The Agency Credit Spread

Abstract

Lack of shareholders' commitment about debt and investment policies, although mitigated by debt covenants, maturity, and other contractual provisions, contributes a significant part of the firm's cost of debt, which we refer to as the agency credit spread (ACS). We propose a dynamic model of investment and financing, in which we characterize the debt protection against agency distortions as a reduced form specification of the value function. The model features long-term debt and allows for several possible distortions of the optimal policy, including debt claim dilution, underinvestment, and asset stripping. After structural estimating the parameters of the model, we are able to measure the agency credit spread at about 39% of the average credit spread in the sample. We show that the shareholders' incentive to deviate from debt policies aimed at maximizing the value of the firm, the "leverage ratchet effect," is at least as important as underinvestment, the "debt overhang effect," in transferring wealth from debt to equity.

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How large is the effect of misalignment of the incentives of debt and equity on the cost of debt? A large body of literature explores the economics of those particular agency conflicts and formalizes strong qualitative predictions: the lack of commitment of equity holders to implement policies that maximize firm (i.e., equity plus debt) value results in a wealth transfer from debt to equity, thus reducing the value of debt and increasing the credit spread.

Most of the literature has focused on the impact of debt overhang on investment decisions. Recently, Admati, DeMarzo, Hellwig, and Pfleiderer (2017) and DeMarzo and He (2017) also propose a qualitative discussion of the incentive of equity holders to issue more debt whenever it suits them, and to resist a debt reduction even when it would be optimal from the firm value perspective. These authors dubbed the new agency conflict *leverage ratchet effect*, which is a form of debt overhang on the debt policy itself.

Fully capturing the quantitative implications of all conflicts of interest between equity and debt holders, thus including under investment and the leverage ratchet effect, is difficult. The complication arises from the need to build a model that produces endogenous deviations from firm value maximizing decisions of investment and debt policies, which can feedback on each other. We fill the gap in this paper.

We propose a neoclassical model of the firm with dynamic investment and long-term debt. The debt policy is dynamic and a crucial assumption of our model is that, when debt is increased or reduced, equity holders are *not* forced to repurchase all existing debt. Also, we assume that incremental debt is issued under a *pari passu* convention (i.e., new securities have the same seniority - and price - as existing ones). These two assumptions generate the leverage ratchet effect in our model. We analyze how leverage policy distortions influence investment decisions made by self-interested equity holders. Although the model is parsimonious, it generates several types of known agency conflicts, like underinvestment, debt claim dilution, and asset stripping (to follow the classification suggested by Smith and Warner, 1979).

We study the wealth transfer from debt to equity caused by future deviations from firm value optimizing policies. Ex ante, this transfer generates a discount on the value of debt that the firm can issue, ultimately reducing the value of equity and of the firm. We show that agency conflicts contribute a significant part of a firm's cost of debt, which we refer to as the *agency credit spread*.

The notion of agency credit spread can be introduced with a simple example. Assume that an un-levered firm has two compound options: an option to invest and an option to change (expand or reduce) the initial investment. The capital expenditures at both exercise dates are financed by issuing a blend of internal funds, equity and unsecured *long-term* debt (i.e., it matures after the follow-on option is exercised). Hence, there are two possible debt issuances: each has no covenants, the same priority at default, and are fairly priced at the time of the issuance. Because when the first debt is issued the firm is un-levered, the investment and capital structure decisions maximize both equity and total firm value. On the contrary, when the second option is exercised, the new capital structure and investment decisions maximize only the value of the shareholders' claim, as the equity holders cannot commit to maximize the value of the firm. The existing bondholders might be affected in two ways: the exercise of the option may lead to either underinvestment (or asset stripping), or it may lead to the issuance of new debt with equal priority on the liquidation value of the firm (i.e., claim dilution). Both lead to a decrease in the value of existing debt. Because, at the date of the first issuance, investors anticipate the deviations from the value maximizing decisions that will occur in the future, the credit spread will be higher than it would otherwise be absent the agency conflicts, for the same amount of issued debt, and the difference is the agency credit spread.[1]

We extend the idea illustrated above to a quantitative infinite-horizon discrete-time partial equilibrium model, in which a firm is faced by both idiosyncratic and systematic productivity shocks. Dynamic investment and capital structure decisions expose the firm to real and financing frictions, and debt decisions can be unrelated to investment decisions. The debt contract used by the firm is a redeemable infinite-maturity callable bond with no protective covenants, on which the shareholders can default. The price of such bond is determined using a stochastic discount factor that captures time and state-dependent counter-cyclical risk premia, while maintaining a constant risk-free rate (Jones and Tuzel, 2013). We derive the equilibrium value of equity and debt by finding the fixed-point of a Bellman operator that solves simultaneously the equity and debt valuation equations.

The purpose of our quantitative model is to capture the debt-equity agency conflicts present in the data, and to assess the extent to which they affect the observed corporate credit spreads. The main challenge in this undertaking is that empirically observed debt contracts have different types of protective covenants and other priority provisions, which reduce the incidence of such agency conflicts. Simultaneously including all these contractual provisions would make the model intractable. Considering only some of them would bias our conclusions.

[1]It is important to note that, at the initial date, with full shareholders' commitment the firm would issue more debt (because the cost is lower) than it does with agency conflicts. Therefore, it only makes sense to think of the agency credit spread in relation to the debt issued by the firm without commitment.

We address this problem in our model, which features pari passu debt with infinite-maturity and no covenants, by assuming that protection against agency distortions is achieved by shareholders offering to hold part of the debt, as opposed to offering debt contracts endowed with specific covenants. Indeed, by offering to hold the proper amount of debt, shareholders can achieve the same effect as with any particular debt covenant. Interestingly, although they probably arise for different reasons, dual holdings are present in the data and Jiang, Li, and Shao (2010) use them as a way to measure the reduction of debt-equity agency conflicts. This approach has a simple economic intuition: if in the model equity holders owned the entire debt, there would be no debt-equity conflict, and the policies maximize the value of the firm. On the other hand, because the debt in the model is infinite horizon and unprotected, zero dual holdings would allow the highest degree of agency conflicts and polices maximize only the value of equity.

In particular, we specify the value function of the firm as the sum of equity and a fraction $1-\eta$ of debt, for $0 \leq \eta \leq 1$. In the extreme case with $\eta = 0$, all debt is owned by the shareholders, who for this reason pursue firm value maximization. If $\eta = 1$ there is no dual holding, which leads to equity maximization. In all the intermediate cases of partial dual holdings, debt protection is imperfect, giving rise to more agency distortions the higher η, everything else equal. Therefore, the parameter η is inversely related to the protection against agency conflicts.

The parameter η can be conceptualized as proportional to the protection delivered by a hypothetical debt covenant, whereby $\eta = 1$ corresponds to the covenant being ineffective and $\eta = 0$ to the case of a *perfect covenant*, in the sense it achieves the (constrained) first best by avoiding any distortions of firm policies caused by lack of commitment. In fact, because less dual ownership of debt is necessary to deliver the same protection against agency issues, when we explicitly introduce an imperfect covenant in the model, we obtain a calibrated value of η that is higher.

Another way to mitigate debt-equity agency conflicts is to shorten the maturity of the debt contract. The choice of modeling infinite maturity debt with dual holdings, as opposed to finite average maturity (with or without covenants) is dictated by technical reasons. We calculate the equilibrium price of debt and equity simultaneously in the context of a recursive infinite-horizon problem. In this context, the consideration of a debt contract with finite average maturity presents numerical challenges that would render most of the methods used in the paper impractical.[2] Therefore, in our baseline model we adopt an unprotected

[2] A model with multi-period debt cannot be solved using the numerical approach introduced by Cooley and Quadrini (2001) and extended by Moyen (2007), Hennessy and Whited (2007), and Gomes and Schmid

infinite maturity contract, and introduce the parameter η to gauge protection against agency conflicts. We discuss the implications of introducing specific protections in the alternative specifications reported in the robustness section.

We estimate the parameters of the model by simulated method of moments using a large set of investment, leverage, and pricing moments obtained from a sample of large firms (i.e., that belong to the S&P 500 index) for which we can observe CDS prices. In particular, differently from many other studies that investigate credit risk, we focus our attention on credit spreads and observed default frequencies at very long horizon (i.e., 15 years), thus allowing us to conform the simulated economy in which debt has infinite maturity to the empirical data.

The parameters obtained from the basic estimation produce a simulated economy that compares well to the empirically observed data. In particular, the model generates credit spreads that are adequate to the amount of default risk observed in the real economy. As for the parameter gauging protection against agency conflicts, η, our estimation exercise delivers a value of 0.73 (i.e., a figurative dual holding of 27% of debt by shareholders), indicating that a relatively low degree of protection is necessary for the model to produce a representative economy.

Critical to our study is that η is well identified by the data and that the model is properly specified. In particular, the parameter is identified by the payout policy of the firm, which is inversely related to the protection against debt-equity conflicts. For instance, if a firm foregoes a positive NPV investment and does not invest cash that is currently available, it reduces the continuation value and increases the cash available to all stakeholders next period. Equity holders take advantage of underinvestment by paying out the cash as dividend, to the extent that this is allowed by the current protection of the debt, while the reduction in continuation value reduces the value of the debt holders' claim. Therefore in the model, given the state of the firm, equity payouts are lower when the protection against agency conflicts (i.e., the dual holdings of debt) is stronger, thus providing our basic identification strategy. We confirm the validity of our choice by computing the sensitivity measure proposed by Gentzkow and Shapiro (2017). We find that η is mostly sensitive (and positively related) to the average payout, and less so to other quantities.

(2010). On the other hand, multi-period debt with finite average maturity presents severe numerical challenges, as convergence of the algorithm can not always be achieved. Lack of convergence manifests itself also with infinite maturity debt, although to a much lesser extent. A technical discussion on the subject can be found in the sovereign debt literature; see for example Chatterjee and Eyigungor (2012).

We conduct several checks to validate the model and our estimation procedure. First, we confirm that the interpretation and estimation of η is proper by considering a variant of the model that allows explicitly for debt covenants. As described above, by including a protective –although imperfect– covenant in the model, the estimate of η is higher, because a reduced dual holding of debt is necessary in the model to replicate the level of protection against agency distortions in the data.

Second, we repeat the estimation of the basic model for two extreme groups of firms sorted with respect to asset maturity (i.e., highest vs. lowest asset maturity). The causal relationship between asset maturity and debt maturity is understood to be unidirectional: firm choose first the appropriate productive asset maturity for their business, determined by the nature of the activity, and then they set the maturity of the debt. Firms tend to match the maturity of debt to the maturity of assets and so the sorting based on asset maturity offers a sufficient endogenous variation on debt maturity. Because in our model (with infinite maturity debt) the protection against agency distortions is delivered by dual holdings of debt and equity, a lower protection is required for the sample of firms with shorter maturity of asset. We find a positive relation between the average asset maturity and the estimated dual holdings (i.e., the estimates for η are higher for low asset maturity), which confirms the validity of the interpretation of η and our choice of moments used in the SMM estimation.

Next, we quantify the agency credit spread in the simulated economy. The calculation of the agency spread can not be directly obtained from the model, but requires an approach that isolates the effects on today's debt price of *future* agency deviations from value maximization, given the estimated level of protection of debt from agency conflicts, $\hat{\eta} = 0.73$. Because the calculation requires that we control for the current policy of the firm, the agency spread is determined using a numerical approximation. We find that the average agency credit spread in the simulated economy is 88bps, or approximately 39% of the average credit spread. We study the agency spread in the cross section, and find that it is larger, in absolute terms and relative to the credit spread, for firms closer to financial distress, with higher leverage, lower capital stock, lower market to book ratios, and higher payouts. Along the time-series dimension, we find that the agency credit spread is significantly higher, in absolute value and relative to the credit spread, during economic downturns.

The second main takeaway from the simulation of the representative economy is that it allows us to study the relative importance of agency deviations. We show that, after standardizing deviations from optimal policies and thus setting them on equal footing, deviations from firm value maximizing financing decisions have a comparable, if not larger, impact on the agency spread to deviations from firm value maximizing investment decisions.

The outline of the paper is as follows. In Section 1 we discuss the related literature. In Section 2, we present the model of the firm, the valuation framework for corporate securities, and the way agency conflicts are gauged in the model. Next, in Section 3 we structurally estimate the model. In Section 4, we calculate and analyze the agency credit spread, and the way it depends on lack of commitment on investment and financing decisions. In Section 5 we check the validity of our conclusions by conducting additional tests. Section 6 concludes.

1. Related literature

A key feature of our model is the lack of shareholders' commitment on financing decisions. Similarly to Admati, DeMarzo, Hellwig, and Pfleiderer (2017), we assume that equity holders can freely issue debt of non-inferior seniority (in our case, pari passu) to current debt. This assumption is achieved by removing a covenant that would force the firm to repurchase all current debt before new debt is issued.

As anticipated by Admati, DeMarzo, Hellwig, and Pfleiderer (2017), the lack of commitment on the leverage policy generates a debt overhang issue, called the "leverage ratchet effect," whereby equity holders resist to debt reductions that would maximize the value of the firm,[3] and have an incentive to issue more (pari passu) debt whenever this generates a positive tax shield for themselves, even if this decision increases bankruptcy and agency costs going forward.

A second key feature, and differently from Admati, DeMarzo, Hellwig, and Pfleiderer (2017), we assume that shareholders cannot commit on the value maximizing investment policy.

A dynamic version of the leverage ratchet effect has been proposed in a continuous-time setup by DeMarzo and He (2017), under the assumption of zero equity and debt issuance costs that allows them to derive the value of corporate securities and the leverage policy in closed-form. To implement pari passu debt, they assume zero recovery at default. They analyze the interaction between the lack of commitment on leverage policy and the investment policy. Investment, in their model, affects the drift of the cash flow process and requires an instantaneous cost.

[3] The resistance to debt reduction is also in Dangl and Zechner (2004) on p. 187, and Hugonnier, Malamud, and Morellec (2015), in Proposition 5. Importantly, this resistance remains true also if the firm can save. We discuss this point in Section 5.

Relative to this literature, we analyze the leverage ratchet effect and its implications on investment/disinvestment policy in a quantitative model featuring decreasing returns to scale and realistic frictions of both equity and debt issuance, on the one side, and of investment and asset liquidations on the other. Differently from the papers cited above, we do not assume zero transaction costs. While this prevents us from having convenient closed-form solutions for the value of corporate securities and policies, our model allows a quantitative analysis of the compounding effects of the different types of debt overhang stemming from lack of shareholders' commitment. Moreover, the model is realistic enough to be taken directly to the data with a structural estimation.

Dangl and Zechner (2016) propose a dynamic leverage tradeoff model in which the debt is protected by a covenant, whereby all existing debt must be repurchased to issue new debt. In their model, shareholders optimally decide the fraction of maturing debt that is rolled over, which corresponds to an optimal debt maturity choice. This allows for frictionless downward leverage flexibility and reduction of debt overhang costs. Because the debt contract is protected by such covenant, in Dangl and Zechner's model the lack of commitment regards only the decision to reduce the debt.[4] The main purpose of their analysis is to derive an optimal maturity structure that trades off the overhang cost against the default cost of debt. Differently from them and similar to Admati, DeMarzo, Hellwig, and Pfleiderer (2017) and DeMarzo and He (2017), we remove such protective covenant and analyze the full impact of lack of commitment.

The traditional analysis of debt-equity agency issues has been focussed on the effect of debt overhang on investment described by Myers (1977). Early contributions are Mello and Parsons (1992), who analyze the overhang effect on operating decisions, and Parrino and Weisbach (1999), who analyze under- and over-investment distortions in a setting where firm's decisions are not endogenous.

