The Real Effects of Credit Default Swaps

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Abstract

We examine the effect of introducing credit default swaps (CDSs) on firm value. Our model allows for dynamic investment and financing, and bondholders can trade in the CDS market. The model incorporates both negative and positive effects of CDSs. CDS markets lead to more liquidations, but they also reduce the probability of costly debt renegotiation, and reduce costly equity financing. After calibrating the model, we find that firm value increases by 2.9% on average with the introduction of a CDS market. Firms also invest more and increase leverage. The effect on firm value is strongest for small, financially constrained, and low-productivity firms.

Keywords: credit default swaps, CDS, empty creditor, restructuring, bankruptcy
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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. We show that while the net effect of credit derivatives on firm value and investment can be positive or negative, it 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 2.9% 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 model

[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.

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 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, to renegotiate with debt holders, or to file for bankruptcy. The model features several real-life frictions, such as limited commitment of equity holders, as well as equity issuance, bankruptcy, and renegotiation costs. 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.[3]

Whether the net effect of a CDS market on firm value is positive or negative in the model is not clear a priori, because CDSs affect firm value in multiple ways. We show that the introduction of a CDS market leads to more firm liquidations, which reduces firm value due to bankruptcy costs. This effect is very similar to the so-called empty creditor problem in Hu and Black (2008) and Bolton and Oehmke (2011). The intuition is that if bondholders are hedged with CDS contracts, they demand a higher payoff in debt renegotiation, which in some cases makes renegotiation infeasible.

At the same time, bondholders' ability to hedge with CDS contracts reduces the probability of costly debt renegotiation, which increases firm value. Again, this is because the hedged bondholders demand a higher payment in debt renegotiation, which makes renegotiation a less attractive option to the firm. In some states, therefore, the firm chooses to repay the debt instead of renegotiating it. Also, we show that CDS markets increase the market value of debt, which leads to a further positive effect on firm value at the point in time when debt is issued. In some cases, the higher market value of debt allows the firm to buy more capital with issuing the same face value of debt. Alternatively, it allows the firm to rely less on costly equity with the same investment in capital and the same face value of debt.

[3]This methodology is used increasingly in corporate finance to answer questions about capital structure (e.g., Hennessy and Whited, 2007), financial intermediation (e.g., Schroth et al., 2014), executive compensation (Taylor, 2010), or agency conflicts (e.g., Nikolov and Whited, 2014).

The model is able to explain several recent empirical findings. Ashcraft and Santos (2009) report that CDS contracts have no significant effect on the cost of debt for the average borrower. Saretto and Tookes (2013) find that firms with CDSs can borrow more and can maintain higher leverage ratios. Subrahmanyam et al. (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 (2016) shows that if bondholders are more likely to hold CDSs, an out-of-court debt restructuring is less successful on average. We show that all of these findings are endogenous outcomes of our model.

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, financially constrained firms, and low-productivity firms benefit the most from the introduction of credit derivatives. For other types of firms, the net effect is smaller, but this does not imply that CDS contracts do not affect them. It is rather that the positive and negative effects on firm value offset each other.

We also test certain predictions of the model in reduced form empirical tests. The purpose of these tests is not to estimate causal effects, but to check if several endogenous variables in the model are correlated in a way that is similar to the data. To that end, we first derive several testable predictions of the model concerning the hedge ratio of bondholders. The model predicts that the hedge ratio should be positively related to leverage and to the fraction of non-fixed assets, which is a proxy for liquidation costs, and negatively related to Tobin's Q. Since the hedge ratio of bondholders is not observable, we construct a proxy using data from the Depository Trust and Clearing Corporation (DTCC). The results of these tests are consistent with the predictions of the model.

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 et al. (2014), and Danis (2016). 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. 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 (2015) explore the effect of CDS markets on liquidity in the corporate bond market, and Chernov et al. (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 would 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 et al. (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 et al. (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 hold-

ers. 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 renegotiating the debt. In the second game, played when debt is renegotiated, the two claim holders engage in Nash bargaining, which determines the renegotiated debt level. Our analysis of this strategic interaction between the equity holder and bondholders shows how CDS markets can mitigate the strategic default problem identified in this literature.

1. Model and discussion

1.1. The model

We construct a partial equilibrium dynamic model with equity and debt financing, as well as a CDS market. All agents in the model, the firm owner, the bondholders, and the CDS dealer, are risk-neutral. The horizon is infinite and time is discrete. There is a firm with per-period profit function $\pi(xz, k) = xzk^{\alpha} - f$, where $\alpha \in]0, 1[$ is the return-to-scale parameter, $f \geq 0$ is a fixed production cost, and k is the firm's capital.

The firm's profit shock, z, is a continuous-state Markov process with compact support and with transition probability $\Gamma(dz'|z)$. 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. As in Cooley and Quadrini (2001), the firm's decisions are affected by an independent second shock, x, which takes non-negative values in a finite set $\{x_0, x_1, \ldots, x_N\}$ and follows a first order Markov process with transition probability $\Psi(x'|x)$, such that $x_0 = 0$, and $\Psi(x_0|x_0) = 1$, which means that x_0 is an absorbing state.

The firm's capital depreciates at a rate $\delta \in]0, 1[$, and the ex post book value of the asset

is defined as

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

We denote as w the firm's net worth:

$$w = w(xz, k, b) = a - b, \tag{2}$$

where b is the face value of debt. The debt is an unsecured zero-coupon bond with a maturity of one period. There is a possibility that the debt holders receive less than full face value at maturity, so the debt is not risk-free.

There is a competitive market for insuring against credit risk, similarly to Bolton and Oehmke (2011). In particular, debt holders can purchase a CDS from a dealer (protection seller). The debt holders (protection buyers) choose a hedge ratio h, which is defined as the fraction of the face value of debt b that is covered by the CDS contract. The dealer sets a fair CDS spread, in the sense that the transaction has zero NPV. The protection seller, like all agents in the model, has rational expectations: He understands that selling CDS protection to the debt holders changes the probability of default, and adjusts the CDS spread accordingly. Finally, the general model nests an important special case where there is no CDS market, which can be obtained by setting $h = 0$ in every period.

There are several frictions in the economy. The main one is that the owner cannot commit to debt repayment. In particular, she cannot write a contract that binds her not to default on debt payments in the future. The firm can be liquidated, in which case a fraction $\xi \in]0, 1[$ of firm value is lost due to bankruptcy costs. If the debt is renegotiated in the future, which is explained in more detail below, the renegotiation fails with an exogenous probability $\gamma \in]0, 1[$. A failed renegotiation is followed by liquidation, which makes renegotiations costly in expectation. Equity issuance is costly as well, and the parameter λ measures the proportional equity issuance costs. Finally, the discount factor of equity holders, β, is lower than the discount factor of debt holders, $1/(1 + r)$. This makes equity financing more expensive than

debt financing, which captures the tax advantages of debt and a debt-induced reduction in managerial agency costs.

These frictions are the reason why CDS markets affect firm value. Because of the lack of commitment, the owner may renegotiate debt in the future by threatening to file for bankruptcy if the debt holders do not accept a lower debt payment. This opportunistic behavior is anticipated by the bondholders, who purchase CDS protection in order to improve their bargaining position in a future renegotiation. At the point in time in which renegotiation takes place, this is both costly and beneficial in terms of total firm value. On the one hand, it reduces the owner's incentive to renegotiate, which increases firm value because it avoids a costly liquidation with probability γ. On the other hand, it reduces firm value because it increases the bargaining position of bondholders so much that the owner might prefer to liquidate the firm. Also, at the point in time when the firm makes its payout, investment, and financing decisions, CDSs can affect firm value. This is because CDSs can reduce the cost of debt financing, allowing the firm to rely less on expensive equity financing and to invest more.

Every period, the following sequence of events takes place: First, the firm's owner observes $(x_t, z_t, k_t, b_t, h_t)$, and makes a default decision. This means choosing between repaying the existing debt in full, renegotiating the debt, or liquidating the firm. At the next stage, the owner makes a payout decision, which determines the dividend d_t that is paid out. This is followed by the investment and financing decision, where the owner selects the next period's capital level, k_{t+1}, as well as the new face value of debt, b_{t+1}. The bondholders observe the new capital and debt levels, and choose their hedge ratio h_{t+1} accordingly. Since this whole sequence of events takes place in the same period t, we only discount payoffs once per period instead of discounting at every stage. The sequence of events is summarized in Figure 1. We follow this timeline and derive the optimal default, payout, investment and financing, and hedging policies below.

In order to derive the owner's optimal default decision, we denote $V(x, z, w)$ as the cum-

dividend equity value in the state (x, z, w). This is the payoff to the owner if debt is fully repaid. If the owner decides to liquidate the firm, her payoff is $\max\{(1-\xi)a - b, 0\}$, which is the liquidation value of the firm, net of the payment to debt holders, subject to a limited liability constraint.

If the owner decides to renegotiate the debt, she enters into a Nash bargaining game with the bondholders. The outcome of the bargaining game is a new debt value, b_r, which solves the following optimization problem:

$$b_r(x, z, k, b, h) = \arg\max_p \left[V(x, z, w(xz, k, p))\right]^{1-q} \times \left[p - hb - (1-h)(1-\xi)a(xz, k)\right]^q, \quad (3)$$

with constraints

$$p \leq a(xz, k) - w_d(xz), \text{ and } p \geq hb + (1-h)(1-\xi)a(xz, k), \quad (4)$$

where p denotes a payment from the owner to the bondholders, and $w_d(xz)$ is defined as the unique zero of $V(x, z, \cdot)$, i.e., the w_d such that $V(x, z, w_d) = 0$. The parameter $q \in [0, 1]$ measures the bargaining power of the debt holders, and $1 - q$ is the owner's bargaining power. The two constraints in (4) determine if the bargaining problem has a feasible solution. Intuitively, the first constraint specifies that the payoff to the owner is at least her outside option.[4] Similarly, the second constraint makes sure that the bondholders' payoff is at least as large as their outside option. Their outside option can be decomposed into hb, the payoff they receive from the protection seller, $(1-\xi)a(xz, k)$, the liquidation value of the firm, and $-h(1-\xi)a(xz, k)$, which is the payment to the protection seller. The outcome of a successful renegotiation is a new debt level $b_r = b_r(x, z, k, b, h)$, and the owner's resulting payoff is $V(x, z, w_r)$, where $w_r = w(xz, k, b_r)$ is the net worth ensuing from renegotiation.

[4]The first constraint derives from the assumption that the outcome of renegotiation is acceptable to the owner if $V(x, z, w(xz, k, p)) \geq 0$, or equivalently $V(x, z, w(xz, k, p)) \geq V(x, z, w_d(xz))$ by definition of $w_d(xz)$. Therefore, from $w(xz, k, p) \geq w_d(xz)$, using equation (2), we have $a(xz, k) - p \geq w_d(xz)$.

We can now derive the optimal default policy, for a fixed (x, z, k, b, h). If $x = x_0$, the firm is immediately liquidated, and the payoffs to the owner and to the bondholders are zero. The interesting case is where $x \neq x_0$ and $b > 0$. Figure 2 illustrates the owner's optimal default decision and the corresponding payoffs in this case. Paying back the debt is optimal when $V(x, z, w)$ is sufficiently high. However, there are states in which instead of repaying the debt, the owner maximizes her value by renegotiating the debt or by liquidating the firm. If the liquidation value of the firm's assets is higher than the face value of debt, or $(1-\xi)a \geq b$, then the owner's threat to liquidate is not credible, and therefore she will repay the debt. In this case, the owner's payoff is $\mathcal{V} = V(x, z, w)$.

In the case where the firm's liquidation value is below the debt obligation, or $(1-\xi)a < b$, the renegotiation threat is credible, because debt holders can get a payoff lower than b if renegotiation fails. From (4), renegotiation is not feasible if $a(xz, k) - w_d(xz) < hb + (1 - h)(1 - \xi)a(xz, k)$, or equivalently, if

$$h > H(x, z, k, b) = \frac{\xi a - w_d}{\xi a - w}, \tag{5}$$

where H is positive because $w_d \leq 0$, $w < \xi a$, and $a(xz, k) \geq 0$ (assuming $f = 0$).[5] It is worthwhile mentioning that condition (5) is never satisfied in the model without a CDS market, because $h = 0$ and $H \geq 0$. Therefore, renegotiation is always feasible in the no-CDS model.

When (5) is satisfied, the debt is repaid if $V(x, z, w) \geq 0$, while the firm is liquidated if $V(x, z, w) < 0$. The owner's payoff is $\mathcal{V} = V(x, z, w)$ in the case of repayment and $\mathcal{V} = 0$ in

[5] We provide the argument for $w_d(xz) \leq 0$ in Appendix B. Also, throughout the solution of the model, we assume that $f = 0$, which implies $a(xz, k) \geq 0$ for all (x, 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 2, we allow for a positive fixed cost f. After solving the model numerically, we check that $a(xz, k) < 0$ never occurs in the simulated data. Finally, $w < \xi a$ is the same as $(1 - \xi)a < b$, and the latter is true by assumption.

the case of liquidation.

In the case where debt renegotiation is feasible, i.e., if $h \leq H$, the owner prefers repayment to renegotiation when $V(x, z, w) \geq (1-\gamma)V(x, z, w_r)$, where the term $(1-\gamma)$ accounts for the fact that renegotiation can fail with probability γ. If the inequality holds, she prefers repayment and her payoff is $\mathcal{V} = V(x, z, w)$; otherwise, she prefers renegotiation with expected payoff $\mathcal{V} = (1-\gamma)V(x, z, w_r)$. Finally, if $(1-\xi)a < b$ and $b = 0$, the firm is liquidated if V is negative.

We summarize the owner's default decision and her corresponding payoffs in the following equation:

$$\mathcal{V}(x, z, k, b, h) = \begin{cases} V(x, z, w) & \text{if } (1-\xi)a \geq b, \\ \max\{V(x, z, w), (1-\gamma)V(x, z, w_r)\} & \text{if } (1-\xi)a < b, b > 0, h \leq H, \\ \max\{V(x, z, w), 0\} & \text{if } (1-\xi)a < b, b > 0, h > H, \\ & \text{or if } (1-\xi)a < b, b = 0. \end{cases} \tag{6}$$

In the next stage, following the timeline in Figure 1, the owner makes her payout decision. The owner's optimal dividend payment, d, is the solution of the following optimization problem:

$$V(x, z, w) = \max_d \left\{ d^+ + (1+\lambda)d^- + v(x, z, w-d) \right\}, \tag{7}$$

where d can have either sign; if it is negative, it is the amount of injected equity capital. In this case, the firm incurs the transaction cost λ per unit of equity capital. In (7), $v(x, z, w-d)$ denotes the market value of the firm's ex dividend equity, at the *revised net worth*, $e = w-d$, which is determined by the payout decision.

