The Real Effects of Credit Default Swaps

András Danis Andrea Gamba*

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ABSTRACT

We examine the effect of introducing credit default swaps (CDSs) on firms' investment and financing policies. Our model allows for dynamic investment and dynamic financing using equity and debt, and debt holders can trade in the CDS market. After calibrating the model, we compare an economy with a CDS market to an economy without one. The model contains both positive and negative effects of CDS contracts. While they reduce the risk of strategic default, they also increase the probability of bankruptcy. The first effect dominates, which leads to higher leverage, investment, and firm value. The effect on firm value is strongest for small and high growth firms.

Keywords: credit default swaps, CDS, empty creditor, restructuring, bankruptcy
JEL classification: G33, G34

*Danis is at the Scheller College of Business, Georgia Institute of Technology. Gamba is at Warwick Business School, University of Warwick and acknowledges financial support from BA/Leverhulme (Small Research Grant SG142329). We would like to thank conference participants at ESSFM Gerzensee (2014), the USC Fixed Income Conference (2015), the CICF (2015), the EFA Meeting (2015), and the EEA Congress (2015). We also thank seminar participants at the International Monetary Fund, McGill University, Scheller College of Business, University of Milan "Bicocca", and Warwick Business School for their comments. We are grateful to Sudheer Chava for sharing his dataset on bankruptcies. We thank Hui Chen and Kristian Miltersen for their insightful discussions, and Toni Whited for many suggestions and support. Corresponding author: András Danis, Scheller College of Business, Georgia Institute of Technology, 800 West Peachtree Street NW, Atlanta, GA 30308, andras.danis@scheller.gatech.edu, +1 404 385 4569.

What is the effect of credit default swaps on firm value? Did the introduction of a market for credit risk in the 1990s increase the ability of firms to access financing and therefore improve the broad economy? These questions are fundamentally important, and we argue that we need a more thorough economic analysis to guide the current policy debate on CDS contracts. In this paper, we examine the positive and negative effects of CDSs simultaneously and estimate their net effect on firm value. From the perspective of a firm, we show that while the net effect of credit derivatives on firm value and firm investment can be positive or negative, the net effect is likely to be positive. After calibrating our dynamic model to empirical data, we find that for public corporations in the United States the introduction of the CDS market increases firm value by 5.3% on average.

The public debate on the welfare effects of CDSs, ignited by the recent financial crisis, together with CDS-related regulatory changes are evidence for the importance of these results. Several investors and market commentators have argued that credit derivatives reduce social welfare and should be regulated. Some even call for a ban on CDSs.[1] Around the same time and in support of the view that CDSs are useful, financial regulators in the U.S. and Europe have started introducing new rules for the CDS market. On November 1, 2012, the European Union banned trading in the sovereign CDS market unless investors also buy the underlying bonds. By 2014, regulators in the U.S. and Europe had implemented rules so that most trading in the CDS market is cleared by central counterparties.[2] Our analysis of the costs and benefits of CDS markets could be useful for the current policy discussion.

In order to estimate the net effect of CDSs on firm value, we construct a dynamic economy with stock, bond, and CDS markets, and calibrate the model to the data. In the model, the firm optimally chooses investment and financing each period, allowing for equity and debt

[1] George Soros wrote in *The Wall Street Journal* on March 24, 2009, that "CDSs are toxic instruments whose use ought to be strictly regulated." *Fortune* published an article on June 18, 2012, entitled "Why it's time to outlaw credit default swaps." Similar articles were published in the *Financial Times*, March 6, 2009, *The Atlantic*, March 30, 2009, and *The New York Times*, February 27, 2010.

[2] *Financial Times*, October 19, 2011, "EU ban on naked CDS to become permanent," and "New Rules for Credit Default Swap Trading: Can We Now Follow the Risk?," June 24, 2014, Federal Reserve Bank of Cleveland.

issues. Debt holders can trade in the CDS market and purchase or sell CDS protection from a dealer who sets actuarially fair prices. Each period, the firm optimally decides whether to repay the debt, renegotiate with debt holders, or to file for bankruptcy. The model features several real-life frictions, such as equity issuance, bankruptcy, and renegotiation costs, which allow us to match several important data moments. The calibrated model allows us to do a counterfactual analysis of what the firm's value, investment, and financing would be exactly under the same conditions except for access to credit risk insurance. We show how the sign and size of this effect depends on parameters such as bankruptcy costs, debt renegotiation frictions, and bargaining power between equity and debt. We also show how the effect changes in relation to firm characteristics, such as size, growth opportunities, and financing constraints.

Even though we are ultimately interested in the net effect of CDSs, the model is designed to capture both positive and negative effects. A trade-off between the costs and benefits of CDS contracts has been analyzed by Bolton and Oehmke (2011). On the positive side, CDS contracts allow debt holders to demand better terms in an ex post debt renegotiation, which deters strategic default. Debt holders anticipate this, leading to lower ex ante spreads when the debt is issued and increasing debt capacity. On the negative side, debt holders who are hedged with CDSs demand such a high payoff in renegotiation that equity holders sometimes find it optimal to file for bankruptcy, even though it would be cheaper to renegotiate. This is the so-called empty creditor problem first suggested by Hu and Black (2008). The higher probability of bankruptcy is priced in ex ante, yielding higher credit spreads.

To the model setup described above, we add a trade-off between debt and equity, whereby equity is a more costly form of financing than debt, and we endogenize the firm's capital structure. As a first step, we construct a single-period model that illustrates the intuition of the positive and negative effects of CDSs on firm value. This model is already an extension of Bolton and Oehmke (2011) for several reasons. Differently from their model, in ours the state variable has continuous values, the firm has a flexible production function with continuous investment levels, and we allow for equity issuance.

However, in a single-period model, the equity holders' incentives to debt renegotiation are distorted because they do not account for the long-term consequences of renegotiation. Also, while the effect of CDSs depends on the current state, in a static model the analysis is necessarily based on an arbitrary initial point. Therefore, we extend the model to a dynamic setup in which the firm can invest in long-term real assets and exogenous shocks to firm productivity follow a Markov chain. With a dynamic model, we endogenize the current state of the firm and the debt holders' hedging policy, thus excluding off-equilibrium state points that would otherwise distort the quantitative results. More importantly, the long-term consequences of debt renegotiation for equity are properly accounted for, giving a more realistic dynamic of strategic default. Because the analytic results of the single-period model cannot be easily extended to the more general dynamic model, we rely on a numerical simulation analysis to illustrate the effect of CDSs.

We argue that our structural approach is better suited to address the research question on the effect of CDSs on firm value than reduced form estimation techniques. In a perfect experiment, CDS contracts would be randomly assigned to firms, ideally staggered over time. Unfortunately, that is not the case, and unobservable firm characteristics might be correlated with the assignment of CDSs to firms. Also, it is not easy to find a good source of exogenous variation, like a natural experiment or a strong instrumental variable, which would approximate the random assignment of CDSs to firms. Therefore, we propose an analysis based on a calibrated dynamic model as a more appropriate technique. This method is used increasingly in corporate finance to answer questions about capital structure (e.g., Hennessy and Whited (2007)), financial intermediation (e.g., Schroth, Suarez, and Taylor (2014)), executive compensation (Taylor (2010)), or agency conflicts (e.g., Nikolov and Whited (2014)).

The dynamic model is able to explain several recent empirical findings. Ashcraft and Santos (2009) report that CDS contracts increase the cost of debt for high risk firms, while there is no significant effect on the average borrower. Saretto and Tookes (2013) find that firms with CDSs can borrow more and can maintain higher leverage ratios. Subrahmanyam, Tang, and Wang (2014) report that the introduction of CDS markets increases the probability of bankruptcy, although this need not imply that firm value is reduced by CDSs. Using a sample of out-of-court debt restructurings, Danis (2014) shows that if bondholders are more likely to hold CDSs, it is more difficult for a firm to reduce its debt through a restructuring. Also, he finds that after a change in the standard CDS restructuring clause that makes it more likely that a protection buyer is an empty creditor, there are fewer out-of-court debt restructurings for firms with CDSs, but there is no such decrease for firms without CDSs. All these contributions try to estimate the causal effect of CDS contracts on firm outcomes. They use instrumental variables and natural experiments as plausible sources of exogenous variation. In our model, however, we can easily compare an economy with and without a CDS market to estimate its purely causal effect on firm outcomes.

In addition to our findings on the net effect for the average public corporation in the U.S., we look at how the effect of CDSs depends on different firm characteristics. We find that small firms and firms with high growth opportunities benefit the most from the introduction of credit derivatives. For other types of firms, the net effect is smaller. This does not imply that CDS contracts have no effect at all. It is rather that the positive and negative effects on firm value offset each other. Finally, we do not find a type of firm with negative effects on firm value.

Our paper contributes to several strands of the literature. First, the literature on the costs and benefits of introducing CDS markets. From the perspective of the firm, we have mentioned the empirical findings of Ashcraft and Santos (2009), Saretto and Tookes (2013), Subrahmanyam, Tang, and Wang (2014), and Danis (2014). On the theoretical side, Bolton and Oehmke (2011) provide a stylized model that predicts both positive and negative value effects. Outside of corporate finance, there are several other contributions. Duffee and Zhou (2001) and Morrison (2005) examine the effect of CDS contracts on bank loans. Fostel and Geanakoplos (2012) show how the CDS market may have contributed to the crash of 2007-2009. Oehmke and Zawadowski (2014) explore the effect of CDS markets on the liquidity in the corporate bond market, and Chernov, Gorbenko, and Makarov (2013) show that CDS auctions can be biased. Among these theoretical contributions, our paper is most closely related to Bolton and Oehmke (2011), as the channels through which CDSs affect firm value are very similar. While the other papers are important contributions for our understanding of CDS markets, they do not provide models of the effect of CDSs on the interaction of equity holders and debt holders. In this sense, we focus on the corporate finance aspect of credit derivatives. However, for a full welfare analysis, it might be necessary to include other aspects of the CDS market as well.

Second, the literature on credit risk and strategic default. On the theoretical side, Anderson and Sundaresan (1996), Mella-Barral and Perraudin (1997), Mella-Barral (1999), Fan and Sundaresan (2000), Hege and Mella-Barral (2005), and Acharya, Huang, Subrahmanyam, and Sundaram (2006) examine the effect of strategic default on credit risk. Garlappi and Yan (2011) show that strategic default plays a significant role in the distress puzzle. On the empirical side, Davydenko and Strebulaev (2007) find that the risk of strategic default is reflected in credit spreads. Favara, Schroth, and Valta (2012) use a cross-country sample to show that strategic default risk affects equity beta and volatility. Our model differs from the existing theories in several ways. First, we endogenize the firm's investment policy, whereas most authors assume an exogenous cash flow process. Second, we expand the strategic interaction between equity holders and debt holders. In the game at the beginning of each period, the equity holders choose their investment and financing policies and strategically decide whether to repay the debt, to renegotiate the debt, or to file for bankruptcy. The debt holders, on the other hand, strategically trade in the CDS market in order to deter the firm from strategic default. In the second game at the end of the period, played when debt is renegotiated, the two claim holders engage in Nash bargaining, which determines the renegotiated debt level. Our strategic analysis shows how CDS markets can mitigate the strategic default problem identified in this literature.

1. Single-period Model

In order to derive some preliminary intuition for the effect of CDSs on investment, financing, and default policy, we first consider a single-period setup. The resulting model can be compared to Bolton and Oehmke (2011) model, with the difference that we allow the firm to tap external equity to finance investment, as opposed to using only debt. We also allow for an optimal tradeoff between debt and equity. These differences have important consequences on the overall real effect of CDSs.

All agents in the model are risk-neutral. We model a representative firm, owned by an entrepreneur, who makes investment and financing decisions to maximize her own value. The main driver of the model is the firm's profit shock, a continuous-state random variable with compact support. We assume that, given today's occurrence of the shock, z, the probability of an end-of-period shock, z', is $\Pr\{dz'|z\} = \Gamma(z, dz')$.

Given the current z and an initial endowment e, the firm makes investment and financing decisions in order to maximize the value of equity. We denote by k' the decision about the capital stock for the period. To finance the investment, the firm issues debt alongside using equity, e. The debt contract issued by the firm is an unsecured zero coupon bond with face value b' decided by the firm's owner at issuance. Both k' and b' are non–negative.

We assume a competitive market for insuring against credit risk. In particular, debt holders can purchase a CDS from a dealer (protection seller) at the time the debt contract is issued. The CDS dealer and the debt holders (protection buyer) agree on the fraction h'

of the debt exposure covered by the CDS contract and on the CDS spread (the insurance premium). The CDS spread is endogenously determined and the protection seller has rational expectations. The dealer understands that selling a lot of CDS protection to the debt holders changes the probability of default, and adjusts the CDS spread accordingly.

The debt holders choose the hedge ratio, h', to maximize their value. Because we assumed that the credit risk market is competitive, the CDS spread is fair (and the transaction has zero–NPV for the protection seller). In the first part of this section, h' will be an arbitrary hedge ratio. We discuss later how the optimal hedge ratio is determined by solving the debt holders' optimal program.

The firm's production function determines the cash flow from operations at the end of the period: $\pi(z', k') = z'(k')^{\alpha} - f$, where, $\alpha \in]0, 1[$ is the return-to-scale parameter, and $f \geq 0$ is a fixed production cost. Because capital depreciates at a rate $\delta \in]0, 1[$, the ex post book value of the asset is

$$a(z', k') = a' = (1 - \delta)k' + \pi(z', k'), \tag{1}$$

and we denote as w' the firm's net worth at the end of the period:

$$w' = w(z', k', b') = a' - b'. \tag{2}$$

Based on (z', k', b'), or equivalently, given equation (2), on (z', w'), the owner decides whether to pay b' in full, to renegotiate the debt by paying an amount b_r, or to file for bankruptcy and liquidate the firm. We assume that renegotiation may fail for exogenous reasons with probability $\gamma \in [0, 1[$, in which case the firm is liquidated, the debt holders receive $(1 - \xi)a(z, k)$, and the owner receives nothing.[3] Bankruptcy is costly because the liquidation value of the firm's asset is $(1 - \xi)a(z', k')$, with $\xi \in [0, 1[$.

[3] We introduce this feature, following Davydenko and Strebulaev (2007), to match the observed occurrence of failed renegotiations that lead to bankruptcy.

We next characterize the owner's decision and the consequences for the credit risk of the debt. The payoff to equity at the end of the period, $\mathcal{V}$, depends on the ex post net worth, $w' = a(z', k') - b' = a' - b'$, and on the owner's decision regarding debt repayment. Notably, the continuation value of equity is equal to zero. Therefore,

$$\mathcal{V}(z', w', h') = \begin{cases} a' - b' & \text{if debt is repaid} \\ a' - b_r & \text{if debt is succesfully renegotiated} \\ \max\{(1-\xi)a' - b', 0\} & \text{if the firm is liquidated.} \end{cases}$$

The corresponding payoff to debt is b' when it is repaid in full, and b_r, a value derived later on, in case of successful renegotiation. In the case of liquidation, the payoff to debt is $h'b' + (1-h')(1-\xi)a'$ if $(1-\xi)a' \leq b'$, or equivalently $w' \leq \xi a'$, or b' otherwise. We will derive the optimal default decision for the two cases $w' > \xi a'$ and $w' \leq \xi a'$ separately below.

1.1. The optimal default policy

In what follows, we use a given bargaining power for the debt holders, gauged by $q \in [0, 1]$. When the owner's liquidation payoff is positive, $w' > \xi a'$, the threat of debt renegotiation is not credible because the debt holders can recover the full face value of debt in liquidation. The owner herself prefers repayment to liquidation, because the repayment payoff, $a' - b'$, is higher than the liquidation payoff, $(1-\xi)a' - b'$. Therefore, debt is always repaid if $w' > \xi a'$. The payoffs are $a' - b'$ for equity and b' for debt.

If the liquidation payoff to equity is zero, $w' \leq \xi a'$, then debt renegotiation leads to the following Nash bargaining problem:

$$b_r(z', k', b', h') = \arg\max_p \left[a' - p\right]^{1-q} \times \left[p - h'b' - (1-h')(1-\xi)a'\right]^q ,$$

with constraints $a' \geq p$ and $p \geq h'b' + (1-h')(1-\xi)a'$. Renegotiation is feasible if

$$h'b' + (1-h')(1-\xi)a' \leq a'. \tag{3}$$

If renegotiation is feasible, the solution is

$$b_r(z', k', b', h') = h'b' + (1-h')(1-\xi)a' + q[a' - h'b' - (1-h')(1-\xi)a']. \tag{4}$$

Debt repayment is preferred to renegotiation when $a' - b' \geq (1-\gamma)(a' - b_r)$, or

$$a'\left[1 - (1-\gamma)(1-q)s(h')\right] \geq b'\left[1 - (1-\gamma)(1-q)h'\right], \tag{5}$$

where $s(h') = \xi + h'(1-\xi)$. Renegotiation feasibility depends on the sign of $s(h') = \xi + h'(1-\xi)$, whose only zero is

$$h_0 = -\frac{\xi}{1-\xi} < 0.$$

When $h' > h_0$ (i.e., $s(h') > 0$), renegotiation is feasible if

$$a' \geq \frac{h'b'}{1 - (1-h')(1-\xi)} = a_R. \tag{6}$$

Because the numerator of the last term on the right–hand side of (6) is negative when $h' \in]h_0, 0]$, then renegotiation is feasible for all $a' > 0$. Otherwise, for $h' > 0$, renegotiation is feasible for $a' \geq a_R > 0$. When $h' = h_0$ (i.e., $s(h') = 0$), then equation (3) is always satisfied, and so renegotiation is feasible for all $a' > 0$. Finally, if $h' < h_0$ (i.e., $s(h') < 0$), renegotiation is feasible if $a' \leq a_R$, and in this case, $a_R > 0$. Therefore, renegotiation is feasible for $a' \in]0, a_R]$ when $h' < h_0$.

The choice between debt repayment and renegotiation depends on the sign of $1-(1-\gamma)(1-q)s(h')$, and the only zero of this function is

$$h_1 = \frac{1-\xi(1-q)(1-\gamma)}{(1-q)(1-\xi)(1-\gamma)}, \tag{7}$$

with $h_1 > h_0$, and $h_1 > 1$. When $h' < h_1$ (i.e., $1-(1-\gamma)(1-q)s(h') > 0$), repayment is optimal for

$$a' \geq \frac{b'\left[1-h'(1-\gamma)(1-q)\right]}{1-(1-\gamma)(1-q)s(h')} = a_P. \tag{8}$$

Because the numerator in the second term defining a_P in (8) is negative for $1/[(1-\gamma)(1-q)] \leq h'$, and $1/[(1-\gamma)(1-q)] < h_1$ (this is equivalent to $(1-\gamma)(1-q) < 1$, which is consistent with our assumptions), then for $h' \in [1/[(1-\gamma)(1-q)], h_1[$, $a_P \leq 0$, and repayment is optimal for all $a' > 0$. Otherwise, for $h' \leq 1/[(1-\gamma)(1-q)]$, repayment is optimal for $a' \geq a_P$.