Hennessy (2004) analyzes the dynamic investment decisions in a neoclassical model of the firm with debt overhang. He concludes that distortions to the value maximizing investment policy, induced by the fact that equity holders do not benefit from the asset after default, are empirically important. Moyen (2007), like Hennessy (2004), studies the effect of debt overhang on dynamic investment policies. She considers two scenarios, one with long-term

[4]The interaction of debt-equity agency issues and debt maturity has been investigated in several other contributions including Diamond and He (2014) and DeMarzo and He (2017). Moyen (2007) analyzed the interaction of a dynamic leverage policy using short-maturity debt with underinvestment due to debt overhang. She found that while shareholders decide to reduce leverage in downturns, they increase leverage in upturns to capture the tax shield. Therefore, debt overhang remains significant in upturns, contrary to the received wisdom that shorter maturity reduce debt-equity agency costs.

non-callable debt and one with short-term debt. With a calibrated model, she shows that agency costs due to underinvestment relative to a firm value maximizing policy are large. While the model with long-term debt captures just the overhang effect on investment, the model with short-term debt describes the incentive of the equity holders to increase leverage in an upturn. However, when this decision is made, the firm is all-equity financed, similarly to what would happen under the protective covenants described above. Therefore, the model is silent on the leverage ratchet effect that we quantify.

Titman and Tsyplakov (2007) analyze the impact on dynamic investment and debt decisions of debt-equity agency conflicts. Relative to their model, ours presents two crucial differences: we do not have the covenant requiring that the current debt is repurchased at every new debt issuance, and we consider partial reversibility of investments and its effect on credit risk. Therefore, in their setup the agency distortions due to the leverage ratchet effect and to asset liquidations are absent.

Childs, Mauer, and Ott (2005) and Hackbarth and Mauer (2012) model a firm with an exogenously given growth option that can be also financed with unsecured consol bonds and show that optimal capital structure and debt priority structure can virtually eliminate under- or over-investment. We complement their work because, while our model is silent on the implications of different debt priority structures, we study a broader range of agency distortions (i.e., leverage ratchet effect, asset stripping, and excess distributions), and we endogeneize growth options.

In this literature on debt-equity agency costs, the most recent contributions are Sundaresan, Wang, and Yang (2015) and Chen and Manso (2017). The first paper presents a model of a firm with a finite sequence of growth options that can be optimally exercised and financed with a blend of debt and equity. Importantly, they assume that the debt can be changed only at the time a growth option is exercised and is protected by a covenant forcing the firm to repurchase all existing debt when new debt is issued. Because their model is silent on the leverage ratchet effect and the ensuing distortion on the optimal investment policy, they analyzes only the traditional debt overhang on investment. Relative to Sundaresan, Wang, and Yang (2015), our paper presents a model of a firm with an infinite sequence of compound real options to increase and reduce the scale of the operations, when equity holders cannot commit to maximize the value of the firm with their investment and financing decisions. In particular, by decoupling the financing decision from the investment decision, we allow debt claim dilutions and asset stripping, which they ignore.

Chen and Manso (2017) investigate the debt overhang distortion of the exercise policy of a one-time real option to grow. They analyze the interaction of underinvestment and macroeconomic risk, which exacerbates the debt overhang issue in an economic downturn through the discount factor channel. Although this is not the focus of our paper, because we introduce macroeconomic risk to ensure realism of the calibration of our model to prices, we have the same interaction between aggregate risk and debt overhang in our model. Relative to Chen and Manso (2017), because we have a setup with repeated investment and financing decisions, we analyze different types of debt-equity agency issues, most notably the leverage ratchet effect and asset stripping, besides the classic debt overhang distortion of investment.

While the above cited literature is focussed mostly on measuring the impact of agency on total firm value, we focus our attention on the differential in the value of debt. As such, our work contributes to the credit risk literature based on structural models, including but not limited to Chen, Collin-Dufresne, and Goldstein (2009), Bhamra, Kuehn, and Strebulaev (2010a), Chen (2010), and Gomes and Schmid (2010), who model state-dependent risk premia. Similar to Chen and Manso (2017), our paper explores an alternative economic channel to solving the credit spread puzzle, as we highlight the importance of debt-equity agency conflicts.

Titman, Tompaidis, and Tsyplakov (2004) calibrate a model of debt overhang with dynamic investment, similar to Hennessy (2004), to analyze the extent to which the credit spread on the debt issued initially is affected by underinvestment. Similarly to them, we calculate a measure of agency credit spread and relate this to firm's characteristics (e.g., asset maturity). The main difference with respect to their study is that our model captures all agency distortions on investment and financing decisions related to lack of commitment of shareholders. In particular, their model ignores the leverage ratchet effect.

Finally, our work contributes to the literature on dynamic models of corporate finance decisions by adding lack of commitment of equity holders to the classical setup. For example, Cooley and Quadrini (2001), Hennessy and Whited (2007), and Gomes and Schmid (2010) among others, describe the interaction between investment and financing policies in a firm with endogenous default risk, one-period debt and endogenous investment. However, if debt is single-period and it is issued simultaneously to investment, agency deviations from value maximizing decisions are absent, because when such decisions are made the firm is all-equity financed. By incorporating long-term debt with no covenant that forces the repurchase of all existing debt, our model allows for the independent effects of deviations from optimal investment and financing decisions.

2. Model

In this section we introduce a model of corporate securities valuation in a setting with endogenous investment, dynamic capital structure decisions, long-term debt and endogenous default. A simple stochastic discount factor that features countercyclical risk premia is used to evaluate contingent claims as a way to include macroeconomic risk in the valuation of corporate debt, as in Chen, Collin-Dufresne, and Goldstein (2009), Chen (2010), and Bhamra, Kuehn, and Strebulaev (2010b),

2.1. Economic environment

There are two sources of risk. One is of systematic nature, with high persistence and low conditional volatility. The second one is of idiosyncratic nature, and has lower autocorrelation and higher conditional volatility. For the purpose of calibrating and testing the implications of the model, we will assume an economy with a finite number of firms. Each company in the economy is exposed to a firm-specific idiosyncratic risk, which is independent of the systematic risk and of the other companies' specific risk.

We denote macroeconomic risk with u, and assume that it is an autoregressive process, $u_{t+1} = \rho_u u_t + \sigma_u \varepsilon^u_{t+1}$, where ρ_u is the autocorrelation, with $|\rho_u| < 1$, σ_u is the conditional standard deviation, and ε^u_{t+1} are i.i.d. and have a truncated standard normal distribution. We denote company-specific risk with z, and assume it also follows an autoregressive process, $z_{t+1} = \rho_z z_t + \sigma_z \varepsilon^z_{t+1}$, where the parameters have similar meanings as above. The two random terms ε^u_t and ε^z_t are independent.

The EBITDA (operating cash flow before taxes) of the individual firm is $\pi(u, z, k) = e^{u+z} k^\alpha - \psi$, where $k > 0$ is the book value of assets, $\psi > 0$ is a fixed cost that summarizes all expenses, and $\alpha < 1$ models decreasing returns to scale of the asset. We assume that each individual firm can change the level of production capacity. Capital stock has a unit price when added to the firm, and a lower price $\ell \leq 1$ when liquidated. This costly reversibility will generate investment hysteresis in the simulated economy.[5]

[5]The assumption $\ell \leq 1$ serves other purposes, all material to the goal of this analysis. First, it makes investment in physical asset a costly way of corporate savings. This is different from what Hennessy and Whited (2007) and Moyen (2007) assume, because in their models the asset is fungible, or equivalently, capital stock is as liquid as money market investments. Secondly, ℓ can be interpreted as the extent to which the firm's asset is pledged as collateral to the debt contract, in the spirit of Morellec (2001): if ℓ is zero, the asset cannot be sold and is totally pledged; if ℓ is one, the asset can be disposed at no cost by shareholders before default. Lastly, ℓ gauges a degree of uniqueness of the asset: the lower ℓ the higher the extent to which the capital stock is specific to a firm or industry. These aspects will be important later, when discussing the agency implications of the model on the cost of capital.

In our model, capital depreciates at a constant rate $\delta > 0$. Therefore, Earnings Before Taxes (EBT) are EBITDA minus depreciation and the interest on outstanding debt, $w = \pi(u, z, k) - \delta k - rb$, where r is the coupon rate and b is the par value of debt. Corporate taxes net of the effect of personal taxes on payouts and coupon payments are a convex function of EBT, to model a limited loss offset provision. For simplicity we assume a positive net tax rate τ on positive EBT and zero tax credit on negative EBT, so that the tax function is $\tau \max\{w, 0\}$.

The individual firm can raise funds by issuing equity and debt. In our partial equilibrium framework, we assume that financial markets rationally price the claims of these securities. The debt contract is a risky callable consol bond with face value $b \geq 0$ and with a floating coupon rate, r. The firm can dynamically change the level of the debt incurring an adjustment cost of $\theta \geq 0$ per unit of debt change, regardless of the sign of the change.

External financing can be obtained also by issuing equity. In this case, the equity holders bear a flotation cost due to underwriting fees. Hence, if the amount raised by the firm is v, the actual (negative) cash flow for the equity holders is $(1 + \lambda)v$, where $\lambda \geq 0$ is a cost parameter.

The dynamic framework has infinite-horizon and discrete-time. We assume that the firm has two control levers: the book value of assets in place, k, and the face value of debt, b. For convenience, we use the notation without the prime to denote current value, and with a prime to denote next period value of the variables.

2.2. Investment, capital structure change, and default

At any date, the firm can decide to invest or disinvest to achieve a new level k' from the current depreciated capital stock $(1 - \delta)k$. Investment, $I = k' - (1 - \delta)k$, has unrestricted sign. If it is positive, it is financed either with internal or external funds. On the other hand, if negative, it generates cash at a cost $(1 - \ell)I$, so that the net cash inflow is $-\ell I$. For convenience, to describe the payoff from investment/disinvestment we define the function $h(I, \ell) = I\chi_{\{I \geq 0\}} + \ell I \chi_{\{I<0\}}$, where $\chi_{\{\cdot\}}$ is an indicator function.

Equity holders may decide to change the debt to a new level b' for the next period. If $b' > b$, the incremental debt is issued at the market price per unit of par value, $D(b')/b'$, so that the cash inflow is $(b' - b)\, D(b')/b'$. To keep the model tractable, we assume a *pari passu* convention, in the sense that old and new debt holders have the same priority when the firm goes bankrupt.[6] If $b' < b$, the reduction is done by repurchasing the debt at par, so that the cash outflow is $b' - b$.[7]

To summarize (Figure 1 can help intuition), given the previous period actions $a = (k, b)$, after observing $x = (u, z)$ the firm chooses new actions (i.e., capital and debt) $a' = (k', b')$, which determine the current cash flow to shareholders and the continuation value of the firm as a going concern. If the firm is solvent, investment and financing decisions are unrestricted.

In the alternative event of insolvency, default is chosen by equity holders to limit their liabilities. In bankruptcy, debt absolute priority applies and debt holders become the new equity holders and recover the residual value of the unlevered asset net of proportional verification costs, modeled by a parameter $\zeta \leq 1$. To preserve the stationarity of the infinite-horizon model, we assume that at default no decision is made regarding investment, and the firm is restarted unlevered from the current level of depreciated asset, with the possibility to make investment and financing decisions later on.

2.3. Security valuation

Following Berk, Green, and Naik (1999) and Zhang (2005), we do not model the equilibrium of financial markets and instead assume that the representative agent's preferences are summarized in a reduced-form stochastic discount factor that depends on macroeconomic conditions driven by u.

As proposed by Jones and Tuzel (2013), the one-period discount factor given the transition to state u_{t+1} from the current state, u_t is $M(u_t, u_{t+1}) = \beta e^{-g(u_t)\varepsilon^u_{t+1} - \frac{1}{2}g(u_t)^2\sigma^2_{u_t}}$, where the state-dependent coefficient of risk-aversion is defined as $g(u) = \exp(\gamma_1 + \gamma_2 u)$, with $0 < \beta < 1$, $\gamma_1 > 0$ and $\gamma_2 < 1$.[8] Using this pricing kernel, we can evaluate the securities issued by the firm.

The debt contract is a callable and defaultable consol bond with a floating coupon rate, r. The coupon is set at the beginning of each period depending on the state of the econ-

[6]Another way to limit the complexity introduced by multiple debt seniority in a dynamic setup is to assume zero recovery at default, as in DeMarzo and He (2017). We cannot adopt this simplification, because the purpose of this paper to give a quantitative account of the effect of debt related agency issues on the cost of debt capital.

[7]This is different from what Fischer, Heinkel, and Zechner (1989), Titman and Tsyplakov (2007) and other similar models do. They assume that the current debt holders are protected by a contractual covenant that gives them the power to block any additional debt issuance, whereby all the outstanding debt must be repurchased at par when the debt level is changed. This covenant is aimed at avoiding precisely one of the debt related agency issues, the leverage ratchet effect, that we want to analyze and for this reason we exclude it from our model.

[8]Given our assumptions, the yield of a risk-free zero coupon bond is $1/\mathbb{E}_t\left[M_{t+1}\right] = 1/\beta$. The numerical implications of this restriction are discussed in Appendix A.

omy, u. In general, this would add complexity to the model. However, by adopting the stochastic discount factor above we avoid this issue and keep the model tractable. To see this, we exclude default and the call provision so that perpetual debt is valued at par if the coupon is properly chosen. Formally, the value at t of a default-free, non-callable consol bond paying a stream of payments based on stochastic coupon rates $\{r_{t+i}, i = 1, 2, \ldots\}$ and face value b is $B_t = b\mathbb{E}_t\left[\sum_{i=1}^{\infty} r_{t+i-1} \prod_{j=0}^{i} M_{t+j}\right]$ or, using a recursive representation, $B_t = \mathbb{E}_t\left[M_{t+1}(r_t b + B_{t+1})\right]$. The par coupon rate is such that $B_t = b = B_{t+1}$, from which $1/(1+r_t) = \mathbb{E}_t\left[M_{t+1}\right] = \beta$. Hence, the coupon is equal to the state-independent real risk-free rate.[9]

We assume perfect and symmetric information between equity holders and bondholders and rule out managerial agency issues. Given our focus on the conflict of interest between the firm's bondholders and stockholders, the valuation model for corporate securities is a dynamic program pursuing value maximization of either total firm (equity plus debt) or of a specified blend of debt and equity. In the first case, debt-equity agency issues are absent, whereas in the second case agency conflicts may reduce the value of the debt holders' claim, as we will explain in Section 2.4. We denote the resulting state dependent optimal policy with $a' = \varphi(x, a)$.

The value of the firm's equity, denoted $S(x, a)$, is the solution of equation[10]

$$S(x, a) = \max\left\{0, s(x, a, \varphi(x, a)) + \mathbb{E}_x\left[M(x, x')S(x', \varphi(x, a))\right]\right\}, \tag{1}$$

where the actual cash flow to shareholders conditional on firm's solvency and based on the choice $a' = \varphi(x, a)$ is $s(x, a, a') = \left(1 + \lambda\chi_{\{v(x,a,a')<0\}}\right) v(x, a, a')$, with

$$\begin{aligned} v(x, a, a') = \pi - \tau \max\{w, 0\} - rb - h(I, \ell) \\ + \chi_{\{b'>b\}}(b' - b) D(x, a, a')/b' + \chi_{\{b'<b\}}(b' - b) - \theta|b' - b|. \end{aligned} \tag{2}$$

In equation (2), $D(x, a, a')$ is the ex-coupon price of debt at the current state (x, a), considering the action $a' = \varphi(x, a)$. The first line of (2) at the right-hand side is the after tax operating cash flow net of the effect of a change in the capital stock. The second line of (2) is the flow from a capital structure change net of the direct cost.

[9] With a different specification of the pricing kernel, the risk-free (and the coupon) rate would be state dependent. So, to preserve the Markov property of the model, the state space should be augmented to include the coupon rate, which would be computational expensive.

[10] In equation (1), the expectation is computed with respect to the transition probability of the process $x = (u, z)$, conditional on the current state, $Q(x, x')$, given by the product of the conditional transition probabilities of u and z.

In equation (1), if the right-hand side, $s + \mathbb{E}_x[MS]$, is negative, the firm defaults and the optimal policy φ reflects this event with $k' = (1-\delta)k$ and $b' = 0$. We denote $\omega(x, a)$ the default indicator function.