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

$$v(x, z, e) = \max_{(k', b')} \beta \sum_{x'} \int \mathcal{V}(x', z', k', b', h')\Gamma(dz'|z)\Psi(x'|x). \tag{8}$$

The owner takes into account that her decision affects the bondholders' hedge ratio. More precisely, the optimal h' is a function of k' and b', which we will derive when we get to the hedging decision.

The owner's decision is subject to the budget constraint

$$k' = e + m(x, z, k', b'), \tag{9}$$

where m is the market value of debt, which we will derive below, as well as to the constraints $k' \geq 0$ and $b' \geq 0$.

Following the owner's investment and financing decision, the bondholders make their hedging decision. In particular, they observe the current shocks x and z, as well as the owner's choices for k' and b', and choose h'. The bondholders take into account the owner's future default policy. In other words, they expect that in some future states (x', z', k', b', h'), the debt will be repaid, and we indicate these states with the indicator function Φ'_c. We suppress the dependence of the indicator function on the state for brevity. Similarly, Φ'_r and Φ'_ℓ indicate states where the owner chooses to renegotiate the debt and to liquidate, respectively.

Next, we derive the value of CDS contracts. The 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:

$$C(x, z, k', b', h') = \sum_{x' \neq x_0} \int \left[h'b' - h'(1-\xi)a(x'z', k')\right] \left[\gamma \Phi'_r + \Phi'_\ell\right] \; \Gamma(dz'|z) \; \Psi(x'|x), \tag{10}$$

where Φ'_r and Φ'_ℓ are the indicators for the states (x', z', k', b', h') in which the firm renegotiates and liquidates, respectively. 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 definition of the CDS payoff corresponds to the Standard North American Corporate (SNAC) contract in the

CDS market.

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

$$\varphi(x,z,k',b',h') = \sum_{x' \neq x_0} \int \{b' \ \Phi'_c + b_r(x',z',k',b',h') \ (1-\gamma)\Phi'_r$$
$$+ [h'b' + (1-h')(1-\xi)a(x'z',k')] \ [\gamma\Phi'_r + \Phi'_\ell]\} \ \Gamma(dz'|z) \ \Psi(x'|x). \quad (11)$$

This includes both the payoff from the bond and the payoff from the protection seller. The first term is the payment when debt is repaid, the second term is the payoff from successful renegotiation, and the third term is the payoff when the firm is liquidated. The expected payoff to bondholders, net of the cost of the CDS, is therefore

$$M(x,z,k',b',h') = \varphi(x,z,k',b',h') - C(x,z,k',b',h'), \quad (12)$$

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

$$M(x,z,k',b',h') = \sum_{x' \neq x_0} \int \{b' \ \Phi'_c + b_r(x',z',k',b',h') \ (1-\gamma)\Phi'_r$$
$$+(1-\xi)a(x'z',k') \, [\gamma\Phi'_r + \Phi'_\ell]\} \ \Gamma(dz'|z) \ \Psi(x'|x). \quad (13)$$

The debt holders' objective is to maximize the present value of their claim by choosing the hedge ratio:

$$m(x,z,k',b') = \max_{h'} \frac{1}{1+r} M(x,z,k',b',h'). \quad (14)$$

The solution of the problem, $h' = h(x,z,k',b')$, is the state–contingent optimal hedge ratio that is considered in the owner's program in (8), and the market value of debt $m(x,z,k',b')$ enters into the budget constraint in (9).

This closes our discussion of the model. To solve it, one has to simultaneously solve the

default decision in equation (6), the payout decision in (7), the investment and financing decision in (8), subject to the budget constraint in (9), and the hedging decision in (14). In the model without a CDS market, we set $h = 0$ in all periods. The algorithm to numerically solve the model and to find all policies is described in Appendix A. We prove the existence of a solution and certain properties of the value function in Appendix B.

1.2. Discussion of the effects of a CDS market on firm value

The introduction of a CDS market has various effects on firm value, and these effects show up at different stages of the model. We go through the different stages in inverse order relative to the timeline in Figure 1: We start with the default decision at the beginning of period $t + 1$, followed by the hedging decision at the end of period t, the investment and financing decision in period t, and the payout decision in period t.

To highlight the costs and benefits of a CDS market at the default decision stage, we will examine the difference in firm value going from $h = 0$ to the optimal hedge ratio $h = h^*$ in the current period. We assume that $h^* \geq 0$, which we prove in Appendix B. While looking at the increase from $h = 0$ to $h = h^*$ in the current period, we hold the existing capital and debt constant. Also, we hold the default policy and all other policies, d, k, b, and h, in all future periods constant.

The first effect of a higher hedge ratio is an increase in the likelihood of liquidation, and a simultaneous decrease in the occurrence of renegotiation. Intuitively, this happens because a higher hedge ratio increases the bondholders' outside option in a renegotiation, which is the minimum payment they demand. In states where the value of the firm is low, the owner cannot justify such a high payment to the bondholders, which makes bargaining infeasible. More formally, we know that renegotiation is only feasible if there is a payment p to the bondholders that solves both inequalities in (4). The first inequality does not depend on h. In the second inequality, however, the lower bound on p is increasing with h. So with a higher h, the first inequality does not change, while the second inequality becomes tighter,

which reduces the likelihood that both inequalities hold.

The second effect of a higher hedge ratio is that it increases the likelihood of repayment, while reducing the probability of renegotiation. In economic terms, this happens because a higher hedge ratio increases the payment that needs to be made to bondholders in a renegotiation, which reduces the attractiveness of a renegotiation from the owner's perspective. More formally, we know that the owner prefers renegotiation to repayment if $(1-\gamma)V(x,z,w_r) \geq V(x,z,w)$. A higher h decreases the chance that this inequality holds, because it decreases the left-hand side. To see this, note that V is an increasing function of w_r, which we prove in Appendix B. Also, w_r is decreasing in h, because w_r is defined as $a(xz,k) - b_r$, and b_r is increasing in h, which we show in Appendix B.

We can now understand how an increase from $h = 0$ to $h = h^*$ affects firm value. The increase in the probability of liquidation reduces firm value, because liquidation creates bankruptcy costs. The higher likelihood of repayment increases firm value, because it reduces attempted renegotiation, and the latter would generate bankruptcy costs with probability γ. The positive effect on firm value does *not* come from a change in the renegotiation payment (b_r), because at this stage that is just a wealth transfer from equity holders to bondholders and does not affect firm value. However, we will see that the change in b_r matters at a different stage.

It is worthwhile mentioning that it is not clear a priori whether the positive or the negative effect will dominate when we compare $h = 0$ to $h = h^*$. The reason is that the bondholders choose the hedge ratio, not the owner. If the owner were allowed to choose the hedge ratio, the model would trivially predict that firm value with a CDS market is higher than without a CDS market. Also, allowing for endogenous values of d, k, and b, we will see additional effects of CDSs on firm value. Once we calibrate the model in Section 2 and find the optimal policies in all periods, we will be able to ask the question that we are ultimately interested in: Do the positive or the negative effects dominate if we go from a no-CDS world to a world with CDS markets? And what is the quantitative effect on firm value?

We now move to the hedging decision stage. Again, we consider a change from $h = 0$ to $h = h^*$, keeping the default policy and all other policies, d, k, b, and h, in all future periods constant. The market value of debt, m, at the optimal hedge ratio is at least as large as the market value of debt at $h = 0$. This follows from the optimization problem in equation (14), where we allow the bondholders to choose $h = 0$ if they want to. Therefore, they can never be worse off in a model with a CDS market than in a model without one. We will use this insight to determine the effect of CDS markets on firm value at the investment and financing stage, as well as at the payout stage.

At the investment and financing stage, the positive effect of a higher hedge ratio on the renegotiation payment (b_r) is no longer value neutral, as it was at the default stage, because equity has a lower discount factor than debt, or $\beta < 1/(1 + r)$. Therefore, an increase in b_r increases the value of debt more than it decreases the value of equity, in present value terms, which increases firm value. Further, since the increase from $h = 0$ to $h = h^*$ has a positive effect on the market value of debt (m), we know from the budget constraint in (9) that, for given revised net worth (e) and debt (b'), a higher m leads to a higher level of capital (k'). In other words, the firm can invest more, even without issuing new debt. This is what we refer to as the *real effect* of CDS markets.

Finally, at the payout stage, the introduction of a CDS market allows the firm to issue less equity, while investing the same amount in capital and issuing the same amount of debt, which saves equity issuance costs. To illustrate this point, for a given b', the change from $h = 0$ to $h = h^*$ increases m in the budget constraint in (9), which allows the owner to keep less equity e in the firm and still achieve the same k'. A lower e means a higher dividend d, since e is defined as $e = w - d$. In states where d is negative, this implies the firm can issue less equity, thus reducing the related flotation costs.

2. Calibration

We calibrate the 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 start by constructing a sample 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, in order to exclude other securities than ordinary common shares of American companies.

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 et al. (2014), and Chava (2014).[6] 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

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

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 (2016). 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 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 1 contains the summary statistics. We use this table as the basis for our calibration. In other words, we choose the parameters of the model to match the averages in this table as closely as possible. Since our model has a large number of parameters, we try to reduce the dimensionality of the problem by assuming standard values from the literature for some of our parameters, and calibrating the others. We choose the value of the risk-free interest rate to be $r = 0.05$, which is similar to the values in Cooley and Quadrini (2001) (0.04), Moyen (2004) (0.0526), and Cooper and Haltiwanger (2006) (0.0526). The depreciation rate is set to $\delta = 0.1$, similarly to Moyen (2004) (0.1) and Gomes (2001) (0.12). We choose the persistence of productivity to be $\rho = 0.75$, which is comparable to Hennessy and Whited (2007) (0.68) and DeAngelo et al. (2011) (0.728). We summarize all these parameter values in Table 2.

As in Cooley and Quadrini (2001), we assume that the variable x has two discrete values and set $x_1 = 1$. To determine the transition matrix for x, we set $\Psi(x_0|x_1) = 0.01$. We can interpret x as a rare but very large negative shock to the firm, which helps us to match the

average credit spread in the data. If the shock hits the firm, the equity value is wiped out, and the recovery rate of bondholders is zero. A less extreme real-world example would be an unexpected asbestos lawsuit that destroys a large fraction of firm value. The role of the shock x in the model is similar to the role of jumps in the jump-diffusion literature in credit risk (e.g., Lando, 2004).

We next calibrate the model by finding values for the parameters $(\beta, \sigma, \alpha, f, \lambda, \xi, \gamma, q)$ so that the simulated firm behavior is close to the behavior of the average firm in our sample. We try to match the following data moments in Table 1: 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. Details of the procedure are in Appendix A.

We present the simulated moments from the model with CDSs in Table 3. For all the metrics except for liquidation frequency, the means are calculated by finding the cross-sectional mean 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 divide the number of bankruptcies in the simulated panel by the total number of observations.

We compare the data moments in Table 1 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 1 is 18.61%, while the simulated mean is 16%. The simulated results are close to what we observe in the data. Operating profitability is 5.5% in the data and 18% 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 1 is substantially higher at 11.14%. The empirical Q-ratio is 2.14, which compares to a simulated average of 1.8. Market leverage in the data is 0.338, while it is substantially higher at 0.67 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.

The empirical payout ratio is -4.46%, and its simulated counterpart is 2%. This discrepancy can be explained by the findings in Fama and French (2001), who show that the average payout ratio in Compustat is tilted downwards by the entrance of small, high-growth firms that do not pay dividends or repurchase shares. They find that while total payouts by all firms in Compustat have not decreased over time, the fraction of firms that pay dividends has fallen dramatically. Therefore, one has to be careful when comparing the average in Compustat, which is exposed to this kind of selection bias, with the mean of a steady-state model like ours.

We are able to match the average credit spread very well. The predicted average spread of 109.76 basis points is right between the 87 bps for A-rated bonds and the 149 bps for Baa-rated bonds in Duffee (1998). Finally, the empirical average bankruptcy rate is 1.45%, while it is slightly lower at 1.03% in the simulated sample. To summarize, our model is able to match certain moments relatively well, while it is not able to match other moments very closely.

Our calibrated parameter values in Table 2 are similar to the values reported in the literature. The value of $\sigma = 0.21$ is higher than Gomes (2001) (0.15), but below the value in DeAngelo et al. (2011) (0.28). This parameter directly impacts metrics such as EBITDA/assets and leverage, and indirectly affects default rates and credit spreads.

The calibrated proportional equity issuance cost of $\lambda = 5.63\%$ is similar to the value in Altinkilic and Hansen (2000) (5.38%) and indirect structural estimates in Hennessy and Whited (2005) (5.9%). Also, it is very close to the average equity issuance cost of 5.36% in

our sample, as reported in Table 1.

We find that the calibrated value for α is 0.475, which is above the value in Moyen (2004) (0.45) and below the value in Cooper and Haltiwanger (2006) (0.592). The fixed production cost of $f = 1.14$ is slightly higher than in Moyen (2004) (0.76). This parameter mainly affects the Q-ratio. Our value for β, the discount factor of equity holders, is 0.9434, which is slightly lower than the value in Cooley and Quadrini (2001) (0.956).

The cost associated with liquidation (ξ) is calibrated to be 42% of the firm's assets. This value is substantially higher than traditional measures of bankruptcy costs, such as in Warner (1977). However, more recently it has been found that estimates based on an ex post sample of bankruptcies are biased downwards, because firms with high costs of financial distress will choose lower leverage ratios and will default less frequently. Glover (2016) reports that after correcting for this bias, bankruptcy costs for the average firm can be estimated to be 45%, which is very close to our calibrated value.

Finally, we calibrate the probability of renegotiation failure γ and the bargaining power of bondholders q to be 0.63 and 0.35, 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 implies that there is a relatively large probability that debt renegotiations fail. Gilson et al. (1990), Asquith et al. (1994), and Demiroglu and James (2015) all find that roughly a half of the firms that attempt an out-of-court debt restructuring end up in bankruptcy. This is consistent with our value of $\gamma = 0.63$.

For the debt holders' bargaining power, since empirical proxies are difficult to find, Morellec et al. (2012) indirectly estimate the parameter using structural estimation, and report that $q = 0.57$. Our value of 0.35 is smaller than that. However, their model is very different from ours, as they assume exogenous cash flows and focus on agency conflicts between management and shareholders. Our value is consistent with a view that equity holders have more bargaining power than bondholders, which allows them to extract rents in a debt renegotiation. This is consistent with the findings of Davydenko and Strebulaev (2007), who

show that the risk of being exploited by equity holders is substantial enough to affect credit spreads. Similarly, Favara et al. (2012) show that this risk has an impact on equity betas.

3. Comparing the models with and without CDSs

3.1. The value effect of CDSs

In Table 3, we compare the results of the calibrated model with CDSs to the model without CDSs. These are unconditional results, using all simulated firm-year observations. Most importantly, we find that the mean firm value in the economy with CDSs (16.08) is higher than the corresponding average in the economy without CDSs (15.63). The exact relative increase in firm value, or value effect, is 2.92%. This magnitude is slightly less than half of the effect of optimal capital structure on firm value in Graham (2000), which is economically plausible.

