Measuring Agency Costs over the Business Cycle*

Ramona Westermann†

September 24, 2013

ABSTRACT

This paper investigates the effects of manager-shareholder agency conflicts on corporate policies in a structural model with intertemporal macroeconomic risk. In the model, a firm consists of assets in place and a growth option, and is run by a self-interested manager who receives part of the firm's free cash flows as private benefits. Fitting the model, parameter estimates imply substantial agency costs due to managerial diversion at issuance (around 3%), and higher agency costs for growth firms than for value firms (3.45% vs. 1.77%). Further, dynamic aggregate agency costs are strongly procyclical (on average, 1.88% in boom and 0.92% in recession periods). The reason for the latter result is that, in times of recession, firms profit from managerial underleverage, which increases the distance to costly default. Finally, the model also generates predictions regarding default and investment rates, as well as on the intertemporal pattern of investment.

*I am grateful to Erwan Morellec for advise. Marc Arnold, Simon Broda, Rajna Gibson Brandon, Oliver Scaillet, Alexander F. Wagner, and seminar participants at the Universities of Geneva and Zurich, EPFL and UNIL Lausanne, and the Gerzensee workshop provided helpful comments. I gratefully acknowledge support from the European Research Council (ERC grant no. 312417) and the FRIC Center for Financial Frictions (grant no. DNRF102).

†Copenhagen Business School, Solbjerg Plads 3, 2000 Frederiksberg, Denmark. email: rw.fi@cbs.dk

1. Introduction

Manager-shareholder agency conflicts, the implications for corporate policies, and the resulting agency costs have received much attention by financial economists since the seminal papers by Jensen and Meckling (1976) and Jensen (1986). It is now well-known that manager-shareholder agency conflicts constitute a crucial determinant of financing and investment policies in the cross section (Smith and Watts, 1992, Rajan and Zingales, 1995). However, corporate policy choices depend heavily on macroeconomic conditions (Hackbarth, Miao, and Morellec, 2006, Bhamra, Kuehn, and Strebulaev, 2010a, Halling, Yu, and Zechner, 2012). Despite the striking importance of both manager-shareholder agency conflicts and macroeconomic conditions for corporate policies, little is known on how they interact and on the implications for agency costs. My paper contributes to the literature by analyzing the impact of manager-shareholder agency conflicts on corporate policy choices and agency costs for heterogenous firms in the presence of macroeconomic risk.

Economic intuition suggests the existence of interaction effects between manager-shareholder agency conflicts and macroeconomic conditions. In standard tradeoff models and in the absence of agency conflicts, shareholders select leverage by balancing tax benefits of debt against bankruptcy costs (Mello and Parsons, 1992). Tax benefits of debt are larger in boom, and bankruptcy costs are larger in recession due to higher default probability and larger loss given default (Hackbarth, Miao, and Morellec, 2006). Hence, financing decisions depend on the current state of the economy. Similarly, by way of asset substitution, investment decisions correspond to a risk transfer between equityholders and bondholders (Jensen and Meckling, 1976). Because default risk varies over the business cycle investment policies depend on macroeconomic conditions as well. In the presence of agency conflicts, managerial decisions reflect not only the impact of these market frictions, but also take into account managers' private benefits. Managers choose lower debt levels and invest more aggressively due to the disciplining effect of debt and the increase in expected value of future private benefits upon investment (see, e.g., Morellec, 2004). Additionally and importantly, the regime-dependency of both the costs of debt and the expected value of future cash flow renders manager-selected financing and investment policies sensitive to macroeconomic conditions.

While qualitative implications of agency conflicts have been analyzed extensively in the literature, the quantification of agency costs has been studied only recently. Notably, Parrino, Poteshman, and Weisbach (2005) measure manager-shareholder agency costs when managers are risk-averse and show that agency costs vary with firm and project characteristics, whereas Habib and Ljungqvist (2005) use a stochastic frontier approach to empirically quantify the loss in Tobin's q due to manager-shareholder agency conflicts. Ultimately, the importance of manager-shareholder agency conflicts depends not only on the magnitude of the resulting agency costs, but also on their ability to explain empirical regularities. The magnitude of agency costs is important to claimholders per se, because these agency costs constitute welfare losses. In addition, manager-shareholder agency conflicts can explain a number of observed patterns in firm behavior. For example, Morellec (2004) shows that manager-shareholder agency conflicts lead to conservative debt levels as observed empirically, e.g., by Graham (2000). Further, Nikolov and Whited (2011) find that manager-shareholder agency conflicts are a determinant of firms' cash holdings, and Morellec, Nikolov, and Schürhoff (2012) conclude that agency conflicts have an impact on the implied dynamics of leverage.

The purpose of this paper is, therefore, to investigate the impact of macroeconomic risk and agency conflicts for heterogenous firms on corporate policies and the magnitude of agency costs. To do so, I develop a structural tradeoff model with intertemporal macroeconomic risk, explicitly taking into account manager-shareholder agency conflicts.[1] Changing macroeconomic conditions imply time variations in the risk free rate. Further, I assume that the stochastic discount factor prices both firm-specific shocks and economy-wide shocks. Market frictions are introduced by incorporating taxes and bankruptcy costs in case of default. Firms are heterogenous in their asset composition, a feature included by modeling both assets in place and expansion options. Each firm is run by a manager who controls financing and investment decisions, while shareholders decide about default. Agency conflicts arise because managers divert part of the free cash flow to equity as private benefits and exercise control rights on financing and investment in their own best interest. In this framework, I investigate manager-selected investment and financing policies and the implied effects on the loss in firm value. Further, I analyze the impacts on default and investment rates as well as the timing of investment.

The distortions in managerial policies have important effects on the value of the firm. Due to the tradeoff mechanisms, managerial policies, and, hence, the loss in firm value depend explicitly on macroeconomic conditions and on the importance of investment opportunities. My paper quantifies agency costs stemming from manager-shareholder agency conflicts depending on a firm's asset composition in different economic regimes. Agency costs, reported as the percentage loss in firm value compared to the first-best scenario in which firm value maximizing strategies are employed are substantial and weakly procyclical. In boom [recession], agency costs rise from 1.78% [1.73%] for a value firm, to 2.83% [2.68%] for an average firm, and to 3.48% [3.37%] for a growth firm. I show that total agency costs for all firms are mainly driven by managers' desire to underleverage: Underleverage costs as a percentage of total agency costs vary between 85% for a typical growth firm and 100% for a value firm. The procyclicality of agency costs stems from two sources. First, and importantly, the loss in tax benefits due to lower debt levels chosen by the manager is larger in boom. Second, firms are more prone to invest when economic conditions are favorable, increasing the probability of suboptimal investment in boom.

In a dynamic aggregate economy, I find that agency costs remain substantial (on average, 1.56% of the first-best firm value) and become strongly procyclical (on average, 1.88% in boom and

[1]Surprisingly, existing structural tradeoff models typically include only one of these two crucial features. For models on manager-shareholder agency conflicts, but without macroeconomic conditions, see, for example, Stulz (1990), John and John (1993), Hart and Moore (1995), Zwiebel (1996), Morellec (2004), Malmendier and Tate (2005), Hackbarth (2008), or Lambrecht and Myers (forthcoming). Corporate models with macroeconomic conditions, but not taking into account agency conflicts, are, for example, Hackbarth, Miao, and Morellec (2006), Bhamra, Kuehn, and Strebulaev (2010a), Bhamra, Kuehn, and Strebulaev (2010b), Chen (2010), or Arnold, Wagner, and Westermann (2013).

0.92% in recessions). The strong procyclicality can be explained by the fact that the managerial tendency to underleverage reduces default risk, particularly so in recessions, when both default risk and the loss given default are more prevalent. Interestingly, for firms close to default, the total impact on firm value because of reduced default risk is positive, such that these firms enjoy "agency benefits." Similarly, Hackbarth (2008) finds a possible positive role of manager-shareholder agency conflicts by way of investigating the effects of managerial traits for single firms, even without the need to appeal to optimal incentive contracts. Surprisingly, investigation of the time series of agency costs reveals that agency benefits may persist even in the aggregate economy at some points in time when taking into account changing macroeconomic conditions.

Further, comparing default and investment rates in the aggregate economy to an economy in which first-best policies are applied yields that the presence of self-interested managers strongly decreases the aggregate default rate (by approximately 50%) and slightly increases the aggregate investment rate (by approximately 11%). Finally, manager-shareholder agency conflicts generate predictions regarding the intertemporal pattern of investment. Compared to a first-best economy, the investment hazard function is decreased for short and intermediate horizons up to approximately four years, but increased for longer horizons.[2] In particular, the non-monotone effect on the investment hazard function implies that it is important to take into account the severity of manager-shareholder agency conflicts when investigating empirical hazards.

This study relates to different strands of literature. First, it belongs to the theoretical field of research that investigates manager-shareholder conflicts, their impact on firms' financing and investment decisions, and the implications for the value of the firm. This stream of literature builds on early work by Jensen and Meckling (1976), who investigate formally the impact of agency conflicts on the cost of equity and debt, and Jensen (1986), who discovers the disciplining effect of debt by way of reducing the free cash flow. Harris and Raviv (1990) provide a theory of capital structure in which debt serves not only as a disciplining device, but also has an informational role when managers are reluctant to disclose information relevant for the default decision. Further, Stulz (1990) investigates under- and overinvestment stemming from managerial discretion.[3] As a refinement, Hart and Moore (1995) show that, in particular, long-term debt is a determinant of managerial under- or overinvestment. On the one hand, long-term debt can prevent managers from investing in negative NPV projects, but, on the other hand, long-term debt may result in underinvestment because of the debt overhang problem as identified by Myers (1977). Chang (1993) and John and John (1993) investigate optimal compensation contracts to reduce agency costs. Dynamic capital structure under managerial entrenchment is addressed by Zwiebel (1996). Morellec (2004) shows that an empire-building manager has an incentive to choose low debt levels. Conversely, in a real options model with both investment and disinvestment, Lambrecht and Myers (2008) show that firms with weaker investor protection choose higher debt levels.

[2]The investment hazard function is the probability that a firm invests at a certain time after issuance given it has not invested yet.

[3]For a survey on early models of agency problems as well as early empirical evidence, see Harris and Raviv (1991).

Early empirical work is, for example, presented by Agrawal and Mandelker (1987), who document a positive relationship between managerial security holdings and changes in financial leverage. The authors conclude that the findings support the view that executive security holdings reduce agency conflicts. Similarly, Amihud, Lev, and Travlos (1990) present evidence consistent with the hypothesis that managers value control. Jung, Kim, and Stulz (1996) provide strong support of the agency model with respect to a firm's financing decisions. Furthermore, Berger, Ofek, and Yermack (1997) document that entrenched managers choose lower debt levels, a finding which is consistent with the results in my model. On the contrary, the empirical study by Graham and Harvey (2001) finds only little evidence of relations between managerial discretion and free cash flow or asset substitution.

The closest paper to mine is Morellec, Nikolov, and Schürhoff (2012), who use a dynamic tradeoff model with manager shareholder agency conflicts to investigate the impact on the dynamics and the cross section of leverage. The modeling of self-interested managers is analogous in my model, but there are three important differences between the two papers. First, Morellec, Nikolov, and Schürhoff (2012) do not consider macroeconomic risk. Second, they do not account for the heterogeneity in the asset base of firms', i.e., they do not consider investment. And, third, to investigate the dynamics of leverage, Morellec, Nikolov, and Schürhoff (2012) allow for a dynamic capital structure, while I allow for refinancing only at the time of investment. Importantly, by introducing macroeconomic risk, I am able to analyze the evolution of agency costs in different economic regimes, and to derive new predictions for aggregate default and investment behavior of firms. Two related papers by Levy and Hennessy (2007) and Chen and Manso (2010) also investigate agency costs and macroeconomic regimes. Levy and Hennessy (2007) propose a general equilibrium model in discrete time to analyze the relation between financial flexibility and cyclical variation in leverage. In their model, single-period financial contracts are issued, and the authors show that no managerial diversion takes place in equilibrium. My paper differs in that it considers long-term financial contracts, and it investigates agency costs over the business cycle stemming from exogenously given managerial diversion. Finally, Chen and Manso (2010) find that the agency costs of debt overhang are substantially higher in the presence of macroeconomic regimes, and they quantify the costs of debt overhang depending on the value of a firm's growth option. On the contrary, my paper focuses on the implications of manager-shareholder conflicts through financing and investment decisions, and not exclusively on the debt overhang problem.

Second, this paper relates to the macroeconomic literature that investigates macroeconomic agency costs defined as the loss in aggregate productivity. Traditionally, this literature emphasizes countercyclical agency costs (see, for example, Bernanke and Gertler, 1986, or Eisfeldt and Rampini, 2008). Here, the focus is on corporate agency costs, i.e., the loss in firm value due to suboptimal managerial behavior. In particular, corporate agency costs as calculated in my paper are not directly comparable to the macroeconomic agency costs as defined in the macroeconomic literature.

Finally, this study belongs to the field of structural corporate finance. In detail, the proposed model is in the spirit of Mello and Parsons (1992), as extended by Hackbarth, Miao, and Morellec (2006) for macroeconomic regimes. Manager-shareholder agency conflicts are introduced by way of assuming private benefits, as in La Porta, de Silanes, Shleifer, and Vishny (2002) or Morellec, Nikolov, and Schürhoff (2012). Further, investment opportunities are modeled as in Arnold, Wagner, and Westermann (2013), and the stochastic discount factor is implied by the work of Bhamra, Kuehn, and Strebulaev (2010b) or Chen (2010).

The paper proceeds as follows. Section 2 presents and solves the model. Section 3 quantifies and decomposes agency costs for firms with different asset composition ratios. In Section 4, I investigate the evolution of agency costs in the aggregate economy, and the implications for investment and default rates as well as the intertemporal pattern of investment. Finally, Section 5 concludes.

2. The model

I consider agency conflicts between managers and shareholders within the framework of a structural model for financing and investment decisions of firms with assets in place and an investment opportunity. The economy is subject to intertemporal macroeconomic shocks. The structural tradeoff model is similar to Arnold, Wagner, and Westermann (2013), and, additionally, agency conflicts are introduced as in Morellec, Nikolov, and Schürhoff (2012). I first describe the economy, then the firms, and, finally, I turn to manager-shareholder agency conflicts.

2.1. Assumptions

I start by specifying a probability space $\left(\Omega, (\mathcal{F}_t)_{t\geq 0}, \mathbb{P}\right)$, in which $\mathbb{P}$ is the physical probability measure. In the following, the presented processes are adapted to this probability space. Assets are continuously traded in complete and arbitrage-free markets. The risk neutral probability measure, denoted by $\mathbb{Q}$, is implied by the stochastic discount factor. In the analysis, this setup is used to investigate default and investment rates under the historical measure.

The economy. The economy includes a large number N of infinitely lived firms, a large number of identical infinitely lived households, and a government collecting taxes. Macroeconomic uncertainty is modeled by a time-homogeneous Markov chain I_t with state space $\{B, R\}$, in which the two states correspond to boom (B) and recession (R), and generator $Q := \begin{bmatrix} -\lambda_B & \lambda_B \\ \lambda_R & -\lambda_R \end{bmatrix}$, in which $\lambda_i \in (0, 1)$ denotes the rate of leaving state i. The realization of the Markov chain I_t at time t, i.e., boom or recession, constitutes an economy-wide state variable at time t. Following

Hackbarth, Miao, and Morellec (2006), I assume that the regime boom is more persistent than the regime recession, i.e., $\lambda_B < \lambda_R$.[4]

Following Chen and Manso (2010), I specify an exogenous stochastic discount factor, which is determined by the regime-dependent risk free rate, and the risk prices for firm-level shocks and regime shifts, respectively. Chen (2010) and Bhamra, Kuehn, and Strebulaev (2010b) show that this pricing kernel is the solution of a representative agent problem, in which the agent has the continuous-time analog of Epstein-Zin-Weil preferences (Epstein and Zin, 1989 and Weil, 1990), given that the expected growth rate and volatility of aggregate output is regime-dependent.[5]

The firm. A firm n consists of assets in place and an investment opportunity. At each time, assets in place generate a nominal cash flow stream X_t^n, which constitutes the firm-specific state variable in the model. For the sake of a parsimonious exposition, I suppress the firm dependence on the cash flow. The cash flow X_t of the firm follows a regime dependent Brownian motion under the physical measure $\mathbb{P}$,

$$\frac{\mathrm{d}X_t}{X_t} = \mu_i \mathrm{d}t + \sigma_i \mathrm{d}Z_t, \tag{1}$$

in which μ_i and σ_i are the regime-dependent drift and volatility, respectively, and Z_t is a Brownian motion under $\mathbb{P}$. As in Chen (2010), the drift and the volatility of the nominal cash flow process are determined by the dynamics of the real cash flow process and a stochastic price index. The real cash flow process, in turn, depends on the realization of aggregate consumption and a firm specific idiosyncratic component. Details on the setup, the derivation of the cash flow dynamics, and the derivation of risk neutral parameters are presented in Appendix A. Because the part of volatility which is connected to the evolution of aggregate consumption is smaller in boom than in recession (Ang and Bekaert, 2004), I obtain that the total volatility, σ_i is also smaller in boom, i.e., $\sigma_B < \sigma_R$. Following Bhamra, Kuehn, and Strebulaev (2010b), I assume that the regime-dependent drift is higher in boom than in recession, i.e., $\mu_B > \mu_R$. Formally, the state variable in the model is given by the vector $[X_t, I_t]$ in which the first component corresponds to the firm-specific cash flow level realization, and the second component constitutes the economy-wide realization of the regime.

An investment opportunity of the firm is modeled as an American call option on the cash flows, analogous to Arnold, Wagner, and Westermann (2013). Specifically, if the firm decides to invest at time $\bar{t}$, it pays exercise costs K and achieves an additional future cash flow of $(s-1)\,X_t$

[4]The following properties hold: The probability that the regime switches from state i to state j during an infinitesimal time interval Δt corresponds to $\lambda_i \Delta t$, and the probability that the duration of state i is larger than $t \geq 0$ is given by $e^{-\lambda_i t}$. The expected duration of regime i is $\frac{1}{\lambda_i}$, and the expected fraction of time spent in regime i is calculated by $\frac{\lambda_j}{\lambda_i + \lambda_j}$.

[5]Technical details of the derivation and the resulting stochastic discount factor can be found in Appendix A. It is also important to highlight the main limitations of this approach in my framework. First, I assume that aggregate output is given exogenously, in particular, I abstract away from the impacts of firm-specific default and investment on aggregate output. This assumption may be justified by considering a large number of firms in the economy, such that each firm's contribution to aggregate output is minor. Second, the model ignores the impact of agency conflicts on the state-price density. While this feedback effect is certainly important, solving the corresponding model is beyond the scope of this work.

for some firm-specific factor $s > 1$ for all future times $t \geq \bar{t}$. After investment, the firm consists of only invested assets. Intuitively, the increased cash flows can be attributed either to a larger asset base, or, equivalently, to a higher productivity of existing assets. The investment decision is irreversible. As in Morellec and Wang (2004), financing of the exercise price K takes place by issuing a mix of equity and debt. Fixed financing of the investment opportunity (e.g., debt or equity only) introduces distortions in option exercise policies. To obtain a closed-form solution of the model, I assume that at the time of investment, first, debt is called at par, and, second, new debt with coupon c_n is issued.[6] This assumption is similar to Goldstein, Ju, and Leland (2001), Chen (2010), and Morellec, Valta, and Zhdanov (2013), who also suppose that upon refinancing debt is first called at par. Further, Hackbarth and Mauer (2012) show that it is, in general, suboptimal to separate investment and financing decisions.

The firm is financed by issuing equity and debt. To facilitate the analysis, I present the case of infinite maturity debt. After debt has been issued, a firm pays a total coupon rate c_o to debtholders, until the firm defaults or invests. The total coupon after investment is denoted by c_n. Subsequently to paying the coupon, the firm pays corporate taxes at a constant rate τ, under the assumption of full loss offset corporate taxation. Hence, after paying debt service and taxes, the free cash flow is given by $(1 - \tau)(X - c)$, in which $c = c_o$ (before investment) or $c = c_n$ (after investment). Following the standard in the literature, I assume that, in case the required debt service exceeds the cash flows, shareholders may inject funds to finance the coupons. Alternatively, shareholders have the option to default on their debt obligations (Leland, 1998). If shareholders decide to default, the firm is immediately liquidated and bondholders enjoy absolute priority of debt claims, resulting in a payment worth the unlevered asset and growth option values times the regime-dependent recovery rate $\alpha_i \in (0, 1]$. Recovery rates are assumed to be lower in recession than in boom, i.e., $\alpha_R < \alpha_B$, an assumption being consistent with the literature introducing search frictions for corporate bonds in structural models, because liquidity tends to dry out in recession resulting in larger search cost (He and Milbradt, 2012). This setup implies that default costs are a regime-dependent fraction $1 - \alpha_i$ of the unlevered values of the assets in place and the growth option at default. While tax benefits encourage debt financing by way of shielding part of the firm's cash flow from taxation, costly default reduces the incentive to issue debt.

The manager. Agency conflicts are introduced by assuming that a firm is run by a self-interested manager. The manager diverts a fraction ϕ of the firm's free cash flow as private benefits (as in La Porta, de Silanes, Shleifer, and Vishny, 2002, Lambrecht and Myers, 2008, Albuquerque and Wang, 2008, and Morellec, Nikolov, and Schürhoff, 2012). Examples for managerial private benefits include perquisites, excessive salary, transfer pricing, or employing relatives and friends who are not qualified.[7] The fraction of free cash flow that the manager diverts, ϕ, is assumed

[6]The firm's motivation to do so may be justified by existing debt covenants concerning investment and/or financing.

[7]For evidence of private benefits of control, see Barclay and Holderness (1989) or La Porta, de Silanes, Shleifer, and Vishny (2000). For a catalog of legal and illegal forms of managerial tunneling, see Johnson, La Porta, de Silanes, and Shleifer (2000).

to be exogenous and captures the severity of manager shareholder agency conflicts in the model. Because the manager receives a fraction ϕ of free cash flow, i.e., $\phi(1-\tau)(X_t - c_o)$, equityholders get only a fraction $(1-\phi)$ of free cash flow, i.e., $(1-\phi)(1-\tau)(X_t - c_o)$. Further, as in Nikolov and Whited (2011) or Morellec, Nikolov, and Schürhoff (2012), managers own a fraction $\psi > 0$ of the firm's equity. Hence, the total cash flow to the manager is given by the sum of his equity share and managerial diversion, i.e., $\psi(1-\phi)(1-\tau)(X_t - c_o) + \phi(1-\tau)(X_t - c_o) = (\psi - \psi\phi + \phi)(1-\tau)(X_t - c_o)$. When private benefits are zero, i.e., $\phi = 0$, no diversion takes place, and, hence, there is no agency conflict between managers and shareholders on corporate policies. I abstract away from the market of corporate control.[8] In the analysis, I consider fixed values of ϕ and ψ based on the empirical results of Morellec, Nikolov, and Schürhoff (2012), and then investigate the magnitude and dynamics of agency costs for firms with investment opportunities over the business cycle.