To compute $D(x, a, a')$, the price of debt conditional on firm's solvency and based on current action $a' = \varphi(x, a)$, we need to define the corresponding end-of-period value to debt holders. At that point, if the decision $a'' = \varphi(x', a')$ is made, the value of debt holders' claim is (see also Figure 1)

$$
\begin{aligned}
d(x', a', a'') &= \omega(x', a')(1-\zeta) \min\left\{(1-\tau)\pi(x', k') + (1-\delta)k' + \tau\delta k', b'\right\} \\
&\quad + (1-\omega(x', a'))\left[rb' + \chi_{\{b'' \geq b'\}} b' D(x', a', a'')/b'' + \chi_{\{b'' < b'\}}\left(D(x', a', a'') + b' - b''\right)\right]. \quad (3)
\end{aligned}
$$

The first line of equation (3) is the recovery on default, which is the unlevered asset value net of taxation of profits and including the tax shield from capital depreciation, after accounting for bankruptcy costs. The second line is the value to current bondholders if the firm is solvent: it is the prorated market value of new debt if it is either increased or kept constant and is equal to the net proceeds plus the continuation value of the residual debt, if it is reduced. Hence, the ex-coupon value of the debt at the beginning of the period is

$$
D(x, a, a') = \mathbb{E}_x\left[M(x, x') d(x', a', a'')\right]. \quad (4)
$$

Finally, the credit spread is $cs(x, a, a') = rb'\left(1/D(x, a, a') - 1/D^f(x, a, a')\right)$, where D^f is the price obtained from (4) by excluding the event of default (i.e., $\omega = 0$), and therefore putting D^f in place of D when defining d in equation (3).

2.4. Debt-equity agency issues

Debt-equity agency distortions are generated by shareholders' lack of commitment, as they pursue the maximization of the equity as opposed to the total value of the firm. The incidence of these distortions depends on economic conditions as well as on specific provisions in the debt contract, such as protective covenants, maturity, and seniority structure. For tractability, we cannot include all these provisions in one model. On the contrary, if we studied any one specific provision we would produce a quantitative model unable to make general predictions, as it would lack the other features which are present in the real economy.

We propose a reduced form approach that captures the economics of agency conflicts, makes the model tractable, and delivers general results. Our approach relies on the idea that dual holdings of equity and debt mitigate agency conflicts between equity and debt holders (Jiang, Li, and Shao, 2010). If shareholders owned 100% of the *unsecured*, *perpetual*, *redeemable*, and *defaultable* debt, the incentives of equity and debt holders would be perfectly aligned. Conversely, if the fraction of debt owned by the shareholders were small (or zero), agency conflicts would be big (or maximum). Any positive fraction of dual holdings would reduce agency conflicts and therefore reduce the incentive of shareholders to deviate from firm value maximizing policies. This simple setting allows us to accommodate many different contractual provisions with one structural parameter.

In the model therefore, because the debt is a perpetual, redeemable, defaultable, unprotected contract, the protection that is not provided by contractual features (such as covenants, maturity, seniority) is achieved by holding a fraction $1-\eta$ of the debt, with $\eta \in [0,1]$. Because it is a structural parameter, η is assumed to be independent of (x,a). The actual extent of agency conflicts, for a given protection $1-\eta$, depends on (x,a), namely the state of the economy, the profitability of the firm, and the leverage ratio. Also, for a given state (x,a), the lower the protection, $1-\eta$, the more severe the agency conflicts. If $\eta = 0$ shareholders own all claims to the firm cash flows, the debt is fully protected and no agency conflicts are present. If $\eta = 1$, no protection is present and shareholders take only self interested decisions.

This implies that if the debt contract in the model had a feature (like a covenant or shorter maturity) that offered some (although not complete) protection to the debt holder, the corresponding share of ownership of debt $1-\eta$ that delivered the same protection would need to be lower (i.e., η is higher). We confirm this intuition in Section 5.

In this framework, the optimal policy, $\varphi(x,a;\eta)$, of a solvent firm is defined as

$$\begin{aligned}\varphi(x,a;\eta) = \arg\max_{a'} \{ & s(x,a,a') + \mathbb{E}_x\left[M(x,x')S(x',a')\right] \\ & +(1-\eta)\left[rb + \chi_{\{b' \geq b\}} bD(x,a,a')/b' + \chi_{\{b'<b\}}\left(D(x,a,a') + b - b'\right)\right]\}. \quad (5)\end{aligned}$$

All values of η in $[0,1]$ are possible. The case where $\eta = 1$, wherein no debt is owned by shareholders, yields the equity maximizing policy. On the opposite extreme, if $\eta = 0$ there is no distinction between equity and debt and the optimal policy is maximizing the value of the whole firm. To show this, consider the case $\eta = 0$. After substituting $s(x, a, a')$ with the cash flow to equity holders, the objective function at the right-hand side of (5) becomes

$$\begin{aligned} &\max_{a'} \left\{\pi - \tau \max\{w, 0\} - h(I, \ell) - \lambda v \chi_{\{v<0\}} + D(x, a, a') + \mathbb{E}_x \left[M(x, x')S(x', a')\right]\right\} \\ &= \max_{a'} \left\{\pi - \tau \max\{w, 0\} - h(I, \ell) - \lambda v \chi_{\{v<0\}} + \mathbb{E}_x \left[M(x, x') \left(S(x', a') + d(x', a', a'')\right)\right]\right\}. \end{aligned}$$

Defining $F = S + d$ as the total value of the firm, for $\eta = 0$ the program of the solvent firm a the right-hand side of (5) becomes

$$F(x, a) = \max_{a'} \left\{f(x, a, a') + \mathbb{E}_x \left[M(x, x')F(x', a')\right]\right\},$$

where $f(x, a, a') = \pi - \tau \max\{w, 0\} - h(I, \ell) - \lambda v \chi_{\{v<0\}}$ is the total cash flow to all stakeholders, while accounting for real, equity issuance and tax frictions.

We can further highlight the economic intuition of our modeling choice by considering the limiting case of single-period debt for a general value of $\eta \in [0, 1]$. When the debt contract is single-period, the firm value maximizing policy coincides with the equity maximizing policy, as the debt price fully incorporates the effect of agency distortions at each decision date. It should therefore be the case that, with single-period debt, optimal policies are independent of the debt protection parameter η (that is, of the portion of debt owned by shareholders, $1 - \eta$). In the non-default state, the payoff to single-period debt holders from (3) is $(1 + r)b'$ and the right-hand side of (5) becomes

$$\begin{aligned} &\max_{a'} \left\{\pi - \tau \max\{w, 0\} - h(I, \ell) - \lambda v \chi_{\{v<0\}} + D(x, a, a') + \mathbb{E}_x \left[M(x, x')S(x', a')\right] - \eta(1 + r)b\right\} \\ &\qquad = \max_{a'} \left\{f(x, a, a') + \mathbb{E}_x \left[M(x, x')F(x', a')\right]\right\} - \eta(1 + r)b, \end{aligned}$$

As η does not enter the objective function, the firm maximizing policies are implemented regardless of the degree of agency conflicts. The economic intuition is immediate: because with single-period debt the price of new debt always reflects the possible end-of-period distortions, the cost of such distortions is fully paid by shareholders, who therefore refrain from deviating from a value maximizing policy.

In practice because of covenants, priority rules, and finite debt maturity, firms are neither entirely firm value maximizers nor equity value maximizers. Consequently, the estimation of the parameter η, which we describe in the next section, is aimed at capturing all contractual features that address, although not completely resolve, agency conflicts in the data.

The program in equation (5) with constraints (1) and (4) must be solved numerically. In Appendix A we describe the numerical method we use to solve the valuation problem to obtain S and D.

3. Structural estimation

In this section we describe the procedure used and results obtained from estimating the model using SMM. There are seventeen free parameters. We set the coefficients of the systematic risk process and of the stochastic discount factor equal to the annualized equivalent of the values found in Jones and Tuzel (2013): $\rho_u = 0.9224$, $\sigma_u = 0.0136$, $\gamma_1 = 3.22$, $\gamma_2 = -15.30$. The value of β gives a constant annual risk-free rate of 5%.

We fix a few of the parameters that characterize the firm choices. Operating costs and depreciation rates pose some serious identification problems when considered together. Because many asset pricing studies have found that operating costs are essential to calibrate dynamic models to prices (e.g., Carlson, Fisher, and Giammarino, 2004; Kuehn and Schmid, 2014), we choose to include the operating cost parameter in the estimation and fix the depreciation rate δ at an average sample value of 7.5%. Moreover, the estimation of equity adjustment costs relies typically on equity issuances and distributions, thus creating a potential problem with the identification strategy for η (see Section 3.2). Therefore, we fix the equity adjustment costs to 5%, similarly to Warusawitharana and Whited (2016). The remaining nine parameters are estimated by simulated method of moments, which we briefly describe in Appendix B.

3.1. Data

The data used in the model estimation is assembled from different sources. Firm-level accounting and financial information is obtained from the merged CRSP-COMPUSTAT files. Most variables are constructed directly from COMPUSTAT data items and follow standard practices: investments are defined as the sum of capex, acquisitions, and increase in investments (IVCH) minus the sum of sales of property, plant and equipment and the sales of investments; profitability is EBITDA; total debt is defined as the sum of long term debt plus financial debt in current liabilities; equity distributions are defined as the sum of all dividends minus net equity issuances. All variables, with the exception of leverage, are scaled by total assets. In obtaining a measure of leverage we divide debt by the sum of debt plus the book value of equity, thus eliminating the impact of cash and current liabilities that are not part of the model. Other variables follow a more unique construction: operating leverage is calculated at the firm level by running regressions of sales on operating expenses as in Kahl, Lunn, and Nilsson (2012). Asset maturity is calculated by averaging the turnover ratio of various components of physical assets as in Barclay and Smith (1995).

We rely on the spreads of senior unsecured CDS contracts to extract a measure of credit spreads. Our model features infinite-maturity debt and therefore the yield spread computed in the model has the same maturity. A careful consideration must then be applied in choosing the empirical equivalent measure. CDS data is available for maturities ranging from 1 to 30 years, with the most liquid being the 5-year contracts. We select the 15-year contract for a few reasons. The average term structure appears to flatten out significantly at the 15-year maturity (i.e., the average 20- and 30-year CDS spreads are only a few basis points higher in our sample). On the other hand, the quality of the data (i.e., number of quotes) declines substantially when going from 15- to 20- or 30-year tenors. Finally, as our sample covers exactly 15 years, we can match the maturity of the contract with the default frequency (which we compute for the entire sample period and describe below).

We obtain the data from Markitt for the period from 2001 throughout 2015. In order to align market and accounting data, we compute the average of the daily mid-point CDS quotes over the last two months of the fiscal cycle. In a further effort to eliminate concerns about liquidity of market CDS prices, we focus on firms that belong to the S&P 500 index. Additionally, we eliminate from the sample utilities and firms in the financial sector.

Default events are collected by merging several sources: Moody's KMV, Bloomberg, Standard and Poor's, and FISD Mergent. These events include Chapter 7 and Chapter 11 filings, missed payments of interest and principal, and are related to both bank and publicly held debt. We only consider defaults that happen in the last year a firm is listed in one of the three exchanges, and for which we can observe CDS prices in the immediate past (i.e., in the fiscal year preceding the default event). The sample default frequency (which corresponds to a 15-year default probability) is computed as frequency of defaults in the entire sample.[11]

As part of our subsample analysis we sort firms based on the specificity of their asset. We use the U.S. Industry Account Dataset published by the Bureau of Economic Activity

[11] Note that because we estimate the model's parameters by SMM we require a valid weight matrix. Following Warusawitharana and Whited (2016), we compute the weighting matrix by means of influence functions, which in turn require data at the firm level. It is therefore impossible for us to include quantities aggregated at the rating class (i.e., the average BBB corporate spread and default rates) as moments. In that regards our paper is different from studies that calibrated models of credit risk such as Chen, Collin-Dufresne, and Goldstein (2009), Bhamra, Kuehn, and Strebulaev (2010a), Chen (2010), Feldhütter and Schaefer (2018).

(BEA) to construct a measure of capital specificity. For each industry and for each year, BEA reports net stocks and investments in fixed asset decomposed in 75 categories. We denote $x(j,s,t)$ the amount of capital s employed in industry j at time t. The measure of capital specificity that we adopt is a variation of a concentration ratio, wherein each type of asset used in every industry is weighted by the relative importance of that type of asset in the entire economy:

$$\text{Capital Specificity}(j,t) = \sum_{s=1}^{S} \left(\frac{x(j,s,t)}{\sum_{s=1}^{S} x(j,s,t)} \right)^2 \times \left(\frac{\sum_{j=1}^{J} x(j,s,t)}{\sum_{s=1}^{S} \sum_{j=1}^{J} x(j,s,t)} \right). \tag{6}$$

We report descriptive statistics of the data in Table 1.

3.2. Identification

In our estimation, we chose not to impose any particular identification restriction and consider instead several moments that are related to firm policies. As we follow this strategy, we do not expect an exact identification relation between moments and parameters but rather that certain groups of moments are more important for certain groups of parameters. We follow Li, Whited, and Wu (2016) and include average and standard deviation of policies that are observable in the model (i.e., investments, distributions, leverage). To aid the identification of certain parameters that are related to dynamic aspects of the model, we also include autocorrelation of profitability and leverage. Finally we include moments related to pricing of equity and debt: average and standard deviations of Tobin's Q (i.e., market-to-book ratio) and of credit spreads of long term bonds (as proxied by the spread of a 15-year CDS contract). Finally we include the sample default frequency (rate of default over 15 years), thus obtaining fifteen moment conditions that are used to estimate ten parameters.

Most of the moments are common to many production models similar to ours, and hence the identification of most parameters follow standard practice (e.g., Nikolov and Whited, 2014; Li, Whited, and Wu, 2016; Warusawitharana and Whited, 2016). For example, the parameters of the idiosyncratic productivity shocks (i.e., ρ_z and σ_z) are identified by the variance and autocorrelation of profitability. The production function parameter is related to the average profitability. Taxes are mainly identified by leverage and profitability, and debt adjustment costs by the autocorrelation of leverage. The operating cost parameter, ϕ, is identified by average investment, while the liquidation value of the asset, which is a type of capital adjustment cost, gauges the standard deviation of investments. Average and standard deviation of credit spreads, jointly with the default frequency, are responsible for pinning down bankruptcy costs.

A crucial aspect of our identification relates to the parameter η. We rely on indirect inference based on the *ex ante* behavior of the firm in the presence of agency conflicts, *given* some imperfect contractual protection against such conflicts.[12] In particular, the payout policy is influenced by the intensity of such conflicts, which at a given point in time affect the current cash flow to debt and equity as well as the continuation value. For instance, if a firm liquidates some assets, making a negative NPV decision, there is a reduction in the continuation value of the firm and an increase in the total cash available for equity and debt. If the cash increment was saved in the firm, this would benefit both equity and debt in future periods. Hence, to take advantage of asset stripping, equity holders pay the cash out as dividend, reducing the claim of the debt, which depends on continuation value only. The same intuition applies when additional cash flow originates from underinvestment or a debt increment: if kept within the firm, the additional cash would also benefit debt holders, and therefore shareholders appropriate it by paying it out, while leaving the debt backed by a reduced continuation value. As a consequence, in our estimation strategy, η is identified primarily by the average payout to equity holders.

To study the effectiveness of the identification strategy we construct the sensitivity measure proposed by Gentzkow and Shapiro (2017). The measure allows to compare the relative impact of moment conditions on estimated parameters. We present the analytic formulation of the sensitivity measure in Appendix B. We note here that, because it depends on the moments' gradient, the measure is ultimately a function of the actual parameter estimates (which we discuss in Section 3.3), and not just of the specification of the model. In other words, a different set of estimates would lead to a different sensitivity of all parameters to all moments. Another important aspect of the sensitivity measure proposed by Gentzkow and Shapiro (2017) is that the absolute value is not as critical as the relative comparison: so for example the contribution of two moments to a parameter can be best evaluated only in relative terms, rather than by the magnitude of the individual measure.