The sources of this value effect are the same as in Section 1.2. The total value effect is a composition of negative and positive forces. On the one hand, CDSs destroy firm value because they increase the probability of costly bankruptcy. Table 3 shows that the probability of liquidation increases slightly from 1.01% to 1.03%. On the other hand, CDSs alleviate the commitment problem between equity holders and bondholders. As bondholders are less worried about debt renegotiation, the cost of debt financing goes down. This allows the firm to invest more in physical capital. As reported in Table 3, average assets increase from 8.83 to 9.14. Also, since equity financing is more expensive than debt financing, the firm can use more debt in its capital structure to further increase firm value. In our unconditional results, average market leverage increases from 0.58 to 0.67. The strength of our model is its ability to quantify the net effect on firm value, which itself is a combination of these negative and positive effects.

The model is able to explain several findings in the empirical literature. First, the increase in the probability of liquidation is consistent with Subrahmanyam et al. (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, 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.

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 in Table 4. We present the average firm value in the model with CDSs as well as in the model without CDSs using the base case parameter values in Table 2. 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.

Apart from robustness, Table 4 also provides some economic insights into the effects of CDS contracts. The first seven rows of Table 4 show how firm value changes with respect to parameters q, ξ, and γ. Interestingly, in the model without CDSs, firm value changes substantially across these seven rows, but in the model with CDSs, firm value is almost constant. Also, these are exactly the parameters of the model that gauge the commitment problem between equity holders and bondholders the most. What we can learn from this observation is that the introduction of CDSs allows bondholders to protect themselves against exploitation

by equity holders. Most changes in the risk of exploitation caused by the parameters q, ξ, or γ can be hedged using CDSs. This ultimately benefits not just the bondholders, but also the equity holders.

Another way to see the value effect is to compare a firm in the with-CDS economy to a firm in the no-CDS world, both starting at the same point in the state space (z, k, b). This is what we do in Figure 3. It shows the firm at a specific point in the state space, where capital is $k = 11.12$ and the face value of debt is $b = 13.12$. The points are chosen to be relatively close to the average values of capital and debt in Table 3. To choose the value of the hedge ratio h, we first use the policy functions of the model to find all the points in the state space for h that are consistent with the chosen values for k and b. We then pick the maximum of these values, which is $h = 0.97$.[7] For the no-CDS firm we set $h = 0$.

The x-axis in Figure 3 represents different values of current productivity z. Circles show a firm without CDSs, while diamonds 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 will focus on the empty circles/diamonds first, because they represent a healthy firm that is not currently in default.

We see that firm value increases with the introduction of CDSs. This value effect is especially pronounced for intermediate values of z. There is also a small but positive value effect for high values of z, but it is not easy to see due to the scale of the plot. We will illustrate the effect for high values of z later on. The figure also shows that equity value is lower, compared to the model without CDSs, and the book value of debt is higher in all states, which results in higher leverage with CDSs. All of these observations are consistent with our unconditional results in Table 3.

If we look at the solid circles and diamonds in Figure 3, which correspond to very low values of the productivity shock, we see that it is possible for the value effect to be negative.

[7] In unreported results, we also draw the figure using the minimum value of h that is consistent with k and b, and the plots look qualitatively very similar.

These are the states when the firm is in default. The intuition for a negative value effect is that the firm without CDSs can renegotiate in a way that is more favorable for equity holders. As a result, firms in the no-CDS economy emerge from renegotiation with more equity, which more than outweighs the disadvantage of not having a CDS market.

We have shown that for a healthy firm that is currently not in default, the effect of CDSs on firm value is positive. However, Figure 3 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. Therefore, we examine other points in the state space. In Figure 4, for example, we choose $k = 6.57$ and $b = 0$, which represents a small firm with no debt (and hence also $h = 0$). Most interestingly, the value effect is never negative. Due to the scale of the plot for firm value, it might seem that the value effect is zero, when it is in fact positive. To get around the scale problem, Figure 5 presents the difference between firm value in the with-CDS economy and firm value in the no-CDS economy, at the same point $k = 6.57$ and $b = 0$. It shows that the value effect is positive at all values of z. Also, while it seemed in Figure 3 that the value effect is zero for high values of z, Figure 5 shows that this is not true: The value effect is positive even for very high values of z.

Figures 6 and 7 are analogous to Figures 3 and 4, but with different values of (k, b). Figure 6 depicts a large firm with no debt, while Figure 7 illustrates a small firm with high debt. In both figures, the effect of CDSs on firm value is positive for firms that are not in default, which suggests that our conclusion is robust. Also, it is interesting to observe that the large firm with no debt (Figure 6) behaves very similarly to the small firm with no debt (Figure 4). Likewise, the small firm with high debt (Figure 7) is very similar to the large firm with high debt (Figure 3). Together these observations suggest that leverage is a more important determinant of outcomes than firm size. Also, the value effect is larger for firms with high leverage compared to low-leverage firms.

3.2. The real effect of CDSs

The positive net effect on firm value in Table 3 is to a substantial part driven by the ability of firms in the with-CDS economy to accumulate capital to an amount that is closer to the frictionless first-best capital level. It is in this sense that CDSs have a real effect on firms. We document this real effect in several different ways. First, as shown in Table 3, the unconditional mean of capital is higher in the economy with CDSs, at 9.14, compared to the economy without CDS markets, at 8.83. This difference translates to an economically significant relative increase in capital of 3.5%.

The second way to see the real effect is to compare a firm in the with-CDS economy to a firm in the no-CDS world, both starting at the same point in the state space (z, k, b), and to check if there is a difference in the chosen capital level k'. This is what we do in Figures 3, 4, 6, and 7. Consistent with the real effect documented in Table 3, the firm with CDSs chooses a higher level of capital in all four figures. Interestingly, the magnitude of the real effect is not the same for every value of z. If the productivity shock z is very high, CDSs have a very small effect on capital. Finally, Figures 3, 4, 6, and 7 show that the real effect is larger for firms with high leverage, which is analogous to our findings for the value effect.

We have shown that CDSs have an effect on the unconditional mean of capital, as well as on the optimal capital k' starting from a given point (z, k, b). The third way to see that there is a real effect is to check if the steady state of capital is indeed higher in a world with CDSs. In Figure 8, we examine the evolution of capital and its convergence to the steady state. Figure 8 (a) shows how firms evolve after their entry into the economy. The solid red line shows the average over all simulated paths in the with-CDS economy, while the dotted blue line shows the average path in the no-CDS economy. As the figure shows, both firms reach the steady state after approximately eight periods. Most importantly, the with-CDS firm converges to a higher steady-state value of capital than the no-CDS firm.

Even though Figure 8 (a) shows that CDSs increase the steady-state value of capital, the two firms start at a different initial value of capital. This difference in the initial capital

arises endogenously in the model, and is also a positive effect of CDSs. However, it might create the wrong impression that the higher steady state value is driven by the higher starting value of capital. To rule out this explanation, we condition the simulated firms on the same initial capital, and follow them through time. The solid red line in Figure 8 (b) presents the average path for the with-CDS firm, while the dotted blue line shows the average path for the no-CDS firm. As before, in an economy with CDS markets, capital converges to a higher steady-state value. This suggests that the difference in steady states is not driven by the difference in initial values of capital.

We conclude by observing that the addition of a CDS market has a real effect on firms. The reduction in the cost of debt financing allows firms to invest more in capital. The result is a higher steady state of capital in the with-CDS economy. This is beneficial because in an economy with financial frictions, capital is usually below its first-best value. The introduction of a CDS market allows the firm to move closer to the first-best value of capital.

3.3. The effect of CDSs on different types of firms

In Tables 5 and 6, we look at the effect of CDSs on small firms and large firms, respectively. We perform a 4×3 double sort on all simulated firm/year observations in the no-CDS economy, where the sorting variables are k and z, respectively. Small firms are defined as the intersection of observations in the second quartile group for k and those in the intermediate tercile group for z, while large firms are the intersection of the third quartile for k and the intermediate tercile group for z. We perform the same sorting in the with-CDS economy. The two tables show the value effect of CDSs is 4.00% for small firms, but only 2.67% for large firms. In other words, small firms benefit more from the introduction of CDS markets than large firms, although the value effect is positive for both types of firms. A caveat of comparing firms in different bins like in Tables 5 and 6 is that one cannot simply compare the mean of assets in both the economies to infer the size of the real effect of CDSs. The reason is that average assets in these tables represent conditional means at a given point in time in

the firm's life, so they only reflect the average capital at the time the bins are formed. Unlike the unconditional mean of capital, they do not say anything about what level of capital the average firm will achieve in the future.

Another prediction of our model is that the value effect of CDSs is larger for firms with financial constraints. We argue that in the context of our model, the exogenous equity issuance cost λ is the best measure for financial constraints. If λ is high, it is more expensive for the firm to obtain outside equity financing, other things being equal. Table 4 shows that $\lambda = 0.05$ is associated with a value effect of 3.02%, and that $\lambda = 0.06$ leads to a value effect of 3.55%. Therefore, firms that are more financially constrained benefit more from the introduction of CDS markets.

As an alternative measure for financial constraints, we rank firm-year observations by their payout ratio and argue that a low payout ratio is a sign of financial constraints. A low payout ratio has been used as a measure of financial constraints in the empirical literature [Farre-Mensa and Ljungqvist (2016) provide a recent review]. The advantage of this measure is that it is varying over time, and that it not only measures the cost of equity issuance. The disadvantage is that it is not an exogenous parameter such as λ. Tables 7 and 8 provide summary statistics for firms with low and high equity payout ratios, respectively. In the no-CDS economy, we define low payout firm-year observations in the bottom tercile group of the distribution of payout ratios. High payout firms are defined as observations in the top tercile group. We repeat this sorting for the with-CDS economy. The two tables show that for firms with a low payout ratio the value effect is 4.24%, while with a high payout ratio the value effect is slightly negative at -1.22%. While these results can be interpreted in a way that the value effect is smaller for unconstrained firms, one has to keep the limitations of our methodology in mind when looking at the negative effect of -1.22%. What seems to be a negative value effect is a consequence of an inherent limitation of our sorting procedure. Sorting firms into buckets in Table 8 selects slightly higher capital firms in the no-CDS economy compared to the with-CDS economy. The difference in capital levels biases the

value effect downwards. To conclude, the results in Tables 7 and 8 are consistent with the observations in Table 4, and suggest that financially constrained firms benefit more from the introduction of CDS markets.

In Tables 9 and 10 we compare low and high productivity firms, respectively. We perform a 3×4 double sort on k and z, and classify observations in the intermediate bin for k and in the second bin for z as low productivity firms. Analogously, high productivity firms are defined as the intermediate bin for k and the third bin for z. Tables 9 and 10 show that the value effect for firms with low productivity shocks is 7.00%, while for high productivity firms it is 2.03%. In other words, low productivity firms benefit more from the introduction of CDS markets. The intuition for this result is that low productivity firms are more likely to be financially constrained, since the productivity level z also affects the current operating cash flow $\pi(xz, k)$. Therefore, these firms benefit more from the reduction in the cost of debt financing caused by CDS contracts. This is consistent with the results on financial constraints in Tables 4, 7, and 8.

We conclude this analysis of different firm types by observing that while the CDS market on average has a positive net effect on firm value, it is especially beneficial for small firms, financially constrained firms, and low productivity firms.

4. Empirical tests

Our model can be used to derive several new predictions for the hedge ratio. In this section we perform empirical tests for a few of these predictions. The model predicts that the hedge ratio $h'(z, k', b')$ will vary across firms and across time, depending on the current state of the firm. Since the state of the firm is not directly observable, but firm characteristics are, we can in principle test the relationship between the hedge ratio and firm characteristics. While this is not a detailed empirical analysis, it demonstrates how the model can be used to understand certain aspects of the amount outstanding in the CDS market. Also, the results

can be seen as an indirect empirical validation of the model.

Based on the model, we can derive the following three simple testable predictions. First, we expect a positive relationship between lagged market leverage and the hedge ratio. The intuition is that higher leverage increases the probability of renegotiation in the next period. Bondholders want to protect themselves against expropriation by equity holders, which increases the hedge ratio. Second, we expect a negative relationship between lagged Q and the hedge ratio. Intuitively, a higher Q–ratio signals that the firm has experienced a high productivity shock. This reduces the probability of renegotiation in the next period, which then reduces the need for hedging. Table 11 formalizes these predictions in a simulated regression framework. It contains the results of regressions using simulated data that is created using the numerical procedure in Appendix A, and confirms that market leverage is positively correlated with the hedge ratio, while the Q–ratio has a negative coefficient.

Third, we expect a positive relationship between non-fixed assets, defined as 1 minus the fraction of fixed assets, and the hedge ratio. Davydenko and Strebulaev (2007) argue that this is a good proxy for liquidation costs, which corresponds to the parameter ξ in our model. The intuition is that in debt renegotiation, a higher value of ξ improves the bargaining position of equity holders, because it reduces the outside option of debt holders, since the liquidation value of the firm is lower. More formally, in the second inequality in (4), the right-hand side is decreasing in ξ. Therefore, bondholders are especially vulnerable to expropriation if ξ is high, so they choose a higher hedge ratio to protect themselves. This prediction of the model is confirmed in a simpler setup by Danis and Gamba (2016). We also check numerically that ξ increases the average hedge ratio in the dynamic model, but omit a separate table for brevity.

The hedge ratio of real-world bondholders is not observable, because there is no available database on the identity of CDS investors. Therefore, we construct our own proxy for the hedge ratio, using data published by the Depository Trust and Clearing Corporation (DTCC). In October 2008, the DTCC started reporting the total amount of CDSs outstanding for the

global top 1,000 reference entities every week. We download this data from the time it became available to the end of 2013, which corresponds to the end of the sample period for our main Compustat/CRSP sample. We clean the data by removing sovereign reference entities and municipalities, and reference entities outside of the Americas region. We then manually match each firm in the remaining DTCC sample to a GVKEY based on firm name, only keeping U.S. reference entities. The result is a sample of 456 U.S. corporate reference entities which can be linked to firms in Compustat/CRSP. Matching this sample with Compustat/CRSP yields an unbalanced panel of 2,069 firm-year observations.

We define our proxy for the aggregate hedge ratio of bondholders, *NetNotional/Debt*, as the net notional amount of CDSs outstanding for firm i in year t, divided by the sum of debt in current liabilities and long-term debt. We focus on the net notional amount because this way a short CDS position of an investor, created to close a previously created long position in the same CDS reference, will not inflate the total amount of CDSs outstanding. The gross notional amount, however, would be biased upwards because of these offsetting trades. Oehmke and Zawadowski (2016) explain in more detail why the net notional amount is a better measure for the amount outstanding. If the denominator of *NetNotional/Debt* is zero, we drop the observation from the sample.

