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Agency Conflicts and Investment: Evidence from a Structural Estimation

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We develop a dynamic capital structure model to study how agency conflicts between managers and shareholders affect the joint determination of financing and investment decisions. We show that there are two agency conflicts with opposing effects on a manager's choice of investment: first, the consumption of private benefits channel leads managers not only to choose a lower optimal leverage, but also to underinvest, and second, compensation linked to firm size may lead managers to overinvest. We fit the model to the data and show that the average firm slightly overinvests, younger CEOs invest more than older ones, while CEOs with longer tenure overinvest more than CEOs with shorter tenure. (*JEL* G12, G31, G32)

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How do conflicts between managers and shareholders affect firms' investment and financing policies? Do managers have strong incentives to let firms grow beyond what is optimal for shareholders (i.e., empire-building as in Jensen, 1986, 1993), or do they prefer the quiet life? For example, managers might prefer to consume private benefits at the expense of shareholders' value (Bertrand and Mullainathan, 2003; Hicks, 1935). We are interested in how agency conflicts jointly affect firms'

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financing and investment decisions, and whether they lead firms, on average, to underinvest or overinvest compared to what would be optimal for shareholders.

Several authors have relied on quasi-natural experiments to examine distortions in managerial investment behavior around particular events in the life of the firm (for example, a cash windfall from a won lawsuit in Blanchard, Lopez de Silanes, and Shleifer [1994], the proceeds from the sales of assets in Bates [2005], or an unexpected change in pension plan contributions in Franzoni [2009]). The common feature of these studies is that they analyze a small sample of the entire economy and, as such, their findings cannot be easily generalized to the average firm in the economy.[1] Differently from these studies, we analyze firms' investment and financing decisions by estimating a model using simulated method of moments (SMM), thereby documenting the behavior of the average firm.

The structural estimation allows us: (i) to quantify the level of agency conflicts that make our model consistent with empirical data for both financing and investment; (ii) to gauge insights about the effects that agency conflicts have on firms' financing and investment decisions; and (iii) to provide a counterfactual analysis to identify whether, on average, firms overinvest or underinvest. Together with the evidence provided by the aforementioned studies, our results deepen our understanding of the overinvestment and underinvestment phenomenon. While managers overinvest during particular times in the life of the firm, we provide evidence that, on average, they invest more than what would be optimal for shareholders, which is consistent with the empire-building hypothesis (Jensen, 1986, 1993).

Since conflicts of interests cannot be observed and variables that serve as proxies are scarce, we develop a dynamic capital structure model with irreversible investment in which managers make both financing and investment decisions. As in Morellec, Nikolov, and Schürhoff (2012), managers own a portion of the firm, they can divert resources for their own private benefit, and they receive compensation that is linked to firm size.[2] As in Sundaresan, Wang, and Yang (2015), the firm is modeled as a collection of growth options (known ex ante by managers) and assets in place. As the firm moves through time, managers choose the timing of investment for each growth option and how to finance it. The firm starts with no assets in place, and its value is equal to the expected value of all

[1] Providing evidence of a causal relationship between specific agency conflicts and firms' behavior has proven difficult due to the endogeneity of the data: good firms might choose better managers, or they might be better at designing compensation contracts that align managerial incentives to those of shareholders.

[2] There is strong empirical evidence that supports the hypothesis of a positive relation between executives' compensation and firm size; see, for example, Gabaix and Landier (2008) and Gabaix, Landier, and Sauvagnat (2014). Also, Nikolov and Whited (2014) used a similar modeling technique to link firm size and managerial compensation.

future growth options. When a growth option is exercised, it generates assets in place, which increases cash flows for the company.