In Figure 2 we present each moment's contribution to η using bars. The figure confirms that the most positive important drivers of the estimated debt protection against agency issues is the average payouts to equity, followed by the default frequency. This makes perfect sense within the model: lower dual holdings of debt (i.e., a higher η) is related to more payouts and defaults because the protection against distortions is lower. Other moments play a role. For example, higher profitability implies a lower estimate of η. Again, this is because a positive status of the firm reduces the agency conflicts, everything else equal. If

[12] Realized dual holdings of debt and equity are empirically too small to be considered.

η is to capture this effect, this is obtained by increasing dual holdings, or equivalently, by reducing η.

3.3. Model fit

In Table 2 we present parameter estimates and in Table 3 a comparison of the target moments and their counterparts in the simulated economy.

Generally speaking the simulated economy is relatively close to the real one. The moments in simulated economy are statistically different from the observed counterparts only in three cases: average and standard deviation of market-to-book ratio (as is the case for example in Nikolov and Whited, 2014) and the standard deviation of distributions. For all the other moments, the null of the difference test (between observed and simulated quantities) cannot be rejected at conventional statistical thresholds. The model produces realistic prices, especially for debt, for which both average and standard deviation of credit spreads are very close to the observed counterparts.

As for the parameter estimates, all parameters with the exception of the debt adjustment costs are statistically significant. The idiosyncratic shocks has lower persistency than the aggregate shock, 0.502 versus 0.922, and higher volatility, 0.174 versus 0.014. Both parameter estimates are statistically significant and close to values commonly used in the literature.

The estimated marginal corporate tax rate, τ, is 0.153 and statistically significant and close to the average estimated marginal tax rate after depreciation of 0.16 computed by Professor John Graham based on the methodology discussed in Graham (1996a) and Graham (1996b) for the firms in our sample and during the period that we study. The estimated production function parameter, α, is 0.438 which falls in the middle of a very large range of values in similar structural estimations of the firm: from 0.30 in Zhang (2005) to 0.75 in Riddick and Whited (2009).[13] The fixed cost parameter comes in at 1.32. As the steady state level of capital is approximately 8.2, that implies that an average attrition rate of about 16%. The linear liquidation price parameter is 0.72, indicating that more than half of the value of capital is wasted in an asset sale.

Debt adjustment cost is estimated to be 1.3% and it is on the upper end of underwriting fees that Altinkilic and Hansen (2000) estimate (as an average percentage of the offered amount) in the range of 0.61%-1.24%. To analyze the impact of such large estimate, we conduct robustness check analyses in Section 5, as well as on other adjustment costs (real

[13]Gomes (2001) sets α to 0.3, Hennessy and Whited (2005) estimate a value of α equal to 0.551, while Hennessy and Whited (2007) estimate a value of 0.620. Gomes and Schmid (2010) use 0.65.

and financial) that play a critical role in the model. The bankruptcy cost is estimated at 0.334, which is in line with empirical evidence and estimates provided in similar models. For example, Gomes and Schmid (2010) use a proportional bankruptcy cost parameter of 0.25, and consider also fixed deadweight cost of liquidation of 0.1. Glover (2016) estimates default cost parameters at the firm level and finds an average value of 0.432, and values ranging between 0.189 for lower rated firms and 0.568 for AAA rated companies.

Finally, η is estimated at 0.73, thus implying a relatively low degree of protection from agency distortions in the data. In line with the interpretation presented in Section 2.4, an estimate of η of 0.73, implies that the protective covenants and other measures that are present in the data to decrease agency conflicts could be reproduced in the context of our model by having the shareholders hold 27% of the unprotected debt outstanding.

The parameter gauging protection against agency conflict affects the model in several dimensions. We display the behavior of average policies relative to changes in η in Figure 3. Each panel is constructed by simulating an economy, for values of η in the interval centered at 0.73 and width of 0.5, while all the other parameters are kept constant at the values reported in Table 2. For each simulated economy we then compute the average investment, leverage, and payouts. As η increases (i.e., there is less protection against agency conflicts) the firm chooses a slightly lower investment, and the leverage is lower as a consequence of the higher cost of debt due the agency costs. Therefore a higher percentage of profits remains available for payouts to equity. At the same time, the choice of lower leverage determines the lower default frequencies and credit spreads for higher η.

3.4. Subsamples

We use heterogeneity in the data that is not directly used as part of the estimation procedure (i.e., as a moment condition) to alleviate concerns about the identification of parameters that are difficult to relate to the dynamic corporate finance literature. The model has three parameters that are, by virtue of modeling choices, not immediately comparable to estimates existing in other papers: the asset liquidation price ℓ, the fixed production cost parameter ψ, and the parameter that measures debt protection against agency conflicts, η.

We proceed as follows. First, we create subsamples by sorting firms based on some empirically observable characteristics, which are not included in the moment conditions because they cannot be computed in the simulated economy. We chose one observable characteristic for each of the three parameters. The three observable quantities responsible for generating subsamples are operating leverage of the firm, the asset specificity of capital in the industry, and the maturity of the asset. Precise definitions of the construction of the variable are provided in Section 3.1. We then create two groups of firms corresponding to the lower and higher terciles and re-estimate the parameters using the moment conditions obtained from the respective firms. For each parameter, we then obtain two estimates. If the identification strategy discussed Section 3.2 is correct, we should observe a direct relation between the magnitude of the estimate and the group from which the estimate is calculated.

We report results in Table 4. Operating leverage is directly linked to the fixed production cost parameter ψ. In the model, a higher ψ increases the incidence of fix costs on the firm profits, thus increasing the firm operating leverage. The estimation exercise confirms that, despite operating leverage not being included in the set of moments, the sample of firms with higher operating leverage lead to a higher estimation of ψ. The estimations produce coefficients that straddle the estimate for the full sample of 1.3: for the lowest operating leverage tercile we obtain 1.20, while for the top tercile we obtain 1.99.

Asset specificity affects the resale value of capital and is therefore related to the asset liquidation price that is captured by ℓ in the model. A higher degree of asset specificity presumably involves technology that cannot be easily transferred to other industries and is therefore more difficult to sell when a firm needs to downsize. Similar to the previous case, we also obtain estimates that straddle the parameter obtained for the entire sample. Firms with low asset specificity produce a value of ℓ of 0.74, while firms with high asset specificity have a lower resale unit price for capital of 0.64, in line with the economic intuition.

Finally, the average asset maturity has implications on the maturity of the debt, given the empirically observed degree of coordination between investment and financing decisions. This is because firms choose first the asset maturity specific to the industry to which they belong, and then they set the maturity of the debt, as shown by the empirical investigation conducted by Barclay and Smith (1995), Stohs and Mauer (1996), Johnson (2003), Billett, King, and Mauer (2007), Datta, Iskandar-Datta, and Raman (2005), and Saretto and Tookes (2013), among others. Hence, firms endogenously match the maturity of debt with the maturity of assets. For firms with short asset maturity, the short debt maturity offers protection against agency conflicts. Therefore, we expect a high estimate of η for low maturity firms, because in this subsample there are less agency conflicts and a lower protection against agency conflicts is required to match the moments. The estimation exercise confirms the relationship. Firms with short asset maturity produce an estimate of η of 0.95, while firms with long asset maturity produce an estimate of 0.62. We interpret the estimation exercise reported in this section as a confirmation of the validity of the identification strategy discussed in Section 3.2.

4. The agency credit spread

We now describe how we obtain the agency credit spread, how it is related to firm characteristics, and the impact that deviation of future investment and debt policies from (constrained) first best have on it.

4.1. Derivation of the agency credit spread

Given a pre-determined level of protection η of the debt against agency issues, the agency credit spread is the incremental cost of the debt issued by the firm, under lack of shareholders' commitment, due to future distortions of the firm maximizing policy. With reference to Figure 1, given a particular level of η, the incremental cost due to agency issues for the debt issued at t, with face value b' and price $D(x, a, a')$, is the expectations that future policies, $a'' = \varphi(x', a', \eta)$, will be different from those that would maximize the value of the firm at $t + 1$. The agency credit spread therefore determines how much higher the credit spread on current debt is relative to the case with no future agency conflicts.

While we can provide a definition of the agency credit spread, we cannot directly compute it from the solution of model. We require instead an approach that isolates, for a given η, the effects on the price of the debt at time-t of agency deviations from value maximization realized at time $(t + 1)$, while controlling for the policy that is chosen at time t. More precisely, including into the definition of credit spread all dependencies, $cs(x, a, a'(\eta); \eta)$, we note that η not only affects the credit spread directly, but also determines the state contingent policy at the current date, $a' = (k', b')$. In other words, the effect of η on future agency issues is internalized by the *current* policy, a'. However, the agency credit spread measures the impact on the price of current debt of *future* (as opposed to current) deviations on investment and financing policies, due to lack of shareholder's commitment.

If we had a imperfect protective covenant instead of dual holdings, we would calculate the agency spread by comparing the credit spread on the debt with such covenant to the credit spread on the debt absent agency distortions (i.e., with a perfect covenant), in the same state and under the same decision as per the current level of debt. The comparison of the price of debt with the (imperfect) covenant to the price of debt with no agency issues, under their respective current policies, say b' and b^*, would instead lead to the wrong counterfactual analysis. The decision b^* in fact would endogenize also the *current* shareholder's commitment on maximizing firm value. Think for example to the case were a firm would like to issue, say, \$100 of face value of debt with a certain level of protection against future agency conflicts. The quantity we are interested in computing is the increment in credit spread that such firm has to offer to sell the \$100 of debt, relative to what the firm would be able to offer to issue the same amount of debt, if it had no future agency conflicts.[14] In other words, we are interested in measuring the agency credit spread that corresponds to a certain choice of capital and debt (i.e., the current policy) on the part of the firm with agency conflicts.

In the simulated economy, the agency credit spread is therefore the difference between the credit spread at $\hat{\eta} = 0.73$ and the one at $\eta = 0$, given the policy, $a'(\hat{\eta})$:

$$ACS(x, a, \hat{\eta}) = cs(x, a, a'(\hat{\eta}); \hat{\eta}) - cs(x, a, a'(\hat{\eta}); 0). \tag{7}$$

where $cs(x, a, a'(\hat{\eta}); 0)$ cannot be obtained by solving the model of the firm. In fact, simply generating a new simulated economy imposing a restriction that $\eta = 0$, we would obtain $cs(x, a, a'(0); 0)$, which depends on the policy $a'(0)$, and therefore incorporates the absence of agency distortions in the *current decision*, whereas the correct counterfactual is calculated at the policy $a'(\hat{\eta})$.

We work around the impediment by approximating at a given state (x, a) the function $cs(x, a, a'(\eta); \eta)$ with high-order polynomials of the policy $a'(\eta) = \varphi(x, a; \eta)$ and of η, and then calculate $ACS(x, a, \hat{\eta})$ by computing the difference between the fitted credit spread evaluated at $\hat{\eta} = 0.73$, $\widehat{cs}(x, a, a'(\hat{\eta}); \hat{\eta})$, and the fitted credit spread evaluated at $\eta = 0$, $\widehat{cs}(x, a, a'(\hat{\eta}); 0)$. Notably, this approach captures the dependence of the agency spread on $\hat{\eta}$, which measures the estimated level of protection from agency distortions, controlling for the effect that such parameter has on the current policy, $a'(\hat{\eta})$, while at the same time allowing future policies to deviate from firm-maximizing optimal levels. The numerical approximation is detailed in Appendix D.

To give a visual representation of the output, in Figure 4 we plot the agency credit spread against current book leverage, b/k, for $\hat{\eta} = 0.73$ and for a point $x = (u, z)$ that corresponds to the average of the productivity shocks. We plot credit spread and the associated agency component for different levels of agency conflict in the top panel. In the bottom panel, we plot the proportion of the credit spread due to agency conflicts. We note that for very low leverage, the agency component of credit spread is close to zero. At $\hat{\eta} = 0.73$, a minimum level of leverage of circa 0.27 is required for the agency credit spread to be positive. Moreover, not only the difference between credit spread and its agency component keeps increasing as current leverage grows higher, but also the relative proportion is increasing. For very high

[14] Therefore, we must abstract from the fact that, under the assumption of zero agency conflicts, the debt would be cheaper and the firm would decide to issue more debt than \$100.

leverage, the agency consideration becomes a more important driver of the firm's total credit risk.

Since the estimation provides guidance as to what the steady state book leverage is in the model, the number that we record as the agency credit spread for this particular point of the state space is found at $b/k = 0.45$. At this value, for the specific (x, a) considered in Figure 4, 88 basis points or 38.6% of the credit spread at this point is due to agency considerations alone, while the remaining 61.4% can be ascribed to default risk alone (i.e., the credit spread that the firm would have when no agency issues were present).

To highlight the impact of productivity shocks, in Figure 5 we display the agency credit spread for all levels of leverage and for a value of $\hat{\eta}$ equal to 0.73. In particular we focus on the effect of the macroeconomic shock, u, on the agency credit spread. Hence, we plot the agency credit spread for low and high systematic productivity shocks (keeping the idiosyncratic shock at the average value). Clearly, the impact of aggregate shocks is very significant, in line with the findings by Chen and Manso (2017), but extended here to debt-equity agency issues other than underinvestment.

Table 5 presents summary statistics for the agency credit spread and the ratio of agency spread to total credit spread in the simulated economy obtained as described in Appendix D. We report mean, standard deviation, tenth, fiftieth and ninetieth percentiles for the entire simulated sample as well as for subsamples conditional on the magnitude of the systematic shock, the firm-specific shock, the size of the firm, leverage, market-to-book ratio, and the ratio of payout to assets. Subsamples are obtained by sorting stocks in each period of each simulation, and the averaging, in order, across period and simulation.

Table 5 shows that the distributions of the agency spread and of the ratio of agency to total credit spread are positively skewed. The agency credit spread has an average value of 88.3 basis points and a median value of 21 basis points. Similarly, the ratio of agency to total credit spread has an average value of 38% and a median of 34%. The dependence of the agency spread on systematic risk is strongly negative. Also the dependence on idiosyncratic risk is negative, although not as strong. This is because firm-specific risk affects only the cash flow of the firm, whereas the aggregate risk impacts the value of securities both through the cash flow and the discount factor channels, as explained by Hackbarth, Miao, and Morellec (2006).

We also find that the agency spread and the ratio of agency to total credit spread are higher for small firms (i.e., with lower capital stock), for highly levered firms, and for firms with low market-to-book ratio. Sorting on the basis of the payout ratio, delivers ambiguous results: the average agency spread is higher for high payout firms, but the median is lower, suggesting that the distribution of the agency spread is highly skewed within each payout subsample.

4.2. Agency credit spread and deviation from optimal policies

We describe here how deviations from optimal policies manifest in the simulated data and how they relate to the agency credit spread estimated above. The simulation approach on which the following analysis is based is described in Appendix A.

We want to relate the current agency credit spread to future deviations from the value maximizing policy due to lack of shareholders' commitment. To do so, given a point of the state space, (x, a), at t and the contemporaneous optimal policy $a' = \varphi(x, a; \hat{\eta})$, for the estimated $\hat{\eta}$, we calculate the agency spread $ACS(x, a, \hat{\eta})$. Next, moving along the simulated path (see Figure 1), we analyze deviations from the firm value maximizing policy in the simulated point (x', a') at $t + 1$, as the difference between the policy implemented by the calibrated firm, $\omega(x', a')$ and $a'' = \varphi(x', a'; \hat{\eta})$, and the policy implemented by a firm with no agency distortions, $\omega^*(x', a')$ and $a^{**} = \varphi(x', a'; 0)$, with all other parameters set as in Table 2. In Appendix C we show that deviations in $t + 1$ can happen because the default policy with no agency issues, $\eta = 0$, is different from the default policy under $\eta = \hat{\eta}$, that is $\omega^*(x', a') \neq \omega(x', a')$, and because there can be a shortfall in the debt continuation value due to deviations from the value maximizing policy a^{**}. These deviations can happen either because $k'' \neq k^{**}$, or because $b'' \neq b^{**}$, or both. In our simulated economy, we find that the difference in price due to a different frequency of single-period defaults is negligible. Therefore, in what follows we focus on deviations in the investment and financing policies.