In the model, agency costs arise due the allocation of control rights within the firm. Specifically, I presume that the manager controls investment and capital structure decisions, whereas shareholders decide about default. When making financial and investment decisions, the manager acts in is own interest to maximize the present value of total cash flows from managerial rents and equity stake. Managers' control rights on investment policies are the standard in the literature, see, e.g., Zwiebel (1996), Morellec (2004) or Nikolov and Whited (2011). Simultaneously with the manager choosing his investment decision, equityholders select the default policy that maximizes equity value (for a discussion, see Morellec, 2004). Managers' control rights on capital structure decisions are in line with Morellec (2004), Hackbarth (2008) or Morellec, Nikolov, and Schürhoff (2012). In particular, in my model, the manager chooses his preferred coupon at the two points in time when debt is issued: upon investment and at issuance. Upon investment, existing debt is called at par. Next, the manager chooses the coupon of the new debt that is issued.[9] At issuance, the manager chooses the coupon that maximizes his objective function, anticipating his own investment policy, equityholders' default policy, as well as his preferred financing policy at the time of investment. This specification of the model gives rise to three sources of agency costs, namely, through suboptimal investment, through suboptimal leverage, and through interaction effects between the two.

[8] Morellec (2004) includes a market of corporate control can be modeled in a similar framework. As a result, the manager is partially entrenched, and his policy choices also depend on the manager's desire to preclude control challenges.

[9] Since the manager controls the investment decision, this setup implies that the manager can issue equity to finance a suboptimal investment decision from the point of view of shareholders. To justify this assumption, I suppose that it is costly for shareholders to act collectively, and, hence, they cannot directly influence decisions taken by managers (Hackbarth, 2008). Alternatively, Morellec (2004) takes into account the market for corporate takeover, presuming that the incumbent manager has specific skills in administering the firm's assets, and control challenges are costly. As a consequence, the manager has some discretion over policy choices.

2.2. Model solution

The model is solved by backward induction. I begin with the calculation of the value functions after investment. Subsequently, the value functions before investment and the capital structure chosen by the manager are presented. Finally, I define agency costs in my model.

2.2.1. Value functions and capital structure after investment

In this subsection, I derive the value functions after investment for equity and the manager's claim to cash flows in boom and recession, denoted by $\hat{e}_i$ and $\hat{m}_i$, respectively. Suppose that $\hat{D}_B, \hat{D}_R$ are the default boundaries after investment in boom and recession, respectively, and recall that c_n is the coupon after investment. I present the case in which the default boundary in boom is lower than then one in recession, i.e., $\hat{D}_B < \hat{D}_R$.[10]

The value of equity after investment, $\hat{e}_i$, corresponds to the present value of the expected payoffs to shareholders until default, i.e.,.

$$\hat{e}_i\left(X\right) = \mathbb{E}^{\mathbb{Q}}\left[\int_t^{\hat{D}} e^{-r^n_{I_u}(u-t)}\left(1-\tau\right)\left(1-\phi\right)\left(X_u - c_n\right)\mathrm{d}u\,|X_t = X\right], \tag{2}$$

in which $\hat{D}$ is the firm's default time, defined as $\hat{D} = \inf\left\{t \geq 0 : X_t \leq \hat{D}_i \;\&\; I_t = i\right\}$.Total free cash flow corresponds to the cash flows after debt services and taxes have been paid, i.e., $\left(1-\tau\right)\left(X - c_n\right)$. Eq. (2) displays that the fraction of free cash flow paid out to equityholders is a fraction $(1-\phi)$ of total free cash flows. The reason is that the manager diverts a fraction ϕ of the total free cash flow. The corresponding Hamilton-Jacobi Bellman equation and its solution is presented in Appendix B.

Similarly, the value of corporate debt, $\hat{d}_i\left(X\right)$, can be derived. The corresponding system of ODEs, the boundary conditions, and the solution are stated in Appendix B.

Next, I present the valuation approach for the manager's claim to cash flows after investment, $\hat{m}_i\left(X\right)$. The value of manager's claim to cash flow corresponds to the present value of the expected payoffs to the manager until default, i.e.,

$$\hat{m}_i\left(X\right) = \mathbb{E}^{\mathbb{Q}}\left[\int_t^{\hat{D}} e^{-r^n_{I_u}(u-t)}\left(1-\tau\right)\left(\phi + \psi - \phi\psi\right)\left(X_u - c_n\right)\mathrm{d}u\,|X_t = X\right], \tag{3}$$

in which $\hat{D}$ is the firm's default time as defined above. Cash flows to the manager stem from two sources: First, managerial diversion results in a cash flow $\phi\left(1-\tau\right)\left(X - c_n\right)$, because it is assumed that the manager diverts a fraction ϕ of free cash flows. Second, as the manager

[10]Optimal default boundaries for reasonable parameter values satisfy this inequality. Further, also Hackbarth, Miao, and Morellec (2006), Bhamra, Kuehn, and Strebulaev (2010a), Chen (2010), or Arnold, Wagner, and Westermann (2013) find lower default boundaries in boom than in recession.

holds a fraction ψ of equity, he also receives cash flows of $\psi(1-\tau)(1-\phi)(X-c_n)$. Hence, total cash flows to the manager are given by $\phi(1-\tau)(X-c_n)+\psi(1-\tau)(1-\phi)(X-c_n) = (1-\tau)(\psi+\phi-\psi\phi)(X-c_n)$, as displayed in Eq. (3). The corresponding Hamilton-Jacobi-Belman equation and its solution are given in Appendix B.

Once debt has been issued, equityholders select the default policy that maximizes the value of equity ex-post. Value matching requires that the value of equity at the time of default be zero:

$$\begin{cases} \hat{e}_B\left(\hat{D}_B\right) &= 0 \\ \hat{e}_R\left(\hat{D}_R\right) &= 0. \end{cases} \tag{4}$$

Hence, shareholders' optimal default policy $\left[\hat{D}_B^*, \hat{D}_R^*\right]$ is determined by the smooth-pasting conditions:

$$\begin{cases} \hat{e}'_B\left(\hat{D}_B^*\right) &= 0 \\ \hat{e}'_R\left(\hat{D}_R^*\right) &= 0. \end{cases} \tag{5}$$

The firm value after investment, $\hat{v}_i$, is given by the sum of equity and debt value, i.e.,

$$\hat{v}_i(X) = \hat{e}_i(X) + \hat{d}_i(X). \tag{6}$$

Upon investment, existing debt is first called at par. Next, the new capital structure is chosen and new debt is issued. Because the issue proceeds of new debt accrues to shareholders, shareholders' ex-ante objective function at the time of investment takes into account the value of new debt as well. The manager owns a fraction ψ of equity. Hence, to determine the capital structure, the manager selects the coupon level $c_{n,i}^*$ that maximizes the ex ante value of his claims in regime i:

$$c_{n,i}^* := \text{argmax}_{c_n}\left(\hat{m}_i(X;c_n) + \psi\hat{d}_i(X;c_n)\right). \tag{7}$$

At the time of investment, a scaling property holds: Conditional on the current state, the manager-selected coupon, the default boundaries, the values of total debt and equity, and the manager's claim to cash flows are all homogenous of degree one in cash flows.[11] This scaling property is based on the scaling property of Fischer, Heinkel, and Zechner (1989) and Goldstein, Ju, and Leland (2001) for the case of only one regime, and extended by Hackbarth, Miao, and Morellec (2006), Bhamra, Kuehn, and Strebulaev (2010a), Bhamra, Kuehn, and Strebulaev (2010b) and Chen (2010) for regime-switching models.[12] In the next section, I exploit the scaling

[11]In my model, the firm structure is different before and after investment. Before investment, the firm has the investment opportunity, and the possibility to recover part of the investment opportunity value in case of bankruptcy. After investment, the firm consists of only invested assets. Hence, the scaling property does not imply that value functions after investment can be expressed as the product of a factor times the corresponding value function before investment. As discussed in Goldstein, Ju, and Leland (2001), this property is fulfilled only in models in which the firm structure is not changed, e.g., in models of dynamic refinancing.

[12]In the presence of macroeconomic conditions and the opportunity of investment being financed with debt, the assumption of debt being called at par guarantees a closed-form solution of the model via the scaling property. While a closed-form solution might be achieved under the non-standard assumption of debt being called at market

property of corporate securities at the time of investment when calculating the value of corporate securities before investment.

2.2.2. Value functions, corporate policies, and capital structure before investment

In this subsection, I show how to derive the value functions before investment for equity and the manager's claim to cash flows in boom and recession, denoted by e_i and m_i, respectively. Consider a set of default and investment boundaries, D_B, D_R, X_B, and X_R. I present the case in which default and investment boundaries are lower in boom than in recession for both default and investment, i.e., $D_B < D_R$ and $X_B < X_R$. Optimal policies fulfil these inequalities for reasonable parameter values.[13] Recall that the coupon before investment is denoted by c_o.

The value of equity e_i corresponds to the present value of future cash flows to shareholders. This value is given by

$$\begin{aligned} e_i(X) &= \mathbb{E}^{\mathbb{Q}}\left[\int_t^S e^{-r^n_{I_u}(u-t)}(1-\tau)(1-\phi)(X_u-c_o)\,\mathrm{d}u\,|X_t=X\right] \\ &+\mathbb{E}^{\mathbb{Q}}\left[1_{S=O}\int_S^{\hat{D}} e^{-r^n_{I_u}(u-t)}(1-\tau)(1-\phi)(sX_u-c_n)\,\mathrm{d}u\,|X_t=X\right] \\ &+\mathbb{E}^{\mathbb{Q}}\left[1_{S=O}\left(-K-P+\int_S^{\hat{D}} e^{-r^n_{I_u}(u-t)}c_n\mathrm{d}u+\alpha_{I_{\hat{D}}}y_{I_{\hat{D}}}sX_{I_{\hat{D}}}\right)|X_t=X\right], \end{aligned} \tag{8}$$

in which S denotes the stopping time of default or investment, whichever happens first, i.e.,

$$S := \inf\{D, O\}. \tag{9}$$

Here, D is defined as the default time, i.e.,

$$D := \inf\{t \geq 0 : X_t \leq D_i \;\&\; I_t = i\}, \tag{10}$$

and O denotes the time of option exercise, i.e.,

$$O := \inf\{t \geq 0 : X_t \geq X_i \;\&\; I_t = i\}. \tag{11}$$

Similar to the valuation of equity after investment, Eq. (8) uses the fact that the cash flow to shareholders before investment is given by $(1-\tau)(1-\phi)(X_s-c_o)$, as reflected in the first line of Eq. (8). If $S = D$, i.e., default happens first, shareholder receive zero; if $S = O$, i.e., investment happens first, equityholders' payoff is given by equityholders' payoff after investment [see Eq. (2)], corresponding to the second line of Eq. (8). Additionally, investment costs, K, and the costs for calling debt, P, have to be paid [first two terms in line three of Eq. (8)], and the issue proceeds

value, the existence of a closed-form solution of the model is not trivial when assuming that existing debt at investment is not called at all, and only additional debt is issued.

[13] Chen and Manso (2010) and Arnold, Wagner, and Westermann (2013) also find these relations to hold.

from new debt are received. Because debt is issued at fair price, the issue proceeds from new debt can be written as the coupon payments until default [third term in line three of Eq. (8)] plus the recovery at default [fourth term in line three of Eq. (8)]. Using a no-arbitrage argument, equity requires an instantaneous return equal to the nominal risk-free rate r_i^n. An application of Ito's lemma with regime switches shows that the Hamilton-Jacobi-Bellman equation for equity can be written as follows.

For $0 \leq X \leq D_B$:

$$\begin{cases} e_B(X) &= 0 \\ e_R(X) &= 0. \end{cases} \tag{12}$$

For $D_B < X \leq D_R$:

$$\begin{cases} r_B^n e_B(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_B X e_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 e_B''(X) \\ & \quad + \tilde{\lambda}_B(0 - e_B(X)) \\ e_R(X) &= 0. \end{cases} \tag{13}$$

For $D_R < X < X_B$:

$$\begin{cases} r_B^n e_B(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_B X e_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 e_B''(X) \\ & \quad + \tilde{\lambda}_B(e_R(X) - e_B(X)) \\ r_R^n e_R(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_R X e_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 e_R''(X) \\ & \quad + \tilde{\lambda}_R(e_B(X) - e_R(X)). \end{cases} \tag{14}$$

For $X_B \leq X < X_R$:

$$\begin{cases} e_B(X) &= \hat{e}_B\left(sX; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right) \\ r_R^n e_R(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_R X e_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 e_R''(X) \\ & \quad + \tilde{\lambda}_R\left(\hat{e}_B\left(sX; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right)\right. \\ & \quad \left. - e_R(X)\right). \end{cases} \tag{15}$$

For $X \geq X_R$:

$$\begin{cases} e_B(X) &= \hat{e}_B\left(sX; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right) \\ e_R(X) &= \hat{e}_R\left(sX; c_{n,R}^*\right) - K - P + \hat{d}_R\left(sX; c_{n,R}^*\right). \end{cases} \tag{16}$$

Again, this type of ODEs is typical for the evaluation of corporate claims with business cycle risk and investment (cf. Arnold, Wagner, and Westermann, 2013). To facilitate the reading, I repeat the main intuition of the equations in the following. Whenever the firm defaults, equityholders receive zero because of the absolute priority of debt claims (Eqs. (12), second line of Eqs. (13)). As long a the firm takes no action (first line of Eqs. (13), Eqs. (14), first line of Eqs. (15)), the left-hand side of the equations represents the required rate of return. The right-hand side corresponds to the realized rate of return, consisting of the cash flow to equityholders and the expected change in the value of equity as calculated by Ito's lemma. The last term captures the change in the value of equity in case of a regime switch. When investment takes place (second line of Eqs. (15), Eqs. (16)), the value of equity is given by the value of equity after investment, $\hat{e}_i\left(sX; c^*_{n,i}\right)$, less the option exercise costs, K, and the principal, P, plus the issue proceeds from new debt, $\hat{d}_i\left(sX; c^*_{n,i}\right)$, cf. Hackbarth and Mauer (2012). The boundary conditions are as follows.

$$\lim_{X \searrow D_R} e_B(X) = \lim_{X \nearrow D_R} e_B(X), \tag{17}$$

$$\lim_{X \searrow D_R} e'_B(X) = \lim_{X \nearrow D_R} e'_B(X), \tag{18}$$

$$e_B(D_B) = 0, \tag{19}$$

$$e_R(D_R) = 0, \tag{20}$$

$$\lim_{X \searrow X_B} e_R(X) = \lim_{X \nearrow X_B} e_R(X), \tag{21}$$

$$\lim_{X \searrow X_B} e'_R(X) = \lim_{X \nearrow X_B} e'_R(X), \tag{22}$$

$$e_B(X_B) = \hat{e}_B\left(sX_B; c^*_{n,B}\right) - K - P + \hat{d}_B\left(sX; c^*_{n,B}\right), \tag{23}$$

and

$$e_R(X_R) = \hat{e}_B\left(sX_R; c^*_{n,R}\right) - K - P + \hat{d}_R\left(sX; c^*_{n,R}\right). \tag{24}$$

Eqs. (17) and (18) correspond to the value-matching and smoothness conditions for the equity value in boom at the default boundary in recession. Similarly, Eqs. (21) and (22) are the value-matching and smoothness conditions for the equity value in recession at the investment boundary in boom. Eqs. (19) and (20) represent the value-matching conditions at the default thresholds, and Eqs. (23) and (24) are the value-matching conditions at the investment thresholds. The solution to the system (12)-(16) subject to its boundary conditions (17)-(24) is given in Appendix C, Proposition 2 (ii). Similarly, the valuation of corporate debt can be derived. The solution is stated in Appendix C, Proposition 2 (i).

Next, I present the derivation of the value of manager's claim to cash flows before investment in regime i, denoted by m_i. This value is given by

$$\begin{aligned} m_i(X) \;=\; & \mathbb{E}^{\mathbb{Q}}\left[\int_t^S e^{-r^n_{I_s}(s-t)}(1-\tau)(\phi+\psi-\phi\psi)(X_s-c_o)\,\mathrm{d}s\,|X_t=X\right] \\ & +\mathbb{E}^{\mathbb{Q}}\left[1_{S=O}\int_S^{\hat{D}} e^{-r^n_{I_s}(s-t)}(1-\tau)(\phi+\psi-\phi\psi)(sX_s-c_n)\,\mathrm{d}s\,|X_t=X\right] \\ & +\mathbb{E}^{\mathbb{Q}}\left[1_{S=O}\psi\left(-K-P+\int_S^{\hat{D}} e^{-r^n_{I_s}(s-t)}c_n\mathrm{d}s+\alpha_{I_{\hat{D}}}y_{I_{\hat{D}}}sX_{I_{\hat{D}}}\right)|X_t=X\right], \end{aligned} \tag{25}$$

in which S denotes the stopping time of default or investment, whichever happens first, as defined in Eqs. (9)-(11). The first line of Eq. (25) uses the fact that the cash flow to the manager before investment or default is given by $(1-\tau)(\phi+\psi-\phi\psi)(X_s-c_o)$. If $S=D$, i.e., default happens first, the manager receives zero; if $S=O$, i.e., investment happens first, the manager's payoff is given by the manager's claim to cash flow after investment [as stated in the second line of Eq. (25), cf. Eq. (3)] less the cash flows at investment due to the manager's equity share [corresponding to the third line of Eq. (25), cf. Eq. (8)]. Again, a no-arbitrage argument implies an instantaneous return equal to the nominal risk-free rate r_i^n. Hence, an application of Ito's lemma with regime switches shows that the Hamilton-Jacobi-Bellman equation for the manager's claim to cash flow corresponds to the following system.

For $0 \leq X \leq D_B$:

$$\begin{cases} m_B(X) = 0 \\ m_R(X) = 0. \end{cases} \tag{26}$$

For $D_B < X \leq D_R$:

$$\begin{cases} r_B^n m_B(X) = (1-\tau)(\phi+\psi-\phi\psi)(X-c_o) + \tilde{\mu}_B X m_B'(X) \\ \qquad + \frac{1}{2}\tilde{\sigma}_B^2 X^2 m_B''(X) + \tilde{\lambda}_B(0 - m_B(X)) \\ m_R(X) = 0. \end{cases} \tag{27}$$

For $D_R < X < X_B$:

$$\begin{cases} r_B^n m_B(X) = (1-\tau)(\phi+\psi-\phi\psi)(X-c_o) + \tilde{\mu}_B X m_B'(X) \\ \qquad + \frac{1}{2}\tilde{\sigma}_B^2 X^2 m_B''(X) + \tilde{\lambda}_B(m_R(X) - m_B(X)) \\ r_R^n m_R(X) = (1-\tau)(\phi+\psi-\phi\psi)(X-c_o) + \tilde{\mu}_R X m_R'(X) \\ \qquad + \frac{1}{2}\tilde{\sigma}_R^2 X^2 m_R''(X) + \tilde{\lambda}_R(m_B(X) - m_R(X)). \end{cases} \tag{28}$$

For $X_B \leq X < X_R$:

$$\begin{cases} m_B(X) = \hat{m}_B\left(sX; c_{n,B}^*\right) + \psi\left(-K - P + \hat{d}_B\left(sX; c_{n,B}^*\right)\right) \\ r_R^n m_R(X) = (1-\tau)(\phi+\psi-\phi\psi)(X-c_o) + \tilde{\mu}_R X m_R'(X) \\ \qquad + \frac{1}{2}\tilde{\sigma}_R^2 X^2 m_R''(X) + \tilde{\lambda}_R\left(\hat{m}_B\left(sX; c_{n,B}^*\right)\right. \\ \qquad \left. + \psi\left(-K - P + \hat{d}_B\left(sX; c_{n,B}^*\right)\right) - m_R(X)\right). \end{cases} \tag{29}$$

For $X \geq X_R$:

$$\begin{cases} m_B(X) = \hat{m}_B\left(sX; c_{n,B}^*\right) + \psi\left(-K - P + \hat{d}_B\left(sX; c_{n,B}^*\right)\right) \\ m_R(X) = \hat{m}_R\left(sX; c_{n,R}^*\right) + \psi\left(-K - P + \hat{d}_R\left(sX; c_{n,R}^*\right)\right). \end{cases} \tag{30}$$

This system is similar to the one for equity, Eqs. (12)-(16), and exhibits an analogous intuition. The boundary conditions are as follows.

$$\lim_{X \searrow D_R} m_B(X) = \lim_{X \nearrow D_R} m_B(X), \quad (31)$$

$$\lim_{X \searrow D_R} m'_B(X) = \lim_{X \nearrow D_R} m'_B(X), \quad (32)$$

$$m_B(D_B) = 0, \quad (33)$$

$$m_R(D_R) = 0, \quad (34)$$

$$\lim_{X \searrow X_B} m_R(X) = \lim_{X \nearrow X_B} m_R(X), \quad (35)$$

$$\lim_{X \searrow X_B} m'_R(X) = \lim_{X \nearrow X_B} m'_R(X), \quad (36)$$

$$m_B(X_B) = \hat{m}_B\left(sX_B; c^*_{n,B}\right) + \psi\left(-K - P + \hat{d}_R\left(sX; c^*_{n,R}\right)\right), \quad (37)$$

and

$$m_R(X_R) = \hat{m}_B\left(sX_R; c^*_{n,R}\right) + \psi\left(-K - P + \hat{d}_R\left(sX; c^*_{n,R}\right)\right). \quad (38)$$

Eqs. (31) and (32) correspond to the value-matching and smoothness conditions for manager's expected cash flow in boom at the default boundary in recession. Similarly, Eqs. (35) and (36) are the value-matching and smoothness conditions for the managerial value function in recession at the option exercise boundary in boom. Eqs. (33) and (34) represent the value-matching conditions at the default thresholds, and Eqs. (37) and (38) are the value-matching conditions at the option exercise boundaries. The solution to the system (26)-(30) subject to its boundary conditions (31)-(38) is given in Appendix C, Proposition 2 (iii).

To determine the default and investment policies chosen by the manager, I first derive the value matching conditions of the value of the manager's claim to cash flows. The smooth-pasting conditions are then implied by the value matching conditions. I denote shareholders' default policy simultaneously chosen with manager's investment boundaries by $D_i^{sb;*}$, and the option exercise policy chosen by the manager by X_i^*. Simultaneously, the manager and shareholders solve, respectively,

$$X_i^* = argmax_{X_i} m_i(X), \quad (39)$$

and

$$D_i^{sb;*} = argmax_{D_i} e_i(X). \quad (40)$$

I assume that the solutions to Eqs. (39) and (39) exist and are unique, and verify this conjecture in the quantitative analysis and in the simulations. The smooth-pasting conditions that determine these policies are given by the derivatives of the corresponding value matching conditions. In detail, the value matching conditions of equity at default are stated in Eqs. (19)-(20), and the value matching condition of the manager's expected cash flow at option exercise is given in Eqs.

(37)-(38). Thus, these four optimality conditions translate into smooth-pasting conditions at the respective boundaries:

$$\begin{cases} e'_B\left(D_B^{sb;*}\right) &= 0 \\ e'_R\left(D_R^{sb;*}\right) &= 0 \\ m'_B\left(X_B^*\right) &= \hat{m}'_B\left(sX_B^*; c_{n,B}^*\right) + \psi \hat{d}'_B\left(sX_B^*; c_{n,B}^*\right) \\ m'_R\left(X_R^*\right) &= \hat{m}'_R\left(sX_B^*; c_{n,R}^*\right) + \psi \hat{d}'_R\left(sX_R^*; c_{n,R}^*\right) \end{cases} \tag{41}$$

Next, the manager determines his preferred coupon level by maximizing the value of his objective function ex ante, taking default and investment policies as given. A fraction ψ of the issue proceeds of debt accrue to the manager due to his equity share. Hence, the manager solves:

$$c_{o,i}^* = argmax_{c_o}\left(m_i\left(X; c_o\right) + \psi d_i\left(X; c_o\right)\right). \tag{42}$$

In the presence of manager-shareholder agency conflicts, the problem of the manager thus consists of solving Eqs. (7), (42), and (39) subject to Eq. (40). A closed-form solution of this optimization problems does not exist, and standard numerical procedures are used.