We calculate several variables before testing our three predictions. We define *Market leverage* as total liabilities divided by the sum of total liabilities and the market value of equity. *Q–Ratio* is defined as the sum of market equity, debt in current liabilities, and long-term debt, divided by total assets. We define *Non-fixed assets* as 1 - (net PPE / total assets), as in Davydenko and Strebulaev (2007). Finally, *Size* is calculated as the log of total assets. All variables are lagged by one year, except *NetNotional/Debt*. Also, the variables are winsorized at the 1% and 99% levels, except *Market leverage* and *Non-fixed assets*. Since these two variables should be bounded by the unit interval, we truncate them at zero and one. We only keep observations in the sample for which all variables (*NetNotional/Debt*, *Market leverage*, *Q–Ratio*, *Non-fixed assets*, and *Size*) are available. This results in a final

sample of 1,481 firm-year observations.

Table 12 contains summary statistics for the DTCC sample. The mean of *NetNotional/Debt* is 0.28, so the amount of CDSs outstanding is a bit less than a third of the debt outstanding for the average firm. The variable ranges from 0.0083 to 2.65, which means that for some firms there are more CDSs than bonds outstanding. There are several reasons for this. The most obvious one is that empirically many CDSs are purchased for speculative purposes rather than for hedging an existing bond position, as shown in Oehmke and Zawadowski (2016). The other summary statistics are informative in the sense that they reveal that firms in the DTCC sample are a bit different from the average firm in Compustat/CRSP. Compared to Table 1, DTCC firms have higher leverage and lower Q–ratios. This is broadly consistent with other studies of firms with CDSs, such as Subrahmanyam et al. (2014), who also show that CDS entities are larger than the average firm.

Table 13 presents the results of simple linear regressions testing these predictions. All regressions include *Size* as a control variable. Most importantly, the coefficients of *Market leverage*, *Q–Ratio*, and *Non-fixed assets* have the same signs as predicted by the model. Also, they are statistically significant at the 1% level in all three cases. While these tests are very simplistic, they suggest that our model is able to explain some of the real-world variation in hedge ratios.

5. Conclusions

We examine the effect of CDSs on firm value in the context of a dynamic model where the firm chooses default, investment, equity financing, and debt financing in an optimal manner each period. The model features several real-world frictions: limited commitment by equity holders, 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 2.9% on average.

The model predicts that after the introduction of a CDS market, firm leverage increases, the firm invests in more physical capital, 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, for companies with financial constraints, and for low-productivity 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.

Appendix A. Numerical procedure

The algorithm to solve the dynamic program of the firm is based on value function iteration on a discretized state space. We will focus on the procedure to solve the problem with CDS, as the algorithm for the non-CDS case is nested into it. The description follows below.

1. Choose grid for z and approximate Γ with a discrete-state Markov chain with N_z points using the Tauchen (1986) method. As in Cooley and Quadrini (2001), choose grid $\{0, 1\}$ for x and transition probability such that $\Psi(x_0|x_1) = 0.01$ and $\Psi(x_0|x_0) = 1$. Choose grid for k:

$$\left\{k_j = \overline{k}(1-\delta)^{N_k - j}, j = 1, \ldots, N_k\right\}.$$

   Choose grid for b, dividing $[0, \overline{b}]$ in N_b equal intervals. Choose the grid for h by dividing $[0, 1]$ in N_h equal intervals. $\overline{k}$ and $\overline{b}$ are selected so that they are not binding.

2. Compute net worth w on the grid of points (x, z, k, b) using the identity

$$w = (1-\delta)k - \pi(xz, k) - b.$$

3. Start with guesses for $v(x, z, w)$ and $m(x, z, k, b)$.

4. For each (x, z, k', b'), compute the values for the potential levels of revised net worth, $e = e(x, z, k', b') = k' - m(x, z, k', b')$. From these, calculate the possible dividends: $d = d(x, z, k', b') = w - e$.

5. At each (x, z, w), find $V(x, z, w)$ and the optimal d^* solving the program (7):

$$V(x, z, w) = \max_d \left\{d^+ + (1+\lambda)d^- + v(x, z, w-d)\right\}.$$

6. For each (x, z), use linear interpolation to determine $w_d(xz)$ as the zero of function $V(x, z, \cdot)$ calculated in Step 5.

7. At each (x, z, w),

   - calculate $H(x, z, w)$;
   - if $(1-\xi)a < b$, for each h calculate

$$b_r = (1-q)\left[hb + (1-h)(1-\xi)a(xz,k)\right] + q\left[a(xz,k) - w_d(xz)\right]. \tag{15}$$

     Then, determine $V(x, z, w_r)$ using linear interpolation on V from Step 5, where $w_r = a(xz,k) - b_r$;

   - for each h, find the payoff to equity $\mathcal{V}$ using equation (6) and determine the corresponding payoff to debt.

8. For each (x, z, e), where e is determined in Step 4, update v using

$$v(x,z,e) = \max_{(k',b')} \beta \sum_{x'} \int \mathcal{V}(x',z',k',b',h')\Gamma(dz'|z)\Psi(x'|x)$$

   and update m using equation

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

   with M defined in equation (13). Given the solutions of the equity and debt programs, we update also the optimal state-dependent policy for equity (k^*, b^*), and for debt h^*, respectively.

9. Repeat Steps from 4 to 8 until convergence of the functions v and m.

Regarding the above procedure, there are several comments in order. The function $V(x, z, \cdot)$ is strictly increasing in w, which we show in Appendix B. Therefore, $w_d(xz)$ in Step 6 is uniquely defined.

In the bargaining game, b_r cannot be found analytically solving the problem in (3), because V is determined numerically in the iterative algorithm described above. However, b_r

can be approximated as in equation (15) in Step 7. The argument relies on the assumption that the function V is continuously differentiable, except at the point in which $d = 0$, which we show in Appendix B. States in which the renegotiation threat is credible are such that $d < 0$, as the firm is near the liquidation threshold. Therefore, V is continuously differentiable in these states. If we knew V, we could exactly calculate $b_r = b_r(x, z, k, b)$ by solving the first-order condition of problem (3):

$$(q-1)\left[b_r - hb - (1-h)(1-\xi)a(xz,k)\right] \left.\frac{\partial V(x,z,w)}{\partial w}\right|_{w=w_r} + qV(x,z,w_r) = 0, \tag{16}$$

where $w_r = a(xz,k) - b_r$. A convenient approximation of the solution b_r of (16) can be obtained by observing that if V is a continuously differentiable function at w_1, then

$$V(x,z,w_2) - V(x,z,w_1) \approx (w_2 - w_1) \left.\frac{\partial V(x,z,w)}{\partial w}\right|_{w=w_1}, \tag{17}$$

if w_2 is sufficiently near to w_1. Considering $w_1 = w_r$ and $w_2 = w_d(xz)$, then $V(w_2) = 0$ by definition, and we can put (17) in place of the second addend in (16), obtaining

$$\begin{aligned}(q-1)\left[b_r - hb - (1-h)(1-\xi)a(xz,k)\right] &\left.\frac{\partial V(x,z,w)}{\partial w}\right|_{w=w_r} \\ &\approx q\left(w_d(xz) - a(xz,k) + b_r\right) \left.\frac{\partial V(x,z,w)}{\partial w}\right|_{w=w_1}\end{aligned}$$

Because V is strictly increasing in w, then the partial derivative is strictly positive and we can simplify the above equation and solve it for b_r, obtaining

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

which does not depend directly on V.

The numerical procedure is implemented by discretizing the exogenous variable $\log z$ in the range of $\pm$ 3 times the unconditional standard deviation of the AR(1) process with

$N_z = 11$ points. We also discretize the interval $[0, \overline{k}]$ for k and the interval $[0, \overline{b}]$ for b with 65 points each, and the interval $[0, 1]$ for h with 61 points. The bounds for capital stock and debt are $\overline{k} = 60$ and $\overline{b} = 60$, respectively. The numerical solution of the Bellman problem gives us the optimal policies and the optimal security values. Using a Monte Carlo method, we then simulate an economy comprising 200 firms at their steady state for 1000 years, for a total of 200,000 firm-year observations.

When simulating the economy, to keep the model stationary, we assume that if a firm is liquidated or when $x = x_0$, it is replaced by a new firm, which is started at the value $V(x, z, w_d(xz)) = 0$, and therefore it immediately makes an optimal investment and financing decision based on $e = w_d(xz)$, with $x \neq x_0$, as per the program in (8).

Appendix B. Properties of the solution of the model

B.1. The firm's problem

We summarize in this appendix the model with CDSs, as described in the paper. The problem without CDSs is nested into it, and can be obtained by setting the hedge ratio, h, to zero. For brevity, we report the problem with only the shock z (that is, x is constant). The extension to the case in which also x is stochastic is straightforward and similar to what is done by Cooley and Quadrini (2001). Therefore, we do not report it.

The firm's problem can be stated as

$$\begin{aligned} v(z,e) &= \max_{(k',b')} \left\{ \beta \int V(z', \widetilde{w}(z',k',b',h'))\Gamma(dz'|z) \right\} \\ \text{s.t.} \quad & e = k' - m(z,k',b') \end{aligned} \tag{18}$$

with

$$\widetilde{w}(z,k,b,h) = \begin{cases} w_d(z_d) + (z - z_d)k^\alpha & \text{if } z > z_r \\ w_d(z_d) + (z - z_d)k^\alpha + (b - b_r) & \text{if } z_d < z \leq z_r \\ w_d(z_d) & \text{if } z \leq z_d \end{cases}, \quad \text{if } h \leq H(z,k,b),$$

$$\widetilde{w}(z,k,b,h) = \begin{cases} w_d(z_d) + (z - z_d)k^\alpha & \text{if } z \geq z_d \\ w_d(z_d) & \text{if } z \leq z_d \end{cases}, \quad \text{if } h > H(z,k,b). \tag{19}$$

Denoting $a(z,k) = (1-\delta)k + (zk^\alpha - f)$,

$$H(z,k,b) = \frac{\xi a(z,k) - w_d(z)}{b - (1-\xi)a(z,k)} \tag{20}$$

$$z_d(k,b): \qquad w_d(z_d) = a(z_d,k) - b \tag{21}$$

$$\text{if } h \leq H(z,k,b),\ z_r(k,b): \qquad w_r(z_r) = a(z_r,k) - b \tag{22}$$

$$w_d(z): \qquad V(z, w_d(z)) = 0 \tag{23}$$

$$\text{if } h \leq H(z,k,b),\ w_r(z): \qquad V(z, w_r(z)) = (1-\gamma)V(z, a(z,k) - b_r). \tag{24}$$

If $h \leq H(z,k,b)$ and assuming $q \in]0,1[$, the bargaining problem is

$$\begin{aligned} b_r(z,k,b,h) &= \arg\max_p \left\{ [V(z,a(z,k)-p)]^{1-q} \times [p - hb - (1-h)(1-\xi)a(z,k)]^q \right\}, \\ \text{s.t.} \quad & p \in [hb + (1-h)(1-\xi)a(z,k),\ a(z,k) - w_d(z)]. \end{aligned} \tag{25}$$

The debt holder's problem is

$$m(z,k,b) = \max_{h'} \left\{ \frac{1}{1+r} \int \widetilde{m}(z',k,b,h')\Gamma(dz'|z) \right\} \tag{26}$$

with

$$\widetilde{m}(z,k,b,h') = \begin{cases} b & \text{if } z > z_r \\ (1-\gamma)b_r(z,k,b,h') + \gamma(1-\xi)a(z,k) & \text{if } z_d < z \leq z_r \\ (1-\xi)a(z,k) & \text{if } z \leq z_d \end{cases}, \quad \text{if } h' \leq H(z,k,b),$$

$$\widetilde{m}(z,k,b,h') = \begin{cases} b & \text{if } z > z_d \\ (1-\xi)a(z,k) & \text{if } z \leq z_d \end{cases}, \quad \text{if } h' > H(z,k,b),$$

To close the firm's problem and the model:

$$V(z,w) = \max_e \left\{ (w-e)^+ + (1+\lambda)(w-e)^- + v(z,e) \right\}. \tag{27}$$

The above description of the model can be reconciled with the one in the main text.

Conditions in (19) can be derived from equation (6) as follows:[8] if $h \leq H$

$$\begin{cases} V(z,w) & \text{if } w \geq \xi a \\ \max\{0, V(z,w), (1-\gamma)V(z,a-b_r)\} & \text{if } w < \xi a \end{cases} = \begin{cases} V(z,w) & \text{if } w > w_r \\ (1-\gamma)V(z,a-b_r) & \text{if } w_d < w \leq w_r \\ 0 & \text{if } w \leq w_d \end{cases}$$

where w_d is defined from (23) and w_r from (24). On the other hand, if $h > H$ then

$$\begin{cases} V(z,w) & \text{if } w \geq \xi a \\ \max\{V(z,w), 0\} & \text{if } w < \xi a \end{cases} = \begin{cases} V(z,w) & \text{if } w > w_d \\ 0 & \text{if } w \leq w_d \end{cases}.$$

Because $a(z,k)$ is monotonic in z, we derive from equations (21) and (22) the unique values of z_d and z_r, respectively. This allows us to re-write the owner's payoff $V(z, \widetilde{w}(z,k,b,h))$ as follows. For $h \leq H$

$$\widetilde{w}(z,k,b,h) = \begin{cases} a(z,k) - b & \text{if } z > z_r \\ a(z,k) - b_r & \text{if } z_d < z \leq z_r \\ w_d(z_d) & \text{if } z \leq z_d \end{cases}$$

and, using the definition of z_d in (21), we have the first equation in (19). Similarly, in the case $h > H$,

$$\widetilde{w}(z,k,b,h) = \begin{cases} a(z,k) - b & \text{if } z > z_d \\ w_d(z_d) & \text{if } z \leq z_d \end{cases}$$

from which we find the second equation in (19).

B.2. Existence of the solution of the firm's problem

Following Cooley and Quadrini (2001), we can restrict $e \in [e_{\min}, e_{\max}]$. This is because there is a lower bound $e_{\min}$ below which equity is issued and an upper bound $e_{\max}$ above which

[8] We assume for definiteness $b > 0$, which is the case prevailing in equilibrium.

equity is paid out to shareholders. Similarly, there is an upper bound $\overline{k}$ such that $k > \overline{k}$ would not be economically profitable and would never be chosen in equilibrium. Finally, also b is bounded above, because $k - e$ is bounded above, and m is a non-decreasing function of b. We can omit any consideration of $b > \overline{b}$, where $m(z, \overline{k}, \overline{b})$ is the maximum value of debt at z. In what follows we assume also that the support of z is compact: $z \in [\underline{z}, \overline{z}]$.