In our model, when managers consume a percentage of net income as private benefits, they optimally choose lower values of leverage compared to the equity-maximizing strategy as in Morellec, Nikolov, and Schürhoff (2012).[3] However, contrary to the prediction that lower leverage would lead managers to pursue empire-building strategies (Jensen, 1986, 1993), our model shows that managers optimally choose to delay the exercise of investment opportunities, thus underinvesting compared to the equity-maximizing strategy. The reason is that managers consume the entirety of private benefits and own only a fraction of the firm. Therefore, the decrease in the equity portion of managers' total compensation is lower than the increase in consumption of private benefits managers can enjoy due to the firm having lower leverage. Given that investment projects are costly and need to be financed with debt, managers prefer to wait such that the firm's leverage would be lower than what shareholders would have chosen. This delay in exercising the growth option causes firms to invest less than what would be optimal for shareholders.[4]

The underinvestment due to consumption of private benefits that our model predicts differs from the well-known underinvestment due to debt overhang (Myers, 1977). In the absence of agency conflicts between managers and shareholders, Myers has shown that lower leverage would lead the firm to invest more. The mechanism implied by our model is different. We show that, in the presence of conflicts of interest between managers and shareholders, managers underinvest compared to the equity-maximizing strategy, despite having chosen lower leverage levels.

Our model is also able to generate overinvestment. In addition to diverting resources for their personal benefits, managers own a portion of total equity and have compensation linked to firm size as in Nikolov and Whited (2014). Holding everything else constant, making compensation more tightly linked to firm size leads managers to invest more. This mechanism is consistent with the empire-building hypothesis, according to which managers derive utility from running larger firms and might invest more than what would be optimal for shareholders. As we will discuss later, our goal is to estimate the model and fit it to the data. In

[3] We refer to the "equity-maximizing" strategy as the choice that the firm would make if there were no conflicts of interest between managers and shareholders. Since in this paper, there are no conflicts between shareholders and debtholders, the equity-maximizing strategy is equivalent to the strategy that maximizes firm value.

[4] The agency conflicts in our model differ from Mauer and Sarkar (2005). Mauer and Sarkar (2005) use a model similar to the one used in this paper, but they study agency conflicts between shareholders and debtholders. They show that shareholders overinvest (i.e., exercise the option earlier) compared to the "firm-maximizing" strategy. We differ from them because there are no conflicts of interest between shareholders and debtholders in our model.

doing so, we are able to capture the managerial benefits that are linked to tangible compensation (e.g., bonuses).

We estimate our model using simulated method of moments for all firms from Compustat and ExecuComp. Our structural estimation shows that to match the empirical leverage, total q, and managerial compensation, it is sufficient to have a consumption of private benefits equal to $\sim$0.6% of net income. The structural estimation allows us to examine counterfactuals and show that the average firm overinvests slightly compared to what would be optimal for shareholders, thus providing support to the overinvestment and empire-building hypothesis. Our model predicts that the average firm invests approximately 7.8% more than it would if there were no agency conflicts. Also, the loss in firm value due to the misalignment of incentives between managers and shareholders is approximately 2.12%.

Several authors have studied differences in investment policies as a function of firm and managers' characteristics (e.g., Fahlenbrach, 2009). For example, Serfling (2014) shows that younger CEOs invest less than older ones, and Billett, Garfinkel, and Jiang (2011) show that poor governance is associated with firms investing more (and more often) in large investment projects. These studies document relevant empirical patterns (i.e., which subsample of firms invest more than others) but, in the absence of an equity maximizing benchmark, it is hard to translate them into evidence of overinvestment or underinvestment. We estimate our model on subsamples of the data with different firm and CEO characteristics (i) to answer the question of whether firms in a particular group overinvest or underinvest and (ii) to check whether our model provides the same directional differences in investment between groups as in previous studies. We show that firms with younger CEOs invest more than those with older CEOs, consistent with Serfling (2014). We also find that firms with a higher takeover index (a proxy for good corporate governance, as shown in Cain, McKeon, and Solomon, 2017) exhibit a lower loss in firm value due to agency conflicts than firms with lower takeover index, consistent with the evidence in Cain, McKeon, and Solomon (2017). Furthermore, we estimate the model on subsamples sorted by CEO tenure, which is an indicator for CEO entrenchment. Our findings show that CEOs with a high tenure invest considerably more than those with lower tenure, thus confirming the results in Pan, Wang, and Weisbach (2016) and Chen and Zheng (2014). Last, our results show that firms with low institutional ownership exhibit an investment rate higher than that of firms with high institutional ownership, consistent with the evidence in Billett, Garfinkel, and Jiang (2011).