2.3. Agency costs

To define agency costs in my framework, I consider the first-best solution as a benchmark. The first-best solution is characterized by firm-value maximizing investment and financial policies. Agency costs are then calculated in the second and third best case. In the second best case, shareholders control financial and investment decisions, whereas in the third best solution the manager has control rights over financial and investment policies. In the following, I start by explaining the first-best benchmark. Next, I present the second best solution and the definition of agency costs. Finally, I define agency costs in the third best case.

First-best solution. Investment and financial policies are chosen to maximize firm value. As before, the policies are determined by backward induction. First, I show how the first-best capital structure at option exercise is determined. Next, I explain how to find the first-best investment boundaries, while equityholders still control the default decision. Finally, I present the optimal first-best capital structure.

At exercise, the firm value maximizing coupon solves

$$c_{n,i}^{fb} := \text{argmax}_{c_n} \hat{v}_i\left(X; c_n\right). \tag{43}$$

In standard structural models, the firm value maximizing capital structure is determined by trading off tax benefits of debt against bankruptcy costs (Leland, 1998). In my model, additionally, the realized regime affects both the tax shield and the bankruptcy costs. Furthermore, equityholders face an additional incentive to issue debt, namely, to reduce the free cash flow from which the manager diverts (Jensen, 1986). Hence, the optimal coupon also depends on the realized regime at investment as well as the presence of the manager-shareholder agency conflicts. Next, I denote the first-best investment thresholds in boom and recession by X_B^{fb} and X_R^{fb}, respectively. The default boundaries chosen by shareholders, but, simultaneously, taking into account the optimal first-best investment boundaries, are denoted by $D_B^{sb;fb}$ and $D_R^{sb;fb}$ in boom and recession, respectively. Value matching of the equity and firm value at default and option exercise, respectively, requires:

$$\begin{cases} e_B\left(D_B^{sb;fb}\right) & = & 0 \\ e_R\left(D_R^{sb;fb}\right) & = & 0 \\ v_B\left(X_B^{fb}\right) & = & \hat{v}_B\left(sX_B; c_{n,B}^{fb}\right) - K \\ v_R\left(X_R^{fb}\right) & = & \hat{v}_R\left(sX_R; c_{n,R}^{fb}\right) - K. \end{cases} \tag{44}$$

Hence, the firm-value maximizing investment policy is determined by solving

$$\begin{cases} e'_B\left(D_B^{sb;fb}\right) & = & 0 \\ e'_R\left(D_R^{sb;fb}\right) & = & 0 \\ v'_B\left(X_B^{fb}\right) & = & \hat{v}'_B\left(sX_B^{fb}; c_{n,B}^{fb}\right) \\ v'_R\left(X_R^{fb}\right) & = & \hat{v}'_R\left(sX_R^{fb}; c_{n,R}^{fb}\right) \end{cases} \tag{45}$$

The last two equations of the system (45) postulate smoothness of the firm value at the exercise boundaries. The first-best investment boundaries are determined by trading off the additional realization of interest tax shield earned on debt financing and the decrease in bankruptcy costs, against the exercise price K of the option and the increase in the expected value of managerial benefits.

The first-best capital structure is determined by the coupon that maximizes the firm value, given first-best default and investment policies:

$$c_{o,i}^{fb} = argmax_{c_o}\left(v_i\left(X; c_o\right)\right). \tag{46}$$

Hence, the first best problem consists of solving Eqs. (43), (46), and the last two equations of system (45), subject to the first two equations of system (45). Standard numerical procedures are used.

Second-best solution. Investment and financial policies are selected to maximize equity.

At option exercise, after existing debt is called, equity holders maximize the ex-ante value of equity, i.e., the value of the firm. Therefore, the coupon chosen by equityholders is equal to the first-best optimal coupon after exercise, i.e., $c_{n,i}^{sb} = c_{n,i}^{fb}$, for $i = B, R$, in which $c_{n,i}^{fb}$ is as determined by equation (43).[14] In particular, there is no stockholder-bondholder conflict on the financial policy choice at option exercise. I denote the shareholder's optimal exercise boundaries

[14]Hence, the assumption that debt is called upon investment is equivalent to assuming that shareholders can commit to first-best financing of the option exercise price K, see also Hackbarth and Mauer (2012).

in boom and recession by X_B^{sb} and X_R^{sb}, respectively. The shareholder-selected default boundaries in boom and recession, which are chosen simultaneously with the exercise boundaries, are denoted by $D_B^{sb;sb}$ and $D_R^{sb;sb}$, respectively. The value-matching conditions for equity are stated in (19)-(20) and (23)-(24), leading to the smooth-pasting conditions:

$$\begin{cases} e'_B\left(D_B^{sb;sb};c_o\right) &= 0 \\ e'_R\left(D_R^{sb;sb};c_o\right) &= 0 \\ e'_B\left(X_B^{sb};c_o\right) &= \hat{e}'_B\left(sX_B;c_{n,B}^{sb}\right)+\hat{d}'_B\left(sX_B;c_{n,B}^{fb}\right) \\ e'_R\left(X_R^{sb};c_o\right) &= \hat{e}'_R\left(sX_R;c_{n,R}^{sb}\right)+\hat{d}'_R\left(sX_R;c_{n,R}^{fb}\right). \end{cases} \tag{47}$$

The difference between first-best and second best investment boundaries depends strongly on the financing of the option. If investment is financed by issuing additional equity, shareholders have an incentive to underinvest relative to the first-best policy due to risk shifting or asset substitution (cf. Jensen, 1986). However, if part of the option is exercised by issuing additional debt, shareholders have an incentive to overinvest because they transfer the increased risk of bankruptcy (compared to the first-best solution) to new bondholders (cf. Mauer and Sarkar, 2005). Less valuable growth options induce a higher incentive to adjust the capital structure and to issue additional debt, because they are exercised at larger values of the firm's cash flow. Therefore, shareholders' desire to overinvest is inversely related to the value of the growth option.

Finally, because at issuance shareholders maximize the ex-ante value of their claims, i.e., the value of the firm, the initial coupon is chosen according to

$$c_{o,i}^{sb} = argmax_{c_o}\left(v_i\left(X;c_o\right)\right). \tag{48}$$

The second-best solution is, hence, characterized by solving Eqs. (43), (48), and (47). Standard numerical procedures are used.

The realizations of the objective function v_i are lower in the second-best as in the first-best case, because of equity value maximizing investment boundaries in the second best solution. Hence, the second-best coupon at issuance differs from the first-best coupon at issuance, even though the functional form of the objective function is identical in the first- and second-best case. In detail, to mitigate the risk shifting effects of suboptimal investment, the second-best coupon at issuance is slightly lower than the first-best coupon if shareholders overinvest and vice versa.

I focus on agency costs due to control rights on financial and investment policies. Default policies are always chosen optimally by equityholders. Therefore, when defining agency costs, I explicitly show the dependence of the value function on financial and investment controls, but I omit default boundaries as chosen by shareholders in the value functions before and after investment. Agency costs AC_i^{sb} in the second best case are the difference between the hypothetical first-best firm value and the second best firm value, expressed as a percentage of the first-best firm value:

$$AC_i^{sb}(X) = 100\left(1 - \frac{v_i\left(X; c_{o,i}^{sb}, X_B^{sb}, X_R^{sb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}{v_i\left(X; c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}\right) = 100\left(1 - \frac{v_i^{sb}(X)}{v_i^{fb}(X)}\right). \tag{49}$$

To understand the mechanics of agency costs in my model, I decompose agency costs into three sources: Investment induced agency costs (i.e., due to suboptimal investment), leverage induced agency costs (i.e., due to suboptimal financial policies), and agency costs due to interaction effects between suboptimal investment and financial policies. I start with investment induced agency costs, denoted by $IAC_i^{sb}(X)$. I define investment induced agency costs in the second best case as the loss in firm value relative to the firm value when shareholders choose the investment policy, and first-best financial policies are chosen:

$$IAC_i^{sb}(X) = 100\left(1 - \frac{v_i\left(X; c_{o,i}^{fb}, X_B^{sb}, X_R^{sb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}{v_i\left(X; c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}\right). \tag{50}$$

For consistency, both the nominator and the denominator of Eq. (50) are calculated using equityholders' optimal default policies. For example, the denominator assumes that equityholders default optimally, given first-best financial and second-best investment policies are applied.Analogously to investment induced agency costs, I define leverage induced agency costs, denoted by $LAC_i^{sb}(X)$. Leverage induced agency costs are defined as the loss in firm value relative to the firm value when shareholders choose financial policies, and financial policies are chosen such that the firm value is maximized:

$$LAC_i^{sb}(X) = 100\left(1 - \frac{v_i\left(X; c_{o,i}^{sb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{sb}, c_{n,R}^{sb}\right)}{v_i\left(X; c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}\right). \tag{51}$$

Again, both the nominator and the denominator of Eq. (51) are calculated using equityholders' optimal default policies. Upon investment and after existing debt is called, shareholders maximize the value of the firm, and, hence, the second-best coupon at investment is equal to the first-best coupon at investment, i.e., $c_{n,i}^{fb} = c_{n,i}^{sb}$ for $i = B, R$. However, the second-best coupon at initiation will slightly differ from the first-best coupon. The reason is that equityholders' investment policies do not coincide with the firm-value maximizing ones, and these investment policies, in turn, alter the firm-value maximizing coupon. Therefore, leverage induced agency costs in the second best case are not zero, even though equityholders maximize firm value when making capital structure decisions. Finally, interaction agency costs $SAC_i^{sb}(X)$ are given by the part of total agency costs that are not explained by direct investment and leverage induced agency costs due, i.e.,

$$SAC_i^{sb}(X) = AC_i^{sb}(X) - IAC_i^{sb}(X) - LAC_i^{sb}(X). \tag{52}$$

At issuance, shareholders choose the coupon to maximize the ex-ante value of their claims, i.e., firm value, whereas shareholders exercise the growth option to maximize the ex-post value of their claims, i.e., the value of equity. Hence, shareholders choose the initial coupon to mitigate the negative effect on firm value due to their equity value maximizing investment policy. Therefore, interaction costs SAC_i^{sb} are negative in the second best case. This effect is particularly pronounced in boom, because the increase in bankruptcy costs due to a suboptimal coupon is smaller in boom than in recession. Hence, in boom, it is less costly to adjust the coupon to partially offset shareholders' suboptimal investment decision.

Third-best solution. The manager chooses investment and financial policies to maximize the sum of his private benefits and his equity stake. Eqs. (7), (41), and (42) describe the manager's problems to find his preferred capital structure after investment, the investment boundaries he selects, and his chosen capital structure before investment, respectively. Analogously to Leland (1998) and Childs and Mauer (2008), I define agency costs AC_i^{tb} as the difference between the hypothetical first-best firm value and the firm value with agency conflicts, expressed as a percentage of the first-best firm value:

$$\begin{aligned} AC_i^{tb}(X) &= 100\left(1 - \frac{v_i\left(X; c_{o,i}^*, X_B^*, X_R^*, c_{n,B}^*, c_{n,R}^*\right)}{v_i\left(X; c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{o,B}^{fb}, c_{o,R}^{fb}\right)}\right) \\ &= 100\left(1 - \frac{v_i^*(X)}{v_i^{fb}(X)}\right). \end{aligned} \tag{53}$$

Analogous to the analysis of agency costs in the second best case, I decompose total agency costs $AC_i^{tb}(X)$ into investment induced agency costs, $IAC_i^{tb}(X)$, leverage induced agency costs, $LAC_i^{tb}(X)$, and agency costs due to interaction effects between the two, $SAC_i^{tb}(X)$. Agency costs due to suboptimal investment, $IAC_i^{tb}(X)$ in the third best case, are defined as the loss in firm value relative to firm value when the manager selects the investment policy and financial policies are chosen to maximize firm value:

$$IAC_i^{tb}(X) = 100\left(1 - \frac{v_i\left(X; c_{o,i}^{fb}, X_B^*, X_R^*, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}{v_i\left(X; c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb}\right)}\right). \tag{54}$$

In the model, the manager overinvests to increase his private benefits. This result is in line with the literature, see, for example, Morellec (2004), Malmendier and Tate (2005), and Hackbarth (2008). Definition (54) allows to quantify the costs of managerial desire to overinvest on the firm value.

Next, I define leverage induced agency costs, denoted by $LAC_i^{tb}(X)$, as the loss in firm value relative to the firm value when the manager chooses financial policies, and investment policies are chosen to maximize firm value:

$$LAC_i^{tb}(X) = 100\left(1 - \frac{v_i\left(X; c^*_{o,i}, X_B^{fb}, X_R^{fb}, c^*_{n,B}, c^*_{n,R}\right)}{v_i\left(X; c^{fb}_{o,i}, X_B^{fb}, X_R^{fb}, c^{fb}_{n,B}, c^{fb}_{n,R}\right)}\right). \tag{55}$$

In the model, due to agency conflicts between the manager and shareholders, managerial private benefits distort the capital structure decision of the manager [see eqs. (42) and (7)]. In particular, the manager chooses a lower coupon than the firm-value maximizing one. The manager has two incentives to do so: First, by choosing a lower coupon, the manager increases the value of the free cash flow (cf. Morellec, Nikolov, and Schürhoff, 2012). Second, the manager induces shareholder to defer default, since the required funds to inject are lower. The deferred default decision increases the expected value of future cash flows, and, hence, the manager's private benefits. Typically, the increase of private benefits due to a lower coupon strongly outweighs the reduction in firm value in the manager's objective function. Thus, the manager chooses a lower coupon than the firm value maximizing one, i.e., he underleverages. Underleverage is also in line with the theoretical literature (see, e.g., Morellec, 2004; Morellec and Wang, 2004; Morellec, Nikolov, and Schürhoff, 2012), as well as empirically observed (Berger, Ofek, and Yermack, 1997). Definition (55) allows to measure the loss in firm value due to the managerial desire to underleverage.

Finally, I define interaction agency costs in the third best case, SAC_i^{tb}, as the part of total agency costs that is not explained by direct investment or leverage induced agency costs:

$$SAC_i^{tb}(X) = AC_i^{tb}(X) - IAC_i^{tb}(X) - LAC_i^{tb}(X). \tag{56}$$

In the third best case, interaction agency costs stem from two sources. First, because the manager chooses his preferred capital structure at the time of investment, he has an incentive to overinvest even more than if the first-best capital structure at investment was selected. Second, overinvestment induces the manager to choose a lower coupon at issuance than if firm value maximizing investment boundaries were employed. The decrease in firm value requires a lower coupon to reach the manager's preferred leverage level. In summary, because both suboptimal investment and financial policies reinforce each other, interaction agency costs are positive in the third-best case.

3. Quantitative results

The previous section presented the qualitative properties of second and third best model solutions. In this section, I quantify total agency costs for firms with different portions of growth options in their asset composition depending on the current economic regime. Further, decomposing agency costs into investment induced agency costs, leverage induced agency costs, and interaction induced agency costs permits the quantification of the components of total agency costs. Subsection 3.1 presents the choice of parameters, and Subsection 3.2 quantifies agency costs for firms with different asset composition ratios in boom and recession at the time of debt issue.

3.1. Choice of parameters

I fix the fraction of equity owned by the manager as $\psi = 0.0747$ and the fraction of private benefits as $\phi = 0.01$. The fraction of equity owned by the manager ψ and the fraction of free cash flow diverted as private benefits ϕ are the average values reported in Morellec, Nikolov, and Schürhoff (2012). The remaining parameters are chosen as in Arnold, Wagner, and Westermann (2013), presented in Table I.

3.2. Quantifying agency costs for value and growth firms

This subsection quantifies agency costs for firms with heterogenous asset compositions in economic boom and recession. While the qualitative impact of agency conflicts is well-documented in the literature, the quantitative effect with respect to a firm's asset composition ratio has not been studied extensively, in particular not in the presence of varying macroeconomic conditions. A firm's *asset composition ratio* is defined as the value of the firm divided by the value of invested assets. As in Arnold, Wagner, and Westermann (2013), this measure captures the relative importance of a firm's investment opportunities in the value of its assets. The direct empirical analogon is Tobin's q.

The results are presented in Tables II, III, and IV. Each table shows the investment policy and the resulting asset composition ratio (Panel A), the financial policies and the resulting leverage (Panel B), the value functions of interest (Panel C), and agency costs and their decomposition (Panel D) for the first-best solution (rows one and two), the second best solution (rows three and four), and the third best solution (rows five and six), in boom and recession, respectively. Table II corresponds to a firm with only invested assets, Table III to a (roughly) average firm with a scale parameter of $s = 2.4$, and Table IV displays the result for a growth firm with scale parameter $s = 3.5$.

I start the analysis with the second-best solution, i.e., equityholders select investment and financing policies. Table III presents the results for a firm with only invested assets. Shareholders select the financing policies that maximize the ex-ante value of their claims, i.e., the firm value. Hence, in the absence of an expansion option, the second-best solution is identical to the first-best solution, reflecting the notion that there is no bondholder-shareholder conflict on financing policies for firms with only invested assets. Comparing first- and second-best solutions in Table II (columns 1 and 3, and columns 2 and 4, respectively), yields, hence, that these two solutions are identical. Next, Tables III and IV show the results for an average firm with an option scale parameter of 2.4 and for a growth firm with an option scale parameter of 3.5, respectively. The first observation from the first two rows of Panel A is that shareholders overinvest slightly compared to the first-best solution. For example, for an average firm initiated in boom, shareholders invest at a cash flow value of 1.95 (2.08) in boom (recession), whereas the firm value maximizing strategy invests at 2.00 (2.16). This result is driven by the effective financing of the option exercise at investment. If the option is financed by additional equity, equityholders engage in asset substitution and underinvest (Mauer and Ott, 2000, Moyen, 2002 or Titman and Tsyplakov, 2002). However, as documented by Mauer and Sarkar (2005) or Hackbarth and Mauer (2012), if the option exercise is financed by additional debt, equityholders have an incentive to overinvest. The reason is that equityholders transfer the increased default risk by early option exercise to bondholders, while enjoying the additional tax benefit due to increased cash flows. In my model, the exercise of the option is financed by a mix of equity and debt. Consistent with the literature, I find that equityholders' incentive to overinvest is stronger the larger is the percentage of debt financing of the exercise price. Because more valuable growth options are exercised at lower values of cash flow, and because the new coupon at exercise is linear in cash flow, the percentage of debt financing of the exercise price is decreasing in the asset composition ratio. For example, the first-best solution of an average firm which exercises its growth option at the exercise boundary in boom uses 137.88% debt financing of the option exercise price (i.e., equityholders receive a debt financed dividend, as in Hackbarth and Mauer, 2012). The first-best percentage of debt financing of the option exercise price declines to 106.39% at the exercise boundary in boom for a growth firm (Panel B, row four). Hence, as a result, I find that equityholders' incentive to overinvest is weaker the larger is the asset composition ratio of a firm. In turn, the investment induced agency costs are decreasing with the asset composition ratio, from 100.00% for a value firm to 99.80% for an average firm, and 99.41% for a growth firm initiated in boom (Panel D, row two of Table III and IV, respectively). However, these results are driven by the assumption that upon investment debt is called at par, which, in turn, implies that equityholders can commit to value-maximizing financing of the investment opportunity. Finally, the initial coupon c_o in the second-best case is slightly lower than in the first-best case (for example, 0.6425 in the first-best case and 0.6361 in the second-best case for an average firm initiated in boom, see Panel B, row one). Hence, leverage induced agency costs are small but positive, 2.91% of total agency costs for an average firm initiated in boom, and 2.78% for a growth firm (Panel D, row three of Table III and IV, respectively). The reason for selecting a lower leverage than the first-best is that shareholders choose the initial coupon to maximize firm value, and, hence, mitigate the effects of their own overinvestment. This intuition is reflected in the negative interaction agency cost (-2.72% for an average firm, and -2.19 for a growth firm initiated in boom, Panel D, row four, Tables III and IV, respectively). Total agency costs in the second-best case exhibit an inverse U-shape in the asset composition ratio. Equityholders' desire to overinvest causes agency costs to increase for low asset composition ratios. Because equityholders' incentive to overinvest declines with the value of the option, total agency costs are decreasing for high asset composition ratios. Importantly, absolute values of agency costs are negligibly small in both boom and recession. The agency costs for an average firm initiated in boom are 0.0173% of firm value, and for a growth firm initiated in boom agency costs are 0.0144% (Panel D, row one). This result conforms to

Childs, Mauer, and Ott (2005), who find that stockholder-bondholder agency costs are negligibly small when the firm has financial flexibility. However, the results depend on the assumption that debt is called at par when the investment opportunity is exercised.[15]

Next, I investigate the third best solution, i.e., when the manager controls investment and financing decisions (columns five and six of Tables II, III, and IV). I start by considering a firm with only invested assets (Table II). In row one of Panel B, I find that the manager-selected coupon is significantly lower than the first-best coupon in both boom and recession. The implied first-best leverage is 46.97% (45.75%) in boom (recession), and 21.82% (21.25%) in boom (recession) for the third best solution (Panel B, row two). As in Morellec, Nikolov, and Schürhoff (2012), managers choose a lower coupon to increase net cash flows of which they divert private benefits. Empirical evidence of underleverage can be found in Berger, Ofek, and Yermack (1997), while further theoretical work is, for example, Morellec (2004) or Morellec and Wang (2004).

Tables III and IV present the results for an average firm and a growth firm, respectively. Because the manager diverts private benefits from cash flows, he has an incentive to overinvest in the option. For an average firm initiated in boom, the manager selects investment policies of 1.83 and 1.95 in boom and recession, respectively, while firm value maximizing policies correspond to 2.00 and 2.16 in boom and recession, respectively (Panel A, rows one and two, Table III). Managerial overinvestment is also documented in the literature, see, e.g., Morellec (2004), Malmendier and Tate (2005) or Hackbarth (2008). Simultaneously, as explained in the previous paragraph, the manager underleverages to increase the net cash flow from which he diverts private benefits. Both manager-shareholder agency conflicts and the presence of the investment opportunity decrease optimal leverage (see Morellec, 2004 for the effects of agency conflicts on leverage, and Arnold, Wagner, and Westermann, 2013 for the implications of growth options on optimal leverage). Hence, the resulting optimal leverage in a model with both growth options and agency conflicts is significantly decreased. For example, the optimal leverage for a firm initiated in boom decreases from 39.32% (first-best) to 16.63% (third best) for an average firm, and from 30.20% to 11.00% for a growth firm (Panel B, row two).