If $h' = h_1$ (i.e., $1-(1-\gamma)(1-q)s(h') = 0$), the left–hand side of (5) vanishes, and in the right–hand side, from $1-(1-\gamma)(1-q)h_1$, after rearranging, we have $-\xi[\gamma+q(1-\gamma)]/(1-\xi)$, which is negative. Because the left–hand side is zero and the right–hand side is negative, equation (5) is true and repayment is preferred to renegotiation for all $a' > 0$.

When $h' > h_1$ (i.e., $1-(1-\gamma)(1-q)s(h') < 0$), repayment is optimal for $a' \leq a_P$. However, for $h' > h_1$, we have that $[1-h'(1-q)] < 0$ in (8). Therefore, $a_P > 0$, and repayment is optimal for $a' \in]0, a_P]$.

When renegotiation is not feasible, the equity payoff is $a' - b'$ under debt repayment and zero under liquidation. Therefore, if $a' \geq b'$, the owner prefers repayment, and if $a' < b'$, she prefers liquidation.

We can now derive the firm's optimal default policy, which we summarize below:

Proposition 1. *Given the choices k' and $b' > 0$:*

1. *At t, the equilibrium hedge ratio is $h' \in [0, 1]$;*

2. *At* $t+1$, *it is optimal for the owner to repay the debt for* $a' \geq a_P$, *to attempt renegotiation for* $a_R \leq a' < a_P$, *and to liquidate the firm for* $a' < a_R$, *where* $a_R < b' < a_P$, *and* a_P *is defined in equation* (8), *and* a_R *in equation* (6).

The proof of Proposition 1 is in Appendix A. Figure 1 shows the optimal default decision for different h's. If h' is negative (Case (a)), renegotiation is always feasible, and the firm is never deliberately liquidated. If the asset value of a' is higher than a_P, the debt is repaid in full. If it is lower than a_P, the debt is renegotiated. For intermediate values of h' (Case (b)), liquidation, renegotiation, and repayment are all possible in equilibrium. Low asset values lead to liquidation, intermediate asset values trigger renegotiation, and values of a' lead to debt repayment. Finally, if the hedge ratio h' is higher than one (Case (c)), renegotiation is never feasible. In this case, the firm is liquidated if $a' < b'$, and debt is repaid if $a' \geq b'$. Proposition 1 posits that in equilibrium Case (b) prevails.

Proposition 1 and Figure 1, Case (b), also summarize nicely the positive and negative effects of CDS contracts. On the one hand, if the hedge ratio h' increases, the threshold a_P decreases, because $\partial a_P / \partial h' < 0$. This means that repayment is more likely to occur, while renegotiation is less likely. This is good for debt holders, which they anticipate when the debt is issued, and this decreases credit spreads. On the other hand, if the hedge ratio h' increases, the threshold a_R increases, because $\partial a_R / \partial h' > 0$. This makes liquidation more likely and renegotiation less likely, which is bad for debt holders. They anticipate this outcome and adjust credit spreads upwards when the debt is issued.

The general model and the above solution are appropriate also for the case without a CDS market. More details about this case are in Appendix A. Figure 1, under Case (a), shows that if the bondholders have no CDS protection (i.e., $h' = 0$), the debt is renegotiated if $a' < a_P$, and it is repaid if $a' \geq a_P$.

1.2. Valuation of corporate securities

Proposition 1 states that the equilibrium hedge ratio h' lies in the interval $[0,1]$. This implies that we can focus on Case (b) in Figure 1. Therefore, we only derive the value of equity and debt for Case (b). While a_P and a_R are functions of (b',h'), and b_r is a function of $(a(z',k'),b',h')$, we suppress these dependences for notational convenience.

The value of equity at (z,e) is

$$v(z,e) = \max_{(k',b')} \beta \int \mathcal{V}(z',w',h')\Gamma(z,dz'), \tag{9}$$

where $\beta \in]0,1[$ is the discount factor, and the optimal decision is restricted by the budget constraint

$$k' = e + m(z,k',b'). \tag{10}$$

In (10), m is the equilibrium price of debt, as per the debt holders' program, whose goal is to maximize the value of their claim by choosing the hedge ratio:

$$m(z,k',b') = \max_{h'} \frac{1}{1+r} M(z,k',b',h'), \tag{11}$$

where $0 < \beta < 1/(1+r)$ is used to model an incentive to debt financing, and the argmax of the above program, $h' = h(z,k',b')$, is the state–contingent optimal hedge ratio that is considered in the owner's program in (9).

Given the above discussion on the optimal default policy, the value of equity is

$$\begin{aligned} v(z,e) = \max_{(k',b')} \beta \Bigg[&\int_{a^{-1}(a_R)\vee 0}^{a^{-1}(a_P)\vee 0} (1-\gamma)(a(z',k')-b_r)\Gamma(z,dz') \\ &+ \int_{a^{-1}(a_P)\vee 0}^{\infty} (a(z',k')-b')\Gamma(z,dz') \Bigg]. \end{aligned} \tag{12}$$

In (12), $b_r = b_r(z', k', b', h')$ is from equation (4), based on the optimal h', a^{-1} is the inverse of the function $a(z', k')$ defined in (1) with respect to its first argument, while k' is kept constant and $x \vee y = \max\{x, y\}$.

In the model, the credit event that triggers the CDS payment is bankruptcy/liquidation. An out-of-court debt restructuring does not trigger a CDS payment, in line with the Standard North American Contract (SNAC) of the International Swaps and Derivatives Association (e.g., Bolton and Oehmke (2011)). Therefore, the price of credit protection for a given $h' \in [0, 1]$, to be paid at the end of the period, is the expectation of the net compensation from the protection seller:

$$\begin{aligned} C(z, k', b', h') = &\int_0^{a^{-1}(a_R)\vee 0} [h'b' - h'(1-\xi)a(z', k')]\ \Gamma(z, dz') \\ &+ \int_{a^{-1}(a_R)\vee 0}^{a^{-1}(a_P)\vee 0} \gamma[h'b' - h'(1-\xi)a(z', k')]\ \Gamma(z, dz')\ \Gamma(z, dz'). \end{aligned} \tag{13}$$

For $h' \in [0, 1]$, the expected payoff to debt holders, including the payment from the protection seller in case of a credit event, but excluding the insurance premium $C(z, k', b', h')$, is

$$\begin{aligned} \psi(z, k', b', h') = &\int_0^{a^{-1}(a_R)\vee 0} [h'b' + (1-h')(1-\xi)a(z', k')]\ \Gamma(z, dz') \\ + \int_{a^{-1}(a_R)\vee 0}^{a^{-1}(a_P)\vee 0} &\Big[(1-\gamma)b_r + \gamma[h'b' + (1-h')(1-\xi)a(z', k')]\Big]\ \Gamma(z, dz') + \int_{a^{-1}(a_P)\vee 0}^{\infty} b'\ \Gamma(z, dz'). \end{aligned} \tag{14}$$

The expected value of the debt for a given hedge ratio, h', net of the cost of the CDS is

$$M(z, k', b', h') = -C(z, k', b', h') + \psi(z, k', b', h').$$

Therefore, the price of debt and the optimal h' are found by solving the following program:

$$
\begin{aligned}
m(z,k',b') = \max_{h'} \frac{1}{1+r} \Bigg[&\int_0^{a^{-1}(a_R)\vee 0} (1-\xi)a(z',k')\ \Gamma(z,dz') \\
&+ \int_{a^{-1}(a_R)\vee 0}^{a^{-1}(a_P)\vee 0} [(1-\gamma)b_r + \gamma(1-\xi)a(z',k')]\ \Gamma(z,dz') + \int_{a^{-1}(a_P)\vee 0}^{\infty} b'\ \Gamma(z,dz') \Bigg]. \quad (15)
\end{aligned}
$$

The total firm value is then $v(z,e) + m(z,k^*,b^*)$, where (k^*,b^*) are the argmax of (12).

1.3. Comparative statics

To illustrate the impact of the costs and benefits associated with debt renegotiation and therefore of CDSs, we solve the single-period model (i.e., we solve equations (12) and (15) simultaneously) and report the optimal value of several metrics that characterize either the current status or the policy of the firm. We assume that $\log z'$ is conditionally distributed as a truncated normal (between ± 3 times the unconditional standard deviation).[4]

We define several variables that allow us to illustrate the mechanism through which CDS contracts affect firm value. These variables are the value of equity, $v(z,e)$, the value of debt, $m(z,k^*,b^*)$, the total firm value $v(z,e)+m(z,k^*,b^*)$, the optimal capital stock, k^*, the optimal face value of debt b^*, quasi-market leverage, $b^*/(b^*+v(z,e))$, the optimal hedge ratio, h^*, the credit spread on newly issued debt, the probability of renegotiation, and the probability of liquidation at the end of the period.

Figures 2, 3, and 4 present sensitivity analysis results of the above metrics for the model based on the parameters in Table 1. These plots are based on a specific starting point (z,k,b). We choose $z=1$, the expected value of z, $k=32$, and $b=25$. The starting value of capital is set to be equal to the long-term mean of capital in the dynamic model, which

[4]Because of this assumption, we must solve the problem numerically. However, the numerical approach is very accurate, because it is based on global adaptive quadrature.

will be clarified below. The starting value of debt is set at a lower value than the long-term average, because the firm in the single period model has no continuation value, therefore its borrowing capacity is lower. The resulting market leverage ratio will be very similar to what we get in the dynamic model. Finally, we assume that at this point (z, k, b) the firm is repaying the current debt, so we avoid the issue of solving the current optimal default strategy for the firm.

In Figures 2-4, firm value is higher with a CDS market compared to an economy without CDSs. Equity value is lower with CDS contracts almost everywhere. Since firm value is defined as the sum of equity and debt, the loss in equity value is more than offset by the gain in debt value. The intuition for the increase in debt value, which is also the cause of the increase in firm value, is the following. A CDS market allows debt holders to commit to a stronger bargaining position in case of ex post debt renegotiation. Debt holders make heavy use of this commitment device, as can be seen in the subplots for the hedge ratio. This reduces the equity holders' incentive to engage in unnecessary renegotiation, or strategic default, ex post. Bondholders anticipate this positive effect, which reduces credit spreads ex ante. Firms then make use of the lower cost of debt financing, they invest more (see subplots for capital stock), and they are financing that investment with debt instead of equity (see subplots for debt).

The subplots for the probability of renegotiation show an increase after the introduction of CDS markets, which seems counterintuitive. The reason is that the reduction in the cost of debt is so large that firms want to issue more debt, which actually increases the likelihood of renegotiation in equilibrium. One of the consequences of using more debt is an increase in the leverage ratio, which can be seen in the subplots for quasi-market leverage.

The effect of CDSs on the cost of debt is remarkable. The subplots for the credit spread show that the cost of debt decreases after the introduction of a CDS market. However, this reduction is observable even though the firm issues significantly more debt with CDSs.

These findings suggest that if the face value of debt was held constant, the reduction in credit spreads would be even larger.

Looking only at Figure 2 allows us to understand the effect of debt holders' bargaining power. We see that the amount of value created by CDS markets is highest for low values of q, and is monotonically decreasing for higher values of q. The intuition for this is that with a low q, equity holders can reduce the debt a lot more in renegotiation. This is an outcome that debt holders want to avoid, so they buy more CDS protection, as can be seen in the subplot for the hedge ratio. In the limit, as q moves closer to 1, debt holders have all the bargaining power. Equity holders cannot extract any rents from debt holders, which alleviates the agency conflict between the two parties. As a result, the cases with and without CDSs are identical, making CDSs *redundant*.

Figure 3 shows that the amount of value created is an increasing function of the liquidation cost ξ. The intuition is that a higher liquidation cost reduces the outside option of debt holders in bargaining, which allows the equity holders to extract higher rents. Bondholders are aware of this, so they purchase more CDS contracts to improve their outside options. This can be seen in the subplots for the hedge ratio. CDS contracts become redundant in the limit where ξ approaches zero.

Figure 4 depicts comparative statics with respect to γ, the exogenous probability of renegotiation failure. The increase in firm value is approximately the same for all values of γ. To understand this, we start with the effects of γ without CDS markets. On the one hand, a higher γ reduces a_P, which decreases the likelihood of (attempted) debt renegotiation and increases the probability of debt repayment. On the other hand, it increases the probability of liquidation and decreases the probability of (successful) renegotiation. The first effect outweighs the second one, so the cost of debt decreases with γ. The subfigure for debt shows that the firm reacts to this by issuing less debt. For the case with CDS markets, the two effects described are still present, and the first effect still dominates. The result is the same as before: the cost of debt decreases as γ becomes higher.

2. A Dynamic Model with Investment and Debt Renegotiation

The single-period model has two important limitations. First, the initial point (z, e), which is a first-order determinants of the results, is arbitrary. Second, the long-term consequences of renegotiation are excluded from the shareholder's outside option, as operations are necessarily ceased at the end of the period. In other words, the continuation value of the firm is ignored. This exclusion distorts the incentive to renegotiate. To overcome these limitations, we extend the single-period model to a dynamic setup. The dynamic model does not suffer from the problem of an arbitrary initial point, and it accounts for the continuation value of the firm. We begin with presenting the model without a CDS market, and then we add CDS contracts to the model.

We make the usual assumptions about the economy for a partial equilibrium dynamic capital structure model. The horizon is infinite and time is discrete. The firm's profit shock, z, is a continuous-state Markov process with compact support and whose transition probability $\Gamma(z, dz') = \Pr\{dz'|z\}$ satisfies the Feller property. For definiteness, we assume that the evolution of $\log z$ is an AR(1) process, $\log z' = \rho \log z + \sigma\varepsilon'$, where ε are i.i.d. draws from a truncated standard normal distribution, and $\rho \in]0, 1[$ and $\sigma > 0$ are parameters that are calibrated later.

The state of a firm at the current date is described by (z, k, b), where k and b are determined at the prior date, and z is observed at this date. The ex post book value of the asset is $a(z,k) = (1-\delta)k + \pi(z,k)$ as in equation (1), and the net worth is $w = w(z,k,b) = a(z,k) - b$ as in equation (2).

We denote $V(z,w)$ as the cum-dividend equity value at the current state (z,w), which results from the owner's optimal choice of dividend payment, d,

$$V(z,w) = \max_{d} \left\{ d^{+} + (1+\lambda)d^{-} + v(z,w-d) \right\}, \tag{16}$$

where d can have either sign; if it is negative, it is the amount of injected equity capital. In this case, we assume that the firm incurs a transaction cost λ per unit of equity capital. In (16), $v(z,w-d)$ denotes the market value of the firm's equity, to be determined later, at the *revised net worth*, $e = w - d$, determined by the payout decision.

At (z,k,b), the decision of paying back the debt is optimal when the value of equity, $V(z,w)$, is sufficiently high. However, there are states in which instead of repaying the debt, the owner maximizes her value by renegotiating the debt obligation, or by liquidating the firm. Given the bankruptcy cost ξ, if the liquidation value of the firm's asset, $(1-\xi)a(z,k)$, is not lower than b, then the threat to liquidate posed by the owner is not credible, and therefore she will repay the par value. It is only if $(1-\xi)a(z,k) < b$, or equivalently $w < \xi a(z,k)$, that renegotiation can take place because the threat is credible, as debt holders can get a payoff lower than b if renegotiation fails. While $w < \xi a(z,k)$ is necessary, it is not a sufficient condition for debt renegotiation, as in this case the owner can still optimally choose to repay the debt.

The debt payment resulting from a Nash sharing rule between the owner and debt holders if renegotiation is successful is b_r. In this case, the owner gets $V(z,w_r)$, where

$w_r = w(z, k, b_r)$, and the ensuing revised net worth is $e = w_r - d$, where d is the argmax of the program in (16) solved at w_r. The solution to the bargaining game is

$$b_r(z, k, b) = \arg\max_p \left[V(z, w(z, k, p))\right]^{1-q} \times \left[p - (1-\xi)a(z, k)\right]^q , \tag{17}$$

with constraints

$$p \geq (1-\xi)a(z, k), \text{ and } p \leq a(z, k) - w_d(z),$$

where $w_d(z) \leq 0$ is defined as the unique zero of $V(z, \cdot)$: $V(z, w_d(z)) = 0$.[5] Alternatively, renegotiation is not feasible if $a(z, k) - w_d(z) < (1-\xi)a(z, k)$, or equivalently if $w_d(z) > \xi a(z, k)$. Clearly, the latter condition is never satisfied, because $a(z, k) \geq 0$ (assuming $f = 0$) and $w_d(z) \leq 0$.[6] So renegotiation is always feasible and liquidation would never occur in a model without CDS.[7] Therefore, we assume that renegotiation may fail for exogenous reasons with probability γ, like in the static model. The liquidated firm exits the economy and is replaced by a new firm with initial net worth $e = w_d(z)$. A timeline describing the above options is shown in Figure 5.

[5]The second constraint derives from the assumption that the outcome of renegotiation is acceptable to the owner if $V(z, w(z, k, p)) \geq 0$, or equivalently $V(z, w(z, k, p)) \geq V(z, w_d(z))$ by definition of $w_d(z)$. Therefore, from $w(z, k, p) \geq w_d(z)$, using equation (2), we have $a(z, k) - p \geq w_d(z)$. It results that $w_d(z) \leq 0$, because the continuation value of the firm is non-negative. As a consequence, if $w_d(z) < 0$, the bargaining space for problem (17) would be non-empty even if we assumed $\xi = 0$.

[6]Throughout the solution of the dynamic model we assume that $f = 0$, which implies $a(z', k') \geq 0$ for all (z', k'). This is not a necessary assumption for our results, but it greatly simplifies the analytical expressions. However, in the calibration of the model, Section 4, we allow for a positive fixed cost f. After solving the model numerically, we check that $a(z', k') < 0$ never occurs in the simulated data.