This paper is related to the literature that examines the effects of agency conflicts on firms' decisions and, in particular, their effect on overinvestment and underinvestment.[5] On the one hand, several studies have provided both theoretical evidence (Hart 1983; Hicks 1935) and empirical evidence (Bertrand and Mullainathan 2003; Giroud and Mueller 2010) that managers act as if they prefer the quiet life. These studies suggest that managers underinvest because exercising new growth opportunities imposes private costs on them (e.g., spending more time overseeing the firm's activities). Managers may also underinvest if they are concerned with the firm's short-term performance (Edmans 2009) or if they are risk-averse (Lambrecht and Myers 2017). On the other hand, Jensen (1986, 1993) shows that, without proper control, managers would use the company's resources to grow a firm's size rather than its value. Managers may benefit from an increase in firm size in the form of increased salaries, power, and so on. Blanchard, Lopez de Silanes, and Shleifer (1994) analyze small firms with poor investment opportunities that receive large cash settlements from legal cases and show that managers spend the extra cash on acquisitions that underperform in the market rather than paying it out to shareholders. Bates (2005) examines the use of proceeds derived from sales of assets from 400 transactions and concludes that managers who keep the proceeds within the company overinvest compared to the industry benchmark. Franzoni (2009) studies the effect on investment of a decrease in cash induced by mandatory contributions to pension plans and concludes that both overinvestment and underinvestment are possible. Overinvestment can also manifest itself through managerial reputational concerns (Baker, 2000) or overconfidence. Malmendier and Tate (2005) find that overconfident CEOs' investments are more sensitive to firms' cash flow. Fahlenbrach (2009) shows that founder CEOs invest more than successor CEOs. Ben-David, Graham, and Harvey (2013) find that CEOs who miscalibrate about the stock market invest more than others. We contribute to this literature by showing that, through the lens of our model, the average firm in the economy slightly overinvests.

Our paper is also close to the literature of dynamic capital structure with irreversible investment (Sundaresan, Wang, and Yang 2015; Hackbarth and Mauer 2011; Hackbarth and Sun 2018). Sundaresan, Wang, and Yang (2015) and Hackbarth and Sun (2018) study the effect of debt overhang on investment decisions and its effects on the dynamics of leverage ratio. We contribute to this literature by considering conflicts between managers and shareholders. This paper is also closely related to Morellec, Nikolov, and Schürhoff (2012), who use a dynamic capital structure model to investigate the effect of agency conflicts on leverage

[5] The literature studying managerial behavior is vast. For brevity, we mention only some of the existing papers, but we refer the interested reader to Stein (2003) for a comprehensive treatment of agency conflicts and firms' investment.

and its dynamics. The authors show that a small agency conflict between managers and shareholders can resolve the low-leverage puzzle and explain the dynamics of leverage ratios. Nikolov and Whited (2014) study the effects of agency conflicts on firms' cash policy. They find that managers' consumption of private benefits can explain the level and variability of cash holdings. We differentiate ourselves from their work by studying the joint determination of both financing and investment policies.

1. The Model

Our model allows us to analyze the effects of managerial consumption of private benefits as well as managerial preferences for empire-building on financing and investment decisions. We assume that managers make the financing and investing decisions for the firm. Time t is continuous and uncertainty is modeled by a complete probability space $(\Omega, \mathcal{F}, \mathbb{P})$. At time 0, the firm has no assets in place and N growth options. These growth options can only be exercised sequentially. Once exercised, a growth option creates assets in place for the company; we assume that there are no production costs associated with any of the growth options. One can think of this assumption as if we are normalizing the production costs at zero. We also assume that the firm is financially constrained: it needs to issue debt to pay for the costs of exercising the growth options (e.g., issue debt to buy the necessary equipment to start production). Using a standard assumption in the literature, we assume that debt has infinite maturity, pays a constant and continuous coupon, and is repaid when the next investment option is exercised.

In this setup, financing and investing decisions are intertwined. The firm can invest only if it issues debt, which implies that there is a connection between financing and investment decisions. Our paper aims to study this connection and, as will be clearer later, understand how managerial agency conflicts affect such decisions.