I now turn to the quantification of agency costs depending on the asset composition ratio and on the macroeconomic regime. First, agency costs are strongly increasing in the asset composition ratio. Total agency costs for a firm with only invested assets are 1.78% (1.73%), 2.83% (2.68%) for an average firm, and 3.48% (3.37%) for a growth firm initiated in boom (recession), see row one of Panel D. The reason is that for valuable growth options, the manager's desire to overinvest and underleverage, as well as their interactions, are stronger. The percentage of investment induced agency costs is increasing in the asset composition ratio: 0.00% (0.00%) for a firm with only invested assets, 6.64% (5.23%) for an average firm, and 13.35% (12.32%) for a growth firm in boom (recession), row two of Panel D. Further, also interaction costs are increasing in the asset

[15]If I assume that debt is called at market value instead of at par, I expect the impact on the result to be minor because financial flexibility is maintained. On the contrary, alternative assumptions that reduce financial flexibility such as assuming that debt is non-callable might increase stockholder-bondholder agency conflicts, as in Childs, Mauer, and Ott (2005).

composition ratio, with 0.00% (0.00%) for a firm with only invested assets, 1.03% (1.20%) for an average firm, and 1.51% (1.75%) for a growth firm in boom (recession), row four of Panel D. Consequently, while the absolute value of leverage induced costs is increasing in the asset composition ratio, the relative percentage of leverage induced agency costs in total agency costs is decreasing from 100.00% (100.00%) for a firm with only invested assets, 92.33% (93.57%) for an average firm, and 85.14% (85.93%) for a growth firm in boom (recession), row three of Panel D. Second, agency costs are slightly procyclical at issuance. For example, agency costs of an average firm are 2.83% in boom, but only 2.68% in recession (Panel D, row one). There are two reasons for the procyclicality of agency costs. The first reason is given by the fact that in boom the firm is closer to the investment threshold, and, hence, the probability of suboptimal investment increases. Therefore, investment induced agency costs are larger in boom. The second reason is due to the loss in tax benefits because of the lower coupon chosen by the manager. The loss in tax benefits is larger in boom, where economic conditions are more favorable, and, in particular, the drift of the cash flow is positive.

Similar to bondholder-shareholder agency costs, the quantitative and qualitative properties of manager-shareholder agency costs depend on the assumption that upon investment debt is called at par. If, instead, debt is assumed to be called at market value, the value of debt at issuance would be independent of the investment policies. However, the impacts on the results is expected to be minor. The alternative assumption of non-callable debt prevents a straightforward closed-form solution of the model. Hackbarth and Mauer (2012) show that the impact of financing and priority rules on agency costs of debt can be substantial. I conclude that while the implications of alternative financing rules are potentially important, their formal investigation is not possible in the current framework.

To conclude, I find that in this framework shareholder-bondholders agency costs are negligibly small, but manager-shareholder agency costs are substantial. Even for an average firm, manager-shareholder agency costs are about 3% of first-best firm value in both boom and recession. Further, I find that these agency costs are strongly increasing in the asset composition ratio and weakly procyclical.

4. Aggregate dynamics of agency costs

In this section, implications of manager-shareholder agency conflicts on the level of the aggregate economy are investigated. First, the dynamic properties of agency costs generated by the model-implied economy are analyzed. Second, default and investment rates are considered. Finally, the impact of agency conflicts on investment hazards is presented.

4.1. Time series of agency costs in the aggregate economy

The previous Section 3 presents agency costs at the time of issuance. However, as noted by Strebulaev (2007), it can be substantially misleading to draw empirical implications from the results at the time of issuance. As time evolves, a firm's cash flow deviates from the initial one. This deviation changes the value of the firm, which, in turn, affects agency costs. Because the impact of cash flow variations on firm value is non-linear, the impact of cash flow variation on agency costs is non-linear as well. Therefore, when making predictions for the cross section of firms, it is crucial to take into account the time evolution. For example, Bhamra, Kuehn, and Strebulaev (2010a) show that while leverage is procyclical at issuance, aggregate leverage is countercyclical in the aggregate economy. Because both leverage and agency costs depend on the value of the firm, the dynamic behavior of aggregate agency costs is also expected to deviate substantially from agency costs at the time of issue. Further, the dynamic approach takes into account the time evolution of cash flows given the inter-firm correlation. Hence, this section investigates the effects of aggregate agency costs in the aggregate economy. In the following, I describe the simulation approach and how to measure agency costs in the resulting aggregate economy. Finally, I present the results.

Simulation. The simulation is conducted similarly to Arnold, Wagner, and Westermann (2013), as inspired by Bhamra, Kuehn, and Strebulaev (2010a). The dynamic economy consists of 1,000 firms, all of which have an initial cash flow of one and an asset composition ratio of 1.5 at issuance. This asset composition ratio of 1.5 requires an option scale parameter of $s = 1.90$ if the regime at the time of issuance is boom, and $s = 2.06$ otherwise. The simulation is conducted on a monthly basis. Each month, all firms are subject to the same macroeconomic and inflation shocks, but differ with respect to their idiosyncratic shocks. At each month, each firm observes its current cash flow as well as the current regime and behaves optimally: If the current cash flow is below the default threshold selected by equityholders given the current regime, the firm defaults; If the current cash flow is above the manager-selected investment boundary in the current regime, the firm invests; otherwise, the firm takes no action.

Once a firm defaults or invests, it is replaced by a new firm with an asset composition ratio of 1.5. This substitution ensures a balanced sample in the time evolution of the dynamic economy. Without this substitution, the number of firms in the dynamic economy would decline to zero, because eventually all firms would default. Moreover, the fraction of firms consisting of only invested assets would increase over time, because each firm can invest only once and consists of invested assets only after investment.

First, the dynamic economy as described above is simulated for one hundred years. This pre-simulation guarantees both an inter-firm distribution of cash flows and a distribution of firms' initial regimes that reflect the long-run steady state. Next, the dynamic economy is simulated for one hundred years more, which constitute the time window of the presented aggregate dynamics.

Dynamic agency costs. In the dynamic economy, I define agency costs at each time as the aggregate loss in firm value due to the presence of the managers at this time. To this end, I consider a hypothetical economy consisting of firms employing firm-value maximizing investment boundaries and optimal first-best leverage at issuance. For each firm in the aggregate economy, there exists a corresponding firm in the hypothetical economy, which is hit by the same shock at each point in time. Then, at each point in time, I compare the firm value of each firm in the aggregate economy to the firm value of the corresponding firm in the hypothetical first-best economy. Consistent with the general formula (53), in a dynamic setting, agency costs $AC_i^{n,t}$ for firm n at time t are defined as

$$AC_i^{n,t} = 100\left(1 - \frac{v_i\left(X_t^n \left| c_n^*, X_B^*, X_R^*, c_{o,B}^*, c_{o,R}^*\right.\right)}{v_i\left(X_t^n \left| c_n^{fb}, X_B^{fb}, X_R^{fb}, c_{o,B}^{fb}, c_{o,B}^{fb}\right.\right)}\right), \tag{57}$$

in which X_t^n is the value of the cash flow for firm n at time t, and the superscripts * and ^{fb} refer to manager-selected and first-best policies, respectively. First-best option exercise and default boundaries are higher than manager-selected option exercise and default boundaries. For the computation of agency costs, I consider only firms that are still active both in the first-best and in the manager-controlled case. In particular, once a firm's cash flow falls below its default threshold of the first-best solution, this firm is excluded from the calculation of agency costs for the rest of its firm life. Once a manager-controlled firm exercises its expansion option, it is substituted immediately both in the aggregate and in the first-best economy. Finally, total aggregate agency costs are value-weighted:

$$AC_i^{agg,t} = \frac{1}{\sum_{n=1}^{N} e_i^n\left(X_t^n\right)} \sum_{n=1}^{N} e_i^n\left(X_t^n\right) AC_i^{n,t}. \tag{58}$$

The value weighting of agency costs avoids that the results are driven by firms close to default, for which the relative loss in firm value is large because absolute values are small.

Importantly, dynamic agency costs can be negative, both at the firm level and at the aggregate level. On the contrary, at issuance, the first-best firm value is always greater than the firm value with agency conflicts, and, hence, agency costs are always positive. In the dynamic economy, firms deviate from their optimal leverage due to changes in cash flows. Because the effect of credit risk on firm value is convex in the distance to default, the deviation from optimal leverage in the firm's time series can impact the firm value of the first-best firm more severely than the firm value of the manager-controlled firm. In this case, the firm value of the manager-controlled firm exceeds the firm value of the first-best firm. Hence, agency costs as defined by (57) can be negative for firms which are not at the time of issue.

To understand the sources of agency costs, I decompose agency costs at each point in time for each firm into investment induced agency costs, $IAC_i^{n,t}$, leverage induced agency costs, $LAC_i^{n,t}$

and interaction effects, $SAC_i^{n,t}$. The formulas are analog to the general definitions (50), (51), and (52), respectively:

$$IAC_i^{n,t} = 100 \left(1 - \frac{v_i \left(X_t^n \middle| c_{o,i}^{fb}, X_B^*, X_R^*, c_{n,B}^{fb}, c_{n,R}^{fb} \right)}{v_i \left(X_t^n \middle| c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb} \right)} \right), \tag{59}$$

$$LAC_i^{n,t} = 100 \left(1 - \frac{v_i \left(X_t^n \middle| c_{o,i}^{*}, X_B^{fb}, X_R^{fb}, c_{n,B}^{*}, c_{n,R}^{*} \right)}{v_i \left(X_t^n \middle| c_{o,i}^{fb}, X_B^{fb}, X_R^{fb}, c_{n,B}^{fb}, c_{n,R}^{fb} \right)} \right), \tag{60}$$

and

$$SAC_i^{n,t} = AC_i^{n,t} - IAC_i^{n,t} - LAC_i^{n,t}. \tag{61}$$

As before, formulae (59)-(61) are calculated using optimal default policies chosen by equityholders given financial and investment policies. Aggregate agency costs are obtained by value-weighting, analogous to Eq. (58).

Results. Table V presents the time-series mean, standard deviation and 10%, 25%, 50%, 75%, and 90% Quantiles of aggregate total agency costs, investment induced agency costs, leverage induced agency costs, and interaction agency costs. Panel A shows the overall results, while Panels B and C present the results in boom and recession, respectively. To illustrate the dynamics and time-series properties, I also display aggregate value-weighted agency costs over 50 years in the simulated economy. To start, Figure 1 presents the time-series of value-weighted aggregate total agency costs, in which shaded areas correspond to recessions. The moments and statistics

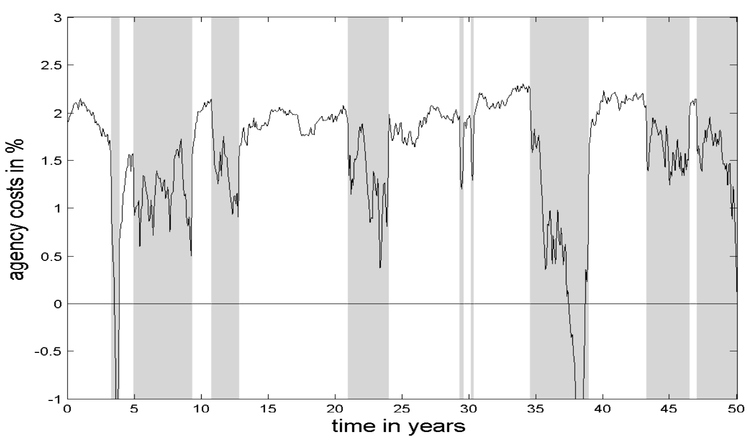

Figure 1. *Time series of value-weighted agency costs.* The solid line shows the aggregate value-weighted agency costs of the simulated economy. The shaded areas represent times of recession. Standard parameters from Table I are used.

for the total aggregate agency costs are shown in row one, Panels A, B, and C of Table V. The overall time-series average of aggregate agency costs is substantial: 1.56% of the first-best firm value with a standard deviation of 0.72 (Panel A). Further, the level as well as the dynamics of agency costs are fundamentally different in boom and recession. I provide the following three novel results concerning the evolution of agency costs over the business cycle. First, agency costs in boom are significantly higher than in recession (on average, 1.88% in boom vs. 0.92% in recession, Panels B and C). Consistent with this observation, when the economy switches from boom to recession [from recession to boom], agency costs decrease [increase] drastically. Second, the volatility of the time series of agency costs is much larger in recession (0.28 in boom vs. 0.89 in recession, Panels B and C). Third, inspection of the quantiles suggests that while the distribution of agency costs is approximately symmetric in boom, it is strongly negatively skewed in recession (Panels B and C).

The procyclical property of simulated agency costs may seem surprising at the first glance, given the fact that the macroeconomic literature typically emphasizes countercyclical agency costs (e.g., Bernanke and Gertler, 1986, Rampini, 2004, or Eisfeldt and Rampini, 2008). However, the macroeconomic literature measures agency costs as costs due to a loss in in productivity ('macroeconomic agency costs'), whereas the corporate finance literature measures agency costs as a loss in firm value ('corporate agency costs'). In the framework of a structural model, the firm has to be run by a manager, and the manager is partially entrenched. I calculate agency costs due to the choice of suboptimal controls. Because macroeconomic models typically abstract away from the possibility of debt financing and the resulting heterogeneity of firms (e.g., Carlstrom and Fuerst, 1998, or Eisfeldt and Rampini, 2008), corporate agency costs are unaccounted for in the macroeconomic literature. Similarly, my structural corporate model does not speak to macroeconomic agency costs as defined above. Managers are entrenched, but a firm's productivity is not affected by the specific manager, nor by his effort, nor by his skill. Further, based on the assumption of a large economy in which a single firm's contribution to aggregate output is negligible, I presume that the aggregate output process is given exogenously (see Eq. (68) in Appendix A). To the best of my knowledge, the literature lacks a model which can address macroeconomic and corporate agency costs simultaneously over the business cycle. Therefore, the relation and interaction between macroeconomic and corporate agency costs is left unexplained. However, I do not exclude the possibility that countercyclical macroeconomic agency costs can be consistent with procyclical corporate agency costs. For example, high macroeconomic agency costs in recession due to low productivity are not conflicting with low corporate agency costs on the firm level due to underleverage.

Next, I investigate the intuition driving my three main results by decomposing agency costs into investment induced agency costs, leverage induced agency costs, and interaction agency costs. The moments and quantiles of investment agency costs, leverage agency costs, and interaction agency costs are presented in row two, three, and four, respectively, of Panels A, B, and C of Table V. The following Figures 2, 3, and 4 depict the time-serious evolution over 50 years in the simulated economy of the three types of agency costs.

Inspection of the figures suggests that the level of aggregate total agency costs is mainly driven by leverage induced agency costs, while the impact of investment induced and interaction

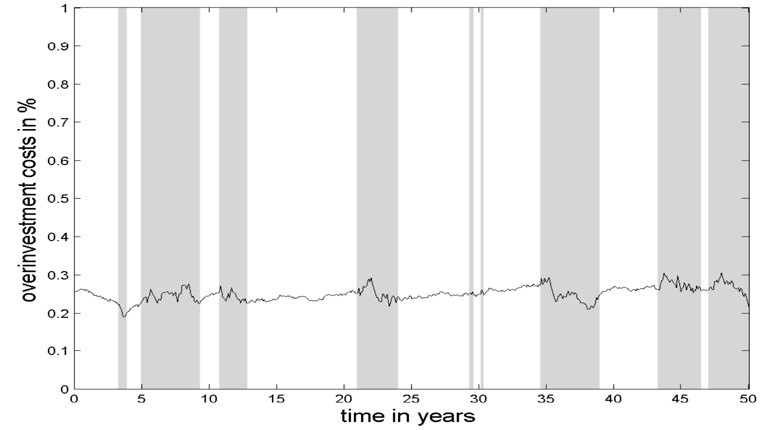

Figure 2. *Time series of value-weighted investment induced agency costs.* The solid line shows the investment induced agency costs in the simulated economy. The shaded areas represent times of recession. Standard parameters from Table I are used.

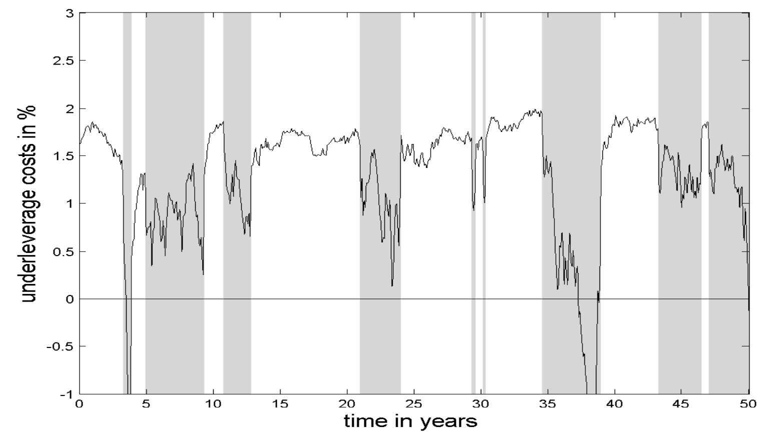

Figure 3. *Time series of value-weighted leverage induced agency costs.* The solid line shows the leverage induced agency costs in the simulated economy. The shaded areas represent times of recession. Standard parameters from Table I are used.

agency costs are much smaller. Indeed, Table V shows that average aggregate leverage induced agency costs are 1.29%, whereas aggregate investment induced and interaction agency costs are only 0.25% and 0.03%, respectively. Similarly to the properties of agency costs at issuance (see Section 3), manager's control rights over financial policies explain a large part of total agency costs over time. Next, Figure 3 suggests that the significant difference in mean and standard deviation of total agency costs in boom and recession is also driven by leverage induced agency costs. Leverage induced agency costs in boom have a mean and standard deviation of 1.60% and 0.27, respectively, (Panel B, row three), whereas leverage induced agency costs in recession have a mean and standard deviation of 0.64% and 0.78, respectively (Panel C, row three). On the contrary, the mean of investment induced [interaction] agency costs in boom is not significantly different from the mean in recession (0.25% vs. 0.25% [0.03% vs. 0.03%] in boom and recession with standard

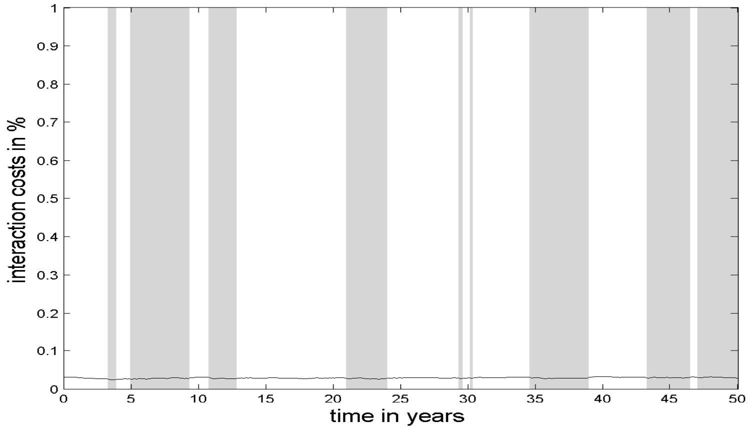

Figure 4. *Time series of value-weighted agency costs due to interaction effects.* The solid line shows the agency costs due to interaction effects between suboptimal investment and financing decisions in the simulated economy. The shaded areas represent times of recession. Standard parameters from Table I are used.

deviations of 0.02 vs. 0.02 [0.0014 vs. 0.0013], respectively). Overinvestment is more costly in recessions, when cash flows are lower. However, firms are closer to their exercise boundaries in boom, leading to an increased probability of investment in boom. Because investment induced agency costs in the aggregate economy are approximately constant across regimes, I conclude that these two effects seem to cancel each other out, at least in the cross section. Further, Figure 3 shows that the strong decrease [increase] in agency costs upon a regime switch from boom to recession [recession to boom] is governed by a strong decrease [increase] in leverage induced agency costs upon switching. To understand these effects, note that leverage induced agency costs are driven by the distance to default and bankruptcy costs. In recession, a firm's distance to default is larger if its leverage is lower, and default is less costly for firms with lower leverage because of lower default boundaries. Hence, leverage induced agency costs are smaller in recession. In particular, leverage induced agency costs can be negative in recession: For example, in Fig. 3, shortly before year 40, even aggregate leverage induced agency costs are negative. That is, on average, shortly before year 40, a firm enjoys agency benefits stemming from the larger distance to default. When the economy switches from recession to boom, firms' distance to default increases, since default boundaries are lower in boom than in recession. However, this effect is weaker for manager-controlled firms, because their default boundaries are lower due to lower leverage. Consequently, the first-best firm value increases more than the one of the manager-controlled firm given a regime switch to boom, and, hence, agency costs increase. The analogous reasoning holds for a regime switch from recession to boom. Finally, also the distributional properties of total agency costs, i.e., the higher volatility in recession as well as the skewness of the regime-dependent distributions, are inherited from the distributional properties of leverage induced agency costs. Because the firm value is more sensitive to changes in cash flow when the firm is closer to default, leverage induced agency costs are more volatile in recession. The negative skewness of the distribution of leverage induced agency costs can be explained similarly. During economic recessions, it is more likely that a number of firms is closed to default, benefiting from managerial underleverage. These benefits increase more strongly the closer the firm is to default, because the probability of actual default increases more strongly. Hence, there are more extreme realizations of leverage induced agency costs for low (negative) values. On the contrary, in boom, firms are, in general, more far away from default, and, hence, the change in default probability does not have the strong systematic asymmetric effect on agency costs. Therefore, the distribution of leverage induced agency costs in boom is approximately symmetric.

4.2. Default and investment rates

Because managers control investment and financing decisions, these control rights have implications for default and investment rates, as well as for the timing of investment. In this subsection, I first explain the simulation approach to investigate the implied changes in default and investment rates in the aggregate economy. Next, I present the implications for default and investment rates. Finally, I show the effects on the timing of investment projects.

Simulation. To investigate the impact of manager-shareholder conflicts on default and investment, I compare the aggregate economy to a hypothetical first-best economy in which firms invest according to the firm-value maximizing policies and also choose the firm-value maximizing capital structure. The aggregate economy, in which managers control default and investment decisions, is designed as described in the previous Subsection 4.1. The first-best economy is hit by the same realization of shocks as the aggregate economy, but the operating strategies correspond to the value maximizing policies. Importantly, whenever a firm defaults or expands in any economy, it is immediately replaced by a new firm. The investment opportunity of a new firm is still intact. This assumption of immediate replacement in the first-best economy is different from the assumption for the simulation in the previous Subsection 4.1.[16] Finally, default and investment rates are calculated as the fraction of firms that default and invest, respectively, relative to the total number of firms populating the economy during the time window used in the simulation.[17]

Implied default and investment rates. First, I compare the default and investment rates of the aggregate economy in which firms are run by self-interested managers to the default and investment rates of the hypothetical first-best economy. Table VI presents the change in default and investment rates in the aggregate economy compared to the first-best economy. Panel A shows the overall results, and Panel B and C present the results in boom and recession, respectively. Comparing the aggregate economy to the first-best economy, I find that the total default rate

[16]Previously, to maintain corresponding firms in both economies at each time, firms are always replaced simultaneously in both economies, e.g., after default in both economies is triggered. Because I now compare investment and default rates, it is not important to refer to corresponding firms as required when calculating agency costs.

[17]Because manager-selected default thresholds are lower than first-best default thresholds, more firms are replaced after default in the first-best economy. However, due to the fact that manager-selected investment thresholds are lower than first-best thresholds, more firms are replaced after investment in the aggregate economy. In total, the simulation reveals that more firms are replaced in the first-best economy. By normalizing with the total number of firms populating the economy (instead of normalizing with the number of firms at each time, i.e., 1,000), I control for the differences in the number of firms that are replaced in the first-best vs. the aggregate economy.

decreases by 50.60%, and the investment rate increases by 10.93%. While the signs of the changes are as implied by overinvestment and underleverage, the magnitudes of the changes are striking. The important decrease in the default rate is due to the strong managerial desire to underleverage. Table VI shows that the decrease in default rates is, surprisingly, slightly lower in boom (-47.42% in boom vs. -52.25% in recession), while the increase in the investment rate is slightly stronger in recessions (+11.89% in boom vs. +6.66% in recession). In summary, the results indicate that agency conflicts have important implication for default and investment rates, particularly in times of economic recession.