[7]Differently from the static model, the problem in (17) cannot be solved analytically, because V must be found numerically. Therefore, we determine $b_r(z, k, b)$ by solving the first-order condition of the problem, which is

$$(q-1)\frac{\partial V(z, w)}{\partial w}\left[b_r - (1-\xi)a(z, k)\right] + qV(z, w(z, k, b_r)) = 0. \tag{18}$$

However, a convenient approximation of the solution can be obtained by observing that V is a smooth function and generally

$$V(z, w_2) - V(z, w_1) \approx \left.\frac{\partial V(z, w)}{\partial w}\right|_{w=w_1} (w_2 - w_1), \tag{19}$$

if w_2 and w_1 are sufficiently close to each other. Putting $w_1 = w(z, k, b_r)$ and $w_2 = w_d(z)$, then the second addend in (18) is replaced, and we can find a convenient approximation of the renegotiated debt payment,

$$b_r(z, k, b) \approx (1-q)(1-\xi)a(z, k) + q\left[a(z, k) - w_d(z)\right],$$

which does not depend directly on V, a convenient feature given we have to solve the problem numerically.

The revised equity value, $\mathcal{V}(z,w)$, results from the owner's decision on debt repayment. In states (z,w) where $w \geq \xi a(z,k)$, the owner will repay the debt and $\mathcal{V}(z,w) = V(z,w)$. Otherwise, for $w < \xi a(z,k)$ with $b > 0$, she will renegotiate if this is better than repaying the debt. With probability $(1-\gamma)$, renegotiation will be successful, the debt payment is $b_r = b_r(z,k,b)$, and the revised equity value is $\mathcal{V}(z,w) = V(z,w_r)$, with $w_r = w(z,k,b_r)$. With probability γ, renegotiation will fail, in which case the debt payment is $(1-\xi)a(z,k)$ and $\mathcal{V}(z,w) = 0$. Therefore, the expected value from renegotiation is $(1-\gamma)V(z,w_r)$. Finally, when $w < \xi a(z,k)$ with $b = 0$, the firm will be liquidated. To summarize:

$$\mathcal{V}(z,w) = \begin{cases} V(z,w) & \text{if } w \geq \xi a(z,k) \\ \max\{V(z,w), (1-\gamma)V(z,w_r)\} & \text{if } w < \xi a(z,k), b > 0. \\ \max\{V(z,w), 0\} & \text{if } w < \xi a(z,k), b = 0. \end{cases} \tag{20}$$

In equilibrium $b_r \leq b$, because, if b_r were higher than b, then in equation (20) $V(z,w)$ would be higher than $(1-\gamma)V(z,w_r)$, and repayment would be optimal instead of renegotiation, which results in a contradiction.

Given the revised net worth e as per the above discussion, the owner makes an optimal decision for the next period capital stock, k', and debt, b', from which v is determined:

$$v(z,e) = \max_{(k',b')} \beta \int \mathcal{V}(z',w')\Gamma(z,dz'), \tag{21}$$

where $k' = e + m(z,k',b')$, $w' = w(z',k',b')$, from equation (2), $k' \geq 0$ and $b' \geq 0$, and $m(z,k',b')$ is the market value of newly issued debt, with face value b', when the new capital stock for the next period is k'. The equilibrium price m is derived as a function of the firm's optimal policy and the stochastic evolution of z.

Given the optimal renegotiation policy, the ex-ante equilibrium price of the debt contract at (z, k, b) is

$$m(z, k', b') = \frac{1}{1+r} \left\{ \int \Phi_c(z', k', b') b' \; \Gamma(z, dz') \right. \\ \left. + \int \Phi_r(z', k', b') \left[(1-\gamma) b_r(z', k', b') + \gamma (1-\xi) a(z', k') \right] \; \Gamma(z, dz') \right\}, \quad (22)$$

where (k', b') are from the optimal investment/financing policy of the firm at (z, k, b) and Φ_r, and Φ_c are the indicator functions for the states in which the owner renegotiates and repays the debt, respectively. In the second addend on the right-hand side of (22), we have the payoff if renegotiation is successful with probability $(1 - \gamma)$, or the liquidation value if renegotiation is unsuccessful with probability γ. In equation (22), similarly to Cooley and Quadrini (2001), we assume that $0 < r < 1/\beta - 1$.

The algorithm to numerically find v and the optimal policy is based on value iteration on a discretized state space and comprises the following stages. At each step of the iteration, based on a guess for v, we solve equation (16) for all (z, w) to determine V and the payout policy. Then, we find $w_d(z)$ as the zero of $V(z, \cdot)$ using linear interpolation. If the current state is $w < \xi a(z, k)$, we determine $V(z, w(z, k, b_r))$ using linear interpolation, where the current net worth is redefined through equation (2) and $b_r(z, k, b)$ is from (17). At this point, given $\mathcal{V}(z, w)$ from (20), we solve problem (21) with condition (10), where $m(z, k', b')$ is found in (22). To keep the model stationary, we assume that if a firm is liquidated, it is replaced by a new firm, which is started at the value $V(z, w_d(z)) = 0$, and therefore it immediately makes an optimal investment and financing decision based on $e = w_d(z)$ as per program (21).

3. Debt Renegotiation with a CDS Market

We now add a CDS market to the dynamic model presented in the previous section. With a CDS market, the firm's objective function depends not only on (z, w), but also on the hedge ratio, h, chosen by the debt holders in the prior period. As before, we denote the revised equity value that accounts for the owner's default decision with $\mathcal{V}(z, w, h)$. If $w \geq \xi a(z, k)$, the threat of renegotiation is not credible and debt is repaid in full. The payoff to equity holders is $\mathcal{V}(z, w, h) = V(z, w)$, where $V(z, w)$ is calculated in (16).

In the case where $w < \xi a(z, k)$ and $b > 0$, the threat of renegotiation is credible, and the Nash bargaining game is

$$b_r(z, k, b, h) = \arg\max_p \left[V(z, w(z, k, p))\right]^{1-q} \times \left[p - hb - (1 - h)(1 - \xi)a(z, k)\right]^q , \tag{23}$$

with constraints

$$p \geq hb + (1 - h)(1 - \xi)a(z, k), \text{ and } p \leq a(z, k) - w_d(z), \tag{24}$$

where hb is the payoff associated with the hedged fraction of the debt, while $(1 - h)(1 - \xi)a(z, k)$ is the payoff for the uninsured part of the debt. Renegotiation is not feasible if $a(z, k) - w_d(z) < hb + (1 - h)(1 - \xi)a(z, k)$, or equivalently, if

$$h > \frac{\xi a(z, k) - w_d(z)}{\xi a(z, k) - w} = H(z, w), \tag{25}$$

where $H(z, w)$ is positive because $w_d(z) \leq 0$. When (25) is satisfied, the debt is repaid if $V(z, w) \geq 0$, while the firm is liquidated if $V(z, w) < 0$. The owner's payoff is $\mathcal{V}(z, w, h) = V(z, w)$ in the case of repayment and $\mathcal{V}(z, w, h) = 0$ in the case of liquidation.

If debt renegotiation is feasible, $h \leq H(z, w)$, the owner prefers repayment to renegotiation if $V(z, w) \geq (1 - \gamma)V(z, w_r)$, where $w_r = w(z, k, b_r)$, and her payoff is $\mathcal{V}(z, w, h) =$

$V(z,w)$; otherwise, she prefers renegotiation with expected payoff $\mathcal{V}(z,w,h) = (1-\gamma)V(z,w_r)$. Figure 6 depicts the owner's optimal default decision and the corresponding payoffs with $b > 0$.[8] Finally, if $w < \xi a(z,k)$ and $b = 0$, the firm is liquidated if V is negative. Therefore, the owner's payoff is

$$\mathcal{V}(z,w,h) = \begin{cases} V(z,w) & \text{if } w \geq \xi a(z,k), \\ \max\{V(z,w), (1-\gamma)V(z,w_r)\} & \text{if } w < \xi a(z,k), b > 0, h \leq H(z,w), \\ \max\{V(z,w), 0\} & \text{if } w < \xi a(z,k), b > 0, h > H(z,w), \\ & \quad\text{or if } w < \xi a(z,k), b = 0. \end{cases} \tag{27}$$

The dependence of $\mathcal{V}$ on h is set through $b_r(z,k,b,h)$ and the dependence of the payoff on the relation between h and $H(z,w)$. Accordingly, we define the indicator function Φ_c for the states where the owner repays debt and continues operations, Φ_r for the states where she renegotiates the debt, and Φ_ℓ for liquidation.

So far, the firm's optimal program in (16), (21) with condition (10), has been solved assuming that there is a schedule of equilibrium debt prices, m, and the corresponding optimal hedging policy, h', for each possible (z,k',b'). However, m (and h') must be found simultaneously with (k',b'), as they are interdependent. In what follows, we assume that the owner's optimal policy, characterized by the indicator functions $(\Phi_c, \Phi_r, \Phi_\ell)$, has been already determined for all possible state points (z,k,b) and arbitrary hs, as seen above.

[8] As before, when renegotiation occurs, the first-order condition to find $b_r(z,k,b,h)$ is solved numerically:

$$(q-1)\frac{\partial V(z,w)}{\partial w}\left[b_r - hb - (1-h)(1-\xi)a(z,k)\right] + qV(z,w(z,k,b_r)) = 0. \tag{26}$$

Using the same linearization as in (19), a convenient approximation of the renegotiated value is

$$b_r(z,k,b,h) \approx (1-q)\left[hb + (1-h)(1-\xi)a(z,k)\right] + q\left[a(z,k) - w_d(z)\right].$$

Under the assumption of a competitive market for credit risk, the current price of credit protection for a given h', to be paid at the end of the period, is the expectation of the net payment from the protection seller:

$$C(z,k',b',h') = \int (h'b' - h'(1-\xi)a(z',k'))\,[\gamma\Phi_r(z',k',b',h') + \Phi_\ell(z',k',b',h')]\;\Gamma(z,dz').$$

From the right-hand side of this expression, credit insurance only covers the loss in case of the firm's liquidation, whether this follows from failed renegotiation or because renegotiation is made infeasible by a high hedge ratio, h. This latter case is exactly the empty creditor problem, as in Hu and Black (2008) or Bolton and Oehmke (2011).

For all possible h', the end-of-period payoff to debt holders for given capital k' and face value b' is

$$\begin{aligned}\varphi(z',k',b',h') &= b\ \Phi_c(z',k',b',h') + b_r(z',k',b',h')\ (1-\gamma)\Phi_r(z',k',b',h') \\ &\quad + [h'b' + (1-h')(1-\xi)a(z',k')]\ \ [\gamma\Phi_r(z',k',b',h') + \Phi_\ell(z',k',b',h')]\,. \qquad (28)\end{aligned}$$

In this expression, the first term is the payment when the firm is solvent, the second term is the payoff from renegotiation, and the third term is the payoff when the firm is liquidated. The expected value of the debt for a given hedge ratio, h', net of the cost of the CDS, is therefore

$$M(z,k',b',h') = -C(z,k',b',h') + \int \varphi(z',k',b',h')\ \Gamma(z,dz'),$$

and using the definition of $C(z,k',b',h')$, the expression can be simplified to

$$\begin{aligned}M(z,k',b',h') = \int &\{b'\ \Phi_c(z',k',b',h') + b_r(z',k',b',h')\ (1-\gamma)\Phi_r(z',k',b',h') \\ &+(1-\xi)a(z',k')\,[\gamma\Phi_r(z',k',b',h') + \Phi_\ell(z',k',b',h')]\}\ \Gamma(z,dz').\end{aligned}$$

Then the debt holders' program is to maximize the value of their claim in (11), and the argmax of the program, $h' = h(z, k', b')$, is the state–contingent optimal hedge ratio that is considered in the owner's program in (9), where the optimal decision is also in this case restricted by condition (10). This closes the problem for the case of an economy with a CDS market.

The algorithm to solve this program is similar to the one in the previous section, with the differences that h and m are found using equation (11), in place of (22), and solving program in equation (23) in place of (17).

4. Calibration

We calibrate the dynamic model with a CDS market so that it resembles the average public corporation in the United States. We select the parameters such that the model is able to match the investment and financing behavior of real firms. We attempt to estimate as many parameters as possible directly from the data. The remaining parameters are chosen in a way that certain simulated moments (e.g., average investment rate, average leverage, etc.) are close to empirical moments.

We start by constructing a dataset from the annual Compustat dataset for the 1994 – 2013 period. The sample period matches the data availability of our other datasets. It also corresponds to the time period after the introduction of a CDS market in the United States. We merge the Compustat sample with CRSP data to calculate the market value of equity and to obtain the SIC code for each firm-year observation. We remove financials (SIC codes between 6000–6999) and utilities (SIC codes between 4900–4999), as well as firms for which the SIC code is missing. We also remove observations where the CRSP share code is different from 10 or 11.

For each firm-year observation, we determine whether the firm has filed for bankruptcy in that year and add a bankruptcy dummy to the dataset. We use the same sample of bankruptcies as in Chava and Jarrow (2004), Alanis, Chava, and Kumar (2014), and Chava (2014).[9] Since some firms file for bankruptcy after they exit from the Compustat database, we also consider bankruptcies that occur up to five years after a firm's last observation in Compustat. For these firms, we set the bankruptcy dummy equal to one in the year of the last observation in Compustat.

Before we calculate the variables of interest, we set total assets (item 6) to missing if it is negative. We then calculate the investment rate as the difference between CAPX (item 30) and the sale of PPE (item 107) divided by lagged gross PPE (item 7), as in Hennessy and Whited (2007). Since the sale of PPE is missing for many firms, we set it to zero when it is not available. Profitability is defined as operating profit (item 13) divided by lagged total assets. The Q-ratio is the sum of the market value of equity from CRSP and liabilities (item 181) divided by total assets. Book leverage is liabilities divided by total assets. Market leverage is liabilities divided by the sum of liabilities and the market value of equity. The payout ratio is dividends (item 127) plus repurchases (item 115) minus stock issuance (item 108), divided by lagged assets. The depreciation rate is depreciation and amortization (item 14) minus amortization of intangibles (item 65), divided by lagged gross PPE. Since the amortization of intangibles is missing for many firms, we set it to zero when it is not available. All these variables are winsorized at the 1% and 99% levels. We delete firm-year observations where all seven variables of interest are missing.

To calculate equity issuance costs, we follow the methodology in Warusawitharana and Whited (2015). The data are based on the SDC Platinum Global New Issuance database. The dataset contains seasoned equity offerings (SEOs) in the U.S. between 1994 and 2013. It excludes rights issues and unit issues. Firms are removed from the SDC sample if they are not in the CRSP-Compustat sample, which leaves us with 6,636 equity offerings. We

[9] We are grateful to Sudheer Chava for sharing this data with us.

define proportional equity issuance cost as total fees divided by total proceeds. The equity issuance cost is also winsorized at the 1% and 99% levels.

Table 2 contains the summary statistics. We use this table as the basis for our calibration. We first estimate as many parameters as possible directly from the data. We are able to estimate the parameters $(\delta, \lambda, \alpha)$ directly from the data. The average depreciation rate of 13.6% in Table 2 is the value we use for parameter δ. This value is close to the 1% monthly rate in Schmid (2008) and Livdan, Sapriza, and Zhang (2009). We also use the average equity issuance cost of 5.36% for parameter λ. This is similar to the value in Altinkilic and Hansen (2000) (5.38%) and indirect structural estimates in Hennessy and Whited (2005) (5.9%).

We estimate the profit function curvature α using the method in Cooper and Haltiwanger (2006). They show that certain parameters of the production function can be estimated separately from the other model parameters using generalized method of moments (GMM) estimation. We apply their methodology to estimate parameter α. The details of the estimation are described in Appendix B. We find that the estimated value for α is 0.603, which is close to the value reported in Cooper and Haltiwanger (2006) (0.592).

We next calibrate the model by finding values for the parameters $(r, \beta, \rho, \sigma, f, \xi, \gamma, q)$ so that the simulated firm behavior is close to the behavior of the average firm in our sample. For simplicity, we assume a risk-free discount rate of $r = 0.05$ for debt holders, which reduces the number of parameters to be calibrated. We try to match the following data moments in Table 2: average investment rate, average operating profitability, average Q-ratio, average market leverage, average payout ratio, and average bankruptcy rate.

For any set of parameter values, we solve the dynamic program using a discrete-state discrete-control version of the model and employing a value iteration approach. In detail, we discretize the exogenous variable $\log z$ in the range of $\pm$ 3 times the unconditional standard deviation of the AR(1) process using Gaussian quadrature with 11 points. We also discretize the interval $[0, \bar{k}]$ for k and the interval $[0, \bar{b}]$ for b with 45 points each, and the interval $[0, 1]$ for h with 61 points. The bounds $\bar{k}$ and $\bar{b}$ are set so that they are never binding in the simulated economy. The numerical solution of the Bellman problem gives us the optimal policies and the optimal security values. We then simulate an economy comprising 5,000 firms at their steady state for 100 years, for a total of 500,000 firm-year observations.

We present the simulated moments from the dynamic model with CDSs (i.e., the model in Section 3) in Table 3. For all the metrics except for liquidation frequency, the means are calculated by finding the cross-sectional mean for a particular economy at a particular point in time, then taking the time series average of these cross-sectional means in the economy. To calculate the liquidation rate, we first measure the number of liquidated firms as a percentage of the number of active firms in the previous period, for each point in time, and then take the time series mean of this rate.

We compare the data moments in Table 2 with the simulated moments in Table 3 to see whether the model has explanatory power for actual firm behavior. Note that we use the model with a CDS market for matching, since our sample period represents a time with a CDS market in the U.S. Also, it is *not* a requirement of our calibration that all firms in the economy have CDSs traded on their debt. The model with a CDS market allows bondholders to buy or sell CDS protection, but bondholders sometimes endogenously choose not to trade in the CDS market.

The empirical investment rate in Table 2 is 18.61%, while the simulated mean is 51%. The simulated results indicate a higher investment rate than what we observe in the data. However, this is partly because the simulated investment rate is highly skewed, with a median of only 14%. While the simulations predict rare but large investment spikes, most of simulated results indicate an investment rate that is closer to real firm behavior. Operating profitability is 5.5% in the data and 19% in Table 3. While the firm in the model is more profitable than real firms, part of this is driven by negative outliers in the data. The median profitability in Table 2 is substantially higher at 11.14%. The empirical Q-ratio is 2.14, which compares to a simulated average of 3.78. The Q-ratio is related to the average profitability of a firm, so the higher Q-ratio is a consequence of the higher profitability of the simulated firm. Also, the median Q-ratio in Table 3 is only 2.91, which is closer to the data.