We will show later that $m(z, k, b)$ is continuous. Therefore, because the domains of e, k, and b are bounded, continuity of m w.r.t. (k, b), is sufficient (see Exercise 3.13 in Stokey and Lucas (1989)) for the correspondence

$$B(z, e) = \left\{(k, b) : k \in [0, \overline{k}], b \in [0, \overline{b}], e = k - m(z, k, b)\right\}$$

that defines the feasible set for problem (18) to be continuous, compact, and convex valued.

Because in problem (27) the payoff is continuous and strictly increasing in w, V is strictly increasing in w. This property of V allows us to uniquely define $w_d(z)$ from (23). Similarly, from the properties of V we uniquely define $w_r(z)$ from (24). Using the same argument as in Proposition 5 of Hennessy and Whited (2007), $w_d(z)$ is negative valued, continuous, and non-increasing, and $w_r(z)$ is continuous. Using the same argument as in Proposition 6 in Hennessy and Whited (2007), z_d and z_r are continuous functions.

Defining from (18) the Bellman operator

$$(Tv)(z, e) = \max_{(k', b') \in B(z, e)} \left\{\beta \int V(z', \widetilde{w}(z', k', b', h'))\Gamma(dz'|z)\right\},$$

T maps continuous and bounded functions into themselves. This is because if v is continuous and bounded, then also V is continuous and bounded, and, as in Cooley and Quadrini (2001), the boundedness and continuity of $\int \widetilde{w}(z', k, b, h)\Gamma(dz'|z)$ and V imply, together with the Feller property of Γ, that the objective function (18) is continuous and bounded. Because the correspondence B is continuous, compact, and convex valued, the maximum exists and v is continuous (see Theorem 3.6 in Stokey and Lucas (1989)). The resulting function Tv is

unique because the operator T is a contraction mapping, as can be proved showing that it satisfies Blackwell's sufficient conditions, using the same argument as on p. 1739 in Hennessy and Whited (2007).

Because V is continuous, then the objective function of problem (25) is continuous in p. The feasible set of the same problem, $[hb + (1-h)(1-\xi)a(z,k),\ a(z,k) - w_d(z)]$, is non-empty if $h \leq H(z,k,b)$, and is a continuous correspondence, because (see Exercise 3.13 in Stokey and Lucas (1989)) $a(z,k)$ and $w_d(z)$ are continuous, as we have proved above. The feasible set is also compact and convex valued. Therefore, the problem (25) has a solution. As we will prove later, v is strictly concave, and so is V as defined in (27). Therefore, because we assume $q \in]0,1[$, the objective function in (25) is strictly concave in p and the optimal solution, $b_r(z,k,b,h)$, is uniquely defined and continuous. We can show that $b_r(z,k,b,h)$ is increasing in both z and h. To see this, we first write the solution of the bargaining game in (25) as

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

This equation implicitly defines b_r. As we will show later, V is differentiable, except at the point in which the dividend is zero. Using the implicit function theorem, we calculate the derivatives of b_r with respect to z

$$\frac{\partial b_r}{\partial z} = k^{\alpha}\frac{(1-q)(1-h)(1-\xi) + q\frac{\partial V}{\partial w}}{1 + q\frac{\partial V}{\partial w}} \geq 0$$

and h

$$\frac{\partial b_r}{\partial h} = \frac{(1-q)\left[b - (1-\xi)a(z,k)\right]}{1 + q\frac{\partial V}{\partial w}} \geq 0,$$

and in both cases we rely on the fact that $\partial V/\partial w > 0$, as shown before.

Because w_d is continuous and decreasing, and because renegotiation is a credible threat only when $b > (1-\xi)a(k,z)$, $H(z,k,b)$ in equation (20) is positive valued, continuous, and increasing in z.

As for the debt holder's problem in (26), because the support of z' is bounded in $[\underline{z}, \overline{z}]$

and H is increasing in z, any $h' > H(\overline{z}, k, b)$ would give the same present value

$$\frac{1}{1+r}\left\{(1-\xi)\int_{\underline{z}}^{z_d} a(z',k)\Gamma(dz'|z) + b[1-\Gamma(z_d|z)]\right\}.$$

Hence, $H(\overline{z}, k, b)$ is a natural upper bound for h' in problem (26).

We now show that there is also a natural lower bound for h', which is $h' \geq 0$. Assume $h' < 0$, then the outcome of the owner's default decision reduces to either renegotiation or repayment. The reason why liquidation will not happen is that renegotiation is always feasible, since $H > 0$, so $h' < H$ is always true, and because the owner prefers renegotiation to liquidation. One can also show that if $h' < 0$, an increase in h' leads to an increase in the expected payoff to bondholders. The reason is that repayment becomes more likely than renegotiation if h' increases. To see this, remember that the owner will choose repayment over renegotiation if $V(z, w) > (1-\gamma)V(z, a - b_r)$. A higher h' increases b_r, which reduces $a - b_r$, which reduces $V(z, a - b_r)$, since V is an increasing function. Therefore, a higher h' increases the expected payoff to bondholders, so $h' < 0$ cannot be optimal.

The boundedness and continuity of $\int \widetilde{m}(z', k, b, h)\Gamma(dz'|z)$, and the fact that the feasible set is a continuous, compact and convex valued correspondence ensure that a solution to problem (26) exists and that $m(z, k, b)$ is continuous (see Theorem 3.6 in Stokey and Lucas (1989)).

B.3. Monotonicity and concavity of v, and differentiability of V

We first show that v is strictly increasing and strictly concave with respect to e in a compact interval $[e_{\min}, e_{\max}]$.

The argument is very similar to the one in Cooley and Quadrini (2001), so we report here the essential steps. If v is concave and $v(0) \geq 0$, then V is strictly increasing and concave because the payoff function $(w-e)^+ + (w-e)^-(1+\lambda)$ is strictly increasing and concave. As $\widetilde{w}$ is strictly increasing, then $V \circ \widetilde{w}$ is strictly increasing. Therefore, the resulting function

Tv is strictly increasing.

We now show that v is concave. Cooley and Quadrini (2001), on pp 1306-1307, impose some restrictions on the (conditional) probability distribution of z', $\Gamma(dz'|z)$. Under these restrictions, to establish strict concavity of $V \circ \widetilde{w}$ with respect to (k, b) it is sufficient to show that $\int \widetilde{w}(z', k, b, h)\Gamma(dz'|z)$ is strictly concave with respect to (k, b). Because we adopt the same distributional assumption on z' as in Cooley and Quadrini (2001), in particular we assume that the conditional distribution of $\log(z')$ is Normal, the argument is valid also in our case.

This approach is required because $\widetilde{w}$ is not strictly concave. To see this, consider for simplicity the case $h > H$ (and so drop the dependence of h for brevity),[9] and for a given z let's choose two arbitrary points (k_1, b_1) and (k_2, b_2). Then, consider convex combinations $(k_\theta, b_\theta) = \theta(k_1, b_1) + (1 - \theta)(k_2, b_2)$ for arbitrary $\theta \in [0, 1]$. Let's define the function

$$\phi(z) = \widetilde{w}(z, k_\theta, b_\theta) - \theta\widetilde{w}(z, k_1, b_1) - (1 - \theta)\widetilde{w}(z, k_2, b_2).$$

Clearly, if $\widetilde{w}$ was concave with respect to (k, b) at z, it would be $\phi(z) \geq 0$ for all $\theta \in [0, 1]$. However, for low enough z, it can happen that $\phi(z) < 0$ for some θ. To show this, assume that $\widetilde{w}(z, k_1, b_1) = w_d(z)$, that $\widetilde{w}(z, k_2, b_2) = a(z, k_2) - b > w_d(z)$, and that for some θ, $\widetilde{w}(z, k_\theta, b_\theta) = w_d(z)$. Then, in this case

$$\phi(z) = (1 - \theta)\left[w_d(z) - a(z, k_2) + b\right] \leq 0.$$

This is the reason why Cooley and Quadrini (2001) assume that the probability distribution of z is such that liquidation, which is where $\widetilde{w}$ is locally convex, is an event occurring with sufficiently low probability, and that overall the function $\widetilde{w}$ is on average 'more convex than concave' with respect to (k, b).

We show that $\int \widetilde{w}(z', k, b, h)\Gamma(dz'|z)$ is strictly concave with respect to (k, b). From a

[9] The argument against concavity of $\widetilde{w}$ can be made also in the case $h \leq H$.

direct calculation, we have

$$\int \widetilde{w}(z', k, b, h)\Gamma(dz'|z) = \int_0^{z_d} w_d(z_d)\Gamma(dz'|z)$$
$$+ \int_{z_d}^{z_r} \left[w_d(z_d) + (z - z_d)k^\alpha + (b - b_r)\right]\Gamma(dz'|z) + \int_{z_r}^{\infty} \left[w_d(z_d) + (z - z_d)k^\alpha\right]\Gamma(dz'|z)$$
$$= (1-\delta)k - b + \mathbb{E}\left[z'|z\right]k^\alpha + k^\alpha \int_0^{z_d} (z_d - z')\Gamma(dz'|z) + \int_{z_d}^{z_r} (b - b_r)\Gamma(dz'|z).$$

The first part, $(1-\delta)k - b + \mathbb{E}\left[z'|z\right]k^\alpha$, is concave in (k, b). The second part, $k^\alpha \int_0^{z_d}(z_d - z')\Gamma(dz'|z)$, under the distributional assumptions, is not very sensitive to changes in (k, b), as in Lemma 1 in Cooley and Quadrini (2001). Finally, the third part, $\int_{z_d}^{z_r}(b - b_r)\Gamma(dz'|z)$, is not very sensitive to changes in (k, b) because b_r is continuous and the difference between b and b_r is not very sensitive to changes in (k, b). Therefore, as in Cooley and Quadrini (2001), the dominating part of $\int \widetilde{w}(z', k, b, h)\Gamma(dz'|z)$ is concave, which is what we need.

Given strict monotonicity and concavity of v, the correspondence of the optimal policy is single-valued (i.e., for each (z, w) there is only one (k', b') that maximizes (18)). Moreover, the policy function is the one characterized by Cooley and Quadrini (2001), with a lower threshold $e_{\min}$ below which the firm issues equity and an upper threshold $e_{\max}$ above which the firm pays out cash.

Finally, we can establish differentiability of V from differentiability of v, which is a consequence of Theorem 9.10 in Stokey and Lucas (1989), and the fact that the payoff function of problem (27) is differentiable for values of $e \neq w$, as at $e = w$ there is a kink.

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Fig. 1. Timeline of the model.

State is (k_t, b_t, h_t) from $t-1$.

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

Default decision: Owner decides between repayment, renegotiation, and liquidation, according to (6).

Payout decision:

- If debt is repaid: d_t is the solution of (7); $e_t = w_t - d_t$.
- If debt is successfully renegotiated: net worth is reset to $w_{rt} = a(x_t z_t, k_t) - b_{rt}$, with b_{rt} from (3); d_t is the solution of (7) at (x_t, z_t, w_{rt}); $e_t = w_{rt} - d_t$.
- If firm is liquidated, it is replaced by a new firm with $e_t = w_d$.

Investment/financing decision: Given e_t, the owner decides k_{t+1} and b_{t+1} according to (8), subject to the budget constraint in (9).

Hedging decision: Given $(x_t, z_t, k_{t+1}, b_{t+1})$, debt holders choose h_{t+1} by solving (14).

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

Fig. 2. Firm owner's default decision tree (for $b > 0$)

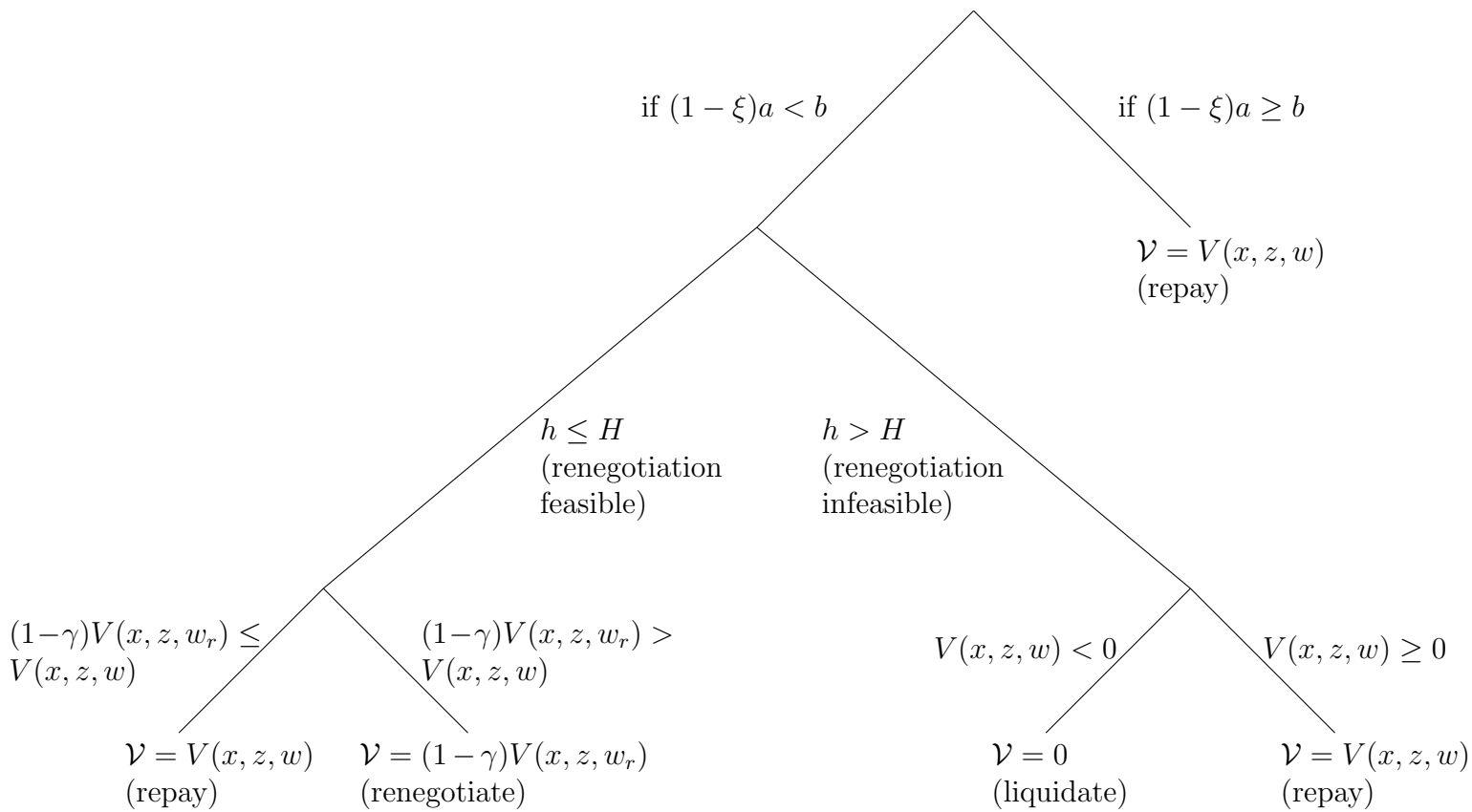

Fig. 3. Comparative statics with respect to the productivity shock z.