We present the frequency and magnitude of such deviations in Table 6. For expositional reasons we organize them in groups that can in part be related to known definitions of agency conflicts. For example, the cases with $k'' < k^{**}$ are instances of underinvestment. Since we model also the leverage ratchet effect, we have three possibilities: the pure underinvestment case, in which the debt policy corresponds to the first best case; cases of debt over-issuance (i.e., a manifestation of shareholders' incentive to issue debt whenever this suits them); and cases in which the firm also under-issues debt (i.e., a case that cannot be classified in the traditional schemes, but is indeed a deviation from firm value maximization). More than sixty per cent of deviations in the simulated economy involve exclusively the debt policy. Among those, the very few cases of debt over-issuance are associated with very large average agency credit spreads, while under-issuances are associated with low average agency spread. The other instance with a high frequency, of about 38%, involves both underinvestment and under-issuance. As those cases are less severe manifestation of agency conflicts, they are associated with low average agency spread, although the dispersion of the agency spread is very large.

To shed a more precise light on the relation between agency spreads and future deviations of the policies from firm value maximization, we calculate the joint distribution of percentage deviations in Table 7. We divide investment and debt deviations in groups based on the magnitude of the deviation in increments of 10%. We then double sort the simulated observations and place them in the corresponding groups. Because not all intervals are populated in the simulated economy, for presentation purposes we aggregate some of the groups.[15]

Similarly to Table 6, in Panel A and B of Table 7 we observe that most of the observations can be found along the row that corresponds to the 0% investment deviations. The center mass of the distribution lays in the south east corner of the table, corresponding to cases with a small deviations from investment policies, equal to about half the asset depreciation rate, and a debt that is approximately 40% smaller than the one under firm value maximization.

Although all future deviations are accounted for in determining the debt price (and the agency credit spread), we can observe the direct impact of deviations by observing the agency spreads in different scenarios. The unconditional average spread in the simulated economy is the weighted average across all these scenarios, with probabilities corresponding to the relative frequencies. We can see in Panel C that the agency spread is increasing in the amount of underinvestment and over-issuance (i.e., the spread increasing moving towards the north east corner of the table). The rate at which the spread increases is almost monotonic, with few exceptions due to groups being scarcely populated.

The above analysis of the simulated economy is admittedly crude. A proper quantification of the relative incidence of the various deviations on the agency spread requires some more detailed analysis. We attempt such measurement by regressing the agency spread, $ACS(x, a, \hat{\eta})$, on the percentage deviations of investment and debt policies, respectively k''/k^{**} and b''/b^{**}, while controlling for the variables that define the state space: the systematic and idiosyncratic shocks and the combination of initial capital and debt (i.e., at the beginning of the period before the shocks are observed), expressed as either leverage ratio, b/k, or credit spread, $cs(x, a, a')$.

We present the results in Table 8. Each column reports coefficients that we obtain by first estimating a panel regression for each simulated economy (i.e., we simulate 50 panels of

[15]For example, despite the lowest deviation of the investment policy is -71%, we aggregate all deviations below -40% in one bin.

500 firms for 15 years), and then averaging coefficients through simulated samples. Standard errors are similarly constructed by computing the standard deviations of the 50 parameters obtained from the panel regressions.

Accepting the assumption of a linear relation, the interpretation of the results in Columns (1) and (2) is that a ten percent underinvestment is associated with an increase in the agency spread of 8 to 11 basis points, depending on whether we control for either book leverage or credit spread (we cannot control for both). Similarly, a ten percent over-issuance of debt leads to an increase of 5 to 6 basis points in the agency spread. If the distributions of investment and debt policy deviations were similar, it would then appear that investment deviations have a larger impact on agency spread than debt policy deviations. However, debt policy deviations are larger and have wider dispersion, thus making the comparison difficult to interpret. For this reason in Columns (3 and (4) we report results after standardizing the regression right-hand side variables. After making this adjustment, the economic magnitude of the marginal effects reverse. A debt policy deviation from value maximization equal to one standard deviation has a slightly larger impact on agency spreads than a corresponding deviation in the investment policy. Based on this interpretation, the leverage ratchet effect seems to be at least as important as underinvestment in determining the wealth transfer from debt to equity measured by the agency credit spread.

5. Robustness checks

We present here two types of robustness checks. The first group contains analyses related to the impact that some parameters have on the agency spread. The second group contains analyses that we perform to investigate the impact on the agency conflicts of certain model choices we have presented in the main analysis.

5.1. Impact of parameters on agency conflicts

The parameters we have used in the analysis so far were obtained either from the literature or from our estimation exercise. While all parameters are important to determine the behavior of the firms in the simulated economy, two coefficients directly affect the investment and debt policies: the debt adjustment cost coefficient and the liquidation price. Another coefficient that is important, equity adjustment cost, was chosen based on values reported in the literature.

We conduct a sensitivity analysis on these parameters to make sure that they are not responsible for the results described in the previous section. In particular we simulate new economies, wherein we adjust the key parameters while keeping all others at the values in Table 2. The sensitivity analysis is done by increasing and decreasing the parameter of interest relative to the base value. In Table 9, for each of the six cases considered, we report the average agency spread and the coefficients of investment and debt policy deviations obtained from regression models similar to those presented in the first column of Table 8.

Changing the parameters has clear effects on the average agency spread: increasing the equity adjustment costs decreases the investment rate of the firm (in particular, it increases disinvestments), and therefore increases the agency conflict; similarly decreasing debt adjustment costs increases the leverage ratchet effect, and consequently the agency spread. Finally, increasing the price the firm receives for liquidating assets increases the shareholders incentive to dispose of the capital stock (asset stripping), thus exacerbating the agency conflicts.

The magnitude of the changes, however, does not qualitatively alter the relationship between agency spread and investment and debt deviations. In each case, a ten per cent positive deviation in the debt policy is associated with an increase in ACS (in absolute terms) at least as large as the one related to a ten per cent deviation in the investment policy.[16]

5.2. Impact of covenants on agency conflicts

In the baseline model, we have adopted a reduced form approach to capture the effect of debt contract provisions that limit debt-equity conflicts using the parameter η. In the model, η is inversely related to the amount of dual holdings of the firm's debt by the shareholders, as a way to achieve a partial protection against agency issues. We showed that a low degree of protection against agency conflicts is necessary to give a realistic model of the firm. In this section, we show that adding (an imperfect) protection, by means of a covenant, to the debt contract reduces the fraction of dual holdings necessary to produce a representative simulated economy. This corroborates the interpretation of η as the parameter in the model that gauges the extent to which the debt is protected against agency distortions.

We modify the basic model by introducing a protective debt covenant. The use of different types of debt covenants has been documented, among others, by Smith and Warner (1979), Bradley and Roberts (2004) Billett, King, and Mauer (2007), Chava and Roberts (2008),

[16]The model is quite non-linear in these parameters, as the sensitivities of investment and debt policies of the base case are not within the estimates provided in Table 9.

Roberts and Sufi (2009), and Nini, Smith, and Sufi (2009). The consensus in the literature is that debt covenants are contractual features that reduce (although not completely) the agency conflicts between equity and debt, and therefore are ultimately welfare improving. We borrow from the model of Gamba and Triantis (2014),[17] and add to the baseline specification a "maximum Debt to EBITDA" covenant. Chava and Roberts (2008) document that this type of covenant is the most recurrent in their sample of private loans and is a good proxy for similar covenants that impose state-contingent restrictions based on financial ratios.

We introduce two relevant thresholds, ξ_d and ξ_u, that characterize the financial covenant. If EBITDA, $\pi(u, z, k)$, is positive and $b/\pi(u, z, k) > \xi_d$ the covenant is violated and a technical default occurs. In this instance, a new decision $a' = (k', b')$ is made subject to the restriction that, if next period's productivity is the same as (u, z), the Debt/EBITDA ratio does not exceed ξ_u. If EBITDA is zero or negative, a technical default also occurs, and the only remedy for the shareholders is to reimburse all the debt (i.e., $b' = 0$). Therefore, the "maximum Debt to EBITDA" covenant results in a state contingent restriction, whereby the investment and financing decisions, a', in equation (5) is constrained if the firm violates the covenant. Otherwise, the set of feasible policies remains unconstrained.

We proceed with two experiments. First, keeping fixed all parameters in Table 2, we calibrate the two thresholds ξ_d and ξ_u so that the model produces a simulated economy with a covenant violation frequency of 10%, and therefore in line with the evidence documented by Nini, Smith, and Sufi (2009). We obtained $\xi_d = 6.54$ and $\xi_u = 8.54$, and a covenant violation frequency of 10.36%. The average firm in this simulation has investment, profitability, distribution, and leverage at values very close to those reported in Table 3, with the differences being statistically insignificant from zero. Despite not reducing the average level of leverage, the covenant is however very effective at reducing credit risk. The average firm has in fact an average credit spread of 33 basis points and an average agency spread of 9 basis points.[18] This first analysis is therefore useful in demonstrating the quantitative impact of the covenant on the riskiness of the firm.

For our second analysis, keeping fixed the covenant specific parameters, as well as all the basic model parameters, we recalibrate the agency conflict parameter η so that the covenant-enhanced model fits the complete set of moments (i.e., those reported in Table 3 plus the covenant violation frequency). Because the inclusion of the covenant increases the protection

[17]Gamba and Triantis (2014) analyze the way in which different types of covenants impact the investment and financing policies of the firm and the channels through which (and to what extent) they reduce these agency issues.

[18]Results are available upon request.

of debt from agency conflicts in the model, we should obtain a higher level of η, than that obtained using the model without covenants, in order to replicate the agency distortions in the data with a more "protected" debt contract. This is because a lower figurative dual-holding of debt and equity, $1-\eta$, is required in the model to give level of debt protection, if explicit provisions in the debt contract already deliver such protection. We find a value of 0.78, in line with the intuition that covenants help reduce, but do not completely eliminate, agency frictions between equity and debt holders.

5.3. Impact of cash holdings on agency conflicts

As a second important model choice, we have not considered a dynamic saving policy. Adding one more state variable would substantially increase the numerical complication in solving and estimating the model. However it would not necessarily change the spirit of the paper. First, our conclusions regarding the leverage ratchet effect would not be changed. Absent external financing costs, Admati, DeMarzo, Hellwig, and Pfleiderer (2017) show that both the incentive of shareholders to increase the debt whenever possible and to resist a debt reduction hold when the marginal value of cash is one. If, in the presence of external financing (in particular equity issuance) costs, $\lambda > 0$, we allow the firm to hoard cash, then the marginal value of savings will be in the interval $[1, 1+\lambda]$. That is, 1 is the marginal value when the firm disposes of the cash by making a dividend payment, $1+\lambda$ is the marginal value of cash when the firm is at the equity issuance margin, and whenever the firm is hoarding cash, the marginal value of savings is in $]1, 1+\lambda[$. Then, our point is very simple: if the firm resists to using cash to repay part of the debt when the marginal value of cash is 1, this is even more true when the marginal value of cash is higher than 1.

Second, if we allowed the firm to save, other agency issues would be affected in an ambiguous way because of two countervailing effects. On the one hand, cash holdings in our model would affect the degree of liquidity of the assets, which increases agency conflicts by allowing sharehodlers to cash out at a lower cost. This aspect is already considered in our analysis through the parameter ℓ, although in an exogenous fashion, whereas cash holdings would endogenize this aspect and the effect that this has on agency conflicts. The expectation is that even an optimal saving policy would increase the instances in which the shareholder decide to "cash out". On the other hand, cash holdings would affect the net leverage (debt minus cash holdings over total asset) of the firm. Managing savings would substantially improve the ability of the firm to dynamically manage the net leverage, in a model with long term debt and debt persistence generated by the leverage ratchet effect. The expectation is that, by adding savings to the model, the increased (net) leverage flexibility introduced by cash holding helps reducing the agency issues. To summarize, the consideration of cash holdings would have an ambiguous impact on cashing out agency issues which would require a quantitative analysis. We believe this is beyond the scope of the current paper and an interesting topic for future research.

6. Conclusions

We develop a discrete-time infinite-horizon dynamic structural model for pricing corporate debt with endogenous investment, endogenous capital structure decisions, and endogenous default. There are two salient features of the model: first, we introduce a long-term bond, which has infinite maturity and is completely free of any debt covenants forcing the firm to repurchase all existing debt to issue more debt. Second, we propose a novel approach in specifying the value function, from which the optimal policies are derived, as a function of a free parameter, interpreted as one minus the figurative portion of firm debt held by the shareholders, that governs the degree of protection against agency conflict in the model.

Those two features allow us to examine the impact of agency conflicts on the credit risk of a firm. We show that an estimation that successfully matches observed data requires a relatively low degree of protection against agency conflicts, which is in line with the idea that debt covenants and other provisions, such as finite maturity and priority structures, help reduce but do not eliminate the agency issues between debt and equity holders.

We then calculate the part of the credit spread that is attributable solely to such agency issues, the agency credit spread, and we relate it to characteristics of the firm. On average, the agency spread is a non-negligible part of the cost of debt of a firm, and it is larger in economic downturns, for firms with high leverage, closer to financial distress, with lower market-to-book, and smaller size.

We also show that deviations from firm maximizing debt policies have at least as large an impact on agency spreads as deviations from investment choices. In other words, the leverage ratchet effect is quantitatively at least as important as underinvestment due to debt overhang, as far as the wealth transfer from debt to equity is concerned.

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A. Model numerical solution

The valuation model for equity and debt is a continuous-decision infinite-horizon Markov Decision Process. The solution method is based on successive approximations of the fixed point solution of the valuation operator given by the Bellman equation (5) with constraints (1) and (4). This method is applied to an approximate discrete-state and discrete-decision operator.

Given the high autocorrelation that characterizes u, we use Rouwenhorst (1995) method to discretize each of the state variables u and z independently. As a result, we will have a finite set of pairs $\{x_j = (u_j, z_j) \mid j = 1, \ldots, N_x\}$ and a probability transition matrix for these states. We set the upper bound for capital stock, k_u, and for the face value of the debt, b_u respectively, so that they are never binding for the equity maximizing program, as resulting from the simulation. We discretize $[0, k_u]$ and obtain the set of capital stock levels $\{k_j = k_u(1-\delta)^j \mid j = 1, \ldots, N_k\}$, and the interval $[0, b_u]$ is discretized into $\left\{b_j = (j-1)\frac{b_u}{N_b} \mid j = 1, \ldots, N_b\right\}$. For the optimal set of parameters in Table 2, we use $k_u = 20$ and $b_u = 20$. We solve the model using $N_x = 21$ (3 discrete points for x and 7 for z), $N_k = 51$, and $N_b = 51$. Tolerance for terminating the value function iteration is set at 10^{-6}.

Because we use a discrete approximation of the state variable u, we need to correct a bias resulting in the discount factor. We do this by calculating a state-dependent adjustment factor $m_t = \mathbb{E}_t[e^{-g(u_t)\varepsilon^u_{t+1} - \frac{1}{2}g(u_t)^2\sigma^2_u}]$ using the discrete-space probability transition matrix found above, and then using the adjusted stochastic discount factor $\widetilde{M}_{t+1} = M_{t+1}/m_t$.

The sample of simulated economies is obtained by a Monte Carlo simulation of $x = (u, z)$ and the application of the optimal policy φ, for a given initial choice of x_0 and $a_0 = (k_0, b_0)$. In particular, we simulate 50 economies, each defined by an independent path of systematic risk, u. Each economy comprises 500 firms, each defined by an independent path of idiosyncratic risk, z. A firm's path is generated for 30 steps, but observed at the steady state only for the final 15 steps, to eliminate the dependence of (k_0, b_0).