4.3. The intertemporal pattern of investment

Second, I investigate the effect of manager-shareholder conflicts on the timing of investment. The simulation is identical to the one in the previous Subsection 4.2. Row two of Panel A in Table VI show that the investment rate increases by more than 12% overall due to the presence of manager-shareholder agency conflicts. Rows two of Panels B and C document that the increase in boom is 11.98%, and the increase in recession 14.61%. Interestingly, the magnitudes of the changes indicate that the presence of manager-shareholder conflicts has important implications for the intertemporal pattern of investment. To investigate this conjecture, I calculate and analyze the simulation-implied distribution of the event investment as well as implied investment hazard rates.

For the analysis, I consider only the subsample of firms that exercise their option, and neglect firms that default. The restriction to this subsample is necessary because the time span between issuance and investment for a firm that defaults is not defined, because default excludes investment in the simulation. This selection method is consistent with the sample construction in the empirical literature, see, e.g., Whited (2006), or Morellec, Valta, and Zhdanov (2013). Next, for all firms in my subsample, I calculate the spell, i.e, the time span between issuance and investment. Formally, I define the random variable T measuring the spell between firm's n issuance and investment. The cumulative probability function F^* of the random variable T is given by

$$F^*(t) = P(T \leq t) \ \ \forall \, t \geq 0. \tag{62}$$

The simulation-implied cumulative distribution of manager-controlled firms of the random variable T, $\hat{F}^*(t)$, is calculated by counting firms that invest, i.e.,

$$\hat{F}^*(t) = \frac{\#\text{firms that invest at s, } s \leq t}{\#\text{firms that invest}}. \tag{63}$$

Analogously, I calculate the cumulative distribution implied by the first-best economy, $\hat{F}^{fb}$ by counting the firms that invest in the first-best economy. The left panel in Figure 5 shows the two estimated cumulative distributions of manager-controlled firms (solid line) and first-best firms (dashed line). I observe that the general shape of the cumulative distribution functions is compa-

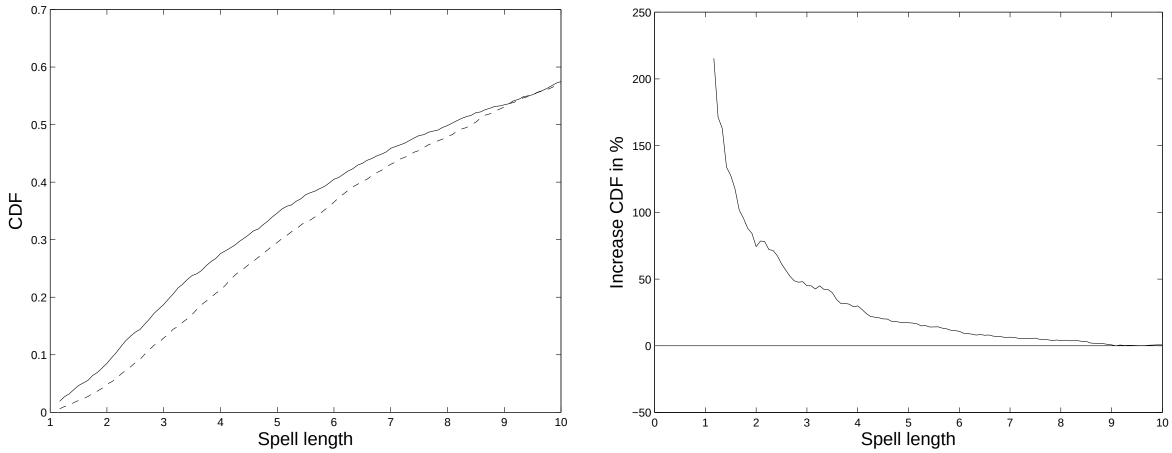

Figure 5. *Estimated cumulative distribution functions of the event investment and relative changes.* The left panel shows the cumulative distribution functions of the event that investment takes place before time t. The solid line corresponds to the cumulative distribution function resulting from the aggregate economy, the dotted line shows the cumulative distribution function resulting from the hypothetical first-best economy. The right panel presents the increase of the cumulative distribution function of the aggregate economy compared to the cumulative distribution function of the hypothetical first-best economy. Standard parameters from Table I are used.

rable to Figs. 1-6 in Whited (2006). To analyze the impact of the presence of manager-shareholder conflicts, the right panel of Figure 5 presents the increase in the cumulative distribution functions of the manager-controlled economy compared to the first-best economy, i.e.,

$$\Delta_F(t) = 100\left(\frac{F^*(t)}{F^{fb}(t)} - 1\right). \tag{64}$$

The right panel in Figure 5 shows the increase of the cumulative distribution function, $\Delta_F(t)$. The smaller is the length of the spell, the bigger is the increase in the cumulative distribution function for a manager-controlled firm compared to a first-best firm. For longer spells, the increase of the cumulative distribution function gradually decreases. For spells around one year, the cumulative distribution function of the manager-controlled firm is more than 200% of the cumulative distribution function for the first-best firm; for spells around ten years, the cumulative distribution functions are close to each other. An increase in the cumulative distribution function can also stem from varying model parameters such as productivity or depreciation, as documented in Whited (2006). My model offers an alternative explication of observed patterns of investment based on manager-shareholder agency conflicts.

Finally, I consider investment hazard rates. The impact of the presence of managers on the cumulative distribution function suggests that their presence may also have an important effect on investment hazard rates. To this end, analogous to Meyer (1990), Leary and Roberts (2005), and Akdogu and MacKay (2008), the investment hazard rate is the probability that a manager-controlled firm will invest in the next time period, given it has not invested yet. Formally, the investment hazard function is defined as

$$h^{*}(t)=\lim_{\delta\to 0}\frac{P(t\leq T<t+\delta\,|T\geq t)}{\delta}. \tag{65}$$

Because I simulate at the monthly frequently, I consider monthly hazard rates, i.e., $\delta = 1$ month. I follow Leary and Roberts (2005) for the intuition that $h^{*}(t)\delta$ is (approximately) the probability that a manager-controlled firm will invest in the next δ units of time, given it has not invested until time t. For example, the hazard function at date $t = 36$ corresponds to the probability that a manager-controlled firm will invest in the next month ($\delta = 1$), conditional on not having invested during the first three years (36 months) after issuance. To calculate the simulation-implied investment hazard rates, I consider the identity

$$h^{*}(t)=\frac{f^{*}(t)}{1-F^{*}(t)}, \tag{66}$$

in which f^{*} is the probability density function of the random variable T, and F^{*} is the corresponding cumulated probability function as defined above in Eq. (62). The simulation-implied hazard rate is estimated by

$$\hat{h}^{*}(t)=\frac{\hat{f}^{*}(t)}{1-\hat{F}^{*}(t)}, \tag{67}$$

in which $\hat{f}^{*}$ is an estimator of the probability density function. Here, $\hat{f}^{*}$ is calculated as the consistent asymmetric kernel density estimator based on the gamma kernel as suggested by Bouezmarni and Scaillet (2005). Analogously, the first-best simulation-implied probability density function $\hat{f}^{fb}$ and hazard rate $\hat{h}^{fb}$ are calculated. The left panel of Figure 6 shows the simulation-implied investment hazard rates of the aggregate economy (solid line) and the first-best economy (dashed line). For example, after 36 months (3 years), the probability for a firm in the aggregate economy to invest in the next month given it has not yet invested is 0.0096, whereas the analogous probability is only 0.0079 for a firm in the first-best economy. For both economies, the hazard rate seems to be increasing for about the first three years and then slightly decreasing or constant. Interestingly, during the first four years, hazard rates are higher in the aggregate economy than in the first-best economy. However, after the first four years, when hazard rates start to decline, the implied investment hazards in the first-best economy are higher than the implied investment hazards of the aggregate economy. In summary, both hazard functions are hump shaped. However, the hump is more prevalent in the hazard function implied by the aggregate economy, and the hazard function is less strongly decreasing in the case of the first-best economy. These findings are also illustrated in the right panel of Figure 6, which demonstrates that the increase in the hazard rates implied by the aggregate economy compared to the first-best economy is largest for small spells. Importantly, the increase in hazard rates is declining, and turns negative for spells longer than approximately four years. Intuitively, manager-controlled firms have a higher probability of reaching the investment threshold sooner, because their boundaries are lower. Hence, the hazard rate for a manager-controlled firm is larger than for a first-best firm for short spells.

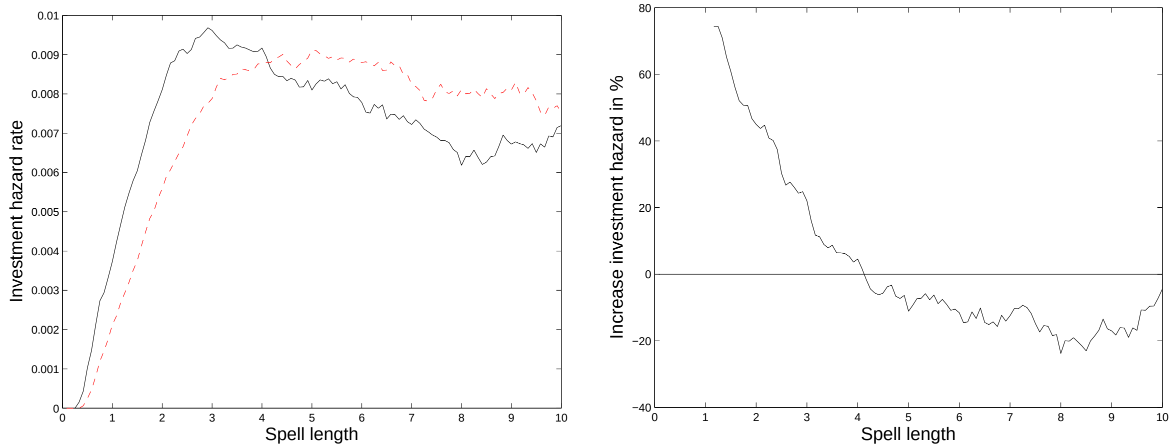

Figure 6. *Investment hazard rates and relative changes.* The left graph shows the simulated investment hazard rates, defined as the probability to invest in the next instant given the firm has not invested yet. The solid line corresponds to the investment hazard rates resulting from the aggregate economy, the dotted line shows the hazard rates resulting from the hypothetical first-best economy. The right graph presents the increase in hazard rates of the aggregate economy compared to the hazard rates of the hypothetical first-best economy. Standard parameters from Table I are used.

As time evolves, the probability to reach the first-best thresholds increases, driving up the hazard rate implied by the first-best economy. Further, the probability of a default in the aggregate economy is lower, because default boundaries are lower. Hence, on average, cash flows in the aggregate economy are also lower than in the first-best economy, and have a greater distance to the investment boundaries. Therefore, the hazard rates implied by the aggregate economy are decreasing more strongly than the hazard rates implied by the first-best economy. I conclude that manager-shareholder agency conflict affect the intertemporal pattern of investment positively in the short and intermediate horizon, whereas the impact of manager-shareholder agency conflicts on the intertemporal pattern of investment in the long term is negative.

These results complement the findings by Akdogu and MacKay (2008), who present evidence that competition increases investment hazard rates. I show that the presence of manager-shareholder agency conflicts is an important determinant of hazard rates. Importantly, the relation between agency conflicts and investment hazard rates are non-trivial and non-monotone: The presence of manager shareholder agency conflicts increases the hazard rate only in the short to medium term. There are three main implications of this result: First, it is essential to control for systematic differences in the severity of agency conflicts when empirically analyzing hazard rates. Second, the analysis of empirical hazard rates might possibly shed light on the implied severities of manager-shareholder agency conflicts, when controlling for other factors influencing the timing of investment (e.g., productivity, adjustment costs, firm size, Whited, 2006, or competition, Akdogu and MacKay, 2008, or credit rationings as well as long-term incentives plans). Third, when investigating empirical hazard rates it is important to take into account the complete distribution over time. As the results above show, it can be misleading to draw conclusion on the general shape of the hazard function based on too few hazard rates.

5. Conclusion

This paper quantifies the costs of manager-shareholder agency conflicts in the presence of macroeconomic risk and investigates their evolution and implications using a dynamic approach. To do so, I develop a structural tradeoff model with intertemporal macroeconomic risk, explicitly taking into account manager-shareholder agency conflicts. Firms are heterogenous in their asset composition, a feature included by modeling both assets in place and investment opportunities. In the model, each firm is run by a manager who controls financing and investment decisions, while shareholders decide about default. Agency conflicts arise because managers divert part of the free cash flow to equity as private benefits and exercise control rights on financing and investment in their own best interest. In this framework, I investigate manager-selected investment and financing policies and the implied effects on the loss in firm value. I find that, at issuance, agency costs are substantial, increasing in the asset composition ratio, and slightly procyclical. In a dynamic aggregate economy, agency costs remain of substantial magnitude and are strongly procyclical. In recessions, when default is particularly likely and costly, firms may benefit from the larger distance to default due to managerial underleverage. Further, the presence of agency conflicts strongly decreases the default rate, and slightly increases the investment rate. Finally, I show that manager-shareholder agency conflicts have important implications for the intertemporal pattern of investment. In detail, the investment hazard decreases in the short and medium term, and increases in the long term.

I contribute to the literature by providing a first analysis of the interaction between manager-shareholder agency conflicts and macroeconomic conditions while recognizing that firms are heterogeneous in their asset composition. My paper raises a number of new research questions. For instance, my paper assumes that issuing additional equity is costless. Assuming costly equity issuances, for example with a linear-quadratic cost function as in Hennessy and Whited (2007), has two direct effects. First, equity issuance costs translate into higher investment costs, leading to deferred investment (Hackbarth and Mauer, 2012). Second, a substitution effect between equity and debt causes leverage ratios to increase. Because both these effects apply to manager-selected and first-best policies the qualitative and quantitative impact on agency costs for firms with different asset compositions constitutes an interesting subject for further research. As a refinement, the implications of cyclicality in equity issuance costs (cf. Bayless and Chaplinsky, 1996) on agency costs could also be investigated. Further, the article abstracts away from the existence of a board of directors, which can possibly mitigate agency costs. Maug (1997) concludes that strong directors are beneficial to a firm if they can acquire information about optimal operating decisions relatively cheap. A future analysis could investigate which corporate governance mechanisms the board might employ to mitigate agency costs. Finally, it would be interesting to study the design of compensation contracts for managers which reduce agency costs, and its implications in a dynamic setting. Importantly, this study suggests that optimal contracts should differ for value and growth firms and require a regime-dependent component.

6. Tables

Table I
Baseline Parameter Choice

This table presents the baseline scenario. Panel A shows the parameters of managerial characteristics. Panel B presents the annualized parameters of a typical BBB-rated S&P 500 firm. Panels C and D contain the parameter values for the investment and the macroeconomy, respectively. The asset composition ratio (ACR) is the value of the firm, divided by the value of the invested assets.

Parameter	Parameter value	
	Boom	Recession
Panel A. Managerial characteristics		
managerial ownership ψ	0.0747	
fraction of managerial diversion of cash flow ϕ	0.01	
Panel B. Firm characteristics		
initial value of cash flows (X)	1	
tax advantage of debt (τ)	0.15	
nominal cash flow growth rate (μ_i)	0.0782	-0.0401
systematic cash flow volatility ($\sigma_i^{X,C}$)	0.0834	0.1334
idiosyncratic cash flow volatility ($\sigma^{X,id}$)	0.168	
recovery rate (α_i)	0.7	0.5
Panel C. Investment parameters of a typical firm (ACR=1.5)		
exercise price (K)	31	31
scale parameter if initiated in boom (s)	1.90	
scale parameter if initiated in recession (s)	2.06	
Panel D. Economy		
rate of leaving regime i (λ_i)	0.2718	0.4928
consumption growth rate (θ_i)	0.0420	0.0141
consumption growth volatility (σ_i^C)	0.0094	0.0114
expected inflation rate (π)	0.0342	
systematic price index volatility ($\sigma^{P,C}$)	-0.00035	
idiosyncratic price index volatility ($\sigma^{P,id}$)	0.0132	
rate of time preference (ρ)	0.015	
relative risk aversion (γ)	10	
elasticity of intertemporal substitution (Φ)	1.5	

Table II

Firm with only invested assets: Investment and financial policies, value functions and agency costs.

This table presents investment and financial policies, value functions, and agency costs for cash flow $X_0 = 1$. 'First-best' presents firm value maximizing investment and financial policies, 'Second best' corresponds to shareholders' optimal investment and financial policies, and 'Third best' presents optimal investment and financial policies from the manager's point of view. The asset composition ratio is defined as firm value divided by invested assets, and leverage is calculated as debt value divided by firm value.

	First-best (firm value)		Second best (equityholders)		Third best (manager)	
	boom	recession	boom	recession	boom	recession
Panel A. Investment policy						
investment boundary boom X_B	–	–	–	–	–	–
investment boundary recession X_R	–	–	–	–	–	–
asset composition ratio	1.0402	1.0389	1.0402	1.0389	1.0217	1.0208
Panel B. Financial policy						
coupon before investment c_o	0.5933	0.4926	0.5933	0.4926	0.2444	0.2029
leverage at issuance	0.4697	0.4575	0.4697	0.4575	0.2182	0.2125
coupon factor at investment c_n^i	–	–	–	–	–	–
% of debt financing of exercise price K at X_i	–	–	–	–	–	–
Panel C. Value functions						
value of debt d_i	7.6825	6.5313	7.6825	6.5313	3.5061	2.9813
value of equity e_i	8.6742	7.7448	8.6742	7.7448	12.5594	11.0473
value of the firm v_i	16.3567	14.2761	16.3567	14.2761	16.0655	14.0286
manager's objective function m_i	1.3095	1.1447	1.3095	1.1447	1.3270	1.1595
Panel D. Agency costs						
total agency costs AC_i in % of firm value	–	–	0.0000	0.0000	1.7800	1.7338
investment induced agency costs IAC_i in % of AC_i	–	–	–	–	0.0000	0.0000
leverage induced agency costs LAC_i in % of AC_i	–	–	–	–	100.0000	100.0000
interaction agency costs SAC_i in % of AC_i	–	–	–	–	0.0000	0.0000

Table III

Average firm: Investment and financial policies, value functions and agency costs.

This table presents investment and financial policies, value functions, and agency costs for cash flow $X_0 = 1$. 'First-best' presents firm value maximizing investment and financial policies, 'Second best' corresponds to shareholders' optimal investment and financial policies, and 'Third best' presents optimal investment and financial policies from the manager's point of view. The asset composition ratio is defined as firm value divided by invested assets, and leverage is calculated as debt value divided by firm value.

	First-best (firm value)		Second best (equityholders)		Third best (manager)	
	boom	recession	boom	recession	boom	recession
Panel A. Investment policy						
investment boundary boom X_B	1.9959	1.9853	1.9506	1.9544	1.8316	1.8350
investment boundary recession X_R	2.1631	2.1521	2.0796	2.0883	1.9503	1.9562
asset composition ratio	1.3249	1.2818	1.3247	1.2817	1.2874	1.2474
Panel B. Financial policy						
coupon before investment c_o	0.6425	0.5297	0.6361	0.5271	0.2353	0.1984
leverage at issuance	0.3932	0.3947	0.3879	0.3930	0.1663	0.1702
coupon factor at investment c_n^i	0.5933	0.4926	0.5933	0.4926	0.2444	0.2029
% of debt financing of exercise price K at X_i	137.8827	141.0080	134.3892	138.5613	57.9480	59.5294
Panel C. Value functions						
value of debt d_i	8.1910	6.9526	8.1176	6.9218	3.3675	2.9177
value of equity e_i	12.6426	10.6623	12.7124	10.6917	16.8763	14.2248
value of the firm v_i	20.8336	17.6149	20.8229	17.6135	20.2438	17.1425
manager's objective function m_i	1.6693	1.4115	1.6707	1.4123	1.7049	1.4401
Panel D. Agency costs						
total agency costs AC_i in % of firm value	–	–	0.0173	0.0081	2.8310	2.6812
investment induced agency costs IAC_i in % of AC_i	–	–	99.8080	99.9460	6.6914	5.2897
leverage induced agency costs LAC_i in % of AC_i	–	–	2.9138	1.5001	92.3206	93.5636
interaction agency costs SAC_i in % of AC_i	–	–	-2.7219	-1.4461	0.9880	1.1467

Table IV

Growth firm: Investment and financial policies, value functions and agency costs.

This table presents investment and financial policies, value functions, and agency costs for cash flow $X_0 = 1$. 'First-best' presents firm value maximizing investment and financial policies, 'Second best' corresponds to shareholders' optimal investment and financial policies, and 'Third best' presents optimal investment and financial policies from the manager's point of view. The asset composition ratio is defined as firm value divided by invested assets, and leverage is calculated as debt value divided by firm value.

	First-best (firm value)		Second best (equityholders)		Third best (manager)	
	boom	recession	boom	recession	boom	recession
Panel A. Investment policy						
investment boundary boom X_B	1.1308	1.1267	1.1153	1.1179	1.0276	1.0305
investment boundary recession X_R	1.2207	1.2174	1.1882	1.1929	1.0947	1.0985
asset composition ratio	1.9174	1.7887	1.9171	1.7885	1.8507	1.7284
Panel B. Financial policy						
coupon before investment c_o	0.7320	0.5967	0.7203	0.5913	0.2251	0.2003
leverage at issuance	0.3020	0.3143	0.2976	0.3118	0.1100	0.1243
coupon factor at investment c_n^i	0.5933	0.4926	0.5933	0.4926	0.2444	0.2029
% of debt financing of exercise price K at X_i	106.3900	110.3414	104.9542	109.4816	45.9786	46.9331
Panel C. Value functions						
value of debt d_i	9.1036	7.7258	8.9726	7.6646	3.2007	2.9531
value of equity e_i	21.0455	16.8546	21.1722	16.9137	25.9004	20.7993
value of the firm v_i	30.1491	24.5804	30.1447	24.5784	29.1011	23.7524
manager's objective function m_i	2.4593	1.9993	2.4627	2.0012	2.5237	2.0508
Panel D. Agency costs						
total agency costs AC_i in % of firm value	–	–	0.0144	0.0081	3.4760	3.3685
investment induced agency costs IAC_i in % of AC_i	–	–	99.4125	99.8800	13.4104	12.4277
leverage induced agency costs LAC_i in % of AC_i	–	–	2.7789	1.9464	85.1312	85.9180
interaction agency costs SAC_i in % of AC_i	–	–	-2.1914	-1.8264	1.4584	1.6543

Table V

Impact of agency conflicts on agency costs in the aggregate economy.

This table presents time series statistics of total agency costs, investment induced agency costs, leverage induced agency costs, and interaction agency costs in the aggregate economy. Panel A shows the overall economy. Panel B and C contain the statistics in boom and recession only, respectively.