Market leverage in the data is 0.338, while it is substantially higher at 0.72 in the simulated sample. This is a well-known problem in the structural credit risk literature. Most credit risk models produce a leverage ratio that is higher than what we observe in the economy, which is sometimes called the low-leverage puzzle. Gomes and Schmid (2010) show that it is possible to make debt financing more costly by introducing a stochastic discount factor. This would help to increase credit spreads and to decrease leverage in our model. However, since the purpose of our model is to examine the effect of CDS markets on firm behavior, we abstract from a stochastic discount factor.

The empirical payout ratio is -4.46%, and its simulated counterpart is -6%. The median payout ratio is 0% in both the data and the simulated data. This is consistent with a firm behavior where equity payouts net of issuance is close to zero during most periods. There are infrequent but large equity issuances, which leads to the negative skewness. This general pattern is very similar in both real firms and the simulation. Finally, the average bankruptcy rate is 1.45%, while it is 3.77% in the simulated sample. The model predicts a higher bankruptcy rate than what we observe empirically, but bankruptcy is still a relatively infrequent event. To summarize, our model is able to match certain moments relatively well, while it is not able to match other moments very closely. This matching, however, is just the result of a rough calibration exercise. A proper estimation of the model using SMM, while significantly more time consuming, would probably result in a more precise match.

The calibrated parameter values are similar to the values reported in the literature. The value of $\rho = 0.725$ is close to those estimated by Hennessy and Whited (2007) (0.66) or DeAngelo, DeAngelo, and Whited (2011) (0.728). Our value of $\sigma = 0.35$ is higher than

Gomes (2001) (0.15) or DeAngelo, DeAngelo, and Whited (2011) (0.28), but below the value in Cooper and Haltiwanger (2006) (0.64). These two parameters directly impact metrics such as EBITDA/assets and leverage, and indirectly affect default rates and credit spreads.

The fixed production cost of $f = 1.5$ is slightly higher than in Moyen (2004) (0.76). This parameter mainly affects the Q-ratio. The cost associated with liquidation (ξ) is calibrated to be 0.15 of the ex post value of the firm's assets. This is roughly comparable to the value estimated by Hennessy and Whited (2007) (10.4%). Our value for β, the discount factor of equity holders, is 0.930, which is slightly lower than the value in Cooley and Quadrini (2001) (0.956).

Finally, we calibrate values for the probability of renegotiation failure γ and the bargaining power of bondholders q to be 0.1 and 0.7, respectively. It is difficult to find evidence of those parameter values in the literature, since both parameters are unobservable empirically. Our value for γ essentially assumes that there is a small but positive probability that debt renegotiations fail. Gilson, John, and Lang (1990) and Asquith, Gertner, and Scharfstein (1994) find that roughly a half of the firms that attempt an out-of-court debt restructuring end up in bankruptcy. However, since bankruptcy filings are observable public events, whereas private debt restructurings often are not, the true probability might be significantly lower. For the debt holders' bargaining power, since empirical proxies are difficult to find, Morellec, Nikolov, and Schurhoff (2012) indirectly estimate the parameter using structural estimation, and report that $q = 0.57$. However, their model is very different from ours, as they assume exogenous cash flows and focus on agency conflicts between management and shareholders. We essentially assume in our $q = 0.7$ value that equity holders have slightly less bargaining power than bondholders, which limits them from extracting large rents in a debt renegotiation.

5. Comparing the Models with and without CDSs

5.1. The effect of CDSs on the average firm

We compare the results of the calibrated model with CDSs in Table 3 to the model without CDSs, which are presented in Table 4. These are unconditional results, using all firm-year observations, and allow us to draw some general conclusions about the effect of CDSs on a firm's investment and financing policies and the value of securities. We find that the mean firm value is higher in the economy with CDSs, in Table 3. The increase from 70.75 to 74.52, or 5.3%, is economically significant. This magnitude is roughly half of the effect of optimal capital structure on firm value in Graham (2000). The main source of this value creation is that the firm uses more debt and less equity financing. The average market value of debt increases from 47.57 to 57.97 after introducing a CDS market, while equity falls from 23.18 to 16.56. This debt-for-equity swap creates value because debt is a cheaper source of financing than equity. Interestingly, the effect on average investment and on average firm size (assets) is small. While the investment rate increases slightly from 45% to 51%, firm size stays roughly the same at 32.08 without and 32.01 with a CDS market. The higher investment rate with CDSs acts as a second source of value creation, but smaller in magnitude than the capital structure effect mentioned above.

The probability of debt renegotiation is higher in the economy with CDS markets (from 0.69% to 32.26%), and the liquidation rate increases from 0.08% to 3.77%. Also, credit spreads increase slightly from 8.28 to 8.91 bps. This creates the impression that the cost of debt financing increases after the introduction of a CDS market. However, the opposite is true. The reason why these three indicators of credit risk do not decrease is that the firm issues so much more debt. The face value of debt increases substantially, from 50 to 60.92. If we held the amount of debt constant, we would observe a reduction in credit spreads with CDSs.

Our findings provide supportive evidence for the empirical literature. First, the increase in the probability of liquidation is consistent with Subrahmanyam, Tang, and Wang (2014), who show that firms are more likely to file for bankruptcy if CDS contracts are introduced on their debt. Second, we find an increase in market leverage from 0.58 to 0.72, which is consistent with the findings of Saretto and Tookes (2013). Third, Ashcraft and Santos (2009) report that CDSs decrease the cost of debt for high-quality borrowers, while increasing it for low-quality borrowers. The authors find no significant effect on the average firm. We find that for a fixed amount of debt, introducing CDSs reduces the credit spread. However, allowing for endogenous debt issuance increases the firm's leverage so much that credit spreads increase. The two effects largely offset each other, consistent with the finding in Ashcraft and Santos (2009) for the average firm.

Figure 7 depicts the effect of CDSs on firm value and firm policies. In contrast to the unconditional results in Tables 3 and 4, it shows the firm at a specific point in the state space, where capital is $k = 30$ and the face value of debt is $b = 66$. The points are chosen to be close to the average values of capital and debt in Table 3. The x-axis represents different values of current productivity z. Curves with circles (in blue) show a firm without CDSs, while curves with diamonds (in red) represent a firm in the economy with CDS markets. Solid circles/diamonds indicate that the firm optimally renegotiates its debt at this point, before choosing the optimal k' and b'. We see that firm value increases with the introduction of CDSs. Equity value is lower in bad states and higher in good states, compared to the model without CDSs. The book value of debt is higher in all states. The result is higher leverage in bad states, and slightly lower leverage in good states. The firm, on whose debt CDSs are traded, chooses a slightly higher level of capital, but only in a very small part of the state space. For the most part, the level of capital is the same.

The probability of debt renegotiation decreases in good states, even though the firm is using more debt. In bad states, however, the renegotiation is more likely. Differently from the unconditional results, the probability of liquidation does not increase with the introduction of CDSs for most values of z. The reason is that there are two ways a firm can end up in liquidation. The first one is the empty creditor problem, where a higher hedge ratio makes renegotiation infeasible. The second is that every renegotiation may fail with probability γ. Since in this state the probability of renegotiation is very high for the firm, on whose debt there are no CDSs, the probability of liquidation is high as well.

To summarize, the effect of CDSs on firm value is positive for all values of the productivity shock z. However, Figure 7 only shows the firm at one point in the state space. It is not clear whether the effect on firm value is positive at other points (k, b) as well. In Appendix C, we present additional figures for different values of (k, b). In all figures, firm value is higher with CDSs, which suggests that our conclusion is robust.

To make sure that the result on the positive net effect of CDSs on firm value does not depend on our set of parameter values, we perform a sensitivity analysis where we try several different parameter values. In Table 5, we compare firm value in the model without a CDS market to firm value with a CDS market. We present the results of the two models using the base case parameter values in Table 1. We also present the results of the two models using deviations from the base case parameter values. We change one parameter at a time, and indicate the new value of the parameter that is changed. The table shows that for a wide range of parameter values, the net effect of CDSs on average firm value is positive. The table also contains the results of a t-test, where we compare firm value in a no-CDS world to firm value in a with-CDS world. The test results indicate that the net effect on firm value is statistically significant in all cases. These findings indicate that our results are robust and do not depend on a particular set of parameter values.

5.2. The effect of CDSs on different types of firms

In Tables 6 and 7, we look at the effect of CDSs on small firms and large firms, respectively. We perform a 2×3 double sort on all simulated firm/year observations in the no-CDS economy, where the sorting variables are k and z. Small firms are defined as the observations with low k and intermediate z, while large firms have high k and intermediate z. We perform the same sorting in the with-CDS economy. The two tables show that small firms have a high investment rate, and finance that investment mostly by issuing debt. The average investment rate for small firms in the no-CDS economy is 0.87 and the change in debt relative to assets is 0.89. Large firms do the opposite, by disinvesting assets and reducing debt. Small firms seem to benefit substantially from CDSs, as their investment and financing policies suggest. The average investment rate increases to 1.0, and the change in debt to 1.0. Even equity issuance increases, indicated by the payout ratio of -0.08. The effect of CDSs on firm policies is different for large firms. Average investment actually drops slightly from -0.24 to -0.28 after the introduction of CDSs, with no difference in medians. Firms with CDSs change debt at a rate of -0.43, which implies more debt reduction compared to the no-CDS economy. However, average leverage is still higher in the model with CDSs. Finally, average firm value is higher with CDS markets, both for small and large firms. This indicates that the introduction of CDSs creates value for both types of firms. However, the relative change in firm value is larger for small firms (47.86 to 52.97) than for large firms (52.93 to 55.61). This shows that small firms strongly benefit from the introduction of a CDS market.

Tables 8 and 9 provide summary statistics for firms with low and high equity payout ratios, respectively. A low payout ratio has been used as a measure of financial constraints [Farre-Mensa and Ljungqvist (2014) provide a recent review]. Using all observations in the no-CDS economy, we use the median payout ratio to classify firms into low and high payout groups. We repeat this sorting for the with-CDS economy. If we compare no-CDS firms with a low payout ratio to no-CDS firms with a high payout ratio, the two tables show that firms with a low payout ratio invest less on average (0.09 vs. 0.86). Also, they are smaller (15.23 vs. 48.17) and have a higher Q-ratio (5.55 vs. 2.25). The intuition for these findings is that low payout ratio firms are typically small firms with very good growth opportunities, so equity holders find it optimal to inject cash into these firms. When we focus on the effect of CDSs on low payout ratio firms, we see that there is a positive effect on investment (0.09 to 0.24), as well as a positive effect on change in debt (-0.07 to 0.08). For high payout ratio firms, we also observe a positive effect on investment (0.86 to 1.28) and debt issuance (0.79 to 1.29). Finally, if we compare average firm value of no-CDS firms and with-CDS firms, we see in both tables that CDSs create firm value on average. However, the relative gain in firm value is slightly larger for low payout ratio firms (39.53 to 44.49) than for high payout ratio firms (108.17 to 114.56). This means that firms with a low payout ratio benefit substantially more from CDS contracts.

Since the payout ratio is a crude proxy for financial constraints, we develop a more accurate measure in the context of our model. We perform a 2×3 double sort on the firm's cashflow available for investment and on z and report the results in Tables 10 and 11. The available cashflow is defined as $\pi(z,k) - b$. We define constrained firms as having low available cashflow and high z, while unconstrained firms have high available cashflow and high z. The high productivity shock z guarantees that the firm has good investment opportunities. Comparing no-CDS firms in the two tables, we find that average investment is significantly higher for unconstrained firms than constrained firms (2.61 vs. 0.26). These findings indicate that our measure of financial constraints captures the problem of firms with good investment opportunities but not enough internal resources to fund investment. However, our unconstrained firms are smaller than the constrained firms, which is in contrast with the intuition that unconstrained firms are large. With this caveat in mind, we observe in Table 10 that the introduction of CDSs only slightly increases investment for constrained firms (0.26 to 0.31), with no effect on median investment. Also, while the effect on leverage is positive for constrained firms (0.68 to 0.77), the effect on the change in debt is small (0.14 to

0.18). For unconstrained firms, the effect on investment is positive (2.61 vs. 2.86), and even median investment increases slightly. There is a positive effect on leverage for unconstrained firms (0.68 to 0.76) and the change in debt (2.48 to 2.91). Finally, the effect on firm value is positive for both constrained (123.27 to 124.65) and unconstrained firms (95.99 to 105.02). However, the relative gain is smaller for constrained firms. Therefore, we cannot confirm the finding that constrained firms benefit more from the introduction of a CDS market. Also, constrained firms actually have slightly higher payout ratios than unconstrained firms (0.13 vs. 0.06). This indicates that one has to be careful with using payout ratios as a proxy for financial constraints in our model.

In Tables 12 and 13 we compare firms with low and high growth opportunities, respectively. We perform a 2×3 double sort on k and z, and classify observations with high k and low z as firms with low growth opportunities. Analogously, high growth opportunities are defined as having low k and high z. Tables 12 and 13 show that firms with few growth opportunities disinvest significantly while, high growth firms invest at very high rates (-0.53 vs. 4.0). Low growth firms reduce their debt, whereas high growth firms issue more debt (-0.77 vs. 3.97). Interestingly, the payout ratios indicate that low growth firms issue equity, while high growth firms are able to pay a small dividend (-0.22 vs. 0.05). The intuition is that high growth firms have more internally generated cash flow, as well as a lower cost of debt financing, which allows them to finance their growth without outside equity. The effect of CDS contracts on low growth firms is positive but negligibly small (34.58 vs. 34.86). In the case with high growth opportunities, CDSs allow the firm to invest more and to increase debt more, without having to issue costly equity. All three of these effects create firm value. As a result, there is a substantial increase in firm value after the introduction of a CDS market (84.22 to 92.56).

We conclude this analysis of different firm types by observing that a CDS market has a large positive effect on firm value for small firms and firms with many growth opportunities.

We find a small but positive effect for large firms, and a negligible effect on firms with few growth opportunities. We find that both financially constrained and unconstrained firms benefit from CDSs, and do not find conclusive evidence that constrained firms benefit more than unconstrained firms.

6. Conclusions

We examine the effect of CDSs on firm value in the context of a dynamic model where the firm chooses investment, equity financing, and debt financing in an optimal manner each period. The model features several real-world frictions: equity issuance costs, bankruptcy costs, and debt renegotiation frictions. We construct two versions of the model, with and without a CDS market. In the version with CDSs, debt holders are able to trade in the CDS market and choose their positions optimally each period.

After calibrating this model to the average public corporation in the U.S., we examine the effect of introducing a CDS market in the economy. Our main result is that while CDS contracts have both positive and negative effects on firm value, the net effect is positive. For public U.S. corporations, our calibration suggests an increase in firm value of 5.3% on average.

The model predicts that after the introduction of a CDS market, firm leverage increases, investment increases, the probability of bankruptcy increases, and credit spreads do not change significantly. These findings are consistent with the existing empirical literature on the effects of CDS contracts. Moreover, while the empirical literature has focused on specific aspects of the introduction of CDSs on corporate finance, we provide a unifying theory of the firm that can explain these facts altogether. In addition, we derive the following new predictions from the model. The effect on firm value is the strongest for small firms and for firms with many growth opportunities. We do not find a different effect for financially constrained firms.

Our model is simplistic in the sense that it only examines the effect of CDS markets from a corporate finance perspective. We neglect other potentially important effects of credit derivatives, such as on risk sharing, liquidity, and banking. Keeping these caveats in mind, our results show that CDSs are useful for the average firm in the U.S. In light of the recent financial crisis and the following policy discussion, the findings are consistent with a view that while CDS contracts can cause problems, their benefits likely outweigh their costs.

References

Acharya, Viral, Jing-Zhi Huang, Marti Subrahmanyam, and Rangarajan K. Sundaram, 2006, When does strategic debt service matter?, *Economic Theory* 29, 363–378.

Alanis, Emmanuel, Sudheer Chava, and Praveen Kumar, 2014, Shareholder Bargaining Power, Debt Overhang, and Investment, *Working Paper*.

Altinkilic, O., and R. S. Hansen, 2000, Are there economies of scale in underwriting fees? Evidence of rising external financing costs, *Review of Financial Studies* 13, 191–218.

Anderson, Ronald W., and Suresh Sundaresan, 1996, Design and Valuation of Debt Contracts, *Review of Financial Studies* 9, 37–68.

Ashcraft, Adam B., and Joao A.C. Santos, 2009, Has the CDS market lowered the cost of corporate debt?, *Journal of Monetary Economics* 56, 514 – 523.

Asquith, Paul, Robert Gertner, and David Scharfstein, 1994, Anatomy of Financial Distress: An Examination of Junk-Bond Issuers, *The Quarterly Journal of Economics* 109, 625–658.

Bolton, Patrick, and Martin Oehmke, 2011, Credit Default Swaps and the Empty Creditor Problem, *Review of Financial Studies* 24, 2617–2655.

Chava, Sudheer, 2014, Environmental Externalities and Cost of Capital, *Management Science* 60, 2223–2247.

Chava, Sudheer, and Robert A. Jarrow, 2004, Bankruptcy Prediction with Industry Effects, *Review of Finance* 8, 537–569.

Chernov, Mikhail, Alexander S. Gorbenko, and Igor Makarov, 2013, CDS Auctions, *Review of Financial Studies* 26, 768–805.

Cooley, Thomas F., and Vincenzo Quadrini, 2001, Financial Markets and Firm Dynamics, *The American Economic Review* 91, pp. 1286–1310.

Cooper, Russell W., and John C. Haltiwanger, 2006, On the Nature of Capital Adjustment Costs, *Review of Economic Studies* 73, 611–633.

Danis, András, 2014, Do Empty Creditors Matter? Evidence from Distressed Exchange Offers, *Working Paper*.

Davydenko, Sergei A., and Ilya A. Strebulaev, 2007, Strategic Actions and Credit Spreads: An Empirical Investigation, *Journal of Finance* 62, 2633–2671.

DeAngelo, Harry, Linda DeAngelo, and Toni M. Whited, 2011, Capital structure dynamics and transitory debt, *Journal of Financial Economics* 99, 235–261.

Duffee, Gregory R., and Chunsheng Zhou, 2001, Credit derivatives in banking: Useful tools for managing risk?, *Journal of Monetary Economics* 48, 25 – 54.

Fan, Hua, and Suresh M. Sundaresan, 2000, Debt Valuation, Renegotiation, and Optimal Dividend Policy, *Review of Financial Studies* 13, 1057–1099.

Farre-Mensa, Joan, and Alexander Ljungqvist, 2014, Do Measures of Financial Constraints Measure Financial Constraints?, *Working Paper*.