This figure is based on the solution of the model, using the base case parameters in Table 2, and shows different metrics against current productivity z for fixed values (k, b, h) of current capital, current debt, and current hedge ratio, respectively. Empty circles and diamonds denote the behavior of a financially healthy firm. Solid circles and diamonds indicate that the firm chooses to renegotiate its debt at this point. The plots show firm value $(v + m')$, equity value (v), hedge ratio (h'), book value of debt (b'), capital stock (k'), and quasi-market leverage $(b'/(b' + v))$.

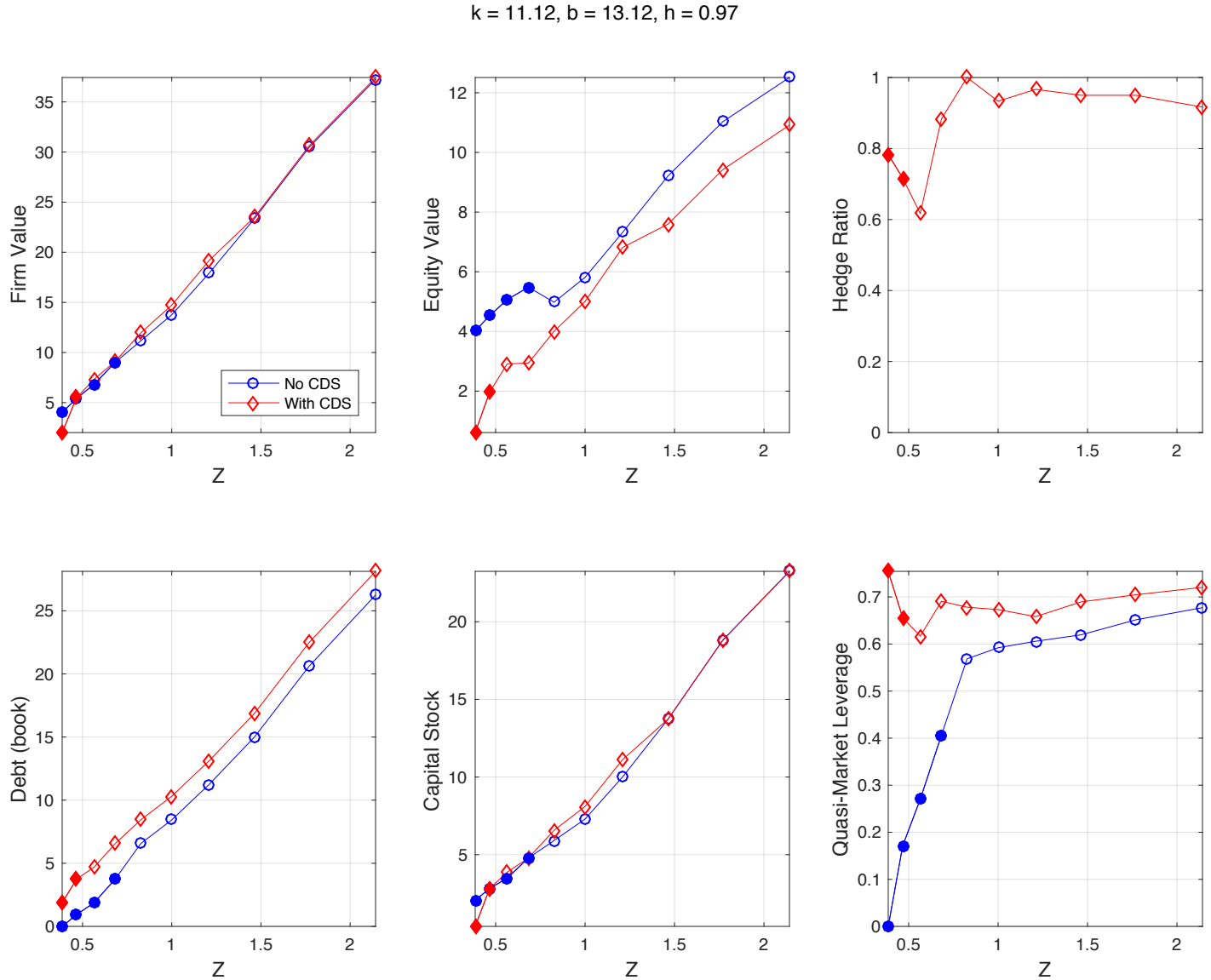

Fig. 4. Comparative statics with respect to the productivity shock z: Small firm, no debt.

This figure is based on the solution of the model, using the base case parameters in Table 2, and plots different metrics against current productivity z for fixed values (k, b, h) of current capital, current debt, and current hedge ratio, respectively. The plots show firm value $(v + m')$, equity value (v), hedge ratio (h'), book value of debt (b'), capital stock (k'), and quasi-market leverage $(b'/(b' + v))$.

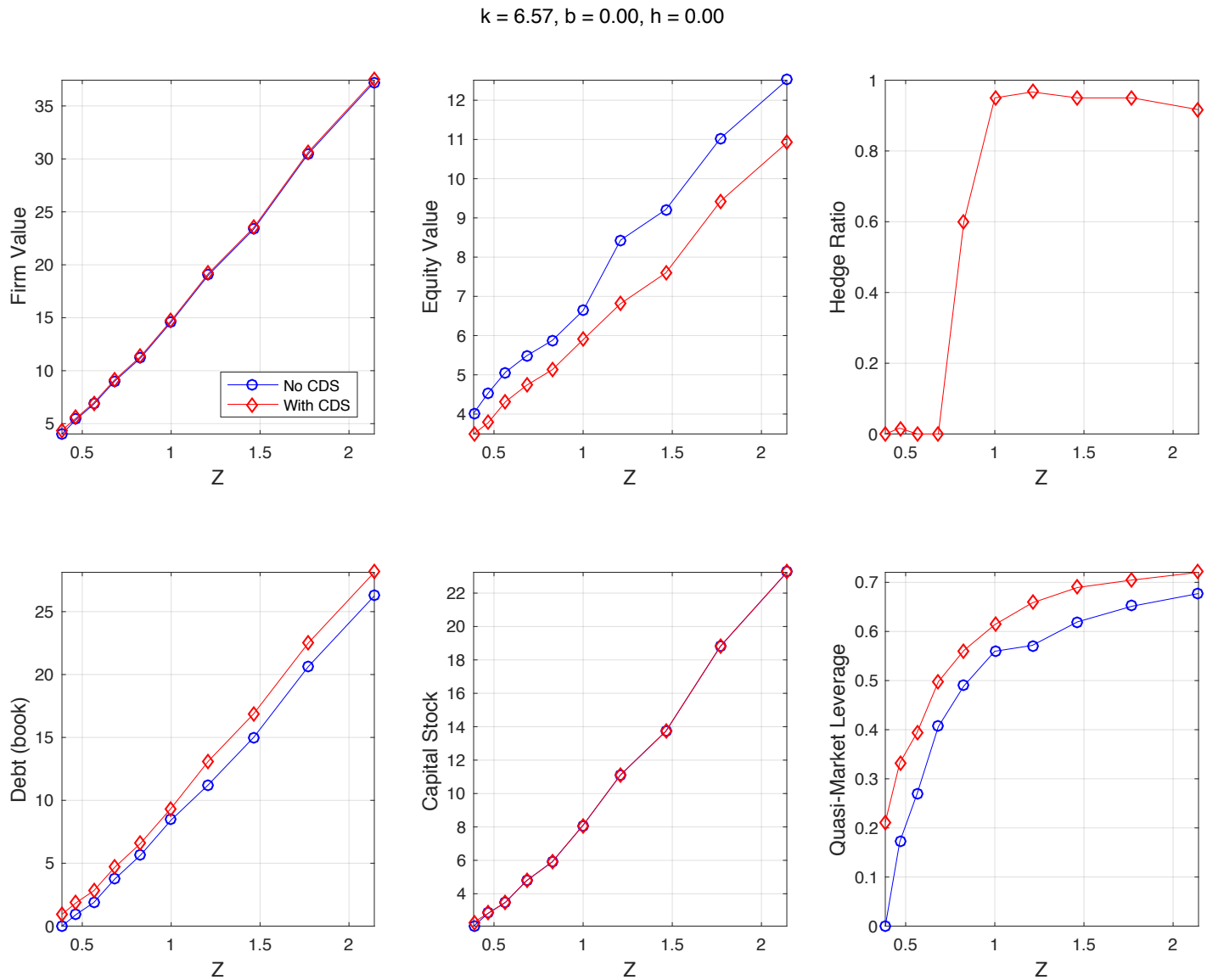

Fig. 5. Value effect for different values of the productivity shock z: Small firm, no debt.

This figure is based on the solution of the model using the base case parameters in Table 2. It shows the difference between firm value $(v + m')$ for a with-CDS firm and firm value for a no-CDS company, for different levels of current productivity z. The values of current capital, current debt, and the current hedge ratio, (k, b, h), are fixed.

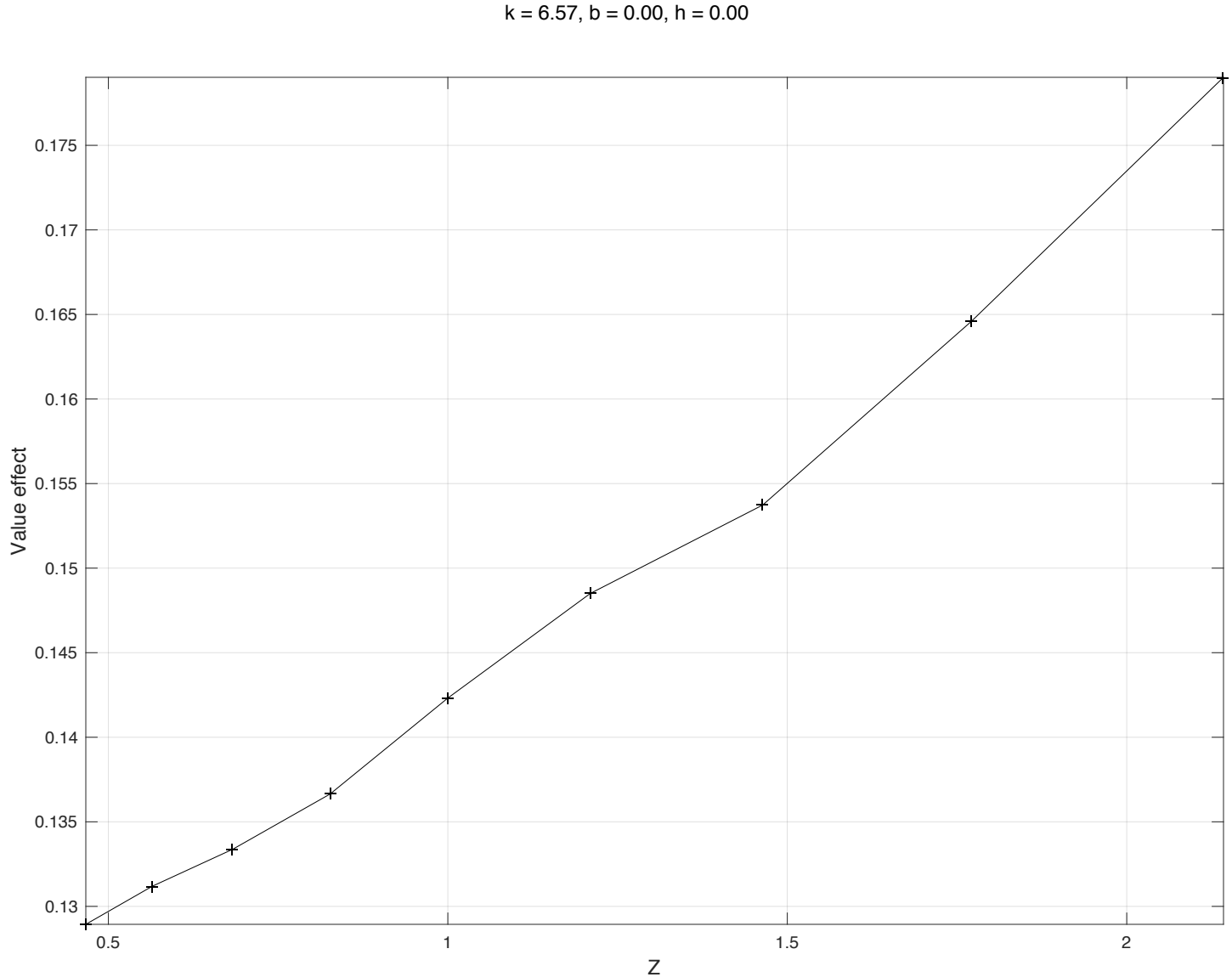

Fig. 6. Comparative statics with respect to the productivity shock z: Large firm, no debt.

This figure is based on the solution of the model, using the base case parameters in Table 2, and plots different metrics against current productivity z for fixed values (k, b, h) of current capital, current debt, and current hedge ratio, respectively. The plots show firm value $(v + m')$, equity value (v), hedge ratio (h'), book value of debt (b'), capital stock (k'), and quasi-market leverage $(b'/(b' + v))$.