B. Estimation method

The model is estimated using the simulated method of moments (SMM) of Gourieroux, Monfort, and Renault (1993) and Gourieroux and Monfort (1996). We estimate the parameters of the firm's model by matching moments constructed on some firm level quantities.

In each step we solve a similar version of the following program

$$\hat{\theta} = \arg\min_{\theta} \left\{ G_S(\theta)' W_S G_S(\theta) \right\}, \tag{8}$$

where

$$G_S(\theta) = m_S - \frac{1}{J} \sum_{j=1}^{J} \widetilde{m}_s^j(\theta)$$

and $W_S = [S \operatorname{var}(m_S)]^{-1})$ is the efficient weighting matrix, m_S are the empirical moments based on S observations, $\widetilde{m}_s^j$ are the simulated moments based on s observations in each sample j. We calculate the efficient matrix $\operatorname{var}(m_S)$ using the influence function approach in Erickson and Whited (2002) and Warusawitharana and Whited (2016). As our sample is composed by N firms over T periods, for notation purposes the total number of observations is equal to $S = NT$. Let ϕ_{it} be the vector representing the influence functions of all moments for firm i at time t. Following Warusawitharana and Whited (2016), we demean the data to compute the influence functions for means and autocorrelation but not for variances and standard deviations. The influence functions can be used to obtain the covariance matrix of the moments

$$\frac{1}{NT} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \phi_{it} \right) \left(\sum_{t=1}^{T} \phi_{it} \right)',$$

the inverse of which is used as the efficient weighting matrix.

We solve the program in (8) using the differential evolution algorithm proposed by Storn and Price (1997). As Price, Storn, and Lampinen (2005) suggest, the algorithm is an efficient global optimizer, and is able to avoid local minima.

We also compute the sensitivity measures of Gentzkow and Shapiro (2017), who provide a measure of parameter sensitivity to moments used in the estimation procedure:

$$\Xi = -(\Gamma' \Lambda^{-1} \Gamma)^{-1} \Gamma' \Lambda^{-1}$$

Ξ is a matrix that has dimension equal to number of moments per number of parameters. Gentzkow and Shapiro (2017) suggest reporting the absolute value of the elements contained in each column of Ξ as the relative importance of each moment in identifying the parameter corresponding to that column. To provide a more easily interpretable measure, Gentzkow and Shapiro (2017) also suggest to standardize the measure by the ratio of the relative standard deviations:

$$\hat{\Xi}_{p,j} = \Xi_{p,j}\sqrt{\frac{\text{var}(\hat{G}_j)}{\text{var}(\hat{\theta}_p)}}$$

where $\hat{G}_j$ is the j-th moment and $\hat{\theta}_p$ is the p-th parameter.

C. The determinants of the agency credit spread

The agency credit spread in a given state (x, a) is defined in equation (7), as the difference between the credit spread under $\eta = \hat{\eta}$ and the credit spread under $\eta = 0$, assuming the policy $a'(\hat{\eta}) = \varphi(x, a; \hat{\eta})$ as given. Because the credit spread is determined as the difference between the yield of the defaultable debt and the yield on the same debt excluding default risk, and because the latter yield is the same for the case with $\eta = \hat{\eta}$ and $\eta = 0$,[19] then

$$ACS(x, a, \hat{\eta}) \propto D^*(x, a, a') - D(x, a, a'),$$

that is, the agency credit spread is proportional to the difference between $D^*(x, a, a')$, the debt price for $\eta = 0$, with no agency distortions, and $D(x, a, a')$, the debt price for $\eta = \hat{\eta}$, with representative agency distortions. Given equation (4), such difference is equal to the present value of the difference $d^*(x', a', a^{**}) - d(x', a', a'')$, where $d(x', a', a'')$ is defined in equation (3), $a'' = \varphi(x', a'; \hat{\eta})$, and

$$\begin{aligned} &d^*(x', a', a^{**}) = \omega^*(x', a')(1-\zeta)\min\left\{(1-\tau)\pi(x', k') + (1-\delta)k' + \tau\delta k', b'\right\} \\ &+ (1-\omega^*(x', a'))\left[rb' + \chi_{\{b^{**}\geq b'\}}b'D^*(x', a', a^{**})/b^{**} + \chi_{\{b^{**}<b'\}}\left(D^*(x', a', a^{**}) + b' - b^{**}\right)\right] \end{aligned}$$

is the same expression, except for ω^*, the default policy under $\eta = 0$, and $(k^{**}, b^{**}) = a^{**} = \varphi(x', a'; 0)$, the $(t + 1)$ optimal policy under the same assumption.

We define the recovery at default as

$$R(x', a') = (1-\zeta)\min\left\{(1-\tau)\pi(x', k') + (1-\delta)k' + \tau\delta k', b'\right\},$$

[19] The difference in the yield of the default-free debt for $\eta = \hat{\eta}$ and $\eta = 0$ in our numerical solution is negligible.

and the continuation value of the debt for $\eta = \hat{\eta}$ as

$$C(x', a') = \chi_{\{b'' \geq b'\}} b' D(x', a', a'')/b'' + \chi_{\{b'' < b'\}} \left(D(x', a', a'') + b' - b'' \right).$$

The continuation value of the debt under $\eta = 0$, denoted $C^*(x', a')$, has the same expression as above except for using on the right-hand side a^{**} in place of a'' and $D^*(x', a', a^{**})$ in place of $D(x', a', a'')$.

Using this notation, and after some manipulations, we have that

$$\begin{aligned} d^*(x', a', a^{**}) - d(x', a', a'') \\ &= \left[\omega(x', a') - \omega^*(x', a')\right] \left[rb' + C(x', a') - R(x', a')\right] \\ &\quad + \left[1 - \omega^*(x', a')\right] \left[C^*(x', a') - C(x', a')\right]. \end{aligned} \tag{9}$$

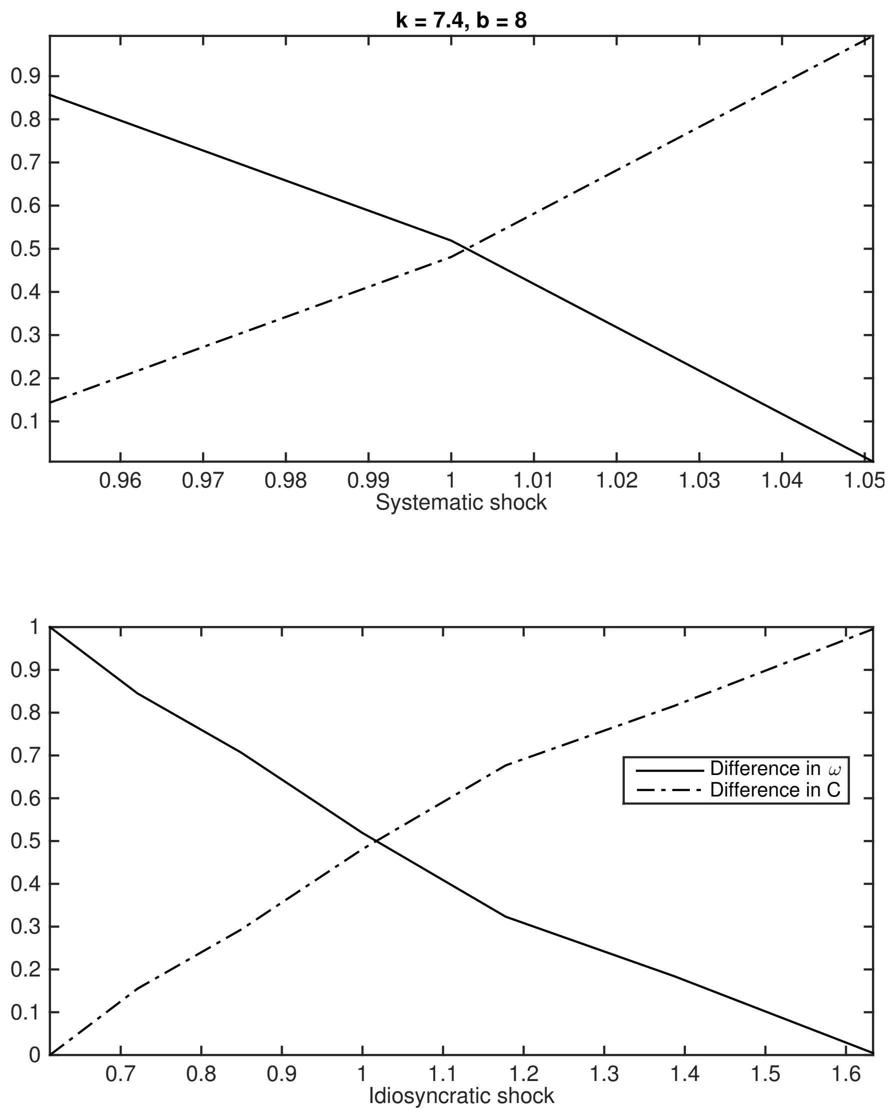
This expression illustrates the two determinants of the agency credit spread. The first determinant, in the second line, is the loss of payoff (which is the interest payment plus the continuation value, net of the recovery at default) due to a more likely default under $\eta = \hat{\eta}$ than in the case without agency issues, $\eta = 0$. The second determinant, in the third line of (9), conditional on the survival of the firm under $\eta = 0$, is the shortfall in continuation value due to deviations from the value maximizing policy a^{**}. In particular, the latter difference is driven by two aspects: the debt policy, b'', can be different from b^{**}, which may result in the dilution of the value of debt going forward; the investment policy, k'', can be different from k^{**}, because it may result in underinvestment or asset stripping.

From (9), we can calculate the price shortfall for the debt as

$$\begin{aligned} D^*(x, a, a') - D(x, a, a') &= \mathbb{E}_x \left\{ M(x, x') \left[d^*(x', a', a^{**}) - d(x', a', a'') \right] \right\} \\ &= \mathbb{E}_x \left\{ M(x, x') \left[\omega(x', a') - \omega^*(x', a')\right] \left[rb' + C^*(x', a') - R(x', a')\right] \right\} \\ &\quad + \mathbb{E}_x \left\{ M(x, x') \left[1 - \omega^*(x', a')\right] \left[C^*(x', a') - C(x', a')\right] \right\}. \end{aligned} \tag{10}$$

This expression is particularly important, as it allows a decomposition of the price shortfall, and therefore of the agency credit spread. This calculation allows us to see whether the main determinant of the price shortfall is the difference in default policy or the difference in continuation value. We can calculate these values explicitly in the model (with no need of approximations) at all states.

In the following figure we plot the second and third lines of equation (10), as a fraction of the total price shortfall, $D^*(x, a, a') - D(x, a, a')$, against either the systematic shock (upper panel) or the idiosyncratic shock (lower panel). We generate the plot at a non-representative state point ($k = 7.4$ and $b = 8$) with high leverage, to magnify the likelihood of default in one period, at $\hat{\eta} = 0.73$, while all the other parameters are from Table 2. While the component due to the difference in the default policy becomes obviously less important as the state improves, given the reduction in the incentive to default under $\eta = \hat{\eta}$, the component due to the difference in continuation value increases. Although this may seem counterintuitive, it can be understood by observing that, when there is an upturn, the firm under $\eta = 0$ has a better policy relative to the firm under $\eta = \hat{\eta}$, which is at a disadvantage. This difference has the effect of increasing the difference $C^*(x', a') - C(x', a')$, and therefore the agency credit spread.



D. Numerical solution of ACS

This section describes the numerical procedure used to compute the agency credit spread at the estimated $\hat{\eta}$, as defined in equation (7). A numerical procedure is needed as only the first term on the right-hand side of equation (7) is directly calculated in the model. The second term, $cs(x, a, a'(\hat{\eta}); 0)$ must be found using a numerical approximation.

To do this, we proceed as follows. First, we partition the interval $[0, 1]$ of values of η, in sub-intervals of equal width of 0.0005. We then solve the model for each of the 2000 values of η, keeping fixed all the other parameters at the values in Table 2. Second, for each point of the state space (x, a), we construct a numerical approximation based on high-order polynomials of the function that relates the credit spread of a firm to the policy a' and to the coefficient η. In particular:

$$\ln\left(cs(x, a, a'(\eta); \eta)\right) = \alpha_0 + \sum_{i=1}^{5} \alpha_i \left(a'(\eta)\right)^i + \sum_{j=1}^{5} \beta_j \eta^j + \varepsilon$$

in which $a'(\eta) = \varphi(x, a; \eta)$. We estimate the coefficient α_i and β_j by linear projection, on the pool sample of observations coming from the 2000 samples of η. Given the estimates $\hat{\alpha}_i$ and $\hat{\beta}_j$, we then compute the agency credit spread at $\hat{\eta}$ as

$$\begin{aligned} ACS(x, a, \hat{\eta}) &= \widehat{cs}(x, a, a'(\hat{\eta}); \hat{\eta}) - \widehat{cs}(x, a, a'(\hat{\eta}); 0) \\ &= \exp\left\{\hat{\alpha}_0 + \sum_{i=1}^{5} \hat{\alpha}_i \left(a'(\hat{\eta})\right)^i + \sum_{j=1}^{5} \hat{\beta}_j \left(\hat{\eta}\right)^i\right\} - \exp\left\{\hat{\alpha}_0 + \sum_{i=1}^{5} \hat{\alpha}_i \left(a'(\hat{\eta})\right)^i\right\}. \end{aligned}$$

Importantly, this approximation captures the dependence of the agency spread directly on the parameter $\hat{\eta}$, which measures the estimated level of protection from agency distortions, controlling for the effect that such parameter has on the current policy, $a'(\hat{\eta})$.

For each (x, a), we have now a measure of the agency credit spreads. Since the process to derive the ACS is numerical, some of these values are very large and some might even be negative. To eliminate the impact of the numerical implementation on the economic measurement of the agency credit spread we apply the following smoothing procedure.

First, for each $x = (u, z)$, we collect all $ACS(x, a, \eta)$ corresponding to all combinations of $a = (k, b)$ and sort them into book leverage, b/k, buckets on intervals of one per cent, from zero to the maximum leverage on the grid. Aggregating agency spread measurements over their respective levels of current leverage, after the policy $a' = (k', b')$ has been controlled for, allows us to capture the economic effect associated to changes in debt protection against agency conflicts for a given level of credit risk, proxied by leverage. For any leverage bucket, the distribution of ACS is skewed by a few outliers. Therefore, we assign to that leverage bucket the median sensitivity among the observations in that group. We use the median as opposed to the average because the latter would be affected by the extreme values in the tails. Second, in order to obtain a smooth curve, we fit the collection of estimated median ACS by using a double exponential model. We tried several alternatives to the double exponential and chose the one with the best average fit.

Figure 1
Model timeline
This figure describes the chronology of the firm's decision problem. At t the shocks $x = (u, z)$ are realized, and the firm's cash flow is determined based on the capital stock k and the debt b, or $a = (k, b)$. Immediately after t, the firm chooses the new set of capital and debt, as the combination $a' = (k', b')$ that maximizes the value of the equity, given by the sum of the current cash flow, $s(x, a, a')$, plus the continuation value. The market value of the debt issued at t, denoted $D(x, a, a')$, depends on the current state, (x, a), and policy, $a' = \varphi(x, a; \eta)$, and incorporates also the effect of the future policy, $a'' = \varphi(x', a'; \eta)$.