	Moments		Quantiles				
	mean	std	10%	25%	median	75%	90%
Panel A. Overall							
total agency costs in % of firm value	1.5648	0.7228	0.7304	1.3820	1.8081	2.0163	2.1549
investment induced agency costs in % of firm value	0.2495	0.0169	0.2298	0.2390	0.2493	0.2604	0.2686
leverage induced agency costs in % of firm value	1.2852	0.7115	0.4735	1.1002	1.5196	1.7327	1.8615
interaction agency costs in % of firm value	0.0301	0.0014	0.0283	0.0292	0.0301	0.0312	0.0319
Panel B. Boom							
total agency costs in % of firm value	1.8836	0.2825	1.4835	1.7543	1.9479	2.0867	2.1784
investment induced agency costs in % of firm value	0.2488	0.0120	0.2330	0.2403	0.2488	0.2586	0.2644
leverage induced agency costs in % of firm value	1.6043	0.2715	1.2148	1.4885	1.6688	1.7973	1.8834
interaction agency costs in % of firm value	0.0305	0.0012	0.0292	0.0297	0.0305	0.0315	0.0321
Panel C. Recession							
total agency costs in % of firm value	0.9200	0.8929	-0.4988	0.5443	1.2196	1.5637	1.7869
investment induced agency costs in % of firm value	0.2509	0.0239	0.2197	0.2340	0.2514	0.2666	0.2837
leverage induced agency costs in % of firm value	0.6398	0.8715	-0.7374	0.2760	0.9356	1.2690	1.4782
interaction agency costs in % of firm value	0.0292	0.0013	0.0278	0.0283	0.0290	0.0302	0.0310

Table VI
Impact of agency conflicts on default and investment rates in the aggregate economy.

This table presents the change in default and investment rates in the aggregate economy. Panel A shows the overall changes. Panel B and C contain the changes in boom and recession only, respectively.

	Moments	
	mean	std
Panel A. Overall		
Δ default rate in %	-50.6017	-40.9493
Δ investment rate in %	+10.9341	+12.9169
Panel B. Boom		
Δ default rate in %	-47.4224	-27.5300
Δ investment rate in %	+11.8914	+15.3260
Panel C. Recession		
Δ default rate in %	-52.2517	-40.9089
Δ investment rate in %	+6.6561	+2.3298

References

Agrawal, A. and G. N. Mandelker (1987): "Managerial incentives and corporate investment and financing decisions," *Journal of Finance*, 42, 823–837.

Akdogu, E. and P. MacKay (2008): "Investment and competition," *Journal of Financial and Quantitative Analysis*, 43, 299–330.

Albuquerque, R. and N. Wang (2008): "Agency Conflicts, Investments, and Asset Pricing," *Journal of Finance*, 63, 1–40.

Amihud, Y., B. Lev, and N. G. Travlos (1990): "Corporate control and the choice of investment financing: The case of corporate acquisitions," *Journal of Finance*, 56, 603–616.

Ang, A. and G. Bekaert (2004): "How regimes affect asset allocation," *Financial Analysts Journal*, 60, 86–99.

Arnold, M., A. F. Wagner, and R. Westermann (2013): "Growth options, macroeconomic conditions, and the cross-section of credit risk," *Journal of Financial Economics*, 107, 350–385.

Barclay, M. J. and C. G. Holderness (1989): "Private benefits from control of public corporations," *Journal of Financial Economics*, 25, 371–395.

Bayless, M. and S. Chaplinsky (1996): "Is there a window of opportunity for seasoned equity issuance?" *Journal of Finance*, 51, 253–278.

Berger, P. G., E. Ofek, and D. L. Yermack (1997): "Managerial entrenchment and capital structure decisions," *Journal of Finance*, 52, 1411–1438.

Bernanke, B. and M. Gertler (1986): "Agency costs, collateral, and business fluctuations," *Proceedings, Federal Reserve Bank of San Francisco.*

Bhamra, H. S., L.-A. Kuehn, and I. A. Strebulaev (2010a): "The aggregate dynamics of capital structure and macroeconomic risk," *Review of Financial Studies*, 23, 4187–4241.

——— (2010b): "The levered equity risk premium and credit spreads: A unified framework," *Review of Financial Studies*, 23, 645–703.

Bouezmarni, T. and O. Scaillet (2005): "Consistency of asymmetric kernel density estimators and smoothed histograms with application to income data," *Econometric Theory*, 21, 390–412.

Carlstrom, C. T. and T. S. Fuerst (1998): "Agency costs and business cylces," *Economic Theory*, 12, 583–597.

Chang, C. (1993): "Payout policy, capital structure, and compensation contracts when managers value control," *Review of Financial Studies*, 6, 911–933.

Chen, H. (2010): "Macroeconomic conditions and the puzzles of credit spreads and capital structure," *Journal of Finance*, 65, 2171–2212.

Chen, H. and G. Manso (2010): "Macroeconomic risk and debt overhang," *Working paper.*

Childs, P. D. and D. C. Mauer (2008): "Managerial discretion, agency costs, and capital structure," *Working paper.*

Childs, P. D., D. C. Mauer, and S. H. Ott (2005): "Interactions of corporate financing and investment decisions: The effects of agency conflicts," *Journal of Financial Economics*, 76, 667–690.

Duffie, D. and L. G. Epstein (1992a): "Asset pricing with stochastic differential utility," *Review of Financial Studies*, 5, 411–436.

——— (1992b): "Stochastic differential utility," *Econometrica*, 60, 353–394.

Eisfeldt, A. L. and A. A. Rampini (2008): "Managerial incentives, capital reallocation, and the business cycle," *Journal of Financial Economics*, 87, 177–199.

Epstein, L. G. and S. E. Zin (1989): "Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework," *Econometrica*, 57, 937–69.

Fischer, E. O., R. Heinkel, and J. Zechner (1989): "Dynamic capital structure: Theory and tests," *The Journal of Finance*, 44, 19–40.

Goldstein, R., N. Ju, and H. Leland (2001): "An EBIT-based model of dynamic capital structure," *The Journal of Business*, 74, 483–512.

Graham, J. R. (2000): "How big are the tax benefits of debt?" *Journal of Finance*, 55, 1901–1955.

Graham, J. R. and C. R. Harvey (2001): "The theory and practice of corporate finance: Evidence from the field," *Journal of Financial Economics*, 60, 187–243.

Guo, X. (2001): "An explicit solution to an optimal stopping problem with regime switching," *Journal of Applied Probability*, 38, 464–481.

Habib, M. A. and A. Ljungqvist (2005): "Firm value and managerial incentives: A stochastic frontier approach," *Journal of Business*, 78, 2053–2094.

Hackbarth, D. (2008): "Managerial traits and capital structure decisions," *Journal of Financial and Quantitative Analysis*, 43, 843–882.

Hackbarth, D. and D. C. Mauer (2012): "Optimal priority structure, capital structure, and investment," *Review of Financial Studies*, 25, 747–796.

Hackbarth, D., J. Miao, and E. Morellec (2006): "Capital structure, credit risk, and macroeconomic conditions," *Journal of Financial Economics*, 82, 519–550.

Halling, M., J. Yu, and J. Zechner (2012): "Leverage dynamics over the business cycle," *AFA 2012 Chicago Meetings Paper.*

Harris, M. and A. Raviv (1990): "Capital structure and the informational role of debt," *Journal of Finance*, 45, 321–349.

——— (1991): "The theory of capital structure," *Journal of Finance*, 46, 297–355.

Hart, O. and J. Moore (1995): "Debt and seniority: An analysis of the role of hard claims in constraining management," *American Economic Review*, 85, 567–585.

He, Z. and K. Milbradt (2012): "Endogenous liquidity and defaultable bonds," *Working paper.*

Hennessy, C. A. and T. M. Whited (2007): "How costly is external financing? Evidence from a structural estimation," *Journal of Finance*, 62, 1705–1745.

Jensen, M. C. (1986): "Agency costs of free cash flow, corporate finance, and takeovers," *American Economic Review*, 76, 323–329.

Jensen, M. C. and W. H. Meckling (1976): "Theory of the firm: Managerial behavior, agency costs and ownership structure," *Journal of Financial Economics*, 3, 305–360.

John, T. A. and K. John (1993): "Top-management compensation and capital structure," *Journal of Finance*, 48, 949–974.

Johnson, S., R. La Porta, F. L. de Silanes, and A. Shleifer (2000): "Tunneling," *American Economic Review*, 90, 22–27.

Jung, K., Y.-C. Kim, and R. M. Stulz (1996): "Timing, investment opportunities, managerial discretion, and the security issue decision," *Journal of Financial Economics*, 42, 159–185.

La Porta, R., F. L. de Silanes, A. Shleifer, and R. Vishny (2000): "Investor protection and corporate governance," *Journal of Financial Economics*, 58, 3–27.

——— (2002): "Investor protection and corporate valuation," *Journal of Finance*, 57, 1147–1170.

Lambrecht, B. M. and S. C. Myers (2008): "Debt and managerial rents in a real-options model of the firm," *Journal of Financial Economics*, 89, 209–231.

——— (forthcoming): "A Lintner model of payout and managerial rents," *Journal of Finance.*

Leary, M. T. and M. R. Roberts (2005): "Do firms rebalance their capital structures?" *Journal of Finance*, 60, 209–231.

Leland, H. E. (1998): "Agency costs, risk management, and capital structure," *Journal of Finance*, 53, 1213–1243.

Levy, A. and C. Hennessy (2007): "Why does capital structure choice vary with macroeconomic conditions?" *Journal of Monetary Economics*, 54, 1545–1564.

Malmendier, U. and G. Tate (2005): "CEO overconfidence and corporate investment," *Journal of Finance*, 60, 2661–2700.

Mauer, D. C. and S. Ott (2000): "Agency costs, underinvestment, and optimal capital structure: The effect of growth options to expand," in *Project flexibility, agency, and competition*, ed. by M. J. Brennan and L. Trigeorgis, Oxford University Press, 151–180.

Mauer, D. C. and S. Sarkar (2005): "Real options, agency conflicts, and optimal capital structure," *Journal of Banking and Finance*, 1405-1428.

Maug, E. (1997): "Boards of directors and capital structure: Alternative forms of corporate restructuring," *Journal of Corporate Finance*, 113–139.

Mello, A. and J. Parsons (1992): "Measuring the agency cost of debt," *Journal of Finance*, 47, 1887–1904.

Meyer, B. (1990): "Unemployment insurance and unemployment spells," *Econometrica*, 58, 757–782.

Morellec, E. (2004): "Can managerial discretion explain observed leverage ratios?" *Review of Financial Studies*, 17, 257–294.

Morellec, E., B. Nikolov, and N. Schürhoff (2012): "Corporate Governance and Capital Structure Dynamics," *Journal of Finance*, 67, 801–847.

Morellec, E., P. Valta, and A. Zhdanov (2013): "Financing investment: The choice between public and private debt," *working paper.*

Morellec, E. and N. Wang (2004): "Capital structure, investment, and private benefits of control," *Working paper.*

Moyen, N. (2002): "How big is the debt overhang problem?" *Working paper.*

Myers, S. C. (1977): "Determinants of Corporate Borrowing," *Journal of Financial Economics*, 5, 147–175.

Nikolov, B. and T. M. Whited (2011): "Agency conflicts and cash: Estimates from a structural model," *Working paper.*

Parrino, R., A. M. Poteshman, and M. S. Weisbach (2005): "Measuring investment distortions when risk-averse managers decide whether to undertake risky projects," *Financial Management*, 34, 21–60.

Rajan, R. G. and L. Zingales (1995): "What do we know about capital structure? Some evidence from international data," *Journal of Finance*, 50, 1421–1460.

Rampini, A. A. (2004): "Entrepreneurial activity, risk, and the business cycle," *Journal of Monetary Economics*, 51, 555–573.

Smith, C. W. and R. L. Watts (1992): "The investment opportunity set and corporate financing, dividend, and compensation policies," *Journal of Financial Economics*, 32, 263–292.

Strebulaev, I. A. (2007): "Do tests of capital structure theory mean what they say?" *Journal of Finance*, 62, 1747–1787.

Stulz, R. M. (1990): "Managerial discretion and optimal financing policies," *Journal of Financial Economics*, 26, 3–27.

Titman, S. and S. Tsyplakov (2002): "A dynamic model of optimal capital structure," *Working paper.*

Weil, P. (1990): "Nonexpected utility in macroeconomics," *Quarterly Journal of Economics*, 105, 29–42.

Whited, T. M. (2006): "External finance constraints and the pattern of intermittent investment," *Journal of Financial Economics*, 81, 467–502.

Zwiebel, J. (1996): "Dynamic capital structure under managerial entrenchment," *American Economic Review*, 86, 1197–1215.

Appendix

A. The model

In this section of the appendix, I present the technical model components that are not directly connected to agency conflicts, and, therefore, omitted in the main text. The technical results stem from Bhamra, Kuehn, and Strebulaev (2010b) and Chen (2010), who use a similar model setup and provide proofs of the formulas. Further, the model components presented here are analogous to Arnold, Wagner, and Westermann (2013), who also build on the results of Bhamra, Kuehn, and Strebulaev (2010b) and Chen (2010), and, hence, this section is analogous to the corresponding parts in the main text and appendix of Arnold, Wagner, and Westermann (2013). For completeness and convenience of the reader, the assumptions and main results are presented here as well.

The dynamics of the aggregate output C_t are given by a regime-switching geometric Brownian motion:

$$\frac{\mathrm{d}C_t}{C_t} = \theta_i \mathrm{d}t + \sigma_i^C \mathrm{d}W_t^C, \ i = B, R, \tag{68}$$

in which W_t^C is a Brownian motion independent of the Markov chain, and θ_i, σ_i^C correspond to the regime-dependent growth-rates and volatilities of the aggregate output, respectively. The partial equilibrium model is solved by postulating equality of aggregate consumption and aggregate output. Hence, in equilibrium, the aggregate consumption dynamics are driven by a regime-switching geometric Brownian motion as well.

Preferences are defined as the continuous-time analog of Epstein-Zin-Weil preferences (Epstein and Zin, 1989; Weil, 1990), which belong to the class of stochastic differential utility (Duffie and Epstein, 1992a,b). The Epstein-Zin-Weil preferences are non time-separable, and, hence, take into account the impact of the intertemporal distribution of consumption risk on the representative household's utility. Specifically, for any consumption path $(C_s)_{0 \leq s \leq t}$, the utility index U_t is given by

$$U_t = \mathbb{E}^{\mathbb{P}} \left[\int_t^{\infty} \frac{\rho}{1-\delta} \frac{C_s^{1-\delta} - \left((1-\gamma) U_s \right)^{\frac{1-\delta}{1-\gamma}}}{\left((1-\gamma) U_s \right)^{\frac{1-\delta}{1-\gamma}} - 1} \mathrm{d}s \,|\mathcal{F}_t \right], \tag{69}$$

in which ρ represents the rate of time preference, γ is the coefficient of relative risk aversion for a timeless gamble, and $\Phi := \frac{1}{\delta}$ corresponds to the elasticity of intertemporal substitution for deterministic consumption paths. Bhamra, Kuehn, and Strebulaev (2010b) and Chen (2010) solve the Bellman equation associated with the consumption problem of the representative agent, and find that the stochastic discount factor sdf_t follows the dynamics

$$\frac{\mathrm{d}sdf_t}{sdf_t} = -r_i \mathrm{d}t - \eta_i \mathrm{d}W_t^C + \left(e^{\kappa_i} - 1 \right) \mathrm{d}M_t, \tag{70}$$

in which M_t is the compensated process associated with the Markov chain, and

$$r_i = \bar{r}_i + \lambda_i \left[\frac{\gamma - \delta}{\gamma - 1} \left(w^{-\frac{\gamma-1}{\gamma-\delta}} - 1 \right) - \left(w^{-1} - 1 \right) \right], \tag{71}$$

$$\eta_i = \gamma \sigma_i^C, \tag{72}$$

$$\kappa_i = (\delta - \gamma) \log \left(\frac{h_j}{h_i} \right). \tag{73}$$

The parameters h_B, h_R solve the non-linear equation

$$0 = \rho \frac{1-\gamma}{1-\delta} h_i^{\delta-\gamma} + \left((1-\gamma)\theta_i - \frac{1}{2}\gamma(1-\gamma)\left(\sigma_i^C\right)^2 - \rho \frac{1-\gamma}{1-\delta} \right) h_i^{1-\gamma} + \lambda_i \left(h_j^{1-\gamma} - h_i^{1-\gamma} \right). \tag{74}$$

r_i are the regime-dependent real risk-free interest rates. Here, $\bar{r}_i$, is defined as

$$\bar{r}_i = \rho + \delta\theta_i - \frac{1}{2}\gamma(1+\delta)\left(\sigma_i^C\right)^2, \tag{75}$$

and w is defined as

$$w := e^{\kappa_R} = e^{-\kappa_B}. \tag{76}$$

These results correspond to Bhamra, Kuehn, and Strebulaev (2010b), Proposition 1.

The stochastic price index is assumed to follow the dynamics

$$\frac{\mathrm{d}P_t}{P_t} = \pi \mathrm{d}t + \sigma^{P,C}\mathrm{d}W_t^C + \sigma^{P,id}\mathrm{d}W_t^P, \tag{77}$$

in which W_t^P is a Brownian motion driving the idiosyncratic price index shock, independent of the consumption shock Brownian W_t^C and the Markov chain. The expected inflation rate is denoted by π, and $\sigma^{P,C} < 0, \sigma^{P,id} > 0$ are the volatilities of the stochastic price index associated with the consumption shock and the idiosyncratic price index shock, respectively. It can be shown that the nominal interest rates r_i^n are determined as

$$r_i^n = r_i + \pi - \sigma_P^2 - \sigma^{P,C}\eta_i, \tag{78}$$

in which $\sigma_P := \sqrt{\left(\sigma^{P,C}\right)^2 + \left(\sigma^{P,id}\right)^2}$ is the total volatility of the stochastic price index.

The dynamics of the real cash flow process X are given by

$$\frac{\mathrm{d}X_{t,real}}{X_{t,real}} = \mu_{i,real}\mathrm{d}t + \sigma_{i,real}^{X,C}\mathrm{d}W_t^C + \sigma^{X,id}\mathrm{d}W_t^f, \quad i = B, R, \tag{79}$$

in which W_t^f is a standard Brownian motion corresponding to an idiosyncratic shock, independent of the aggregate output shock W_t^C, the consumption price index shock W_t^P, and the Markov chain. $\mu_{i,real}$ represent the real regime-dependent drifts, $\sigma_{i,real}^{X,C} > 0$ the real firm-specific regime-dependent volatilities associated with the aggregate output process, and $\sigma^{X,id} > 0$ the firm-specific volatility associated with the idiosyncratic Brownian shock. The idiosyncratic shocks W_t^f are assumed to be independent across firms.

Next, the dynamics of the nominal cash flow process write

$$\frac{\mathrm{d}X_t}{X_t} = \mu_i \mathrm{d}t + \sigma_i^{X,C} \mathrm{d}W_t^C + \sigma^{P,id} \mathrm{d}W_t^P + \sigma^{X,id} \mathrm{d}W_t^f, \quad i = B, R, \tag{80}$$

in which $\mu_i = \mu_{i,real} + \pi + \sigma^{P,C} \sigma_{i,real}^{X,C}$ represent the nominal regime-dependent drifts, and $\sigma_i^{X,C} = \sigma_{i,real}^{X,C} + \sigma^{P,C} > 0$ the nominal firm-specific regime-dependent volatilities associated with the aggregate output process. As suggested by Ang and Bekaert (2004), I assume that these volatilities are larger in recession than in boom, i.e., $\sigma_B^{X,C} < \sigma_R^{X,C}$. Finally, defining

$$\sigma_i = \sqrt{\left(\sigma_i^{X,C}\right)^2 + (\sigma^{P,id})^2 + (\sigma^{X,id})^2}, \tag{81}$$

and a $\mathbb{P}$-Brownian Z_t yields the cash flow dynamics as stated in (1).

Let $\tilde{\mu}_i$ denote the expected growth rates of the firm's nominal cash flow under the risk-neutral measure $\mathbb{Q}$. It can be shown that

$$\tilde{\mu}_i := \mu_i - \sigma_i^{X,C} \left(\eta_i + \sigma^{P,C}\right) - \left(\sigma^{P,id}\right)^2. \tag{82}$$

The risk-neutral transition densities, denoted by $\tilde{\lambda}_i$, are given by

$$\tilde{\lambda}_i = e^{\kappa_i} \lambda_i. \tag{83}$$

Next, the unlevered asset value V_t is determined by

$$V_t = (1 - \tau) X_t y_i \quad \text{for } I_t = i, \tag{84}$$

in which y_i is the price-cash flow ratio in state i defined as

$$y_i^{-1} = r_i^n - \tilde{\mu}_i + \frac{\left(r_j^n - \tilde{\mu}_j\right) - \left(r_i^n - \tilde{\mu}_i\right)}{r_j^n - \tilde{\mu}_j + \tilde{p}} \tilde{p} \tilde{f}_j. \tag{85}$$

$\tilde{p} := \tilde{\lambda}_i + \tilde{\lambda}_j$ represents the risk-neutral rate of news arrival, and $\left(\tilde{f}_B, \tilde{f}_R\right) = \left(\frac{\lambda_R}{\tilde{p}}, \frac{\lambda_B}{\tilde{p}}\right)$ corresponds to the long-run risk-neutral distribution. For reasonable parameter values, the price-cash flow ratio in boom exceeds the one in recession, i.e., $y_B > y_R$ (cf. Bhamra, Kuehn, and Strebulaev, 2010b).

Finally, the total volatility of the cash flow process in regime i is given by

$$\tilde{\sigma}_i = \sqrt{\left(\sigma_i^{X,C}\right)^2 + (\sigma^{P,id})^2 + (\sigma^{X,id})^2}. \tag{86}$$

B. The value of corporate securities after investment

Without loss of generality, I assume that the default boundary in boom is lower than the one in recession, i.e., $\hat{D}_B < \hat{D}_R$. Define r_i^p as the perpetual risk-free rate given by

$$r_i^p = r_i + \frac{r_j - r_i}{\tilde{p} + r_j}\tilde{p}\tilde{f}_j, \tag{87}$$

in which $\tilde{p} = \tilde{\lambda}_1 + \tilde{\lambda}_2$ is the risk-neutral rate of news arrival, and $\left(\tilde{f}_B, \tilde{f}_R\right) = \left(\frac{\lambda_R}{\tilde{p}}, \frac{\lambda_B}{\tilde{p}}\right)$ the long-run risk-neutral distribution.

The valuation of equity. I now derive the Hamilton-Jacobi-Bellman equation for shareholders' optimization problem after investment using the cash flows to shareholders and their payoffs at the various boundaries. To start, as long as the firm is solvent, equity requires an instantaneous return equal to the risk-free rate r_i^n. The realized rate of return is composed of the expected change in equity value and the cash flows to equity holders, and can be computed by an application of Ito's lemma with regime switches. At default, equityholders receive zero due to the absolute priority of debt claims. Thus, the value of equity is the solution to the following system of ODEs.