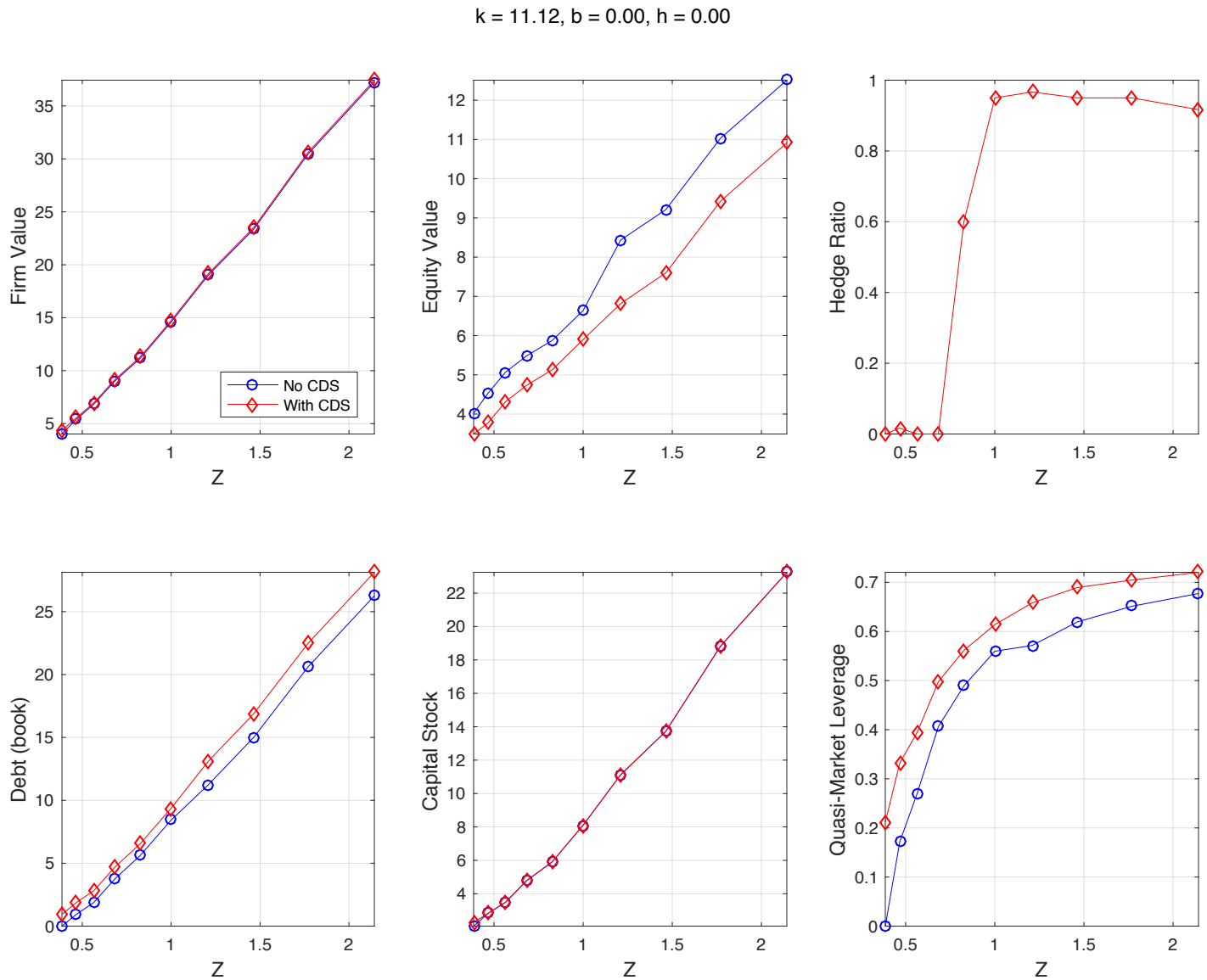

Fig. 7. Comparative statics with respect to the productivity shock z: Small firm, high debt.

This figure is based on the solution of the model, using the base case parameters in Table 2, and plots different metrics against current productivity z for fixed values (k, b, h) of current capital, current debt, and current hedge ratio, respectively. Empty circles and diamonds denote the behavior of a financially healthy firm. Solid circles and diamonds indicate that the firm chooses to renegotiate its debt at this point. The plots show firm value $(v + m')$, equity value (v), hedge ratio (h'), book value of debt (b'), capital stock (k'), and quasi-market leverage $(b'/(b' + v))$.

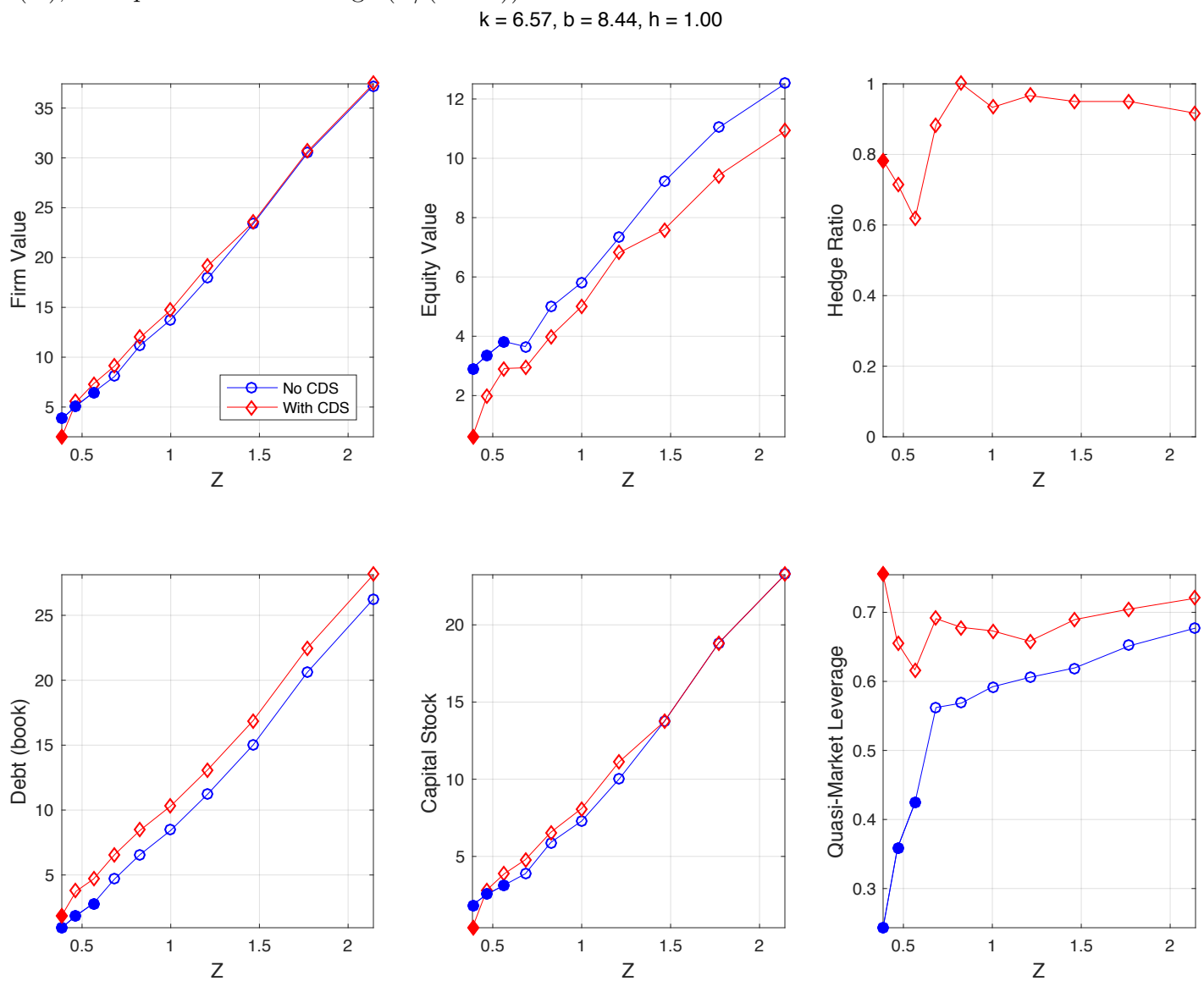

Fig. 8. Evolution of capital over time.

This figure is based on the solution of the model, using the base case parameters in Table 2, and shows the evolution of capital over time. The solid red line shows the economy with CDSs, while the dotted blue line shows the economy without CDSs. Plot (a) shows the evolution of capital after entry for the average firm, where the average is calculated over different simulated paths for z. The starting value of $\log z$ is -0.381, which is below the unconditional mean of $\log z$. Plot (b) shows the evolution of capital where the firms are selected in both economies (with and without CDSs) conditional on the same value of capital, and are observed over the next periods. As before, the lines represent averages over different simulated paths for z.

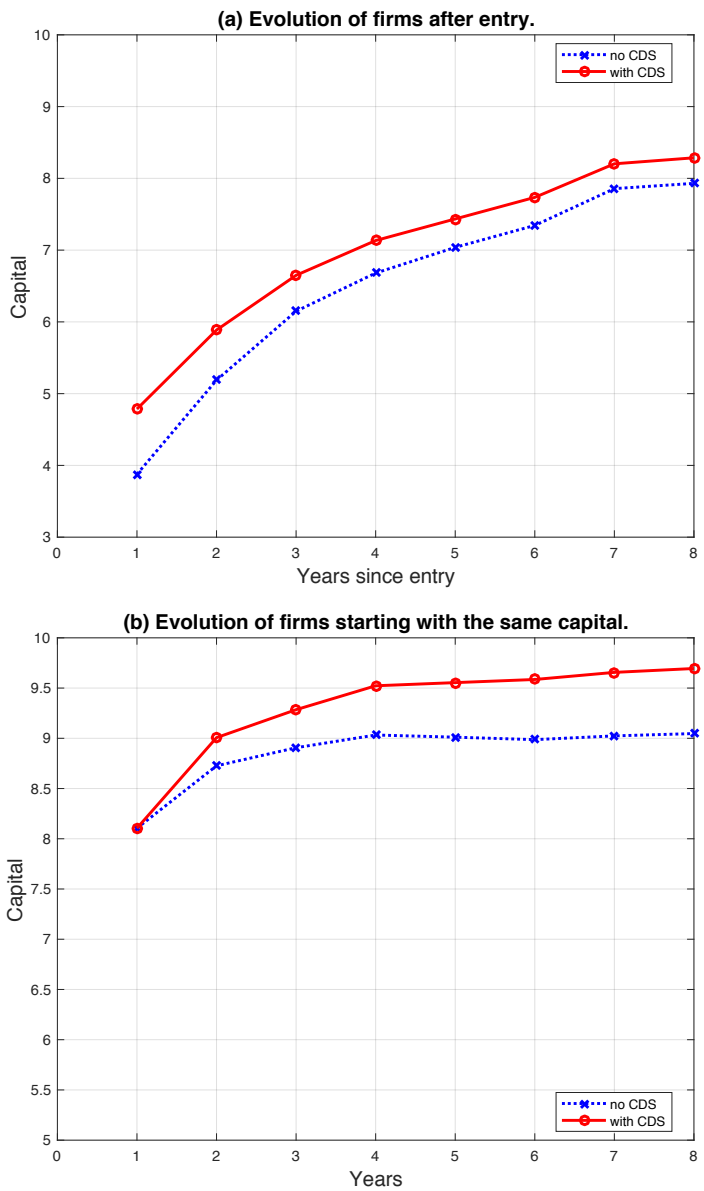

Table 1: **Summary Statistics for a Sample of U.S. Corporations.** The sample is constructed by merging the annual Compustat data with CRSP data, using the sample period 1994–2013. The variables are the investment rate (the difference between CAPX and the sale of PPE divided by lagged gross PPE), operating 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

Symbol	Economic interpretation	Value
β	Time discount factor for equity holders	0.9434
r	Risk-free rate	0.05
ρ	Persistence of productivity shock	0.75
σ	Conditional volatility of productivity shock	0.21
$\Psi(x_0\|x_1)$	Conditional probability of absorbing shock	0.01
α	Return to scale	0.475
f	Fixed production cost	1.14
δ	Annual depreciation rate	0.1
λ	Flotation cost for equity	0.0563
ξ	Proportional liquidation costs	0.42
γ	Probability of renegotiation failure	0.63
q	Bargaining power of debt holders	0.35

Table 2: **Base Case Parameter Values**. This table provides the base case parameters used in the simulations.

Table 3: **Economy with and without CDSs: Simulated Moments of Key Metrics.** This table provides unconditional sample moments for the following variables: firm value ($v + m'$); assets (k); book value of current debt (b); market value of new debt (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) and unconditional percentiles based on simulation using the base parameters shown in Table 2. All moments are reported on an annual basis.

	No CDS					With CDS					
	Mean	SD	25th	Median	75th	Mean	SD	25th	Median	75th	Value Effect
Firm Value	15.63	6.90	11.10	14.50	19.07	16.08	6.74	11.82	14.72	19.27	2.92%
Assets	8.83	4.52	5.86	8.02	11.12	9.14	4.35	6.45	8.10	11.18	
Current Debt (book)	9.55	4.88	6.50	8.44	11.40	11.32	5.08	8.29	10.31	13.22	
New Debt (market)	9.01	4.60	6.13	7.95	10.75	10.67	4.79	7.81	9.71	12.47	
Equity	6.62	2.37	4.96	6.55	8.40	5.41	2.00	3.99	5.01	6.82	
Hedge Ratio	0.00	0.00	0.00	0.00	0.00	0.93	0.08	0.93	0.95	0.97	
Investment/Assets	0.17	0.39	-0.15	0.10	0.45	0.16	0.35	-0.13	0.10	0.38	
EBITDA/Assets	0.18	0.11	0.12	0.19	0.26	0.18	0.11	0.13	0.19	0.25	
Payouts/Assets	0.02	0.12	-0.03	0.03	0.06	0.02	0.13	-0.05	0.02	0.07	
Q–Ratio	1.83	0.13	1.71	1.81	1.89	1.80	0.09	1.73	1.82	1.83	
Market Leverage	0.58	0.03	0.56	0.57	0.60	0.67	0.02	0.66	0.67	0.69	
Chg. Debt/Assets	0.07	0.42	-0.25	0.00	0.33	0.06	0.40	-0.25	0.00	0.32	
Credit Spread (bps)	109.30	5.66	106.26	106.96	108.40	109.76	6.53	106.28	107.74	109.14	
Renegotiation (pct)	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	
Liquidation (pct)	1.01	0.00	0.00	0.00	0.00	1.03	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: **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 2, along with the deviations from the base case parameters, changing only the parameter in the first column.