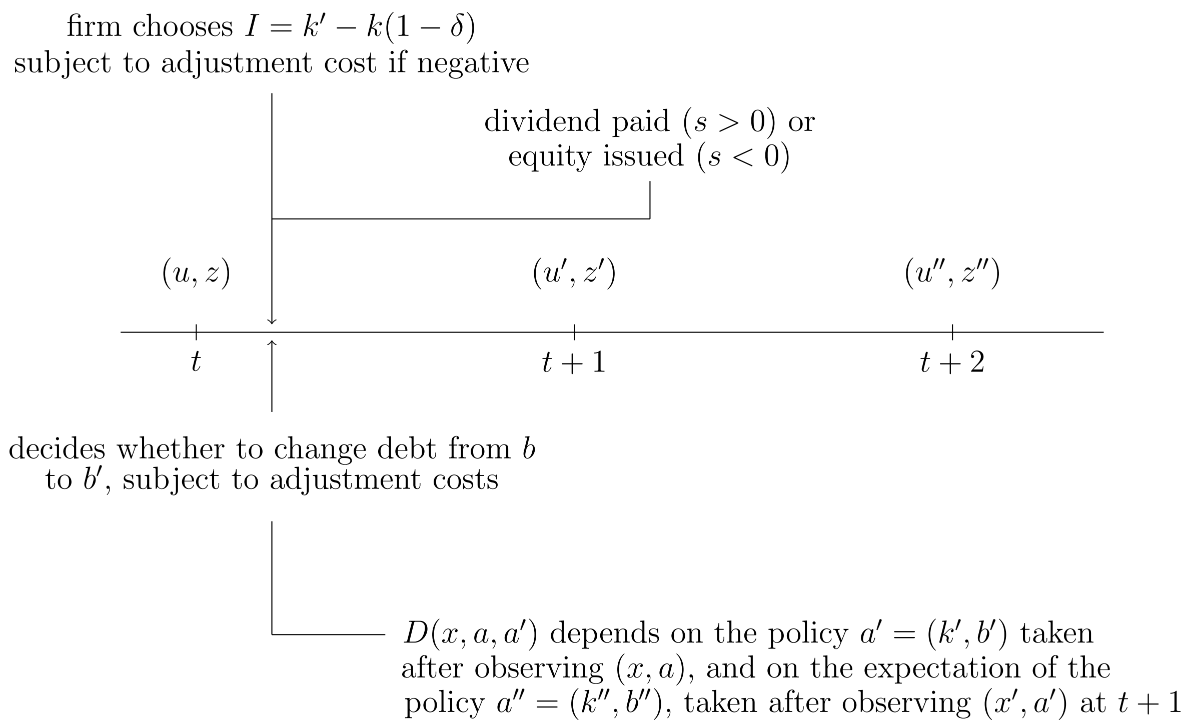


Figure 2
Sensitivities of η to moments

The figure shows the sensitivity measures proposed by Gentzkow and Shapiro (2017). The histogram depicts the contribution of each moment condition to the identification of η, the parameter measuring the protection of debt against agency conflicts. We report details on the construction of the sensitivity measure in Appendix B.

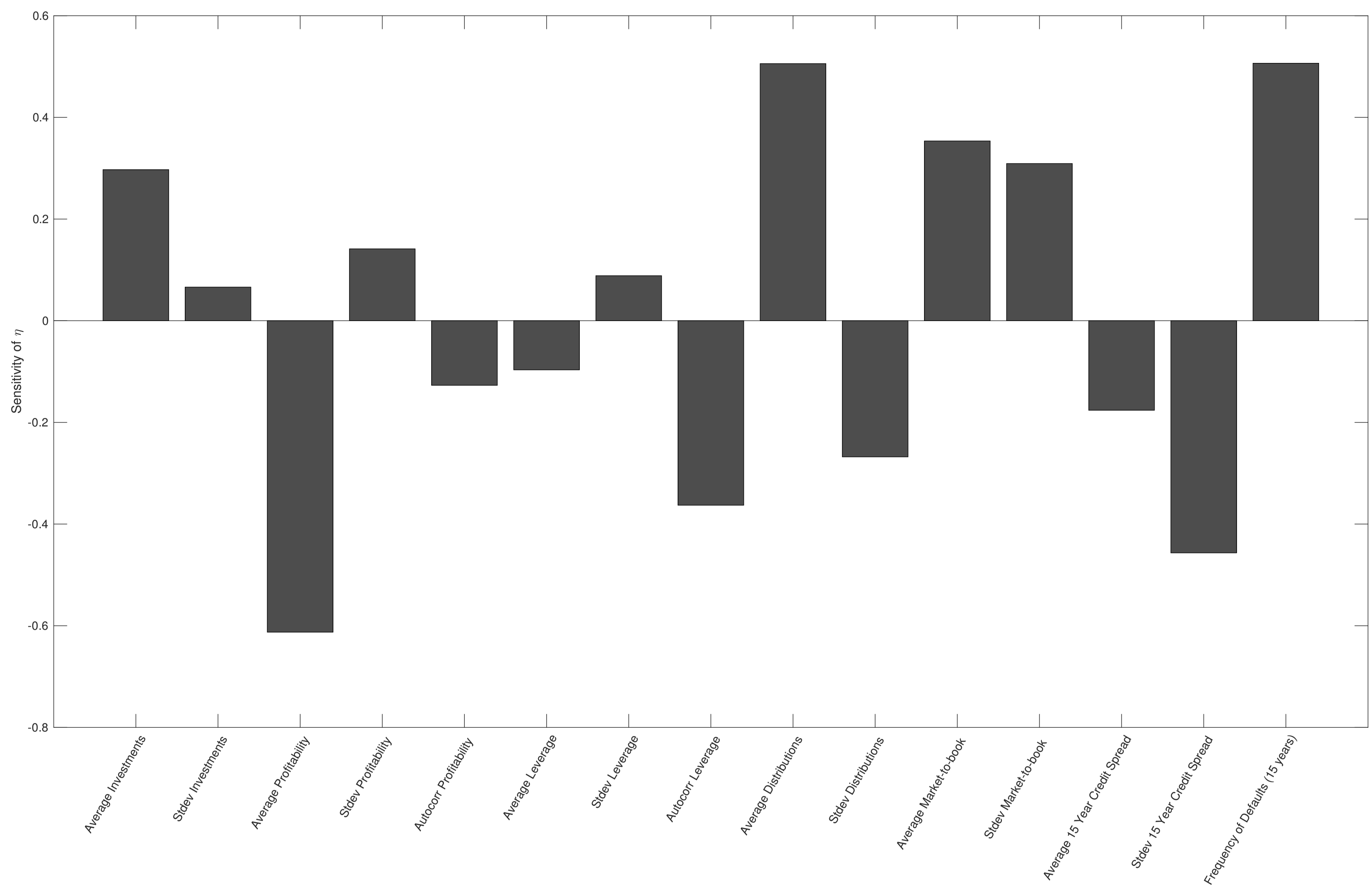


Figure 3

Comparative static of moments relative to changes in η

The figure plots the fifteen moment conditions included in the SMM exercise for various levels of η, the parameter gauging the protection of debt against agency conflicts. To obtain each panel, we simulate the model keeping parameters fixed at the values reported in Table 2 but vary the coefficient η between zero and one.

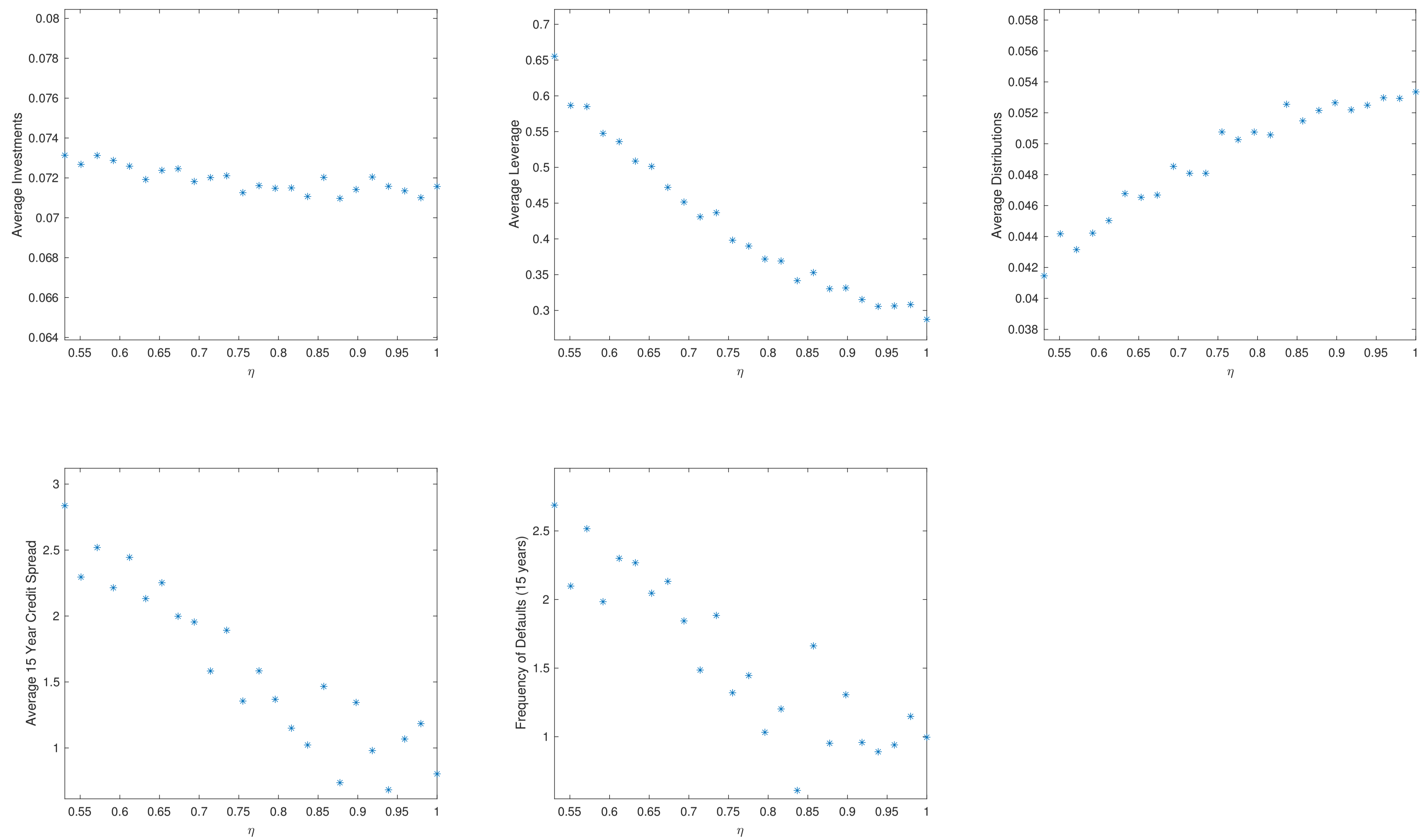


Figure 4
Agency credit spread as function of leverage

The figures plot the agency credit spread against the current book leverage, b/k, from 0 to 1, for the estimated level of the parameter measuring the protection of debt against agency conflicts, $\hat{\eta} = 0.73$, at the steady-state level of the shocks $x = (u, z)$. The bottom panel shows the ratio ACS/cs. The agency credit spread is defined in equation (7), and the numerical approach used to calculate it is described in Appendix D.

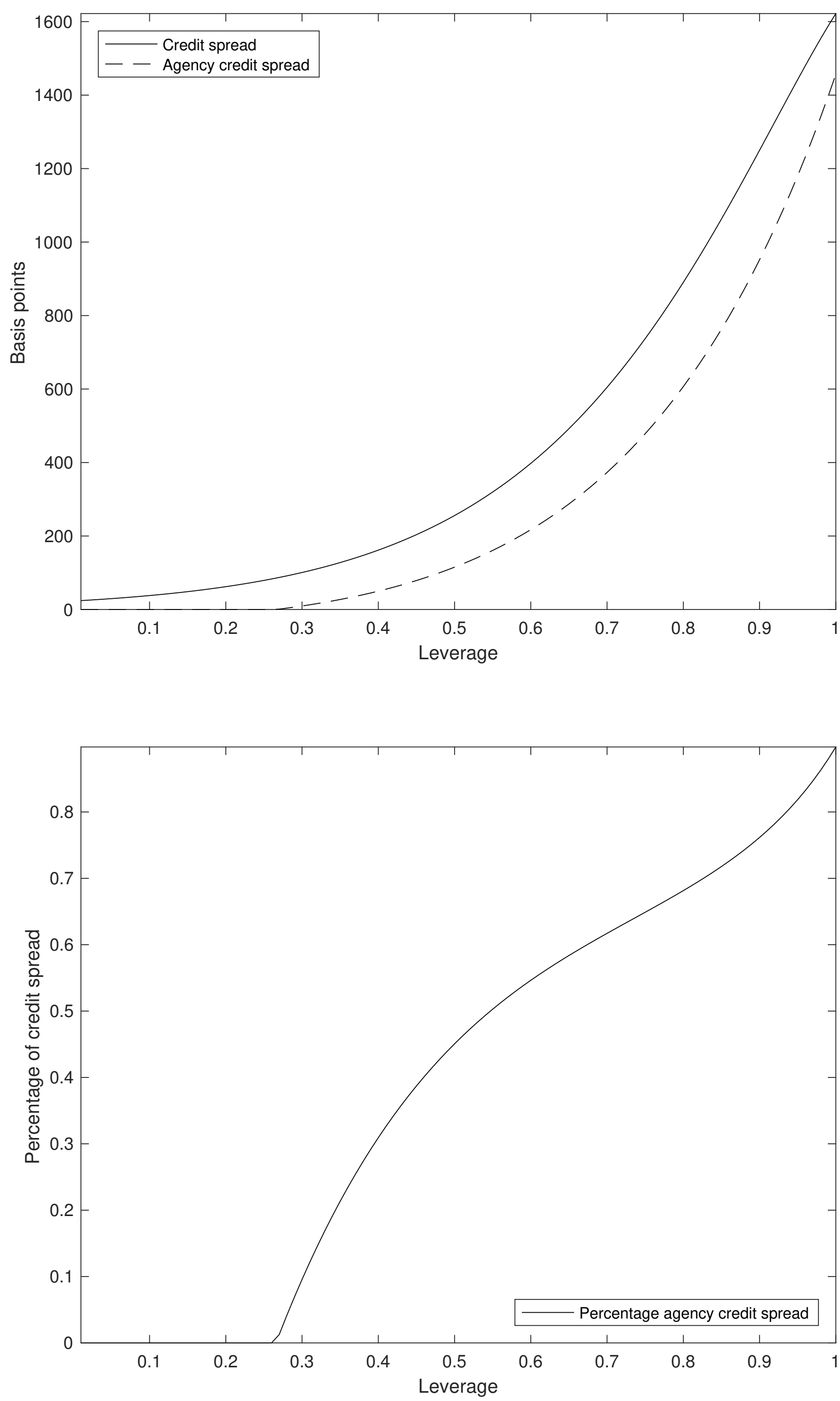


Figure 5
Agency credit spread and productivity shocks

The figure plots the agency credit spread against the current book leverage, b/k, from 0 to 1, for the estimated level of the parameter measuring the protection of debt against agency conflicts, $\hat{\eta} = 0.73$, for a given choice of of the shocks $x = (u, z)$. We plot the agency credit spreads for different realizations of the aggregate productivity shock, u. The agency credit spread is defined in equation (7), and the numerical approach used to calculate it is described in Appendix D.

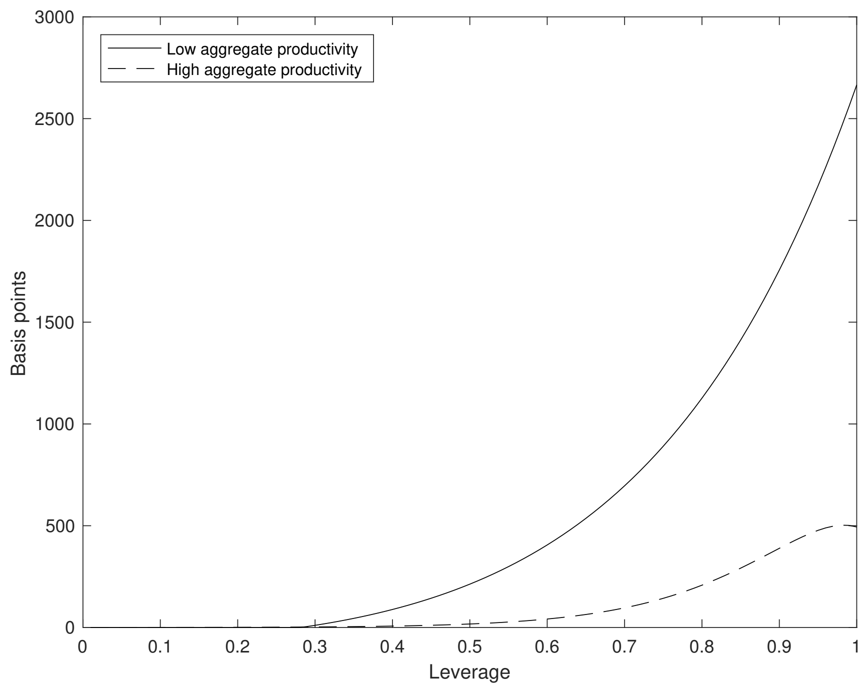


Table 1
Data summary statistics

This table reports summary statistics (i.e., mean, standard deviation, first, fiftieth and ninety-ninth percentile) of the variables used in the paper. Variable construction is described in Section 3.1. The sample contains all industrial firms in the S&P 500 index with traded CDS contracts in the period between 2001 and 2015.