Favara, Giovanni, Enrique Schroth, and Philip Valta, 2012, Strategic Default and Equity Risk Across Countries, *Journal of Finance* 67, 2051–2095.

Fostel, Ana, and John Geanakoplos, 2012, Tranching, CDS, and asset prices: How financial innovation can cause bubbles and crashes, *American Economic Journal: Macroeconomics* 4, 190–225.

Garlappi, Lorenzo, and Hong Yan, 2011, Financial Distress and the Cross-section of Equity Returns, *Journal of Finance* 66, 789–822.

Gilson, Stuart C., Kose John, and Larry H.P. Lang, 1990, Troubled debt restructurings: An empirical study of private reorganization of firms in default, *Journal of Financial Economics* 27, 315 – 353.

Gomes, J. F., 2001, Financing investment, *American Economic Review* 91, 1263–1285.

Gomes, J. F., and L. Schmid, 2010, Levered Returns, *Journal of Finance* 65, 467–494.

Graham, John R., 2000, How Big Are the Tax Benefits of Debt?, *Journal of Finance* 55, 1901–1942.

Hege, Ulrich, and Pierre Mella-Barral, 2005, Repeated Dilution of Diffusely Held Debt, *Journal of Business* 78, 737–786.

Hennessy, C. A., and T. M. Whited, 2005, Debt dynamics, *Journal of Finance* 60, 1129–1165.

Hennessy, Christopher A., and Toni M. Whited, 2007, How Costly Is External Financing? Evidence from a Structural Estimation, *The Journal of Finance* 62, 1705–1745.

Hu, Henry T. C., and Bernard Black, 2008, Debt, equity and hybrid decoupling: Governance and systemic risk implications, *European Financial Management* 14, 663–709.

Livdan, Dmitry, Horacio Sapriza, and Lu Zhang, 2009, Financially Constrained Stock Returns, *Journal of Finance* 64, 1827–1862.

Mella-Barral, P, 1999, The dynamics of default and debt reorganization, *Review of Financial Studies* 12, 535–578.

Mella-Barral, Pierre, and William Perraudin, 1997, Strategic Debt Service, *Journal of Finance* 52, 531–556.

Morellec, Erwan, Boris Nikolov, and Norman Schurhoff, 2012, Corporate Governance and Capital Structure Dynamics, *Journal of Finance* 67, 803–848.

Morrison, Alan D., 2005, Credit Derivatives, Disintermediation, and Investment Decisions, *The Journal of Business* 78, 621–648.

Moyen, N., 2004, Investment-Cash Flow Sensitivities: Constrained versus Unconstrained Firms, *Journal of Finance* 49, 2061–2092.

Nikolov, Boris, and Toni M. Whited, 2014, Agency Conflicts and Cash: Estimates from a Dynamic Model, *Journal of Finance* forthcoming.

Oehmke, Martin, and Adam Zawadowski, 2014, Synthetic or Real? The Equilibrium Effects of Credit Default Swaps on Bond Markets, *Working Paper*.

Saretto, Alessio, and Heather Tookes, 2013, Corporate Leverage, Debt Maturity and Credit Default Swaps: The Role of Credit Supply, *Review of Financial Studies* 26, 1190–1247.

Schmid, L., 2008, A Quantitative Dynamic Agency Model of Financial Constraints, Working paper, Duke Fuqua School.

Schroth, Enrique, Gustavo Suarez, and Lucian A. Taylor, 2014, Dynamic debt runs and financial fragility: Evidence from the 2007 ABCP crisis, *Journal of Financial Economics* 112, 164–189.

Subrahmanyam, Marti, Dragon Yongjun Tang, and Sarah Qian Wang, 2014, Does the Tail Wag the Dog? The Effect of Credit Default Swaps on Credit Risk, *Review of Financial Studies* 27, 2927–2960.

Taylor, Lucian A., 2010, Why Are CEOs Rarely Fired? Evidence from Structural Estimation, *Journal of Finance* 65, 2051–2087.

Warusawitharana, Missaka, and Toni M. Whited, 2015, Equity Market Misvaluation, Financing, and Investment, *Review of Financial Studies* forthcoming.

Figure 1: Single-period model. Optimal default decision

The figure presents three scenarios for h' of the optimal shareholder's decisions, as a function of a', in the single-period model. "Liquidity default" denotes the region where the firm would default even in a world where debt cannot be renegotiated. "Strategic default" denotes the region where the firm would not default if debt could not be renegotiated.

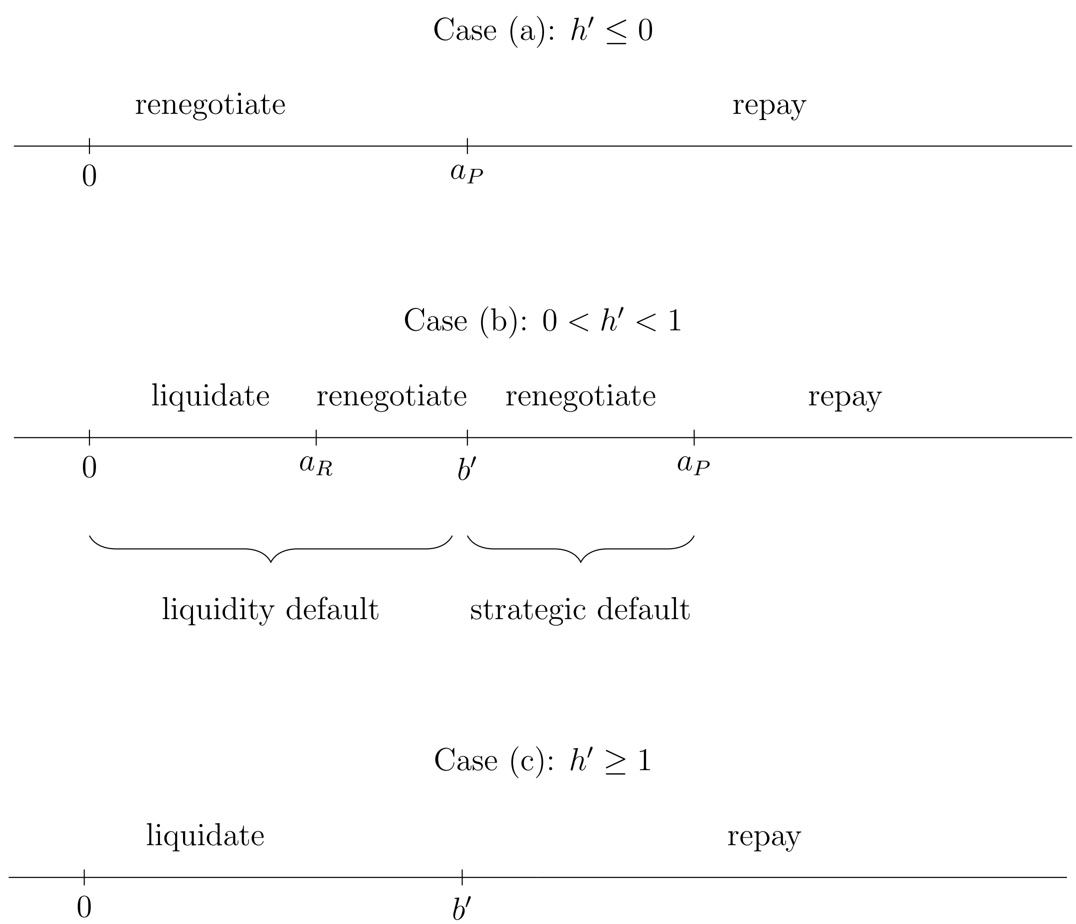


Figure 2: Single-period model. Sensitivity to different levels of debt bargaining power q.

This figure is based on the solution of the single-period model, and the base case parameters in Table 1, for a specific point of the state space, (z, k, b).

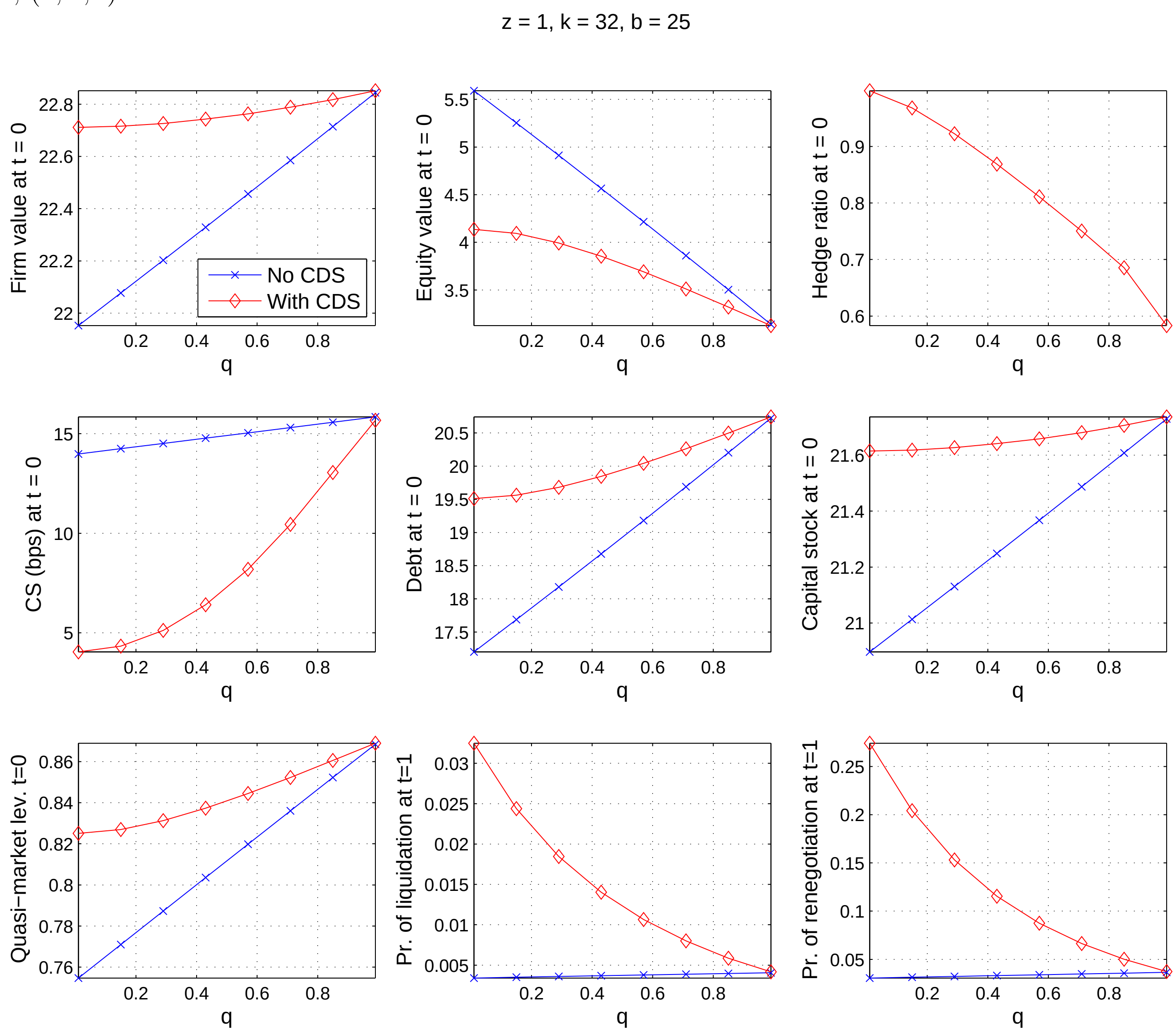


Figure 3: Single-period model. Sensitivity to different levels of liquidation cost ξ.

This figure is based on the solution of the single-period model, and the base case parameters in Table 1, for a specific point of the state space, (z, k, b).

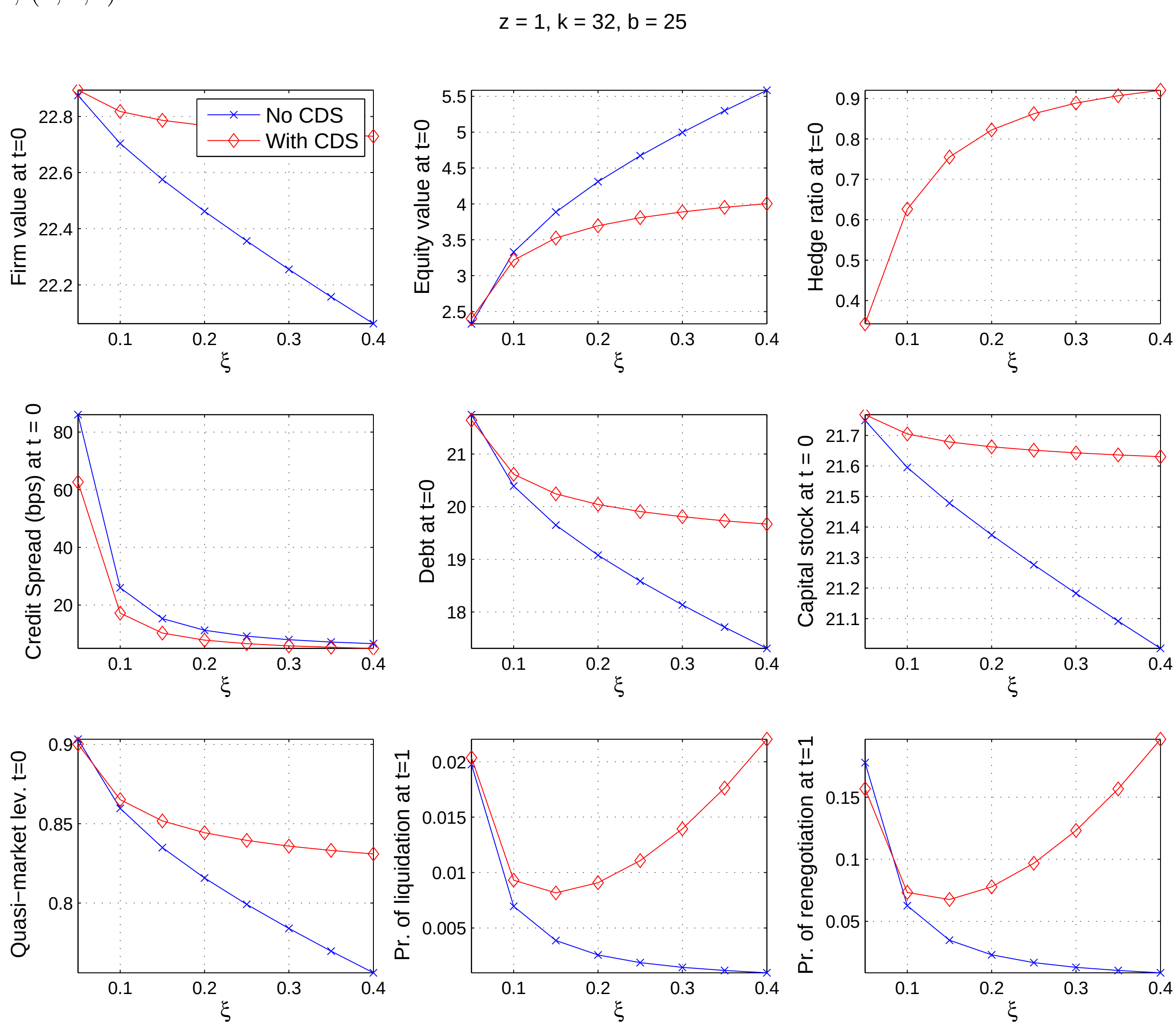


Figure 4: Single-period model. Sensitivity to different levels of renegotiation cost γ.

This figure is based on the solution of the single-period model, and the base case parameters in Table 1, for a specific point of the state space, (z, k, b).

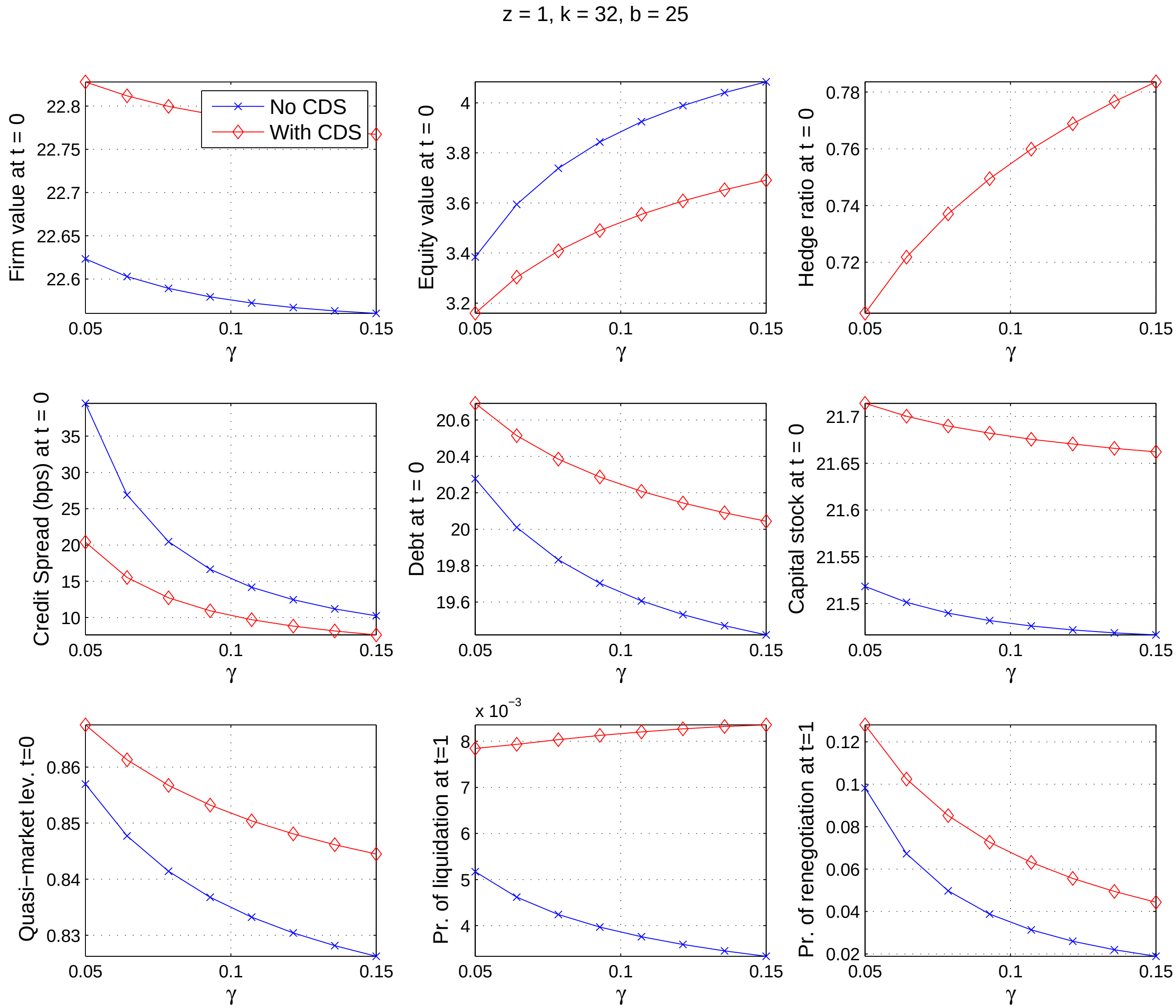


Figure 5: Timeline of the dynamic model in $[t, t+1]$.