For $0 \leq X \leq \hat{D}_B$:

$$\begin{cases} \hat{e}_B(X) = 0 \\ \hat{e}_R(X) = 0. \end{cases} \tag{88}$$

For $\hat{D}_B < X \leq \hat{D}_R$:

$$\begin{cases} r_B^n \hat{e}_B(X) = (1-\tau)(1-\phi)(X - c_n) + \tilde{\mu}_B X \hat{e}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 \hat{e}_B''(X) \\ \qquad + \tilde{\lambda}_B (0 - \hat{e}_B(X)) \\ \hat{e}_R(X) = 0. \end{cases} \tag{89}$$

For $X > \hat{D}_R$:

$$\begin{cases} r_B^n \hat{e}_B(X) = (1-\tau)(1-\phi)(X - c_n) + \tilde{\mu}_B X \hat{e}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 \hat{e}_B''(X) \\ \qquad + \tilde{\lambda}_B (\hat{e}_R(X) - \hat{e}_B(X)) \\ r_R^n \hat{e}_R(X) = (1-\tau)(1-\phi)(X - c_n) + \tilde{\mu}_R X \hat{e}_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 \hat{e}_R''(X) \\ \qquad + \tilde{\lambda}_R (\hat{e}_B(X) - \hat{e}_R(X)) \end{cases} \tag{90}$$

This type of ODEs is standard in regime-switching contingent claim models, see, e.g., Hackbarth, Miao, and Morellec (2006) or Arnold, Wagner, and Westermann (2013). The boundary conditions read

$$\lim_{X\to\infty}\frac{\hat{e}_i\left(X\right)}{X}<\infty,\quad i=B,R, \tag{91}$$

$$\lim_{X\searrow\hat{D}_R}\hat{e}_B\left(X\right)=\lim_{X\nearrow\hat{D}_R}\hat{e}_B\left(X\right), \tag{92}$$

$$\lim_{X\searrow\hat{D}_R}\hat{e}'_B\left(X\right)=\lim_{X\nearrow\hat{D}_R}\hat{e}'_B\left(X\right), \tag{93}$$

$$\hat{e}_B\left(\hat{D}_B\right)=0, \tag{94}$$

and

$$\hat{e}_R\left(\hat{D}_R\right)=0. \tag{95}$$

Condition (91) is the no-bubbles condition. The remaining boundary conditions are the continuity and smoothing conditions (104) and (121), and the value-matching conditions (122) and (123). The functional form of the solution to the system of ODEs (88)-(90) subject to the boundary conditions (91)-(123) is

$$\hat{e}_i(X)=\begin{cases}0 & X\leq\hat{D}_i & i=B,R\\ \hat{C}_1X^{\beta_1^B}+\hat{C}_2X^{\beta_2^B}+\hat{C}_3X+\hat{C}_4 & \hat{D}_B<X\leq\hat{D}_R, & i=B\\ \hat{A}_{i1}X^{\gamma_1}+\hat{A}_{i2}X^{\gamma_2}+\hat{A}_{i5}X+\hat{A}_{i6} & X>\hat{D}_R, & i=B,R,\end{cases} \tag{96}$$

in which $\hat{A}_{B1},\hat{A}_{B2},\hat{A}_{R1},\hat{A}_{R2},A_{B5},A_{R5},\hat{C}_1,\hat{C}_2,C_3,\hat{C}_4,\gamma_1,\gamma_2,\beta_1^B$, and β_2^B are real-valued parameters to be determined.

Solving, I find that

$$\hat{C}_3=\frac{\left(1-\tau\right)\left(1-\phi\right)}{r_B^n+\tilde{\lambda}_B-\tilde{\mu}_B}, \tag{97}$$

$$\hat{C}_4=-\frac{\left(1-\tau\right)\left(1-\phi\right)c_n}{r_B^n+\tilde{\lambda}_B}, \tag{98}$$

$$\hat{A}_{i5}=\left(1-\tau\right)\left(1-\phi\right)y_i, \tag{99}$$

and

$$\hat{A}_{i6}=-\frac{\left(1-\tau\right)\left(1-\phi\right)c_n}{r_i^p}. \tag{100}$$

Next, $\hat{A}_{Bk}$ is a multiple of $\hat{A}_{Rk}$, $k = 1, 2$, with the factor $l_k := \frac{1}{\tilde{\lambda}_B}(r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B\gamma_k - \frac{1}{2}\tilde{\sigma}_B^2\gamma_k(\gamma_k - 1))$, i.e., $\hat{A}_{Rk} = l_k\hat{A}_{Bk}$, and γ_1 and γ_2 are the negative roots of the quartic equation[18]

$$\left(\tilde{\mu}_R\gamma + \frac{1}{2}\tilde{\sigma}_R^2\gamma(\gamma-1) - \tilde{\lambda}_R - r_R^n\right)\left(\tilde{\mu}_B\gamma + \frac{1}{2}\tilde{\sigma}_B^2\gamma(\gamma-1) - \tilde{\lambda}_B - r_B^n\right) = \tilde{\lambda}_R\tilde{\lambda}_B. \tag{101}$$

The reason for taking the negative roots is the no-bubbles condition for equity stated in Eq. (91).

The remaining unknown parameters $\hat{A}_{B1}, \hat{A}_{B2}, \hat{C}_1$, and $\hat{C}_2$ solve

$$\begin{bmatrix}\hat{A}_{B1} & \hat{A}_{B2} & \hat{C}_1 & \hat{C}_2\end{bmatrix}^T = \hat{M}^{-1}\hat{b}, \tag{102}$$

in which

$$\hat{M} := \begin{bmatrix} \hat{D}_R^{\gamma_1} & \hat{D}_R^{\gamma_2} & -\hat{D}_R^{\beta_1^B} & -\hat{D}_R^{\beta_2^B} \\ \gamma_1\hat{D}_R^{\gamma_1} & \gamma_2\hat{D}_R^{\gamma_2} & -\beta_1^B\hat{D}_R^{\beta_1^B} & -\beta_2^B\hat{D}_R^{\beta_2^B} \\ 0 & 0 & \hat{D}_B^{\beta_1^B} & \hat{D}_B^{\beta_2^B} \\ l_1\hat{D}_R^{\gamma_1} & l_2\hat{D}_R^{\gamma_2} & 0 & 0 \end{bmatrix} \tag{103}$$

and

$$\hat{b} := \begin{bmatrix} \hat{C}_3\hat{D}_R + \hat{C}_4 - \hat{A}_{B5}\hat{D}_R - \hat{A}_{B6} \\ \hat{C}_3\hat{D}_R - \hat{A}_{B5}\hat{D}_R \\ -\hat{C}_3\hat{D}_B - \hat{C}_4 \\ -\hat{A}_{R5}\hat{D}_R - \hat{A}_{R6} \end{bmatrix}. \tag{104}$$

The valuation of corporate debt. Using a no-arbitrage argument and applying Ito's lemma, the system of ODEs satisfied by the value of debt is as follows:

For $0 \le X \le \hat{D}_B$:

$$\begin{cases} \hat{d}_B(X) &= \alpha_B(1-\tau)Xy_B \\ \hat{d}_R(X) &= \alpha_R(1-\tau)Xy_R. \end{cases} \tag{105}$$

For $\hat{D}_B < X \le \hat{D}_R$:

$$\begin{cases} r_B^n\hat{d}_B(X) &= c_n + \tilde{\mu}_B X\hat{d}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2X^2\hat{d}_B''(X) \\ & \quad + \tilde{\lambda}_B\left(\alpha_R(1-\tau)Xy_R - \hat{d}_B(X)\right) \\ \hat{d}_R(X) &= \alpha_R(1-\tau)Xy_R. \end{cases} \tag{106}$$

[18]By arguments of Guo (2001), this quartic equation always has four distinct real roots, two of them negative, and two of them positive.

For $X > \hat{D}_R$:

$$\begin{cases} r_B^n \hat{d}_B(X) &= c_n + \tilde{\mu}_B X \hat{d}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 \hat{d}_B''(X) \\ & \quad + \tilde{\lambda}_B \left(\hat{d}_R(X) - \hat{d}_B(X) \right) \\ r_R^n \hat{d}_R(X) &= c_n + \tilde{\mu}_R X \hat{d}_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 \hat{d}_R''(X) \\ & \quad + \tilde{\lambda}_R \left(\hat{d}_B(X) - \hat{d}_R(X) \right). \end{cases} \tag{107}$$

The boundary conditions are given by

$$\lim_{X\to\infty} \frac{\hat{d}_i(X)}{X} < \infty, \quad i = B, R, \tag{108}$$

$$\lim_{X \searrow \hat{D}_R} \hat{d}_B(X) = \lim_{X \nearrow \hat{D}_R} \hat{d}_B(X), \tag{109}$$

$$\lim_{X \searrow \hat{D}_R} \hat{d}_B'(X) = \lim_{X \nearrow \hat{D}_R} \hat{d}_B'(X), \tag{110}$$

$$\hat{d}_B\left(\hat{D}_B\right) = \alpha_B (1-\tau) D_B y_B, \tag{111}$$

and

$$\hat{d}_R\left(\hat{D}_R\right) = \alpha_R (1-\tau) D_R y_R. \tag{112}$$

Condition (108) constitutes the no-bubbles condition. The remaining boundary conditions are the continuity and smoothness conditions (109) and (110), as well as the value-matching conditions (111) and (112). The functional form of the solution is

$$\hat{d}_i(X) = \begin{cases} \alpha_i (1-\tau) X y_i & X \le \hat{D}_i & i = B, R \\ \hat{C}_1 X^{\beta_1^B} + \hat{C}_2 X^{\beta_2^B} + \hat{C}_3 X + \hat{C}_4 & \hat{D}_B < X \le \hat{D}_R, & i = B \\ \hat{A}_{i1} X^{\gamma_1} + \hat{A}_{i2} X^{\gamma_2} + \hat{A}_{i6} & X > \hat{D}_R, & i = B, R, \end{cases} \tag{113}$$

in which $\hat{A}_{B1}, \hat{A}_{B2}, \hat{A}_{R1}, \hat{A}_{R2}, A_{B5}, A_{R5}, \hat{C}_1, \hat{C}_2, C_3, \hat{C}_4, \gamma_1, \gamma_2, \beta_1^B$, and β_2^B are real-valued parameters to be determined.

Solving the system of ODEs (105)-(107) subject to its boundary conditions (108)-(112), I find that

$$\hat{C}_3 = \frac{\tilde{\lambda}_B \alpha_R (1-\tau) y_R}{r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B}, \tag{114}$$

$$\hat{C}_4 = \frac{c_n}{r_B^n + \tilde{\lambda}_B}, \tag{115}$$

and

$$\hat{A}_{i6} = \frac{c_n}{r_i^p}. \tag{116}$$

As before, $\hat{A}_{Bk}$ is a multiple of $\hat{A}_{Rk}$, $k = 1, 2$, with the factor $l_k := \frac{1}{\tilde{\lambda}_B}(r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B\gamma_k - \frac{1}{2}\tilde{\sigma}_B^2\gamma_k(\gamma_k - 1))$, i.e., $\hat{A}_{Rk} = l_k\hat{A}_{Bk}$, and γ_1 and γ_2 are the negative roots of the quartic equation

$$\left(\tilde{\mu}_R\gamma + \frac{1}{2}\tilde{\sigma}_R^2\gamma(\gamma-1) - \tilde{\lambda}_R - r_R^n\right)\left(\tilde{\mu}_B\gamma + \frac{1}{2}\tilde{\sigma}_B^2\gamma(\gamma-1) - \tilde{\lambda}_B - r_B^n\right) = \tilde{\lambda}_R\tilde{\lambda}_B. \tag{117}$$

The reason for taking the negative roots is the no-bubbles condition for debt stated in Eq. (108).

The remaining unknown parameters $\hat{A}_{B1}, \hat{A}_{B2}, \hat{C}_1$, and $\hat{C}_2$ solve

$$\begin{bmatrix}\hat{A}_{B1} & \hat{A}_{B2} & \hat{C}_1 & \hat{C}_2\end{bmatrix}^T = \hat{M}^{-1}\hat{b}, \tag{118}$$

in which

$$\hat{M} := \begin{bmatrix} \hat{D}_R^{\gamma_1} & \hat{D}_R^{\gamma_2} & -\hat{D}_R^{\beta_1^B} & -\hat{D}_R^{\beta_2^B} \\ \gamma_1\hat{D}_R^{\gamma_1} & \gamma_2\hat{D}_R^{\gamma_2} & -\beta_1^B\hat{D}_R^{\beta_1^B} & -\beta_2^B\hat{D}_R^{\beta_2^B} \\ 0 & 0 & \hat{D}_B^{\beta_1^B} & \hat{D}_B^{\beta_2^B} \\ l_1\hat{D}_R^{\gamma_1} & l_2\hat{D}_R^{\gamma_2} & 0 & 0 \end{bmatrix} \tag{119}$$

and

$$\hat{b} := \begin{bmatrix} \hat{C}_3\hat{D}_R + \hat{C}_4 - \hat{A}_{B6} \\ \hat{C}_3\hat{D}_R \\ \alpha_B(1-\tau)\hat{D}_B y_B - \hat{C}_3\hat{D}_B - \hat{C}_4 \\ \alpha_R(1-\tau)\hat{D}_R y_R - \hat{A}_{R6} \end{bmatrix}. \tag{120}$$

Manager's claim to cash flows. To derive the Hamilton-Jacobi-Bellman equation, note that the instantaneous return of the manager must be equal to the risk-free rate r_i^n. If default occurs, the manager's future cash flow are zero. Because of firm liquidation and the absence of cash flows, the manager is unable to divert after default resulting in private benefits of zero, and the value of the manager's equity share is zero due to the absolute priority of debt claims. As long as the firm is solvent, the realized rate of return on the manager's claims is given by the sum of the expected change in his equity share plus the instantaneous cash flows received by the manager. Thus, similar to the valuation approach for equity, the manager's claim to cash flow is determined by the following system of ODEs.

For $0 \leq X \leq \hat{D}_B$:

$$\begin{cases} \hat{m}_B(X) &= 0 \\ \hat{m}_R(X) &= 0. \end{cases} \tag{121}$$

For $\hat{D}_B < X \leq \hat{D}_R$:

$$\begin{cases} r_B^n \hat{m}_B(X) &= (1-\tau)(\psi+\phi-\psi\phi)(X-c_n) + \tilde{\mu}_B X \hat{m}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 \hat{m}_B''(X) \\ & \quad + \tilde{\lambda}_B(0 - \hat{m}_B(X)) \\ \hat{m}_R(X) &= 0. \end{cases} \tag{122}$$

For $X > \hat{D}_R$:

$$\begin{cases} r_B^n \hat{m}_B(X) &= (1-\tau)(\psi+\phi-\psi\phi)(X-c_n) + \tilde{\mu}_B X \hat{m}_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 \hat{m}_B''(X) \\ & \quad + \tilde{\lambda}_B(\hat{m}_R(X) - \hat{m}_B(X)) \\ r_R^n \hat{m}_R(X) &= (1-\tau)(\psi+\phi-\psi\phi)(X-c_n) + \tilde{\mu}_R X \hat{m}_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 \hat{m}_R''(X) \\ & \quad + \tilde{\lambda}_R(\hat{m}_B(X) - \hat{m}_R(X)) \end{cases} \tag{123}$$

Similarly to the boundary conditions for the valuation of equity [Eqs. (91)-(**??**)], the boundary conditions for the manager's claim to cash flows are given by

$$\lim_{X\to\infty} \frac{\hat{m}_i(X)}{X} < \infty, \quad i = B, R, \tag{124}$$

$$\lim_{X \searrow \hat{D}_R} \hat{m}_B(X) = \lim_{X \nearrow \hat{D}_R} \hat{m}_B(X), \tag{125}$$

$$\lim_{X \searrow \hat{D}_R} \hat{m}_B'(X) = \lim_{X \nearrow \hat{D}_R} \hat{m}_B'(X), \tag{126}$$

$$\hat{m}_B\left(\hat{D}_B\right) = 0, \tag{127}$$

and

$$\hat{m}_R\left(\hat{D}_R\right) = 0. \tag{128}$$

The functional form of the solution is

$$\hat{m}_i(X) = \begin{cases} 0 & X \leq \hat{D}_i & i = B, R \\ \hat{C}_1 X^{\beta_1^B} + \hat{C}_2 X^{\beta_2^B} + \hat{C}_3 X + \hat{C}_4 & \hat{D}_B < X \leq \hat{D}_R, & i = B \\ \hat{A}_{i1} X^{\gamma_1} + \hat{A}_{i2} X^{\gamma_2} + \hat{A}_{i5} X + \hat{A}_{i6} & X > \hat{D}_R, & i = B, R, \end{cases} \tag{129}$$

in which $\hat{A}_{B1}, \hat{A}_{B2}, \hat{A}_{R1}, \hat{A}_{R2}, A_{B5}, A_{R5}, \hat{C}_1, \hat{C}_2, C_3, \hat{C}_4, \gamma_1, \gamma_2, \beta_1^B$, and β_2^B are real-valued parameters to be determined.

Solving the system of ODEs (121)-(123) subject to its boundary conditions (124)-(128), I find that

$$\hat{C}_3 = \frac{(1-\tau)(\phi+\psi-\phi\psi)}{r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B}, \tag{130}$$

$$\hat{C}_4 = -\frac{(1-\tau)(\phi+\psi-\phi\psi)\, c_n}{r_B^n + \tilde{\lambda}_B}, \tag{131}$$

$$\hat{A}_{i5} = (1-\tau)(\phi+\psi-\phi\psi)\, y_i, \tag{132}$$

and

$$\hat{A}_{i6} = \frac{-\left(1-\tau\right)\left(\phi+\psi-\phi\psi\right)c_n}{r_i^p}. \tag{133}$$

As before, $\hat{A}_{Bk}$ is a multiple of $\hat{A}_{Rk}$, $k = 1, 2$, with the factor $l_k := \frac{1}{\tilde{\lambda}_B}(r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B\gamma_k - \frac{1}{2}\tilde{\sigma}_B^2\gamma_k(\gamma_k - 1))$, i.e., $\hat{A}_{Rk} = l_k\hat{A}_{Bk}$, and γ_1 and γ_2 are the negative roots of the quartic equation

$$\left(\tilde{\mu}_R\gamma + \frac{1}{2}\tilde{\sigma}_R^2\gamma(\gamma-1) - \tilde{\lambda}_R - r_R^n\right)\left(\tilde{\mu}_B\gamma + \frac{1}{2}\tilde{\sigma}_B^2\gamma(\gamma-1) - \tilde{\lambda}_B - r_B^n\right) = \tilde{\lambda}_R\tilde{\lambda}_B. \tag{134}$$

The reason for taking the negative roots is the no-bubbles condition for the manager's claim to cash flows stated in Eq. (124).

The remaining unknown parameters $\hat{A}_{B1}, \hat{A}_{B2}, \hat{C}_1$, and $\hat{C}_2$ solve

$$\begin{bmatrix}\hat{A}_{B1} & \hat{A}_{B2} & \hat{C}_1 & \hat{C}_2\end{bmatrix}^T = \hat{M}^{-1}\hat{b}, \tag{135}$$

in which

$$\hat{M} := \begin{bmatrix} \hat{D}_R^{\gamma_1} & \hat{D}_R^{\gamma_2} & -\hat{D}_R^{\beta_1^B} & -\hat{D}_R^{\beta_2^B} \\ \gamma_1\hat{D}_R^{\gamma_1} & \gamma_2\hat{D}_R^{\gamma_2} & -\beta_1^B\hat{D}_R^{\beta_1^B} & -\beta_2^B\hat{D}_R^{\beta_2^B} \\ 0 & 0 & \hat{D}_B^{\beta_1^B} & \hat{D}_B^{\beta_2^B} \\ l_1\hat{D}_R^{\gamma_1} & l_2\hat{D}_R^{\gamma_2} & 0 & 0 \end{bmatrix} \tag{136}$$

and

$$\hat{b} := \begin{bmatrix} \hat{C}_3\hat{D}_R + \hat{C}_4 - \hat{A}_{B5}\hat{D}_R - \hat{A}_{B6} \\ \hat{C}_3\hat{D}_R - \hat{A}_{B5}\hat{D}_R \\ -\hat{C}_3\hat{D}_B - \hat{C}_4 \\ -\hat{A}_{R5}\hat{D}_R - \hat{A}_{R6} \end{bmatrix}. \tag{137}$$

C. The value functions before investment

The value of the growth option. The following Proposition 1 states the value of the growth option for any given pair of exercise boundaries. The proposition is as in Arnold, Wagner, and Westermann (2013), and repeated here for completeness and convenience of the reader.

Proposition 1. *(i) For any given pair of exercise boundaries $[X_B, X_R]$, the value of the growth option in regime i is given by*

$$G_i(X) = \begin{cases} \bar{A}_{i3}X^{\gamma_3} + \bar{A}_{i4}X^{\gamma_4} & X < X_B, & i = B, R \\ \bar{C}_1 X^{\beta_1^R} + \bar{C}_2 X^{\beta_2^R} & & \\ +\tilde{\lambda}_R \frac{(s-1)(1-\tau)y_B X}{r_R^n - \tilde{\mu}_R + \tilde{\lambda}_R} - \tilde{\lambda}_R \frac{K}{r_R^n + \tilde{\lambda}_R} & X_B \leq X < X_R, & i = R \\ (s-1)(1-\tau) X y_i - K & X \geq X_i, & i = B, R, \end{cases} \tag{138}$$

in which $\gamma_k, k = 3, 4,$ are the positive roots of the quartic equation

$$\left(\tilde{\mu}_R \gamma + \frac{1}{2}\tilde{\sigma}_R^2 \gamma(\gamma - 1) - \tilde{\lambda}_R - r_R^n\right)\left(\tilde{\mu}_B \gamma + \frac{1}{2}\tilde{\sigma}_B^2 \gamma(\gamma - 1) - \tilde{\lambda}_B - r_B^n\right) = \tilde{\lambda}_R \tilde{\lambda}_B, \tag{139}$$

and β_k^R, $k = 1, 2,$ are given by

$$\beta_{1,2}^R = \frac{1}{2} - \frac{\tilde{\mu}_R}{\tilde{\sigma}_R^2} \pm \sqrt{\left(\frac{1}{2} - \frac{\tilde{\mu}_R}{\tilde{\sigma}_R^2}\right)^2 + \frac{2\left(r_R^n + \tilde{\lambda}_R\right)}{\tilde{\sigma}_R^2}}. \tag{140}$$

$\bar{A}_{Rk}$, $k = 3, 4,$ is a multiple of $\bar{A}_{Bk}$ with the factor

$$\bar{l}_k := \frac{1}{\tilde{\lambda}_B}(r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B \gamma_k - \frac{1}{2}\tilde{\sigma}_B^2 \gamma_k(\gamma_k - 1)). \tag{141}$$

$\left[\bar{A}_{B3}, \bar{A}_{B4}, \bar{C}_1, \bar{C}_2\right]$ solve the linear system

$$\begin{bmatrix} \bar{A}_{B3} & \bar{A}_{B4} & \bar{C}_1 & \bar{C}_2 \end{bmatrix}^T = \bar{M}^{-1}\bar{b}, \tag{142}$$

in which

$$\bar{M} = \begin{bmatrix} \bar{l}_3 X_B^{\gamma_3} & \bar{l}_4 X_B^{\gamma_4} & -X_B^{\beta_1^R} & -X_B^{\beta_2^R} \\ \bar{l}_3 \gamma_3 X_B^{\gamma_3} & \bar{l}_4 \gamma_4 X_B^{\gamma_4} & -\beta_1^R X_B^{\beta_1^R} & -\beta_2^R X_B^{\beta_2^R} \\ 0 & 0 & X_R^{\beta_1^R} & X_R^{\beta_2^R} \\ X_B^{\gamma_3} & X_B^{\gamma_4} & 0 & 0 \end{bmatrix}, \tag{143}$$

and

$$\bar{b} := \begin{bmatrix} \bar{C}_3 X_B + \bar{C}_4 \\ \bar{C}_3 X_B \\ -\bar{C}_3 X_R - \bar{C}_4 + (s-1)(1-\tau) y_R X_R - K \\ (s-1)(1-\tau) y_B X_B - K \end{bmatrix}. \tag{144}$$

(ii) The unlevered value of the growth option, i.e., using value-maximizing exercise boundaries can be calculated using the formulas (138)-(141).
$\left[\bar{A}_{B3}, \bar{A}_{B4}, \bar{C}_1, \bar{C}_2, X_B^{unlev}, X_R^{unlev}\right]$ *are determined by the non-linear six-dimensional equation*

$$\bar{M} \left[\bar{A}_{B3} \quad \bar{A}_{B4} \quad \bar{C}_1 \quad \bar{C}_2\right]^T = \bar{b}, \tag{145}$$

in which

$$\bar{M} = \begin{bmatrix} \bar{l}_3 X_B^{\gamma_3} & \bar{l}_4 X_B^{\gamma_4} & -X_B^{\beta_1^R} & -X_B^{\beta_2^R} \\ \bar{l}_3 \gamma_3 X_B^{\gamma_3} & \bar{l}_4 \gamma_4 X_B^{\gamma_4} & -\beta_1^R X_B^{\beta_1^R} & -\beta_2^R X_B^{\beta_2^R} \\ 0 & 0 & X_R^{\beta_1^R} & X_R^{\beta_2^R} \\ X_B^{\gamma_3} & X_B^{\gamma_4} & 0 & 0 \\ 0 & 0 & \beta_1^R X_R^{\beta_1^R} & \beta_2^R X_R^{\beta_2^R} \\ \gamma_3 X_B^{\gamma_3} & \gamma_4 X_B^{\gamma_4} & 0 & 0 \end{bmatrix}, \tag{146}$$

and

$$\bar{b} := \begin{bmatrix} \bar{C}_3 X_B + \bar{C}_4 \\ \bar{C}_3 X_B \\ -\bar{C}_3 X_R - \bar{C}_4 + (s-1)(1-\tau) y_R X_R - K \\ (s-1)(1-\tau) y_B X_B - K \\ -\bar{C}_3 X_R + (s-1)(1-\tau) y_R X_R \\ (s-1)(1-\tau) y_B X_B \end{bmatrix}. \tag{147}$$

Proof. For the proof, see Arnold, Wagner, and Westermann (2013). □

The value of corporate securities. The following Proposition 2 states the values of corporate securities. I first state the general functional form of the value functions of interest (equity, debt, manager's claim to cash flows), and then present the parameters of the general functional form for each value function.