			Percentiles		
	Mean	Stdev	1^{st}	50^{th}	99^{th}
	Variables used for moment conditions				
Investments	0.072	0.107	-0.109	0.054	0.479
Profitability	0.148	0.075	0.006	0.141	0.341
Leverage	0.462	0.309	0.024	0.426	1.158
Distributions	0.046	0.067	-0.060	0.027	0.269
Market-to-book	1.839	0.821	0.931	1.600	4.687
15-year credit spread (per cent)	1.626	3.348	0.202	0.923	10.455
	Variables used for sorting				
Operating leverage	0.936	0.242	0.072	0.946	1.646
Asset specificity	0.028	0.005	0.020	0.027	0.040
Asset maturity (years)	6.442	5.712	1.202	4.351	26.707
	Other variables				
Total assets (logs)	9.523	1.038	7.500	9.516	12.539
Debt plus equity (logs)	9.047	1.058	7.041	9.016	12.067
Depreciation rate	0.075	0.043	0.025	0.063	0.194

Table 2
Parameter values
The table reports the parameter values that are used in the main analysis of the model. The top panel reports values that are chosen directly from the literature. The bottom panel reports parameter values, as well as standard errors, obtained through SMM estimation described in Section 3.

Parameters set to values found in the literature			
ρ_u	Persistence of macroeconomic risk	0.922	
σ_u	Conditional volatility of macroeconomic risk	0.014	
β	Annual risk-free discount factor	0.952	
γ_1	Constant price of risk parameter	3.220	
γ_2	Time-varying price of risk parameter	-15.300	
δ	Annual depreciation rate	0.075	
λ	Equity issuance cost	0.050	
Parameters obtained from SMM			
ρ_z	Persistence of idiosyncratic risk	0.502	(0.023)
σ_z	Conditional volatility of idiosyncratic risk	0.173	(0.038)
τ	Corporate tax rate parameter	0.153	(0.050)
α	Production return-to-scale parameter	0.438	(0.005)
ψ	Fixed production cost	1.318	(0.037)
ℓ	Asset liquidation price	0.702	(0.021)
θ	Debt adjustment cost	0.013	(0.006)
ζ	Bankruptcy costs	0.334	(0.045)
η	Debt protection parameter	0.733	(0.020)

Table 3
Moment Conditions
The table reports moments condition used in the SMM estimation described in Section 3. The first column displays the moment conditions calculated from the empirical sample, while the second column shows the corresponding quantities obtained from the simulated sample. In the third column we report t-statistics for the difference between the corresponding moments.

	Data	*Model*	*t-stat*
Average Investments	0.072	0.070	0.313
Stdev Investments	0.107	0.102	0.338
Average Profitability	0.148	0.148	-0.084
Stdev Profitability	0.075	0.062	0.313
Autocorr Profitability	0.463	0.489	-0.217
Average Leverage	0.462	0.459	0.133
Stdev Leverage	0.309	0.398	-1.342
Autocorr Leverage	0.540	0.431	1.122
Average Distributions	0.046	0.050	-0.550
Stdev Distributions	0.067	0.085	-2.028
Average Market-to-book	1.839	1.286	8.740
Stdev Market-to-book	0.821	0.420	12.049
Average 15 Year Credit Spread	1.626	1.770	-0.945
Stdev 15 Year Credit Spread	3.348	3.935	-0.904
Frequency of Defaults (15 years)	2.922	2.588	0.154

Table 4
Subsamples estimation

The table reports parameter estimates obtained by fitting different subsamples obtained by sorting the data according to three different characteristics: operating leverage, asset specificity, and asset maturity. We use heterogeneity in the data that is not directly used as part of the estimation procedure (i.e., as a moment condition) to help with identification of parameters that are difficult to relate to the literature. Operating leverage is directly linked to the fixed production cost parameter ψ. Asset specificity, defined in equation (6), affects the resale value of capital and is therefore related to ℓ (i.e., asset liquidation price). Finally, the asset maturity determines the choice of the debt maturity, and therefore it affects the level debt protection against agency conflicts, η.

	Operating Leverage		Asset Specificity		Asset Maturity	
	Low	High	Low	High	Low	High
Persistence of idiosyncratic risk	0.529	0.537	0.518	0.510	0.580	0.445
	(0.016)	(0.010)	(0.018)	(0.015)	(0.008)	(0.016)
Volatility of idiosyncratic risk	0.214	0.218	0.213	0.218	0.202	0.160
	(0.010)	(0.008)	(0.008)	(0.010)	(0.009)	(0.006)
Corporate tax rate parameter	0.170	0.142	0.174	0.166	0.159	0.108
	(0.005)	(0.004)	(0.003)	(0.004)	(0.017)	(0.038)
Production return-to-scale parameter	0.466	0.517	0.458	0.483	0.512	0.381
	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)
Fixed production cost	**1.202**	**1.990**	1.423	1.575	1.847	1.127
	(0.001)	(0.001)	(0.001)	(0.002)	(0.009)	(0.001)
Asset liquidation price	0.828	0.596	**0.745**	**0.642**	0.462	0.855
	(0.023)	(0.017)	(0.014)	(0.043)	(0.130)	(0.035)
Debt adjustment cost	0.015	0.012	0.015	0.006	0.004	0.015
	(0.004)	(0.003)	(0.004)	(0.008)	(0.017)	(0.007)
Bankruptcy costs	0.348	0.323	0.386	0.316	0.333	0.500
	(0.018)	(0.014)	(0.017)	(0.014)	(0.038)	(0.038)
Debt protection parameter	0.849	0.601	0.717	0.728	**0.953**	**0.618**
	(0.048)	(0.030)	(0.021)	(0.063)	(0.061)	(0.082)

Table 5
Agency credit spread

This table illustrates the distribution of the agency credit spread (ACS) and the ratio of agency spread to total credit spread (ACS ratio) in the simulated economy. We report mean, standard deviation, tenth, fiftieth, and ninetieth percentiles for the entire simulated sample as well as for subsamples conditional on the magnitude of the systematic shock, the firm-specific shock, the size of the firm, leverage, market-to-book ratio, and the ratio of payouts to assets. Subsamples are obtained by sorting stocks in each period of each simulation, and the averaging, in order, across period and simulation.

	ACS					ACS ratio				
	Mean	Stdev	10^{th}	50^{th}	90^{th}	Mean	Stdev	10^{th}	50^{th}	90^{th}
	88.3	330.6	2.5	21.3	185.5	0.386	0.304	0.032	0.342	0.860
	Conditional on systematic shock									
Low	191.9	603.8	8.7	45.2	407.1	0.570	0.326	0.238	0.470	1.000
High	11.2	16.0	0.6	7.2	21.6	0.066	0.056	0.006	0.054	0.135
	Conditional on firm-specific shock									
Low	157.2	228.5	36.9	106.5	300.9	0.553	0.180	0.288	0.645	0.680
High	49.4	52.7	21.7	35.7	95.4	0.296	0.073	0.199	0.298	0.379
	Conditional on firm size									
Small	151.0	240.3	19.2	97.8	293.5	0.457	0.219	0.131	0.438	0.706
Large	45.6	37.8	16.7	31.8	96.6	0.299	0.166	0.150	0.259	0.610
	Conditional on firm leverage									
Low	34.3	19.1	16.2	31.7	57.8	0.282	0.117	0.164	0.278	0.399
High	161.0	222.1	32.1	119.2	291.9	0.483	0.226	0.161	0.538	0.700
	Conditional on market-to-book ratio									
Low	113.5	105.9	22.8	89.7	217.8	0.465	0.227	0.123	0.489	0.701
High	69.1	181.3	17.6	33.3	115.2	0.309	0.138	0.170	0.280	0.529
	Conditional on payout									
Low	83.7	79.4	13.6	61.8	180.3	0.432	0.225	0.118	0.408	0.690
High	95.6	199.8	18.3	43.5	188.9	0.338	0.181	0.163	0.281	0.635

Table 6
Policy deviations from value maximization

The table presents the distribution of time-$(t+1)$ deviations of $a'' = (k'', b'')$, with $a'' = \varphi(x', a'; \hat{\eta})$, from firm value maximizing policies, $a^{**} = (k^{**}, b^{**})$, with $a^{**} = \varphi(x', a'; 0)$, in the simulated economy and the associated time-t agency credit spreads. Details on the simulation are in Appendix A. We separate cases based on the direction of deviations for investment and debt policy, respectively. Beside the instance counts and their frequencies, we report mean, minimum and maximum for the relative deviation of k'' from k^{**}, and of b'' from b^{**}. Similarly we report mean, minimum and maximum for the agency credit spread at t that reflects these deviations.

				k''/k^{**} (t+1)			b''/b^{**} (t+1)			ACS (t)		
		Count	Freq	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
$(k'' < k^{**})$	$(b'' = b^{**})$	102	0.000	-0.15	-0.37	-0.07	0.00	0.00	0.00	1079.0	16.9	2748.6
$(k'' > k^{**})$	$(b'' = b^{**})$	0										
$(k'' = k^{**})$	$(b'' < b^{**})$	194678	0.602	0.00	0.00	0.00	-0.37	-0.61	-0.07	39.9	0.0	899.9
$(k'' = k^{**})$	$(b'' > b^{**})$	97	0.000	0.00	0.00	0.00	1.89	0.08	13.16	1216.6	2.3	6109.3
$(k'' < k^{**})$	$(b'' < b^{**})$	121591	0.376	-0.10	-0.64	-0.07	-0.43	-0.66	-0.07	97.1	0.0	2940.9
$(k'' < k^{**})$	$(b'' > b^{**})$	812	0.003	-0.64	-0.71	-0.07	2.63	0.08	9.37	934.6	4.0	3443.5
$(k'' > k^{**})$	$(b'' < b^{**})$	1129	0.003	0.08	0.08	0.08	-0.17	-0.27	-0.07	11.2	0.2	465.1
$(k'' > k^{**})$	$(b'' > b^{**})$	0										

Table 7

Agency credit spread and policy deviations from value maximization

The table presents counts and frequencies of time-$(t+1)$ deviations of investment, k''/k^{**}, and debt, b''/b^{**}, policies from value maximizing ones, as well as averages of the time-t agency credit spread, $ACS(x, a, \hat{\eta})$, in the simulated economy. Details on the simulation are in Appendix A. We organize the output according to percentage deviations, separating them in intervals of 10 per cent each (i.e., from 10% to 20%). Because not all intervals are spanned by the data, for presentation purposes we aggregate some of the groups.

	Panel A: Count								
	b'' deviations (t+1)								
	Min to –40%	–40 to –30%	–30 to –20%	–20 to 10%	–10 to 0	0%	0 to 10%	10 to 20%	20 to Max
k'' deviations (t+1)									
Min to –40%	221	60	16	10					790
–40 to –30%	95	671	83	31	21	6	1		
–30 to –20%	4733	1534	436	113	71	15	10		
–20 to –10%	16671	5867	2697	506	83	51			
–10 to 0%	64016	13307	7354	1944	1051	30	11		
0%	90706	55201	34963	5773	8035	5179	75	2	20
0 to 10%			373	567	189				

	Panel B: Frequency								
	b'' deviations (t+1)								
	Min to –40%	–40 to –30%	–30 to –20%	–20 to 10%	–10 to 0	0%	0 to 10%	10 to 20%	20 to Max
k'' deviations (t+1)									
Min to –40%	0.001	0.000	0.000	0.000					0.002
–40 to –30%	0.000	0.002	0.000	0.000	0.000	0.000	0.000		
–30 to –20%	0.015	0.005	0.001	0.000	0.000	0.000	0.000		
–20 to –10%	0.052	0.018	0.008	0.002	0.000	0.000			
–10 to 0%	0.198	0.041	0.023	0.006	0.003	0.000	0.000		
0%	0.280	0.171	0.108	0.018	0.025	0.016	0.000	0.000	0.000
0 to 10%			0.001	0.002	0.001				

	Panel C: ACS (t)								
	b'' deviations (t+1)								
	Min to –40%	–40 to –30%	–30 to –20%	–20 to 10%	–10 to 0	0%	0 to 10%	10 to 20%	20 to Max
k'' deviations (t+1)									
Min to –40%	919.9	1268.6	1913.1	2172.6					928.4
–40 to –30%	658.4	1062.9	1115.1	1329.7	1893.8	2287.8	2428.8		
–30 to –20%	164.8	546.1	507.4	925.3	1308.8	1459.0	1484.9		
–20 to –10%	55.9	104.2	323.8	758.5	1019.2	1061.9			
–10 to 0%	37.4	79.2	158.3	248.0	479.7	676.5	748.8		
0%	21.2	39.0	65.8	111.6	94.1	182.6	700.4	333.5	3240.3
0 to 10%			12.8	11.8	6.0				

Table 8

Agency credit spread and percentage policy deviations from value maximization

The table presents coefficients of regressions of time-t agency credit spread, $ACS(x, a, \hat{\eta})$, on time-$(t+1)$ investment, k''/k^{**}, and debt, b''/b^{**}, policy deviations in the simulated economy. Details on the simulation are in Appendix A. We control for either the current credit spreads, $cs(x, a, a')$, or leverage, b/k. In Columns (3) and (4) we report results after standardizing the right-hand side variables. Each column reports coefficients that we obtain by first estimating a panel regression for each simulated economy (i.e., we simulate 50 panels of 500 firms for 15 years), and then averaging coefficients for 50 simulated economies. Standard errors, reported in parenthesis, are calculated from standard deviations of the 50 estimates.

	Agency credit spread (t)			
	(1)	(2)	(3)	(4)
Investment % deviation (t+1)	-80.68	-114.83	-3.77	-7.94
	(19.89)	(40.21)	(1.43)	(2.79)
Debt % deviation (t+1)	49.01	59.47	6.59	8.38
	(8.65)	(13.52)	(1.26)	(2.00)
Credit Spread (t)	64.77		65.91	
	(6.80)		(12.88)	
Leverage (t)		742.34		48.19
		(115.88)		(10.09)

Table 9
Robustness check: model parameters

We conduct a sensitivity analysis, wherein we simulate new economies, by independently adjusting the equity adjustment cost (λ), the debt adjustment cost (θ) and the liquidation price (ℓ), while keeping all others at the values reported in Table 2. Details on the simulation are in Appendix A. For each parameter we present two cases, one above and one below the base case value. The table reports, for each of the six cases considered, the average time-t agency spread, $ACS(x, a, \hat{\eta})$, and the coefficients of time-$(t+1)$ investment and debt policy deviations, respectively k''/k^{**} and b''/b^{**}, obtained from regression models similar to those presented in the first column of Table 8.

λ	θ	ℓ	ACS (t)	% Inv Dev (t+1)	% Debt Dev (t+1)
0.04			44.71	-7.68	9.19
0.06			74.73	-18.24	20.36
	0.01		123.36	-37.34	36.10
	0.02		55.52	-8.59	10.86
		0.65	94.13	-30.17	28.18
		0.75	107.99	-23.30	26.34