Firm has (k_t, b_t, h_t) from $t-1$

Nature draws z_t. Net worth $w_t = a(z_t, k_t) - b_t$

Three possible outcomes:

- Debt is repaid: d_t is the argmax of (16), $e_t = w_t - d_t$.
- Debt is successfully renegotiated: net worth is reset to $w_{rt} = a(z_t, k_t) - b_{rt}$, with b_{rt} from (23); d_t is the argmax of (16) at (z_t, w_{rt}); $e_t = w_{rt} - d_t$.
- The firm is liquidated. It is replaced by a new firm with $e_t = w_d$.

Given e_t, the owner decides k_{t+1} and b_{t+1} as argmax of (9).

Given (z_t, k_{t+1}, b_{t+1}), debt holders decide h_{t+1} as argmax of (11).

Firm has $(k_{t+1}, b_{t+1}, h_{t+1})$ from t

Nature draws z_{t+1}. Net worth $w_{t+1} = a(z_{t+1}, k_{t+1}) - b_{t+1}$, etc.

Figure 6: Default decision tree (i.e., for $b > 0$) in the dynamic model

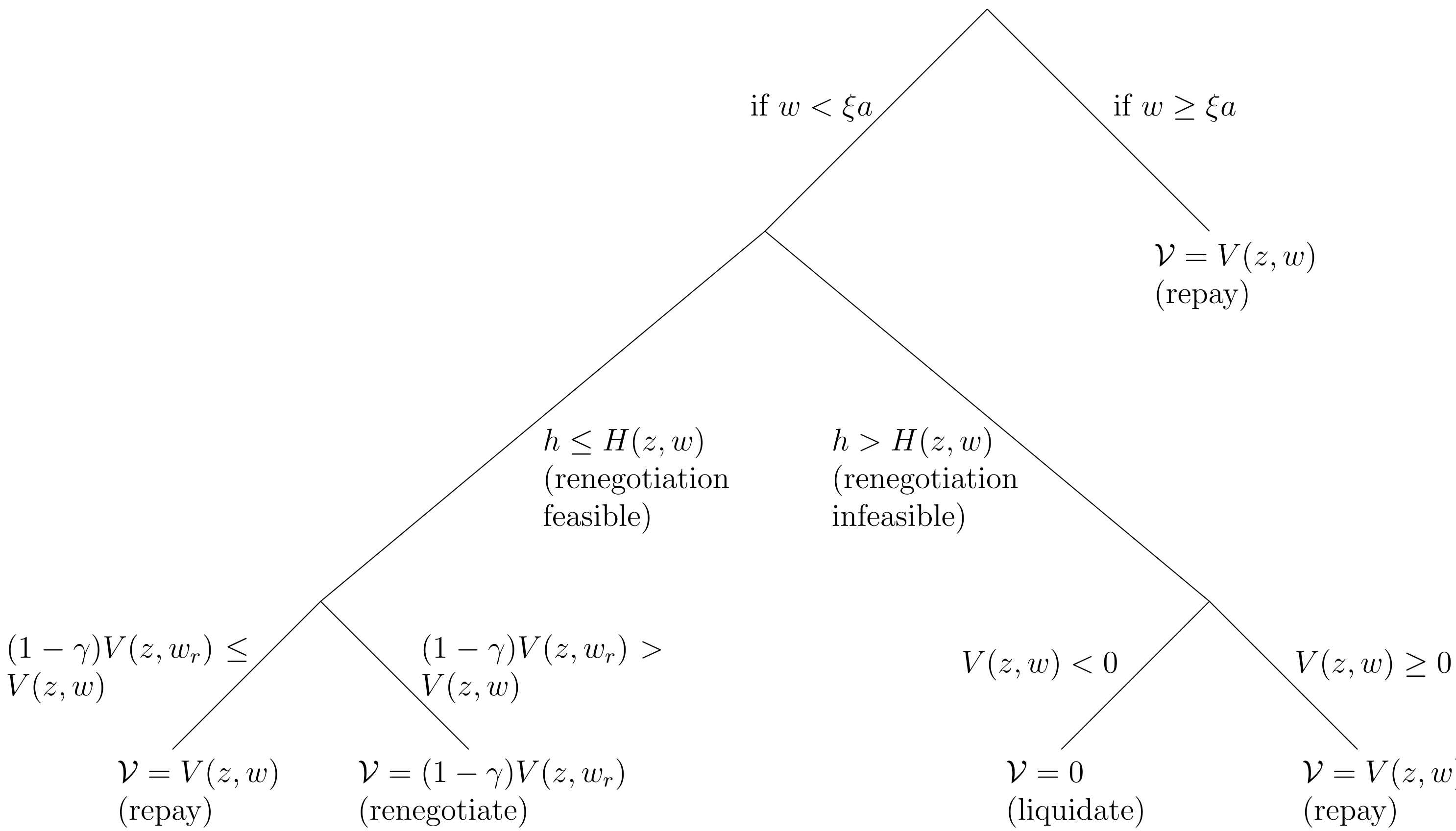
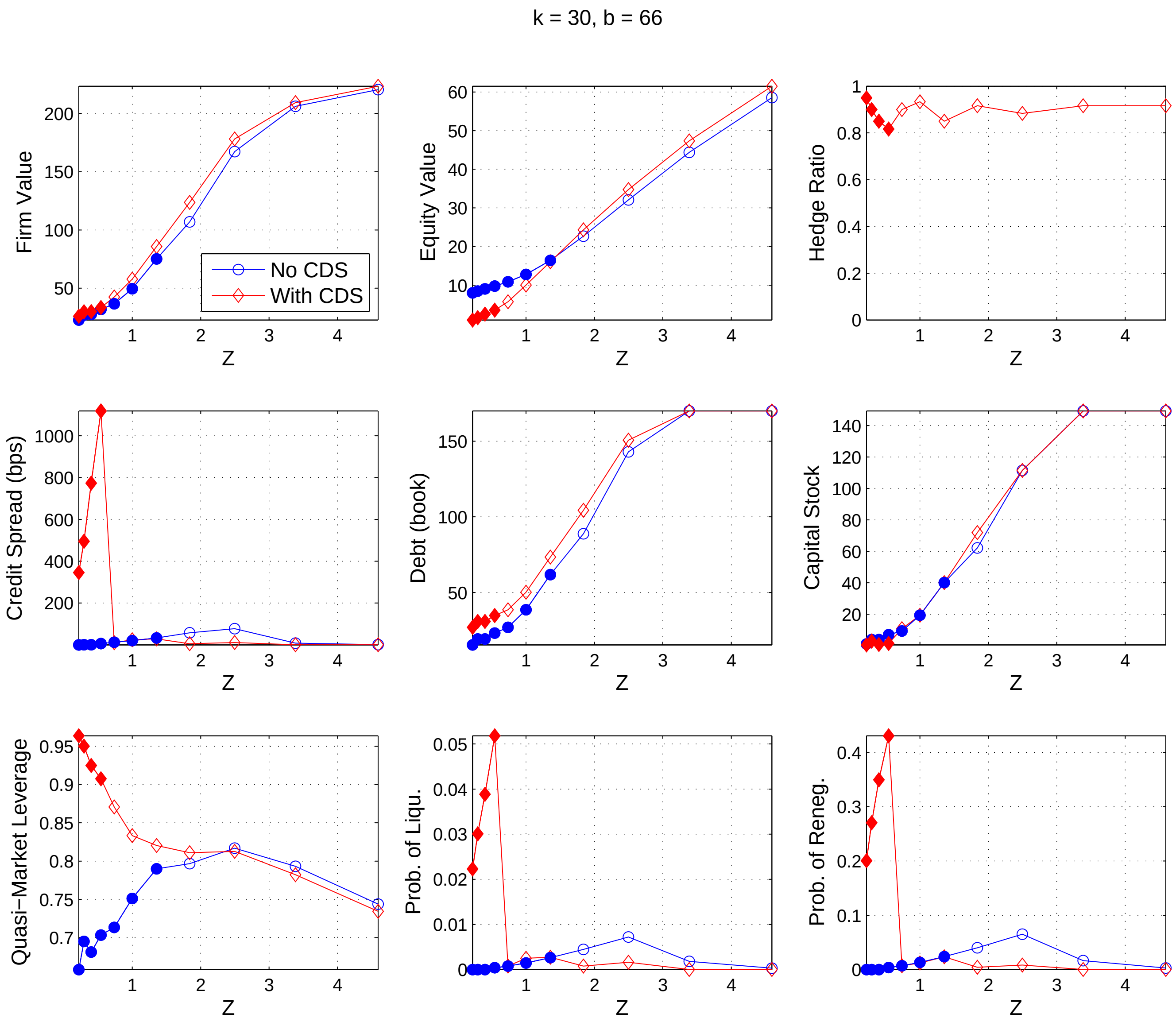


Figure 7: Dynamic model.

This figure is based on the solution of the dynamic model, and the base case parameters in Table 1, and shows the different metrics against current productivity z for a specific pair (k, b) of current capital and current debt, respectively. Solid circles indicate that the firm optimally renegotiates its debt at this point, before choosing the optimal k' and b'.



Symbol	Economic interpretation	Value
β	Time discount factor for equity holders	0.9302
r	Risk-free rate	0.05
ρ	Persistence of productivity shock	0.725
σ	Conditional volatility of productivity shock	0.35
α	Return to scale	0.603
f	Fixed production cost	1.5
δ	Annual depreciation rate	0.136
λ	Flotation cost for equity	0.0536
ξ	Proportional liquidation costs	0.15
γ	Probability of renegotiation failure	0.1
q	Bargaining power of debt holders	0.7

Table 1: **Base Case Parameter Values**. This table provides the base case parameters used in the simulations.

Table 2: **Summary Statistics for a Sample of U.S. Corporations.** The sample is constructed by merging the annual Compustat data with CRSP data, using the sample period 1994–2013. The variables are the investment rate (the difference between CAPX and the sale of PPE divided by lagged gross PPE), operating profitability (operating profit divided by lagged total assets), the Q–Ratio (the sum of the market value of equity from CRSP and liabilities divided by total assets), book leverage (liabilities divided by total assets), market leverage (liabilities divided by the sum of liabilities and the market value of equity), the payout ratio (dividends plus repurchases minus stock issuance, divided by lagged assets), and the depreciation rate (depreciation and amortization minus amortization of intangibles, divided by lagged gross PPE). Equity issuance costs are calculated using data on seasoned equity offerings from the SDC Platinum Global New Issuance database. We remove firms from the SDC sample if they are not in the CRSP-Compustat sample. Equity issuance costs are defined as total fees divided by total proceeds in equity offerings. To calculate the bankruptcy rate, we determine for each firm-year observation whether the firm has filed for bankruptcy in that year. All variables are winsorized at the 1% and 99% levels.

	Mean	SD	25th Perc.	Median	75th Perc.	Observations
Investment Rate	0.1861	0.2688	0.0535	0.1036	0.2035	69,110
Operating Profitability	0.0550	0.2676	0.0068	0.1114	0.1888	69,951
Q–Ratio	2.1444	1.8820	1.0963	1.5153	2.3812	79,085
Book Leverage	0.4847	0.2747	0.2736	0.4644	0.6450	80,106
Market Leverage	0.3382	0.2421	0.1324	0.2924	0.5055	79,085
Payout Ratio	-0.0446	0.2471	-0.0104	0.0000	0.0191	61,569
Depreciation Rate	0.1360	0.1282	0.0665	0.0980	0.1570	69,539
Bankruptcy Rate	0.0145	NA	NA	NA	NA	1,165
Equity Issuance Costs	0.0536	0.0162	0.0458	0.0554	0.0633	6,636

Table 3: **Economy with CDSs: Simulated Moments of Key Metrics.** This table provides unconditional sample moments for the following variables: firm value $(v + m')$; assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate $((k' - k(1 - \delta))/k)$; EBITDA/assets (π/k); payouts/assets $((\pi + k(1 - \delta) - k' - b + m')/k)$; Q–ratio $((v + b')/k')$; leverage $(b'/(b' + v))$; change in debt/assets $((b' - b)/k)$; credit spread $(b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (the annual frequency of liquidation); and abandonment (the percentage of times the firm ceases to exists because the asset is negative while there is no debt). The columns report several unconditional moments ("sd" is the standard deviation, "ac" is the autocorrelation, "sk" is the skewness, "kur" is the kurtosis) and unconditional percentiles based on simulation using the base parameters shown in Table 1. All moments are reported on an annual basis.

	Mean	SD	AC	SK	KUR	1th	25th	Median	75th	99th
Firm Value	74.52	43.70	0.61	1.68	5.89	28.59	46.56	61.60	88.73	220.87
Assets	32.01	32.63	0.62	1.83	6.54	1.86	10.75	19.32	40.06	149.30
Debt (book)	60.92	34.02	0.64	1.54	4.79	27.05	38.64	50.23	69.55	170.00
Debt (market)	57.97	32.39	0.63	1.54	4.79	25.76	36.76	47.73	66.22	161.90
Equity	16.56	13.12	0.42	2.45	15.82	0.00	9.02	14.70	22.14	60.93
Hedge Ratio	0.92	0.06	0.16	-9.85	141.15	0.80	0.90	0.93	0.95	1.00
Investment/Assets	0.51	1.32	-0.13	3.71	29.70	-0.71	-0.31	0.14	0.93	5.89
EBITDA/Assets	0.19	0.18	0.34	-0.65	7.24	-0.48	0.09	0.20	0.28	0.62
Payouts/Assets	-0.06	0.27	0.44	-3.49	75.21	-0.93	-0.16	0.00	0.06	0.46
Q–Ratio	3.78	2.79	0.53	2.14	12.14	0.00	2.22	2.91	4.46	16.43
Market Leverage	0.72	0.19	0.03	-3.47	13.39	0.00	0.76	0.77	0.78	0.85
Chg. Debt/Assets	0.43	1.46	-0.13	3.70	29.83	-0.97	-0.48	0.00	0.87	6.29
Credit Spread (bps)	8.91	14.06	0.16	22.53	1017.74	0.00	2.80	6.12	10.08	36.80
Renegotiation (pct)	30.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquidation (pct)	3.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abandonment (pct)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4: **Economy without CDSs: Simulated Moments of Key Metrics.** This table provides unconditional sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); investment rate ($(k' - k(1-\delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1-\delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); leverage ($b'/(b'+v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1+r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (the annual frequency of liquidation); and abandonment (the percentage of times the firm ceases to exists because the asset is negative while there is no debt). The columns report several unconditional moments ("sd" is the standard deviation, "ac" is the autocorrelation, "sk" is the skewness, "kur" is the kurtosis) and unconditional percentiles based on simulation using the base parameters shown in Table 1. All moments are reported on an annual basis.

	Mean	SD	AC	SK	KUR	1th	25th	Median	75th	99th
Firm Value	70.75	44.64	0.61	1.92	7.01	21.89	42.43	58.65	85.30	229.78
Assets	32.08	34.12	0.62	2.11	7.64	3.86	9.29	19.29	40.06	149.30
Debt (book)	50.00	34.22	0.62	1.93	6.49	19.32	27.05	38.64	57.95	166.14
Debt (market)	47.57	32.56	0.62	1.93	6.49	18.40	25.73	36.73	55.18	158.21
Equity	23.18	14.62	0.40	1.67	11.02	0.00	15.75	21.50	30.11	72.31
Hedge Ratio	0.00	0.00	–	–	–	0.00	0.00	0.00	0.00	0.00
Investment/Assets	0.45	1.23	-0.12	3.92	35.37	-0.71	-0.22	0.14	0.69	5.64
EBITDA/Assets	0.19	0.18	0.36	-0.91	11.55	-0.21	0.07	0.19	0.28	0.63
Payouts/Assets	-0.03	0.20	0.43	-1.72	12.18	-0.59	-0.14	0.00	0.07	0.32
Q–Ratio	3.23	2.26	0.38	2.61	22.25	0.00	1.88	3.02	4.68	8.21
Market Leverage	0.58	0.20	0.00	-2.49	7.61	0.00	0.60	0.63	0.66	0.75
Chg. Debt/Assets	0.35	1.30	-0.11	3.85	35.30	-0.88	-0.42	0.00	0.58	5.64
Credit Spread (bps)	8.28	7.19	0.17	0.60	1.99	0.00	2.77	6.20	12.38	20.36
Renegotiation (pct)	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquidation (pct)	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abandonment (pct)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: **Effect of CDSs on Firm Value: Sensitivity Analysis.** This table provides unconditional sample moments for firm value $(v + m')$. The columns report the mean, median, and standard deviation of firm value. The last column provides p-values for a t-test that compares the mean of the no-CDS firm value to the mean of the with-CDS firm value. The table presents results using the base case parameters shown in Table 1, along with the deviations from the base case parameters, changing one parameter at a time.