Proposition 2. *For any given set of default and exercise boundaries D_B, D_R, X_B, X_R, the general functional form for the value functions of interest in regime i is given by*

$$f_i(X) = \begin{cases} E_{i1} X + E_{i2} G_i^{unlev}(X) & \\ +E_{i3} G_i(X) & X \le D_i, \quad i = B, R, \\ C_1 X^{\beta_1^B} + C_2 X^{\beta_2^B} + C_3 X & \\ +C_4 + C_5 X^{\gamma_3} + C_6 X^{\gamma_4} & D_B < X \le D_R, \quad i = B \\ A_{i1} X^{\gamma_1} + A_{i2} X^{\gamma_2} + A_{i3} X^{\gamma_3} & \\ +A_{i4} X^{\gamma_4} + A_{i5} X + A_{i6} & D_R < X \le X_B, \quad i = B, R \\ B_1 X^{\beta_1^R} + B_2 X^{\beta_2^R} + B_3 X + B_4 & X_B < X \le X_R, \quad i = R \\ F_{i1} X + F_{i2} & X > X_i, \quad i = B, R. \end{cases} \tag{148}$$

G_i^{unlev} denotes the unlevered option value in regime i (see Proposition 1), and

$$\beta_{1,2}^i = \frac{1}{2} - \frac{\tilde{\mu}_i}{\tilde{\sigma}_i^2} \pm \sqrt{\left(\frac{1}{2} - \frac{\tilde{\mu}_i}{\tilde{\sigma}_i^2}\right)^2 + \frac{2\left(r_i^n + \tilde{\lambda}_i\right)}{\tilde{\sigma}_i^2}} \tag{149}$$

$\gamma_k, k = 1,2,3,4$ are the roots of the quartic equation

$$\left(\tilde{\mu}_R\gamma + \frac{1}{2}\tilde{\sigma}_R^2\gamma(\gamma-1) - \tilde{\lambda}_R - r_R^n\right)\left(\tilde{\mu}_B\gamma + \frac{1}{2}\tilde{\sigma}_B^2\gamma(\gamma-1) - \tilde{\lambda}_B - r_B^n\right) = \tilde{\lambda}_R\tilde{\lambda}_B. \tag{150}$$

A_{Rk}, $k = 1,2,3,4$, is a multiple of A_{Bk} with the factor

$$l_k := \frac{1}{\tilde{\lambda}_B}(r_B^n + \tilde{\lambda}_B - \tilde{\mu}_B\gamma_k - \frac{1}{2}\tilde{\sigma}_B^2\gamma_k(\gamma_k - 1)). \tag{151}$$

$[A_{B1}\ A_{B2}\ A_{B3}\ A_{B4}\ C_1\ C_2\ B_1\ B_2]^T$ solve a linear system

$$M\begin{bmatrix} A_{B1} & A_{B2} & A_{B3} & A_{B4} & C_1 & C_2 & B_1 & B_2 \end{bmatrix}^T = b, \tag{152}$$

in which

$$M = \begin{bmatrix}
D_R^{\gamma_1} & D_R^{\gamma_2} & D_R^{\gamma_3} & D_R^{\gamma_4} & -D_R^{\beta_1^B} & -D_R^{\beta_2^B} & 0 & 0 \\
\gamma_1 D_R^{\gamma_1} & \gamma_2 D_R^{\gamma_2} & \gamma_3 D_R^{\gamma_3} & \gamma_4 D_R^{\gamma_4} & -\beta_1^B D_R^{\beta_1^B} & -\beta_2^B D_R^{\beta_2^B} & 0 & 0 \\
0 & 0 & 0 & 0 & D_B^{\beta_1^B} & D_B^{\beta_2^B} & 0 & 0 \\
l_1 D_R^{\gamma_1} & l_2 D_R^{\gamma_2} & l_3 D_R^{\gamma_3} & l_4 D_R^{\gamma_4} & 0 & 0 & 0 & 0 \\
l_1 X_B^{\gamma_1} & l_2 X_B^{\gamma_2} & l_3 X_B^{\gamma_3} & l_4 X_B^{\gamma_4} & 0 & 0 & -X_B^{\beta_1^R} & -X_B^{\beta_2^R} \\
l_1\gamma_1 X_B^{\gamma_1} & l_2\gamma_2 X_B^{\gamma_2} & l_3\gamma_3 X_B^{\gamma_3} & l_4\gamma_4 X_B^{\gamma_4} & 0 & 0 & -\beta_1^R X_B^{\beta_1^R} & -\beta_2^R X_B^{\beta_2^R} \\
X_B^{\gamma_1} & X_B^{\gamma_2} & X_B^{\gamma_3} & X_B^{\gamma_4} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & X_R^{\beta_1^R} & X_R^{\beta_2^R}
\end{bmatrix} \tag{153}$$

and

$$b = \begin{bmatrix}
-A_{B5}D_R - A_{B6} + C_3 D_R + C_4 + C_5 D_R^{\gamma_1} + C_6 D_R^{\gamma_2} \\
-A_{B5}D_R + C_3 D_R + \gamma_1 C_5 D_R^{\gamma_1} + \gamma_2 C_6 D_R^{\gamma_2} \\
-C_3 D_B - C_4 - C_5 D_B^{\gamma_3} - C_6 D_B^{\gamma_4} + E_{B1}D_B + E_{B2}G_B^{unlev}(D_B) + E_{B3}G_B(D_B) \\
-A_{R5}D_R - A_{R6} + E_{R1}D_R + E_{R2}G_R^{unlev}(D_R) + E_{R3}G_R(D_R) \\
-A_{R5}X_B - A_{R6} + B_3 X_B + B_4 \\
-A_{R5}X_B + B_3 X_B \\
-A_{B5}X_B - A_{B6} + F_{B1}X_B + F_{B2} \\
-B_3 X_R - B_4 + F_{R1}X_R + F_{R2}
\end{bmatrix}. \tag{154}$$

(i) The value of corporate debt is determined by the following parameters.

$$E_{i1} = \alpha_i y_i (1 - \tau) \tag{155}$$

$$E_{i2} = \alpha_i \tag{156}$$

$$E_{i3} = 0 \tag{157}$$

$$C_3 = \tilde{\lambda}_B \frac{\alpha_R (1 - \tau) y_R}{r_B^n - \tilde{\mu}_B + \tilde{\lambda}_B} \tag{158}$$

$$C_4 = \frac{c_o}{r_B^n + \tilde{\lambda}_B} \tag{159}$$

$$C_5 = \alpha_R \frac{\bar{l}_3}{l_3} \bar{A}_{B3}^{unlev} \tag{160}$$

$$C_6 = \alpha_R \frac{\bar{l}_4}{l_4} \bar{A}_{B4}^{unlev} \tag{161}$$

$$A_{i5} = 0 \tag{162}$$

$$A_{i6} = \frac{c_o}{r_i^p} \tag{163}$$

$$B_3 = 0 \tag{164}$$

$$B_4 = \frac{\tilde{\lambda}_R f_B^d + c_o}{r_R^n + \tilde{\lambda}_R} \tag{165}$$

$$F_{i1} = 0 \tag{166}$$

$$F_{i2} = P \tag{167}$$

P is the par value of debt corresponding to the value of debt at the time of issuance.

(ii) The value of equity is determined by the following parameters.

$$E_{i1} = 0 \tag{168}$$

$$E_{i2} = 0 \tag{169}$$

$$E_{i3} = 0 \tag{170}$$

$$C_3 = \frac{(1-\tau)(1-\phi)}{r_B^n - \tilde{\mu}_B + \tilde{\lambda}_B} \tag{171}$$

$$C_4 = -\frac{(1-\tau)(1-\phi)\, c_o}{r_B^n + \tilde{\lambda}_B} \tag{172}$$

$$C_5 = 0 \tag{173}$$

$$C_6 = 0 \tag{174}$$

$$A_{i5} = (1-\tau)(1-\phi)\, y_i \tag{175}$$

$$A_{i6} = -\frac{(1-\tau)(1-\phi)\, c_o}{r_i^p} \tag{176}$$

$$B_3 = \frac{(1-\tau)(1-\phi) + \tilde{\lambda}_R s f_i^v}{r_R^n - \tilde{\mu}_R + \tilde{\lambda}_R} \tag{177}$$

$$B_4 = -\frac{(1-\tau)(1-\phi)\, c_o + \tilde{\lambda}_R (P+K)}{r_R^n + \tilde{\lambda}_R} \tag{178}$$

$$F_{i1} = s f_i^v \tag{179}$$

$$F_{i2} = -P - K \tag{180}$$

f_i^v is the factor to calculate the value of a firm with only invested assets given the manager-selected coupon c_n. P is the par value of debt.

(iii) The value of the managerial expected future cash flows is determined by the following parameters.

$$E_{i1} = 0 \tag{181}$$

$$E_{i2} = 0 \tag{182}$$

$$E_{i3} = 0 \tag{183}$$

$$C_3 = \frac{(1-\tau)(\phi+\psi-\phi\psi)}{r_B^n - \tilde{\mu}_B + \tilde{\lambda}_B} \tag{184}$$

$$C_4 = -\frac{(1-\tau)(\phi+\psi-\phi\psi)\, c_o}{r_B^n + \tilde{\lambda}_B} \tag{185}$$

$$C_5 = 0 \tag{186}$$

$$C_6 = 0 \tag{187}$$

$$A_{i5} = (1-\tau)(\phi+\psi-\phi\psi)\, y_i \tag{188}$$

$$A_{i6} = -\frac{(1-\tau)(\phi+\psi-\phi\psi)\, c_o}{r_i^p} \tag{189}$$

$$B_3 = \frac{(1-\tau)(\phi+\psi-\phi\psi) + \tilde{\lambda}_R s f_i^m}{r_R^n - \tilde{\mu}_R + \tilde{\lambda}_R} \tag{190}$$

$$B_4 = -\frac{(1-\tau)(\phi+\psi-\phi\psi)\, c_o}{r_R^n + \tilde{\lambda}_R} \tag{191}$$

$$F_{i1} = s f_i^m \tag{192}$$

$$F_{i2} = -\psi\,(P+K) \tag{193}$$

f_i^m is the factor to calculate the value of managerial future cash flows of a firm with only invested assets given the manager-selected coupon c_n.

Proof. (i) As explained in the main text, the system of ODEs for corporate debt is given by:

For $0 \leq X \leq D_B$:

$$\begin{cases} d_B(X) &= \alpha_B\left((1-\tau)\, X y_B + G_B^{unlev}(X)\right) \\ d_R(X) &= \alpha_R\left((1-\tau)\, X y_R + G_R^{unlev}(X)\right). \end{cases} \tag{194}$$

For $D_B < X \leq D_R$:

$$\begin{cases} r_B^n d_B(X) &= c_o + \tilde{\mu}_B X d_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 d_B''(X) \\ & \quad + \tilde{\lambda}_B\left(\alpha_R\left((1-\tau)\, X y_R + G_R^{unlev}(X)\right) - d_B(X)\right) \\ d_R(X) &= \alpha_R(1-\tau)\left(X y_R + G_R^{unlev}(X)\right). \end{cases} \tag{195}$$

For $D_R < X < X_B$:

$$\begin{cases} r_B^n d_B(X) &= c_o + \tilde{\mu}_B X d_B'(X) + \\ & \frac{1}{2}\tilde{\sigma}_B^2 X^2 d_B''(X) + \tilde{\lambda}_B (d_R(X) - d_B(X)) \\ r_R^n d_R(X) &= c_o + \tilde{\mu}_R X d_R'(X) \\ & + \frac{1}{2}\tilde{\sigma}_R^2 X^2 d_R''(X) + \tilde{\lambda}_R (d_B(X) - d_R(X)). \end{cases} \tag{196}$$

For $X_B \leq X < X_R$:

$$\begin{cases} d_B(X) &= P \\ r_R^n d_R(X) &= c_o + \tilde{\mu}_R X d_R'(X) \\ & + \frac{1}{2}\tilde{\sigma}_R^2 X^2 d_R''(X) + \tilde{\lambda}_R (P - d_R(X)). \end{cases} \tag{197}$$

For $X \geq X_R$:

$$\begin{cases} d_B(X) &= P \\ d_R(X) &= P. \end{cases} \tag{198}$$

The boundary conditions write:

$$\lim_{X \searrow D_R} d_B(X) = \lim_{X \nearrow D_R} d_B(X), \tag{199}$$

$$\lim_{X \searrow D_R} d_B'(X) = \lim_{X \nearrow D_R} d_B'(X), \tag{200}$$

$$\lim_{X \searrow D_B} d_B(X) = \alpha_B \left((1-\tau) D_B y_B + G_B^{unlev}(D_B) \right), \tag{201}$$

$$\lim_{X \searrow D_R} d_R(X) = \alpha_R \left((1-\tau) D_R y_R + G_R^{unlev}(D_R) \right), \tag{202}$$

$$\lim_{X \searrow X_B} d_R(X) = \lim_{X \nearrow X_B} d_R(X), \tag{203}$$

$$\lim_{X \searrow X_B} d_R'(X) = \lim_{X \nearrow X_B} d_R'(X), \tag{204}$$

$$\lim_{X \nearrow X_B} d_B(X) = P, \tag{205}$$

and

$$\lim_{X \nearrow X_R} d_R(X_R) = P. \tag{206}$$

The functional form of the system of ODE (194)-(198) and its boundary conditions (199)-(206) is given in (148). Solving with standard techniques, I find that the parameters correspond to the ones in (155)-(167). The linear system determining the remaining unknowns $A_{B1}, A_{B2}, A_{B3}, A_{B4}, C_1, C_2, B_1, B_2$, (152)-(154), is given by the boundary conditions (199)-(206).

(ii) The system of ODEs for equity are given by (cf. Eqs. (12)-(16)):

For $0 \leq X \leq D_B$:

$$\begin{cases} e_B(X) &= 0 \\ e_R(X) &= 0. \end{cases} \tag{207}$$

For $D_B < X \leq D_R$:

$$\begin{cases} r_B^n e_B(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_B X e_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 e_B''(X) \\ &\quad +\tilde{\lambda}_B(0 - e_B(X)) \\ e_R(X) &= 0. \end{cases} \tag{208}$$

For $D_R < X < X_B$:

$$\begin{cases} r_B^n e_B(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_B X e_B'(X) + \frac{1}{2}\tilde{\sigma}_B^2 X^2 e_B''(X) \\ &\quad +\tilde{\lambda}_B(e_R(X) - e_B(X)) \\ r_R^n e_R(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_R X e_R'(X) + \frac{1}{2}\tilde{\sigma}_R^2 X^2 e_R''(X) \\ &\quad +\tilde{\lambda}_R(e_B(X) - e_R(X)). \end{cases} \tag{209}$$

For $X_B \leq X < X_R$:

$$\begin{cases} e_B(X) &= \hat{e}_B\left(sX; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right) \\ r_R^n e_R(X) &= (1-\phi)(1-\tau)(X-c_o) + \tilde{\mu}_R X e_R'(X) \\ &\quad +\frac{1}{2}\tilde{\sigma}_R^2 X^2 e_R''(X) + \tilde{\lambda}_R\left(\hat{e}_B\left(sX; c_{n,B}^*\right)\right. \\ &\quad \left. -K - P + \hat{d}_B\left(sX; c_{n,B}^*\right) - e_R(X)\right). \end{cases} \tag{210}$$

For $X \geq X_R$:

$$\begin{cases} e_B(X) &= \hat{e}_B\left(sX; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right) \\ e_R(X) &= \hat{e}_R\left(sX; c_{n,R}^*\right) - K - P + \hat{d}_R\left(sX; c_{n,R}^*\right). \end{cases} \tag{211}$$

The boundary conditions are as follows (cf. Eqs. (17)-(24)):

$$\lim_{X \searrow D_R} e_B(X) = \lim_{X \nearrow D_R} e_B(X), \tag{212}$$

$$\lim_{X \searrow D_R} e_B'(X) = \lim_{X \nearrow D_R} e_B'(X), \tag{213}$$

$$e_B(D_B) = 0, \tag{214}$$

$$e_R(D_R) = 0, \tag{215}$$

$$\lim_{X \searrow X_B} e_R(X) = \lim_{X \nearrow X_B} e_R(X), \tag{216}$$

$$\lim_{X \searrow X_B} e_R'(X) = \lim_{X \nearrow X_B} e_R'(X), \tag{217}$$

$$e_B(X_B) = \hat{e}_B\left(sX_B; c_{n,B}^*\right) - K - P + \hat{d}_B\left(sX; c_{n,B}^*\right), \tag{218}$$

and

$$e_R(X_R) = \hat{e}_B\left(sX_R; c_{n,R}^*\right) - K - P + \hat{d}_R\left(sX; c_{n,R}^*\right). \tag{219}$$

The functional form of the system of ODE (207)-(211) and its boundary conditions (212)-(219) is given in (148). Solving with standard techniques, I find that the parameters correspond to the ones in (168)-(180). The linear system determining the remaining unknowns $A_{B1}, A_{B2}, A_{B3}, A_{B4}, C_1, C_2, B_1, B_2$, (152)-(154), is given by the boundary conditions (212)-(219).

(iii) For the manager's claim to cash flows, the system of ODEs is, as in (26)-(30):

For $0 \leq X \leq D_B$:

$$\begin{cases} m_B(X) &= 0 \\ m_R(X) &= 0. \end{cases} \tag{220}$$

For $D_B < X \leq D_R$:

$$\begin{cases} r_B^n m_B(X) &= (1-\tau)(\phi+\psi-\phi\psi)(X-c_o)+\tilde{\mu}_B X m_B'(X) \\ & \quad +\frac{1}{2}\tilde{\sigma}_B^2 X^2 m_B''(X)+\tilde{\lambda}_B(0-m_B(X)) \\ m_R(X) &= 0. \end{cases} \tag{221}$$

For $D_R < X < X_B$:

$$\begin{cases} r_B^n m_B(X) &= (1-\tau)(\phi+\psi-\phi\psi)(X-c_o)+\tilde{\mu}_B X m_B'(X) \\ & \quad +\frac{1}{2}\tilde{\sigma}_B^2 X^2 m_B''(X)+\tilde{\lambda}_B(m_R(X)-m_B(X)) \\ r_R^n m_R(X) &= (1-\tau)(\phi+\psi-\phi\psi)(X-c_o)+\tilde{\mu}_R X m_R'(X) \\ & \quad +\frac{1}{2}\tilde{\sigma}_R^2 X^2 m_R''(X)+\tilde{\lambda}_R(m_B(X)-m_R(X)). \end{cases} \tag{222}$$

For $X_B \leq X < X_R$:

$$\begin{cases} m_B(X) &= \hat{m}_B\left(sX; c_{n,B}^*\right)+\psi\left(-K-P+\hat{d}_B\left(sX; c_{n,B}^*\right)\right) \\ r_R^n m_R(X) &= (1-\tau)(\phi+\psi-\phi\psi)(X-c_o)+\tilde{\mu}_R X m_R'(X) \\ & \quad +\frac{1}{2}\tilde{\sigma}_R^2 X^2 m_R''(X)+\tilde{\lambda}_R\Big(\hat{m}_B\left(sX; c_{n,B}^*\right) \\ & \quad +\psi\left(-K-P+\hat{d}_B\left(sX; c_{n,B}^*\right)\right)-m_R(X)\Big). \end{cases} \tag{223}$$

For $X \geq X_R$:

$$\begin{cases} m_B(X) &= \hat{m}_B\left(sX; c_{n,B}^*\right)+\psi\left(-K-P+\hat{d}_B\left(sX; c_{n,B}^*\right)\right) \\ m_R(X) &= \hat{m}_R\left(sX; c_{n,R}^*\right)+\psi\left(-K-P+\hat{d}_R\left(sX; c_{n,R}^*\right)\right). \end{cases} \tag{224}$$

The boundary conditions are as in (31)-(38):

$$\lim_{X \searrow D_R} m_B(X) = \lim_{X \nearrow D_R} m_B(X), \tag{225}$$

$$\lim_{X \searrow D_R} m'_B(X) = \lim_{X \nearrow D_R} m'_B(X), \tag{226}$$

$$m_B(D_B) = 0, \tag{227}$$

$$m_R(D_R) = 0, \tag{228}$$

$$\lim_{X \searrow X_B} m_R(X) = \lim_{X \nearrow X_B} m_R(X), \tag{229}$$

$$\lim_{X \searrow X_B} m'_R(X) = \lim_{X \nearrow X_B} m'_R(X), \tag{230}$$

$$m_B(X_B) = \hat{m}_B\left(sX_B; c^*_{n,B}\right) + \psi\left(-K - P + \hat{d}_R\left(sX; c^*_{n,R}\right)\right), \tag{231}$$

and

$$m_R(X_R) = \hat{m}_B\left(sX_R; c^*_{n,R}\right) + \psi\left(-K - P + \hat{d}_R\left(sX; c^*_{n,R}\right)\right). \tag{232}$$

The functional form of the system of ODE (220)-(224) and its boundary conditions (225)-(232) is given in (148). Solving with standard techniques, I find that the parameters correspond to the ones in (181)-(193). The linear system determining the remaining unknowns $A_{B1}, A_{B2}, A_{B3}, A_{B4}, C_1, C_2, B_1, B_2$, (152)-(154), is given by the boundary conditions (225)-(232).

□