Following Morellec (2004), Sundaresan, Wang, and Yang (2015), and Hackbarth and Sun (2018), we assume that the firm's cash flows depend on the state variable Y_t, which follows the geometric Brownian motion defined as:

$$dY_t = \mu Y_t dt + \sigma Y_t dB_t \tag{1}$$

Similar to Mauer and Sarkar (2005), Y_t can be interpreted as the price of the commodity that the firm is producing. For example, if the firm produces aluminum, Y_t can be interpreted as the unit price of aluminum. The other parameters are μ, the expected growth rate of the demand for the firm's products; B_t, a standard Brownian motion; and σ, the volatility of growth rate of the demand. We assume that the (risk-neutral) expected growth rate μ is lower than the risk-free rate r to ensure convergence.[6]

Once the n-th growth option is exercised, its associated assets generate cash flows at a rate $z_n Y$ where z_n is a constant that represents the rate of output produced by the n-th assets. Alternatively, z_n can also be interpreted as a cash-flow multiplier. Using the example of aluminum introduced in the previous paragraph, the growth option z_n refers to the ability of the firm to capture cash flows from the aluminum market via a new production technology, new markets, and so on. If the firm has exercised the first n growth options, the total cash flows generated by the company are $Z_n Y$ where $Z_n = \sum_{k=1}^{n} z_k$. Exercising the n-th growth option costs I_n, which is fixed and known at time 0 by the firm.

Let T_n^i denote the time chosen by managers to exercise the n-th growth option. At T_n^i, managers need to issue debt since the firm does not have the required resources to fund the growth option. Managers will have to issue at least as much debt as needed to cover the cost of the growth option. However, they can issue even more debt if they think it is optimal from a capital structure point of view (i.e., they would like to exploit more tax benefits from debt). As in Sundaresan, Wang, and Yang (2015), the firm pays the investment cost I_n, retires any previously issued debt at par value P_{n-1}, and issues new debt with face value P_n. We assume that the firm can only issue debt at investment times $\{T_n^i : 1 \leq n \leq N\}$: after exercising the n-th growth option (for $0 \leq n < N$), the firm operates its existing n assets either until the next growth option is exercised (i.e., when the demand for the firm's products increases to the endogenously determined investment threshold Y_{n+1}^i) or until the firm defaults on its outstanding debt (when the demand for the firm's products decreases to the endogenously determined default threshold Y_n^D). Since cash flows are taxed, the firm has an incentive to issue debt for tax benefits.

Following the work of McDonald and Siegel (1986), the present value of a j-th growth option with exercise cost I_j and cash-flow multiplier z_j is

$$G_j(Y) = [(1-\tau)\frac{z_j Y_k}{r-\mu} - I_j]\left(\frac{Y}{Y_k}\right)^{\beta_1}, \text{ for } Y < Y_k \tag{2}$$

where τ is the corporate tax rate, r is the risk-free rate for a perpetuity, and Y_k is the optimal exercising threshold, which is endogenously determined as follows

$$Y_k = \frac{\beta_1}{\beta_1 - 1} \cdot \frac{r-\mu}{(1-\tau)} \cdot \frac{I_j}{z_j} \tag{3}$$

[6] This is a standard assumption in the literature; for more details, see Dixit and Pindyck (1994) and Stokey (2008).

and β_1 is the positive root of $\frac{1}{2}\sigma^2 x(x-1)+\mu x - r = 0$. The proof of Equation (3) immediately follows from the standard smooth-pasting: $\partial G_j(Y)/\partial Y|_{Y=Y_k} = (1-\tau)z_j/(r-\mu)$.

At the time of default, the firm is liquidated, and it incurs a loss on both its assets in place (γ_A) and its unexercised growth options (γ_G). The firm liquidation value when the first n growth options have been exercised (henceforth stage n) is

$$L_n(Y) = (1-\gamma_A)(1-\tau)\frac{Z_n Y}{r-\mu} + (1-\gamma_G)\sum_{j=n+1}^{N} G_j(Y) \tag{4}$$

where $(1-\tau)\frac{Z_n Y}{r-\mu}$ is the after-tax present value of all n existing assets in place and $G_j(Y)$ is given in Equation (2).

1.1 Pricing of claims

In this section, we solve the model for a given level of debt and investment thresholds; then, in Section 1.2, we provide the conditions for the choice of optimal leverage and investment policies.