	No CDS			With CDS			
	Mean	Median	SD	Mean	Median	SD	p-Value
Base case	70.75	58.65	44.64	74.52	61.60	43.70	0.00
$\beta = 0.935$	73.88	63.55	44.33	76.30	66.10	43.49	0.00
$\beta = 0.926$	68.16	56.66	41.43	71.81	62.78	41.55	0.00
$r = 0.04$	91.72	79.91	48.51	98.01	83.84	47.49	0.00
$r = 0.06$	59.07	48.16	41.13	60.33	50.65	39.40	0.00
$\rho = 0.7$	67.40	58.08	39.26	69.14	61.33	37.75	0.00
$\rho = 0.75$	77.00	64.99	49.03	80.89	68.29	48.47	0.00
$\sigma = 0.3$	57.97	50.36	34.58	61.37	52.69	35.09	0.00
$\sigma = 0.4$	87.90	72.29	54.91	91.43	76.20	51.85	0.00
$\alpha = 0.55$	34.23	30.42	23.97	34.82	29.85	23.42	0.00
$\alpha = 0.65$	137.87	125.71	67.30	142.15	127.72	62.10	0.00
$f = 1.8$	65.70	53.42	44.76	67.98	58.72	41.81	0.00
$f = 1.2$	75.53	65.29	42.49	79.38	68.47	41.58	0.00
$\delta = 0.146$	62.85	53.34	40.36	65.48	54.77	40.09	0.00
$\delta = 0.126$	81.52	68.95	48.10	85.49	74.69	47.17	0.00
$\lambda = 0.07$	70.63	58.62	44.61	74.05	59.29	43.71	0.00
$\lambda = 0.04$	70.78	61.96	42.36	76.29	63.80	43.02	0.00
$\xi = 0.2$	69.45	58.69	42.15	74.55	61.60	43.61	0.00
$\xi = 0.1$	71.88	61.47	43.78	74.54	61.62	43.71	0.00
$\gamma = 0.15$	68.89	61.47	41.53	73.66	62.46	43.18	0.00
$\gamma = 0.05$	72.58	57.83	44.05	76.28	62.40	43.85	0.00
$q = 0.6$	69.87	60.97	42.16	74.41	59.56	43.59	0.00
$q = 0.8$	72.72	59.49	43.62	75.01	63.96	41.57	0.00

Table 6: **Small Firms.** We perform a 2×3 double sort on k and z, and select observations with low k and intermediate z. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1-\delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1-\delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	47.86	44.65	10.63	94416	52.97	49.53	9.40	111016	0.00
Assets	8.32	9.29	2.09	94416	9.55	10.75	3.75	111016	0.00
Debt (book)	25.38	27.05	2.75	94416	36.89	38.64	5.06	111016	0.00
Debt (market)	29.84	25.73	5.42	94416	40.80	36.76	5.63	111016	0.00
Equity	18.02	18.92	6.39	94416	12.17	12.77	4.62	111016	0.00
Hedge Ratio	0.00	0.00	0.00	94416	0.92	0.90	0.03	111016	0.00
Investment/Assets	0.87	0.48	1.08	94416	1.00	1.21	1.15	106819	0.00
EBITDA/Assets	0.16	0.14	0.09	94416	0.16	0.15	0.08	106819	0.00
Payouts/Assets	-0.01	0.02	0.13	94416	-0.08	-0.11	0.12	106819	0.00
Q-Ratio	3.55	3.38	1.43	94416	3.58	4.46	1.18	111016	0.00
Market Leverage	0.55	0.60	0.19	94416	0.72	0.78	0.19	111016	0.00
Chg. Debt/Assets	0.89	0.56	1.18	94416	1.00	1.08	1.32	106819	0.00
Credit Spread (bps)	13.18	12.38	6.41	94416	9.41	10.08	4.76	111016	0.00
Renegotiation (pct)	0.00				29.94				
Liquidation (pct)	0.00				14.67				

Table 7: **Large Firms.** We perform a 2×3 double sort on k and z, and select observations with high k and intermediate z. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate $((k' - k(1-\delta))/k)$; EBITDA/assets (π/k); payouts/assets $((\pi + k(1-\delta) - k' - b + m')/k)$; Q–ratio $((v + b')/k')$; market leverage $(b'/(b' + v))$; change in debt/assets $((b' - b)/k)$; credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	52.93	58.22	9.39	118320	55.61	59.65	8.04	101726	0.00
Assets	32.84	19.29	19.85	118320	35.78	34.61	19.82	101726	0.00
Debt (book)	51.64	38.64	19.87	118320	65.64	69.55	21.18	101726	0.00
Debt (market)	34.41	36.73	8.86	118320	43.69	44.09	6.08	101726	0.00
Equity	18.52	21.49	6.69	118320	11.92	12.93	4.82	101726	0.00
Hedge Ratio	0.00	0.00	0.00	118320	0.92	0.90	0.02	101726	0.00
Investment/Assets	-0.24	-0.38	0.29	118283	-0.28	-0.38	0.30	96985	0.00
EBITDA/Assets	0.17	0.17	0.07	118283	0.17	0.19	0.05	96985	0.00
Payouts/Assets	-0.02	-0.00	0.06	118283	-0.05	-0.03	0.07	96985	0.00
Q-Ratio	3.25	3.12	1.30	118320	3.47	3.52	1.03	101726	0.00
Market Leverage	0.56	0.62	0.19	118320	0.73	0.78	0.17	101726	0.00
Chg. Debt/Assets	-0.37	-0.48	0.31	118283	-0.43	-0.58	0.32	96985	0.00
Credit Spread (bps)	15.49	20.36	6.60	118320	13.76	10.08	6.87	101726	0.00
Renegotiation (pct)	0.23				37.78				
Liquidation (pct)	0.12				18.18				

Table 8: **Low Payout Ratio.** We select observations with a payout ratio below the median. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1 - \delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1 - \delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	39.53	38.07	10.62	158571	44.49	38.94	11.56	159680	0.00
Assets	15.23	9.29	17.61	157002	11.49	10.75	10.69	158091	0.00
Debt (book)	32.68	27.05	18.54	157002	39.08	38.64	12.21	158091	0.00
Debt (market)	23.74	22.06	6.90	158571	34.76	29.42	8.01	159680	0.00
Equity	15.79	16.00	3.81	158571	9.73	9.37	3.79	159680	0.00
Hedge Ratio	0.00	0.00	0.00	158571	0.94	0.95	0.03	159680	0.00
Investment/Assets	0.09	-0.12	1.00	158571	0.24	0.14	0.81	159680	0.00
EBITDA/Assets	0.05	0.09	0.16	158571	0.06	0.09	0.17	159680	0.00
Payouts/Assets	-0.26	-0.24	0.19	158571	-0.33	-0.22	0.29	159680	0.00
Q-Ratio	5.55	5.07	2.26	158571	6.27	7.50	3.07	159680	0.00
Market Leverage	0.61	0.60	0.02	158571	0.78	0.77	0.03	159680	0.00
Chg. Debt/Assets	-0.07	-0.42	1.13	158571	0.08	0.00	0.91	159680	0.00
Credit Spread (bps)	7.59	6.20	4.88	158571	10.59	8.04	23.83	159680	0.00
Renegotiation (pct)	2.17			158571	73.62			159680	
Liquidation (pct)	0.24			158571	8.18			159680	

Table 9: **High Payout Ratio.** We select observations with a payout ratio above the median. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1 - \delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1 - \delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	108.17	85.60	52.25	172961	114.56	89.07	48.76	172214	0.00
Assets	48.17	40.06	40.26	171261	44.62	40.06	40.24	170533	0.00
Debt (book)	66.01	57.95	39.58	171261	73.70	69.55	40.83	170533	0.00
Debt (market)	72.34	55.18	38.52	172961	86.14	66.22	35.78	172214	0.00
Equity	35.83	30.42	15.04	172961	28.42	22.85	14.62	172214	0.00
Hedge Ratio	0.00	0.00	0.00	172961	0.91	0.92	0.08	172214	0.00
Investment/Assets	0.86	0.14	1.52	172961	1.28	0.93	1.72	172214	0.00
EBITDA/Assets	0.33	0.28	0.12	172961	0.33	0.32	0.14	172214	0.35
Payouts/Assets	0.14	0.11	0.09	172961	0.14	0.11	0.14	172214	0.00
Q-Ratio	2.25	2.12	0.61	172961	2.31	2.22	0.91	172214	0.00
Market Leverage	0.67	0.66	0.04	172961	0.76	0.77	0.03	172214	0.00
Chg. Debt/Assets	0.79	0.00	1.59	172961	1.29	0.87	1.90	172214	0.00
Credit Spread (bps)	9.79	4.67	7.58	172961	6.29	5.21	4.92	172214	0.00
Renegotiation (pct)	0.00			172961	0.18			172214	
Liquidation (pct)	0.00			172961	0.02			172214	

Table 10: **Financially Constrained Firms.** We perform a 2×3 double sort on cash flow available for investment and z, and select observations with low available cash flow and high z. Available cash flow is defined as $\pi - b$. This table provides sample moments for the following variables: firm value $(v + m')$; assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate $((k' - k(1-\delta))/k)$; EBITDA/assets (π/k); payouts/assets $((\pi + k(1-\delta) - k' - b + m')/k)$; Q–ratio $((v + b')/k')$; market leverage $(b'/(b'+v))$; change in debt/assets $((b'-b)/k)$; credit spread ($b'/m - (1+r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	123.27	116.39	46.97	117953	124.65	124.84	43.03	124097	0.00
Assets	70.12	62.11	38.63	116786	67.35	71.88	34.96	122865	0.00
Debt (book)	88.49	81.14	38.04	116786	98.68	104.32	34.71	122865	0.00
Debt (market)	83.33	77.24	35.41	117953	94.45	99.30	31.28	124097	0.00
Equity	39.94	39.15	12.85	117953	30.20	25.54	13.25	124097	0.00
Hedge Ratio	0.00	0.00	0.00	117953	0.92	0.92	0.02	124097	0.00
Investment/Assets	0.26	0.14	0.63	117953	0.31	0.14	0.59	124097	0.00
EBITDA/Assets	0.33	0.28	0.09	117953	0.33	0.32	0.09	124097	0.00
Payouts/Assets	0.13	0.09	0.09	117953	0.11	0.06	0.12	124097	0.00
Q-Ratio	1.91	1.88	0.24	117953	1.96	1.81	0.26	124097	0.00
Market Leverage	0.68	0.67	0.03	117953	0.77	0.77	0.02	124097	0.00
Chg. Debt/Assets	0.14	0.00	0.65	117953	0.18	0.00	0.63	124097	0.00
Credit Spread (bps)	4.46	4.67	2.37	117953	6.60	5.21	8.00	124097	0.00
Renegotiation (pct)	0.00				3.33				
Liquidation (pct)	0.00				0.37				

Table 11: **Financially Unconstrained Firms.** We perform a 2×3 double sort on cash flow available for investment and z, and select observations with high available cash flow and high z. Available cash flow is defined as $\pi - b$. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1-\delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1-\delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	95.99	82.90	27.79	52611	105.02	89.07	28.81	46467	0.00
Assets	16.38	19.29	5.68	52071	16.68	16.66	6.36	45992	0.00
Debt (book)	34.97	38.64	6.39	52071	44.90	46.36	6.95	45992	0.00
Debt (market)	65.23	55.18	22.05	52611	79.87	66.22	22.99	46467	0.00
Equity	30.76	27.72	5.97	52611	25.15	22.85	6.02	46467	0.00
Hedge Ratio	0.00	0.00	0.00	52611	0.93	0.93	0.01	46467	0.00
Investment/Assets	2.61	2.36	1.99	52611	2.86	2.86	2.23	46467	0.00
EBITDA/Assets	0.42	0.40	0.11	52611	0.42	0.39	0.11	46467	0.00
Payouts/Assets	0.06	-0.01	0.11	52611	0.20	0.11	0.20	46467	0.00
Q-Ratio	1.98	2.07	0.17	52611	2.07	2.22	0.21	46467	0.00
Market Leverage	0.68	0.68	0.02	52611	0.76	0.76	0.01	46467	0.00
Chg. Debt/Assets	2.48	2.20	2.10	52611	2.91	2.80	2.47	46467	0.00
Credit Spread (bps)	3.41	2.77	1.42	52611	3.71	2.80	1.90	46467	0.00
Renegotiation (pct)	0.00				0.00				
Liquidation (pct)	0.00				0.00				

Table 12: **Low Growth Opportunities.** We perform a 2 $\times$ 3 double sort on k and z, and select observations with high k and low z. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1 - \delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1 - \delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	34.58	35.14	4.00	14986	34.86	35.40	2.53	11288	0.00
Assets	25.49	19.29	12.95	14986	27.19	22.32	12.30	11288	0.00
Debt (book)	44.43	38.64	12.71	14986	56.49	50.23	12.94	11288	0.00
Debt (market)	22.92	22.06	5.56	14986	29.35	29.42	0.52	11288	0.00
Equity	11.66	13.07	4.04	14986	5.51	5.98	2.33	11288	0.00
Hedge Ratio	0.00	0.00	0.00	14986	0.96	0.97	0.03	11288	0.00
Investment/Assets	-0.53	-0.50	0.18	14731	-0.66	-0.63	0.06	10149	0.00
EBITDA/Assets	0.08	0.09	0.03	14731	0.08	0.09	0.02	10149	0.00
Payouts/Assets	-0.22	-0.26	0.10	14731	-0.25	-0.21	0.09	10149	0.00
Q-Ratio	5.09	5.07	1.84	14986	7.69	7.50	2.30	11288	0.00
Market Leverage	0.58	0.64	0.17	14986	0.78	0.77	0.03	11288	0.00
Chg. Debt/Assets	-0.77	-0.80	0.25	14731	-0.93	-0.96	0.07	10149	0.00
Credit Spread (bps)	4.71	6.20	2.65	14986	16.33	4.50	83.46	11288	0.00
Renegotiation (pct)	15.10				80.91				
Liquidation (pct)	6.78				39.26				

Table 13: **High Growth Opportunities.** We perform a 2 $\times$ 3 double sort on k and z, and select observations with low k and high z. This table provides sample moments for the following variables: firm value ($v + m'$); assets (k); face value of debt (b); debt value (m'); ex dividend equity value (v); hedge ratio (h); investment rate ($(k' - k(1 - \delta))/k$); EBITDA/assets (π/k); payouts/assets ($(\pi + k(1 - \delta) - k' - b + m')/k$); Q–ratio ($(v + b')/k'$); market leverage ($b'/(b' + v)$); change in debt/assets ($(b' - b)/k$); credit spread ($b'/m - (1 + r)$, in basis points); renegotiation (annual frequency of renegotiation); liquidation (annual frequency of liquidation). All moments are reported on an annual basis.

	No CDS				With CDS				
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.	p-Value
Firm Value	84.22	82.90	27.16	18603	92.56	87.66	28.12	27492	0.00
Assets	9.03	9.29	1.70	18603	11.77	10.75	3.70	27492	0.00
Debt (book)	26.41	27.05	2.06	18603	39.86	38.64	4.97	27492	0.00
Debt (market)	57.60	55.18	18.65	18603	71.56	66.22	20.83	27492	0.00
Equity	26.62	27.72	9.64	18603	21.00	21.45	8.05	27492	0.00
Hedge Ratio	0.00	0.00	0.00	18603	0.93	0.93	0.01	27492	0.00
Investment/Assets	4.00	3.45	2.50	18603	3.41	2.86	2.65	27492	0.00
EBITDA/Assets	0.40	0.40	0.17	18603	0.39	0.39	0.17	27492	0.00
Payouts/Assets	0.05	-0.02	0.11	18603	0.18	0.09	0.23	27492	0.00
Q-Ratio	1.81	2.07	0.62	18603	1.90	2.22	0.66	27492	0.00
Market Leverage	0.61	0.68	0.21	18603	0.68	0.76	0.23	27492	0.00
Chg. Debt/Assets	3.97	3.33	2.60	18603	3.53	2.88	2.93	27492	0.00
Credit Spread (bps)	2.92	2.77	1.49	18603	3.16	2.80	1.88	27492	0.00
Renegotiation (pct)	0.00				0.00				
Liquidation (pct)	0.00				0.00				

Appendices

A. Proof of Proposition 1

The relation between $b'/(1-\xi)$, a_P, a_R, and b'

Lemma 1 (Compare a_P and b')**.** *If $1-(1-\gamma)(1-q)s(h')>0$ (i.e. $h'<h_1$), and $h'>1$, then $a_P<b'$.*

If $h'<1$ then $b'<a_P$.

If $1-(1-\gamma)(1-q)s(h')<0$ (i.e. $h'>h_1$), then $b'<a_P$.

This can be shown by rearranging the inequality

$$\frac{b'\left[1-h'(1-\gamma)(1-q)\right]}{1-(1-\gamma)(1-q)s(h')}<b'$$

and using the different conditions on h'.

Lemma 2 (Compare a_R and b')**.** *If $s(h')>0$ (i.e. $h'>h_0$), and $h'<1$, then $a_R<b'$.*

If $s(h')>0$ (i.e. $h'>h_0$), and $h'>1$, then $a_R>b'$.

If $s(h')<0$ (i.e. $h'<h_0$), and $h'<1$, then $a_R>b'$.

To show this, assume $s(h')>0$ and $h'<1$. Then, from $h'/s(h')<1$, after rearranging using the different conditions, it follows that the inequality holds. The other two cases are analogous.

Lemma 3 (Compare a_P and $b'/(1-\xi)$)**.** *If $1-(1-\gamma)(1-q)s(h')>0$ (i.e. $h'<h_1$), then $a_P<b'/(1-\xi)$.*

If $1-(1-\gamma)(1-q)s(h')<0$ (i.e. $h'>h_1$), then $b'/(1-\xi)<a_P$.

This can be shown by rearranging the inequality

$$\frac{b'\left[1-h'(1-\gamma)(1-q)\right]}{1-(1-\gamma)(1-q)s(h')} < \frac{b'}{1-\xi}$$

and using the different conditions on h'.

Lemma 4 (Compare a_R and $b'/(1-\xi)$)**.** *If $s(h') > 0$ (i.e. $h' > h_0$), then $a_R < b'/(1-\xi)$. If $s(h') < 0$ (i.e. $h' < h_0$), then $a_R > b'/(1-\xi)$.*

To show this, assume $s(h') > 0$ and $h' < 1$. Then, from $h'/s(h') < 1/(1-\xi)$, after rearranging using the conditions, it follows that the inequality holds. The other two cases are analogous.

Lemma 5 (Compare a_P and a_R)**.** *$a_P \geq a_R$ if and only if*

$$\frac{1-h'(1-\gamma)(1-q)}{1-(1-\gamma)(1-q)s(h')} \geq \frac{h'}{s(h')}.$$

This is proved as follows. Since the denominator can be either positive or negative, we have the following four subcases:

1. Assume $s(h') > 0$ and $1-(1-\gamma)(1-q)s(h') > 0$, which is the same as $h' > h_0$ and $h' < h_1$. In this subcase, it can be shown that

   - If $h_0 < h' < 1$, then $a_P > a_R$.
   - If $1 < h' < h_1$, then $a_P < a_R$.

   This follows from rearranging the inequality above using the conditions, and using the fact that $h_0 < 1 < h_1$.

