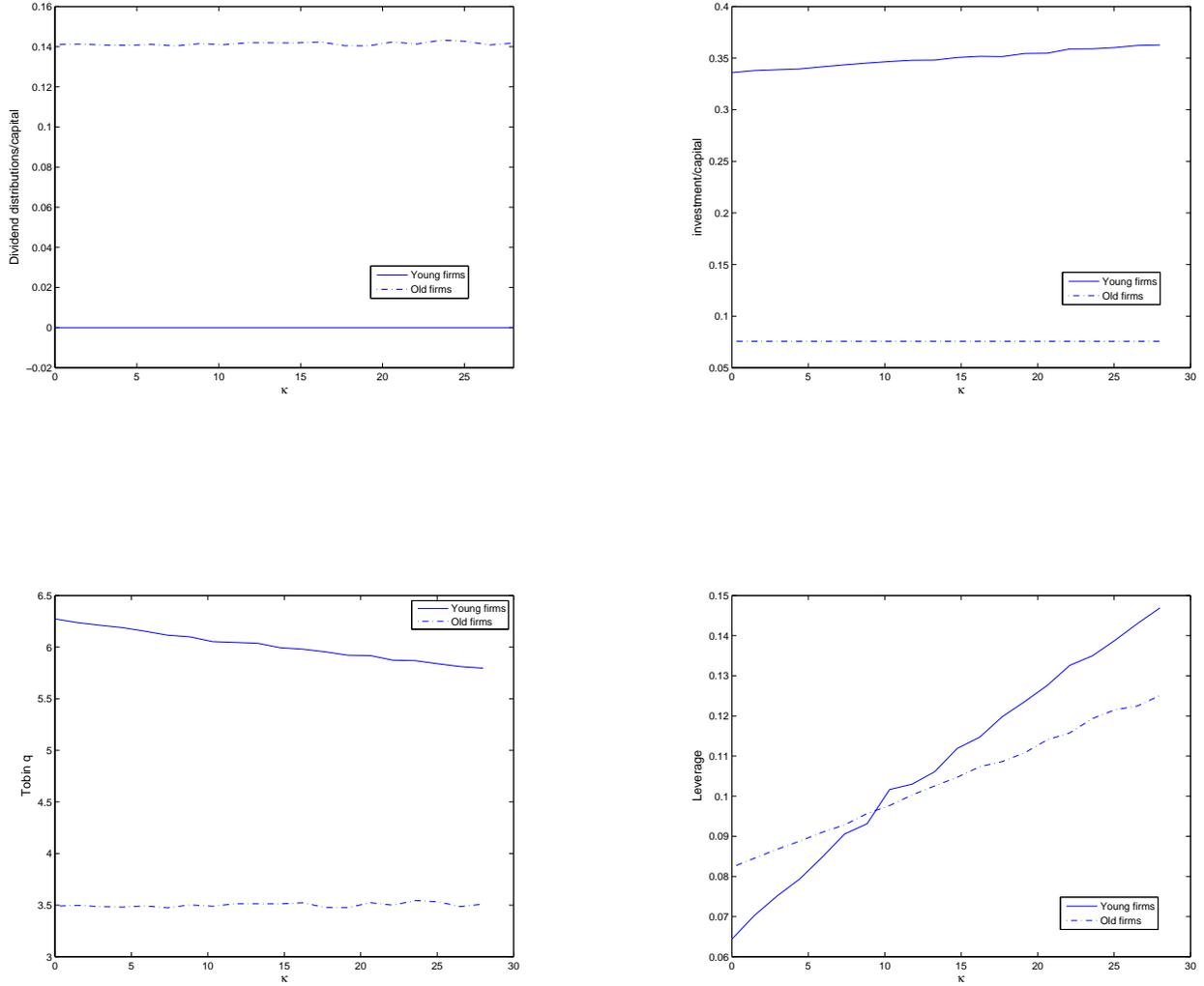
This figure is constructed as follows. We pick a grid for κ, the fixed cost the firm must pay to re-enter the market after it repudiates a contract. We then solve the model for each of the different parameter values, simulate the model for 50 time periods, and then plot average leverage, investment, Tobin's q, and dividends. We use a parameterization that is the average of the parameter estimates from Table 1. "Young" firms are those in the first 10 periods of life, and "old" firms are those in periods 11 to 50.