	No CDS			With CDS				
	Mean	Median	SD	Mean	Median	SD	p-Value	Value Effect
Base case	15.63	14.50	6.90	16.08	14.72	6.74	0.00	2.92%
$q = 0.3$	15.65	14.55	6.89	16.08	14.72	6.74	0.00	2.76%
$q = 0.4$	15.85	14.59	6.84	16.08	14.72	6.74	0.00	1.45%
$\xi = 0.38$	15.76	14.58	6.93	16.09	14.72	6.74	0.00	2.09%
$\xi = 0.46$	15.47	14.07	6.99	16.08	14.72	6.74	0.00	3.99%
$\gamma = 0.58$	15.71	14.55	6.90	16.08	14.72	6.75	0.00	2.37%
$\gamma = 0.68$	15.87	14.60	6.82	16.09	14.72	6.74	0.00	1.40%
$\lambda = 0.05$	15.63	14.50	6.92	16.10	14.76	6.74	0.00	3.02%
$\lambda = 0.06$	15.50	14.34	6.98	16.05	14.70	6.76	0.00	3.55%
$\beta = 0.945$	16.02	14.79	6.84	16.21	14.88	6.76	0.00	1.19%
$\beta = 0.942$	15.45	14.37	6.89	15.80	14.55	6.79	0.00	2.27%
$r = 0.045$	17.91	16.80	7.04	18.25	17.03	7.00	0.00	1.90%
$r = 0.055$	14.23	13.00	6.45	14.29	12.77	6.49	0.00	0.42%
$\rho = 0.73$	15.32	14.37	6.16	15.48	13.70	6.21	0.00	1.01%
$\rho = 0.77$	16.18	14.84	7.72	16.44	14.99	7.64	0.00	1.60%
$\sigma = 0.18$	14.40	13.75	5.68	14.66	13.89	5.61	0.00	1.78%
$\sigma = 0.24$	17.29	15.57	8.19	17.42	15.74	8.30	0.00	0.79%
$\alpha = 0.45$	11.68	10.26	5.63	11.88	10.75	5.55	0.00	1.73%
$\alpha = 0.5$	21.08	19.51	8.55	21.45	19.75	8.40	0.00	1.75%
$f = 1$	18.00	16.78	6.78	18.09	17.02	6.93	0.00	0.54%
$f = 1.3$	12.90	11.34	7.08	13.40	11.39	6.81	0.00	3.84%
$\delta = 0.09$	18.31	17.04	7.61	18.61	17.25	7.71	0.00	1.67%
$\delta = 0.11$	13.51	12.54	5.98	13.69	12.65	6.27	0.00	1.37%

Table 5: **Small Firms.** In the simulated economy, we perform a 4×3 double sort on k and z, and select observations in the second bin for k and the second bin for z. This table provides sample moments for the following variables: firm value $(v+m')$; assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	12.71	11.17	1.62	31426	13.22	11.96	1.38	21368	0.00	4.00%
Assets	6.34	5.91	0.64	31426	6.57	6.57	0.00	21368	0.00	
Current Debt (book)	7.11	6.56	0.83	31426	8.46	8.44	0.13	21368	0.00	
New Debt (market)	7.04	6.19	0.91	31426	8.75	7.95	0.88	21368	0.00	
Equity	5.67	5.27	0.74	31426	4.47	4.00	0.51	21368	0.00	
Hedge Ratio	0.00	0.00	0.00	31426	0.97	1.00	0.03	21368	0.00	
Investment/Assets	0.19	0.10	0.20	31122	0.21	0.10	0.12	21150	0.00	
EBITDA/Assets	0.17	0.13	0.03	31122	0.16	0.13	0.03	21150	0.00	
Payouts/Assets	-0.03	-0.03	0.03	31122	0.00	-0.04	0.05	21150	0.00	
Q-Ratio	1.86	1.89	0.05	31426	1.82	1.82	0.01	21368	0.00	
Market Leverage	0.57	0.57	0.01	31426	0.68	0.68	0.01	21368	0.00	
Chg. Debt/Assets	0.07	0.00	0.19	31122	0.13	0.00	0.14	21150	0.00	
Credit Spread (bps)	107.55	107.74	1.21	31426	108.62	108.22	0.50	21368	0.00	
Renegotiation (pct)	0.00			31426	0.00			21368		
Liquidation (pct)	0.97			31426	1.02			21368		

Table 6: **Large Firms.** In the simulated economy, we perform a 4×3 double sort on k and z, and select observations in the third bin for k and the second bin for z. This table provides sample moments for the following variables: firm value $(v+m')$; assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	13.27	14.59	1.70	24233	13.62	14.73	1.38	29680	0.00	2.67%
Assets	8.53	8.11	0.79	24233	8.29	8.11	0.56	29680	0.00	
Current Debt (book)	8.87	8.44	0.81	24233	10.43	10.31	0.63	29680	0.00	
New Debt (market)	7.24	7.96	0.94	24233	8.96	9.72	0.89	29680	0.00	
Equity	6.02	6.64	0.78	24233	4.66	5.01	0.54	29680	0.00	
Hedge Ratio	0.00	0.00	0.00	24233	0.96	0.93	0.03	29680	0.00	
Investment/Assets	-0.04	-0.09	0.15	23991	0.01	0.10	0.11	29398	0.00	
EBITDA/Assets	0.17	0.18	0.03	23991	0.17	0.19	0.03	29398	0.48	
Payouts/Assets	0.03	0.03	0.01	23991	-0.01	0.02	0.04	29398	0.00	
Q-Ratio	1.84	1.80	0.06	24233	1.82	1.82	0.02	29680	0.00	
Market Leverage	0.56	0.56	0.01	24233	0.67	0.67	0.01	29680	0.00	
Chg. Debt/Assets	-0.13	-0.19	0.14	23991	-0.11	0.00	0.12	29398	0.00	
Credit Spread (bps)	106.80	106.16	0.84	24233	108.63	109.14	0.73	29680	0.00	
Renegotiation (pct)	0.00			24233	0.00			29680		
Liquidation (pct)	1.00			24233	0.95			29680		

Table 7: **Low Payout Ratio.** In the simulated economy, we select observations with a payout ratio in the bottom tercile group. This table provides sample moments for the following variables: firm value ($v+m'$); assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	9.86	11.17	2.81	65825	10.27	11.96	2.41	65703	0.00	4.24%
Assets	5.45	5.91	1.97	65763	6.62	6.57	2.66	66877	0.00	
Current Debt (book)	6.12	6.56	2.11	65763	8.50	8.44	3.17	66877	0.00	
New Debt (market)	5.37	6.19	1.59	65825	6.77	7.95	1.68	65703	0.00	
Equity	4.49	4.98	1.22	65825	3.50	4.00	0.77	65703	0.00	
Hedge Ratio	0.00	0.00	0.00	65825	0.89	0.93	0.14	65703	0.00	
Investment/Assets	0.11	0.10	0.35	65825	0.00	-0.09	0.27	65703	0.00	
EBITDA/Assets	0.08	0.11	0.09	65825	0.08	0.13	0.08	65703	0.73	
Payouts/Assets	-0.10	-0.04	0.09	65825	-0.12	-0.07	0.10	65703	0.00	
Q-Ratio	1.94	1.89	0.10	65825	1.86	1.82	0.05	65703	0.00	
Market Leverage	0.56	0.56	0.02	65825	0.67	0.68	0.03	65703	0.00	
Chg. Debt/Assets	-0.01	0.00	0.36	65825	-0.13	-0.23	0.31	65703	0.00	
Credit Spread (bps)	111.72	107.74	7.75	65825	113.26	108.22	9.22	65703	0.00	
Renegotiation (pct)	0.08			65825	0.03			65703		
Liquidation (pct)	0.00			65825	0.00			65703		

Table 8: **High Payout Ratio.** In the simulated economy, we select observations with a payout ratio in the top tercile group. This table provides sample moments for the following variables: firm value ($v+m'$); assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	22.71	23.35	6.21	67506	22.44	23.51	6.50	68187	0.00	-1.22%
Assets	11.67	11.12	4.66	67427	11.13	11.12	4.78	68118	0.00	
Current Debt (book)	12.47	11.25	5.18	67427	13.58	13.12	5.59	68118	0.00	
New Debt (market)	13.67	14.14	4.56	67506	15.12	15.91	4.90	68187	0.00	
Equity	9.04	9.21	1.70	67506	7.32	7.60	1.63	68187	0.00	
Hedge Ratio	0.00	0.00	0.00	67506	0.95	0.95	0.01	68187	0.00	
Investment/Assets	0.35	0.33	0.41	67506	0.38	0.33	0.36	68187	0.00	
EBITDA/Assets	0.29	0.27	0.07	67506	0.28	0.28	0.07	68187	0.00	
Payouts/Assets	0.13	0.08	0.09	67506	0.14	0.08	0.09	68187	0.00	
Q-Ratio	1.70	1.70	0.06	67506	1.72	1.71	0.06	68187	0.00	
Market Leverage	0.61	0.62	0.03	67506	0.68	0.69	0.02	68187	0.00	
Chg. Debt/Assets	0.28	0.30	0.44	67506	0.33	0.29	0.41	68187	0.00	
Credit Spread (bps)	107.27	106.69	1.71	67506	106.91	106.60	1.11	68187	0.00	
Renegotiation (pct)	0.00			67506	0.00			68187		
Liquidation (pct)	0.00			67506	0.00			68187		

Table 9: **Low Productivity.** In the simulated economy, we perform a 3×4 double sort on k and z, and select observations in the second bin for k and the second bin for z. This table provides sample moments for the following variables: firm value $(v + m')$; assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	11.15	11.17	0.10	23432	11.93	11.96	0.13	23178	0.00	7.00%
Assets	6.86	5.91	0.99	23432	7.40	8.11	0.90	23178	0.00	
Current Debt (book)	7.47	6.56	0.92	23432	9.41	9.38	1.04	23178	0.00	
New Debt (market)	6.16	6.19	0.15	23432	7.92	7.95	0.18	23178	0.00	
Equity	4.99	4.98	0.05	23432	4.01	4.00	0.05	23178	0.00	
Hedge Ratio	0.00	0.00	0.00	23432	0.99	1.00	0.02	23178	0.00	
Investment/Assets	-0.02	-0.09	0.13	23228	-0.00	-0.09	0.11	22974	0.00	
EBITDA/Assets	0.13	0.13	0.00	23228	0.13	0.13	0.00	22974	0.00	
Payouts/Assets	-0.02	-0.03	0.04	23228	-0.05	-0.04	0.02	22974	0.00	
Q-Ratio	1.89	1.89	0.02	23432	1.83	1.82	0.02	23178	0.00	
Market Leverage	0.57	0.57	0.01	23432	0.68	0.68	0.01	23178	0.00	
Chg. Debt/Assets	-0.12	-0.23	0.12	23228	-0.12	-0.23	0.12	22974	0.17	
Credit Spread (bps)	107.74	107.74	0.01	23432	108.19	108.22	0.15	23178	0.00	
Renegotiation (pct)	0.00			23432	0.00			23178		
Liquidation (pct)	0.87			23432	0.88			23178		

Table 10: **High Productivity.** In the simulated economy, we perform a 3×4 double sort on k and z, and select observations in the second bin for k and the third bin for z. This table provides sample moments for the following variables: firm value $(v + m')$; assets (k); book value of current debt (b); market value of new debt (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	Value Effect
Firm Value	14.43	14.59	0.33	26780	14.72	14.73	0.07	27870	0.00	2.03%
Assets	7.12	7.29	0.98	26780	7.70	8.11	0.97	27870	0.00	
Current Debt (book)	7.72	8.44	0.90	26780	9.77	10.31	1.10	27870	0.00	
New Debt (market)	7.95	7.96	0.00	26780	9.67	9.72	0.20	27870	0.00	
Equity	6.48	6.64	0.33	26780	5.05	5.01	0.20	27870	0.00	
Hedge Ratio	0.00	0.00	0.00	26780	0.93	0.93	0.00	27870	0.00	
Investment/Assets	0.24	0.10	0.18	26496	0.17	0.10	0.13	27574	0.00	
EBITDA/Assets	0.20	0.20	0.00	26496	0.19	0.19	0.00	27574	0.00	
Payouts/Assets	0.01	0.03	0.03	26496	0.03	0.02	0.02	27574	0.00	
Q-Ratio	1.82	1.80	0.03	26780	1.82	1.82	0.01	27870	0.31	
Market Leverage	0.57	0.56	0.01	26780	0.67	0.67	0.01	27870	0.00	
Chg. Debt/Assets	0.12	0.00	0.15	26496	0.08	0.00	0.15	27574	0.00	
Credit Spread (bps)	106.87	106.16	1.43	26780	108.99	109.14	0.66	27870	0.00	
Renegotiation (pct)	0.00			26780	0.00			27870		
Liquidation (pct)	1.06			26780	1.06			27870		

Table 11: **Simulated regressions for the determinants of the hedge ratio.** This table presents simulated regression results for the determinants of the bondholders' hedge ratio. The dependent variable is the hedge ratio h. The independent variables are *Market leverage* $(b'/(b'+v))$ and *Q–Ratio* $((v+b')/k')$. The numerical procedure to solve the model and to simulate data is described in Appendix A. We simulate 2,000 firms over 1,000 periods and only keep firms after they enter the economy following the exit of another firm. The numbers in parentheses denote standard errors.

	(1)	(2)
Constant	0.621	1.446
	(0.01)	(0.01)
Market leverage	0.457	
	(0.02)	
Q–Ratio		-0.288
		(0.01)
Obs.	85881	85881
Adj. R^2	0.021	0.096

Table 12: **Summary statistics for the DTCC sample.** This sample is created by merging firms in the DTCC database with firms in our Compustat/CRSP sample in Table 1. The main variable is *NetNotional/Debt*, a proxy for the hedge ratio, defined as the net notional amount of CDS contracts outstanding for firm i in year t, divided by the sum of debt in current liabilities and long-term debt. The other variables are *Market leverage* (total liabilities divided by the sum of total liabilities and the market value of equity), *Q–Ratio* (the sum of market equity, debt in current liabilities, and long-term debt, divided by total assets), *Non-fixed assets* (1 - net PPE / total assets), and *Size* (log of total assets). The sample period starts in 2008, which is when the DTCC started publishing the amount of CDSs outstanding, and ends in 2013, as in the body of the paper. *NetNotional/Debt*, *Q–Ratio*, and *Size* are winsorized at the 1% and the 99% levels. *Market leverage* and *Non-fixed assets* are truncated at zero and one. The variables *NetNotional* and *Debt* are measured in USD millions.

	Mean	SD	Min.	25th Perc.	Median	75th Perc.	Max.	Observations
NetNotional/Debt	0.2826	0.3996	0.0083	0.0618	0.1399	0.3319	2.6538	1,481
NetNotional	925	834	48	408	716	1,151	7,916	1,481
Debt	16,976	66,276	210	2,038	4,441	10,077	763,230	1,481
Market leverage	0.5484	0.2081	0.0721	0.3762	0.5366	0.6946	0.9947	1,481
Q–Ratio	1.0370	0.5605	0.0977	0.6973	0.8970	1.2551	3.2648	1,481
Non-fixed assets	0.6799	0.2486	0.1012	0.4545	0.7322	0.9008	1.0000	1,481
Size	9.7549	1.3068	7.2484	8.8648	9.6543	10.5353	14.0863	1,481

Table 13: **Empirical determinants of the hedge ratio.** This table presents regression results for the determinants of the bondholders' aggregate hedge ratio. The dependent variable is *Net-Notional/Debt*, a proxy for the hedge ratio, defined as the net notional amount of CDS contracts outstanding for firm i in year t, divided by the sum of debt in current liabilities and long-term debt. The independent variables are *Market leverage* (total liabilities divided by the sum of total liabilities and the market value of equity), *Q–Ratio* (the sum of market equity, debt in current liabilities, and long-term debt, divided by total assets), *Non-fixed assets* (1 - net PPE / total assets), and *Size* (log of total assets). The sample period starts in 2008, which is when the DTCC started publishing the amount of CDSs outstanding, and ends in 2013, as in the body of the paper. The numbers in parentheses denote standard errors. Statistical significance at the 10%, 5%, and 1% level is denoted by *, **, and ***, respectively.

	(1)	(2)	(3)
Constant	1.759***	1.997***	1.633***
	(0.069)	(0.070)	(0.067)
Market leverage	0.153***		
	(0.043)		
Q–Ratio		−0.109***	
		(0.016)	
Non-fixed assets			0.359***
			(0.035)
Size	−0.160***	−0.164***	−0.163***
	(0.007)	(0.007)	(0.007)
Adj. R^2	0.27	0.29	0.32
Obs.	1481	1481	1481