2. Assume $s(h') > 0$ and $1-(1-\gamma)(1-q)s(h') < 0$, which is the same as $h' > h_0$ and $h' > h_1$. Because $h_0 < h_1$, these assumptions are equivalent to $h' > h_1$. In this

case, it can be shown that the inequality above always holds strictly, because $h_1 > 1$. Therefore, $a_P > a_R$ for all $h' > h_1$.

3. Assume $s(h') < 0$ and $1 - (1-\gamma)(1-q)s(h') > 0$, which is the same as $h' < h_0$ and $h' < h_1$. Because $h_0 < h_1$, these assumptions reduce to $h' < h_0$. In this case, it can be shown that the inequality above never holds. Therefore, $a_P < a_R$ for all $h' < h_0$.

4. Assume $s(h') < 0$ and $1 - (1-\gamma)(1-q)s(h') < 0$, which is equivalent to $h' < h_0$ and $h' > h_1$. This is impossible, so this subcase can be dropped.

Lemma 6 (Compare 0 and a_R)**.** *If $h' > 0$ and $h' > h_0$ then $a_R > 0$.*

If $h_0 < h' < 0$ then $a_R < 0$.

If $h' < 0$ and $h' < h_0$ then $a_R > 0$.

This follows from the definition

$$a_R = \frac{h'b'}{1 - (1-h')(1-\xi)}.$$

Lemma 7 (Compare 0 and a_P)**.** *If $h' < 1/[(1-\gamma)(1-q)]$ and $h' < h_1$ then $0 < a_P$.*

If $1/[(1-\gamma)(1-q)] < h' < h_1$ then $0 > a_P$.

If $h' > 1/[(1-\gamma)(1-q)]$ and $h' > h_1$ then $0 < a_P$.

This follows from the definition

$$a_P = \frac{b'\left[1 - h'(1-\gamma)(1-q)\right]}{1 - (1-\gamma)(1-q)s(h')}.$$

The optimal default policy

Because $h_0 < 0 < 1 < 1/[(1-\gamma)(1-q)] < h_1$, there are six regions for h'. We will describe the default policy in these regions, from lowest to highest h', and in each of the six cases, for the different a'. Initially we will consider only the interior of these intervals. We will deal with the boundaries (i.e., $h' = h_0$, $h' = 0$, etc.) later on.

1. If $h' < h_0$, because in Lemmas 3, 4, and 7 we have determined that $0 < a_P < b'/(1-\xi) < a_R$, then the following diagram summarizes the optimal actions:

		renegotiate		repay		repay		repay
	0		a_P		$b'/(1-\xi)$		a_R	

2. If $h_0 < h' < 0$, because $a_R < 0 < a_P < b'/(1-\xi)$ from Lemmas 3, 6, and 7, we can derive the following diagram:

				renegotiate		repay		repay
	a_R		0		a_P		$b'/(1-\xi)$	

3. If $0 < h' < 1$, we know from Lemmas 1, 2, 3, and 6 that $0 < a_R < b' < a_P < b'/(1-\xi)$.

		liquidate		renegotiate		renegotiate		repay		repay
	0		a_R		b'		a_P		$b'/(1-\xi)$	

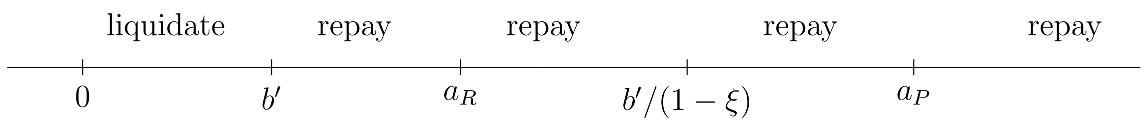
4. If $1 < h' < 1/[(1-\gamma)(1-q)]$, we have determined in Lemmas 1, 2, 4, and 7 that $0 < a_P < b' < a_R < b'/(1-\xi)$.

		liquidate		liquidate		repay		repay		repay
	0		a_P		b'		a_R		$b'/(1-\xi)$	

5. If $1/[(1-\gamma)(1-q)] < h' < h_1$, we know from Lemmas 2, 4, and 7 that $a_P < 0 < b' < a_R < b'/(1-\xi)$. Then the optimal actions are

				liquidate		repay		repay		repay
	a_P		0		b'		a_R		$b'/(1-\xi)$	

6. Finally, if $h_1 < h'$, because from Lemmas 2, 3, and 4 we have $0 < b' < a_R < b'/(1-\xi) < a_P$, then we can derive the diagram



The six diagrams above can be summarized into three main cases. This is done in Figure 1.

We now analyze the optimal decision at the boundaries $h' = 0$ and $h' = 1$.[10] At $h' = 0$, from Lemmas 1 and 2 we have $0 = a_R < b' < a_P$. From this, a graph similar to the above Cases 1 or 2 can be derived, whereby renegotiation is optimal below a_P, and repayment is optimal above a_P. At $h' = 1$, from the previous section we know that $0 < b' = a_P = a_R$. From this, a graph similar to Cases 4, 5, or 6 can be derived, whereby liquidation is optimal below b', and repayment is optimal above b', and renegotiation never occurs.

Proof that the equilibrium hedge ratio is in $[0, 1]$

The proof consists of two parts. In the first part, we show that $h' < 0$ is not optimal. Then we show that $h' > 1$ never occurs.

For the first part, assume that $h' < 0$, which corresponds to Case (a). Note that $\partial a_P / \partial h' < 0$, for any h'. This is because

$$\frac{\partial}{\partial h'} \frac{b' \left[1 - h'(1-\gamma)(1-q)\right]}{1 - (1-\gamma)(1-q)s(h')} < 0$$

can be shown to be equivalent to $(1-\gamma)(1-q) < 1$, which is always true, given our assumptions. Also, we know that the payoff to bondholders is higher for $a > a_P$ than for $a < a_P$. It follows that bondholders can always increase their expected payoff by increasing the hedge ratio h'. Therefore, $h' < 0$ cannot be optimal.

[10] The other boundaries, h_0, $1/[(1-\gamma)(1-q)]$, and h_1 are not relevant, as they are interior points of intervals in which the same action is optimal.

For the second part, assume that $h' > 1$, which corresponds to Case (c). As Figure 1 shows, bondholders receive the liquidation payoff if $a < b'$, and the repayment payoff if $a > b'$. Neither of the two payoffs, nor the threshold b' separating them, depends on h'. Therefore, the bondholders cannot be made better off (or worse off) by increasing their hedge ratio above the point $h' = 1$.

The model without a CDS market

The solution of the model without a CDS market is very similar to the solution of the model with a CDS market. Let's derive the solution following the same logic as before. The case $w' > \xi a'$, is simple, as it does not depend on h', with repayment being always optimal.

If $w' \leq \xi a'$, renegotiation is feasible if $(1-\xi)a' \leq a'$, so renegotiation is feasible for all $a' \leq b'/(1-\xi)$. If renegotiation is feasible, the solution can be written as

$$b_r = (1-\xi)a' + q[a' - (1-\xi)a']. \tag{29}$$

Repayment is preferred to renegotiation when $a' - b' \geq (1-\gamma)(a' - b_r)$, or,

$$a' \left[1 - (1-\gamma)(1-q)\xi\right] \geq b'. \tag{30}$$

We can define $a_P = b'/[1-(1-q)(1-\gamma)\xi]$, where $a_P \geq 0$ under our parameter assumptions. Then, repayment is optimal for $a' \geq a_P$ and renegotiation is optimal for $a' \in [0, a_P[$.

It is easy to show that $a_P < b'/(1-\xi)$. Therefore, the final solution is that renegotiation is optimal for $a' \in [0, a_P[$, and repayment is optimal for $a' \geq a_P$.

B. Description of the Cooper-Haltiwanger method to estimate α

We use the method in Cooper and Haltiwanger (2006) to estimate the profit function curvature parameter α. We briefly explain the idea behind the method and then summarize the empirical implementation. The profit function in our dynamic model takes the form $\pi = zk^{\alpha} - f$. In the model of Cooper and Haltiwanger (2006) there is no fixed cost, i.e., $f = 0$. In the following derivation we set the fixed cost to zero as well, but we will discuss the role of a non-zero fixed cost below. Under this assumption, the profit function simplifies to $\pi = zk^{\alpha}$. By defining $\bar{\pi} = \log \pi$, $\bar{k} = \log k$, and $\bar{z} = \log z$, we can rewrite the profit function as

$$\bar{\pi} = \alpha\bar{k} + \bar{z}.$$

While $\bar{z}$ is not observable in the data, there are empirical proxies for $\bar{\pi}$ and $\bar{k}$. The form of the equation above might one lead to believe that a simple linear regression model could be used to estimate α. Unfortunately, such a regression would lead to biased estimates. However, Cooper and Haltiwanger (2006) show that unconditional moment conditions are sufficient to get unbiased estimates of α, even if the other parameters of the model are unknown. The moment condition for α is simply

$$\mathbb{E}[\bar{\pi}_{it} - \alpha\bar{k}_{it}] = 0.$$

We use this moment condition on a panel of firm-year observations.

To construct the sample for this estimation, we start with the same merged CRSP-Compustat sample that we use as a starting point to calculate our empirical moments in Table 2. We delete the same set of SIC industries from the sample. We use total assets (Compustat item 6) as a measure of k and operating profit (Compustat item 13) as a proxy for π. We set both variables to missing if they take negative values, truncate them at the 1% and 99% levels, deflate them using the Consumer Price Index of the Bureau of Labor Statistics, and take the natural logarithm. Using these two variables, we estimate a curvature parameter of $\hat{\alpha} = 0.603$.

Note that our empirical methodology is an approximation because in our derivation above we have assumed that profit is measured before the subtraction of fixed costs, whereas operating profit in the data will have some fixed costs already deducted. Unfortunately we do not have a good empirical proxy for profits before the deduction of fixed costs. However, it is reassuring that our estimate is very close to the value of 0.592 in Cooper and Haltiwanger (2006), which they estimate using plant-level Census data.

C. Additional figures from the dynamic model

Figure 8: Dynamic model: Large firm, no debt.

This figure is based on the solution of the dynamic model, and the base case parameters in Table 1, and plots the different metrics against current productivity z for a specific pair (k, b) of current capital and current debt, respectively. Solid circles indicate that the firm optimally renegotiates its debt at this point, before choosing the optimal k' and b'.

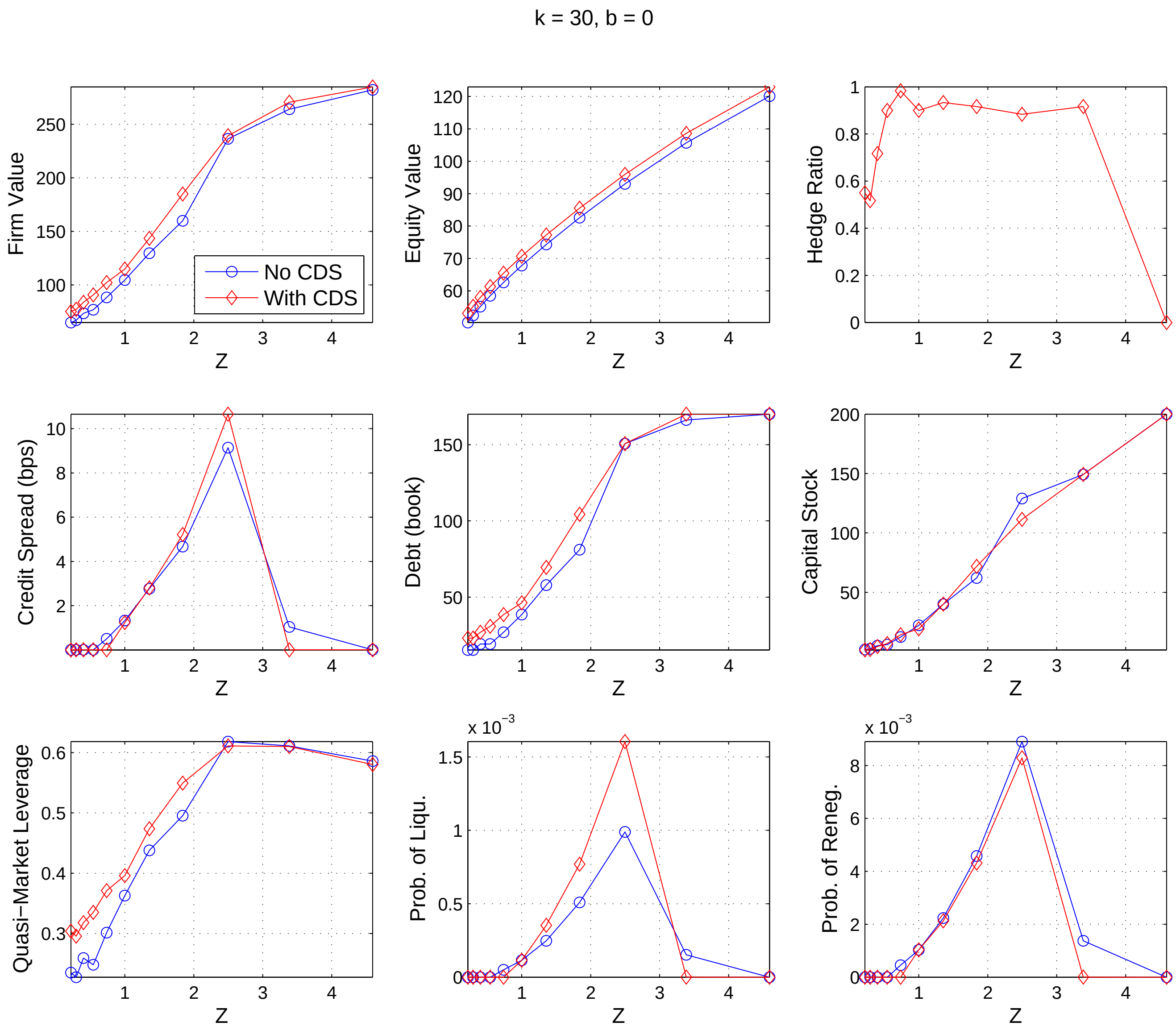


Figure 9: Dynamic model: Small firm, high debt.

This figure is based on the solution of the dynamic model, and the base case parameters in Table 1, and plots the different metrics against current productivity z for a specific pair (k, b) of current capital and current debt, respectively. Solid circles indicate that the firm optimally renegotiates its debt at this point, before choosing the optimal k' and b'.

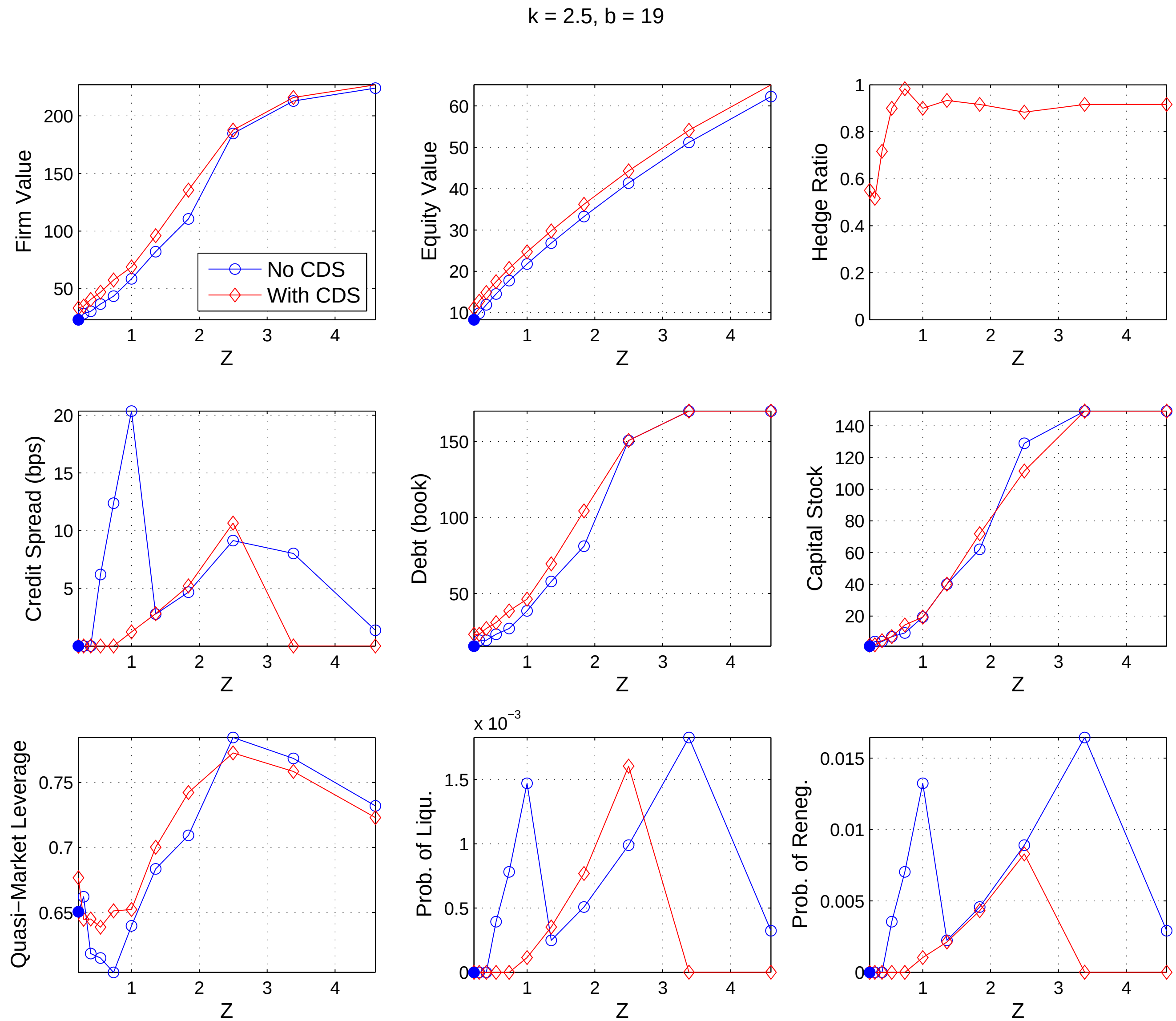


Figure 10: Dynamic model: Small firm, no debt.

This figure is based on the solution of the dynamic model, and the base case parameters in Table 1, and plots the different metrics against current productivity z for a specific pair (k, b) of current capital and current debt, respectively. Solid circles indicate that the firm optimally renegotiates its debt at this point, before choosing the optimal k' and b'.