Note that at stage N immediately after having exercised the N-th growth option, the current demand for its products is Y_N^i and the cash flow to the firm is $Z_N Y_N^i$. The firm's decision making is the same as in Leland (1994). The firm defaults on its outstanding debt when the demand for its products is such that it is worthless for shareholders operating the firm (i.e., the demand for the products reaches a lower boundary Y_N^D). In this section, we provide the solutions, while a formal derivation is outlined in Appendix A.

The value of a claim over net income at stage N, $\mathbf{NI}_N(Y)$, is

$$\mathbf{NI}_N(Y) = (1-\tau)\left[\frac{Z_N Y}{r-\mu} - \frac{C_N}{r} - p_N^D(Y)\left(\frac{Z_N Y_N^D}{r-\mu} - \frac{C_N}{r}\right)\right] \tag{5}$$

where Z_N is the cash-flow multiplier after the exercise of the N-th growth option, C_N is the coupon payment, Y_N^D is the default threshold, and $p_N^D(Y)$ is the present value of \$1 to be received at the time of default. The derivation of a closed form for Y_N^D is provided in Appendix A. We provide the expression for $p_N^D(Y)$ in Appendix B.

The value of a claim over the cash flows to the firm at stage N, $\mathbf{CF}_N(Y)$, can be obtained from Equation (5) by letting the coupon be equal to zero.

$$\mathbf{CF}_N(Y) = (1-\tau)\left[\frac{Z_N Y}{r-\mu} - p_N^D(Y)\frac{Z_N Y_N^D}{r-\mu}\right] \tag{6}$$

The value of debt immediately after exercising the N-th growth option is

$$\mathbf{TD}_N(Y) = \left(1 - p_N^D(Y)\right)\frac{(1-\tau^d)C_N}{r} + p_N^D(Y)L_N(Y_N^D), \tag{7}$$

where τ^d is the personal tax rate on interest income and $L_N(Y_N^D)$ is the firm liquidation value at default, which is defined in Equation (4). Note that debt is issued at par, which implies that we can find an expression for the principal, P_N, as a function of C_N. This is easily solved numerically by imposing the expression on the right-hand side of Equation (7) to be equal to P_N.

As in Morellec, Nikolov, and Schürhoff (2012), managers can divert a percentage ϕ of net income to their own private benefit. Therefore, cash flows to equity are equal to $(1-\phi)\mathbf{NI}_N(Y)$. The parameter ϕ is modeled as an unobservable diversion of cash flows from the firm, and it captures many managerial actions that would lead to a loss of value for shareholders, such as stealing resources from the company or making suboptimal decisions (e.g., hiring friends not qualified for the job), and so on.

The total firm value reflects the expected net present value (NPV) of the cash flows to equity plus the NPV of the cash flows to debt holders minus managers compensation. It follows that firm value is equal to

$$\mathbf{V}_N(Y) = \underbrace{(1-\phi)\mathbf{NI}_N(Y)}_{\text{NPV of cash flows to equity}} + \underbrace{\mathbf{TD}_N(Y)}_{\text{NPV of cash-flows to debt holders}} - \underbrace{\kappa\mathbf{CF}_N(Y)}_{\text{Compensation to managers}} \tag{8}$$

Equity value is equal to firm value minus the value of debt:

$$\mathbf{E}_N(Y) = \mathbf{V}_N(Y) - \mathbf{TD}_N(Y) \tag{9}$$

As in Nikolov and Whited (2014) and Morellec, Nikolov, and Schürhoff (2012), we assume that the manager (i) owns a fraction φ of equity, (ii) diverts a percentage ϕ of net income to her own private benefits, and (iii) receives compensation based on the size of the firm ($\kappa\mathbf{CF}_N(Y)$). As is standard for this class of models, the firm issues debt to pay for the exercise cost of its growth option, and any excess proceeds from debt are paid to shareholders. Therefore, the value of the manager's claim to cash flow at stage N is

$$\mathbf{M}_N(Y) = \underbrace{\varphi\mathbf{V}_N(Y)}_{\text{Managers owns fraction } \varphi} + \underbrace{\phi\mathbf{NI}_N(Y)}_{\text{Manager ``steals'' a fraction } \phi} + \underbrace{\kappa\mathbf{CF}_N(Y)}_{\text{Manager compensation linked to firm size}} \tag{10}$$

The first term on the right-hand side of Equation (10) captures how much "skin in the game" the manager has. As in Morellec, Nikolov, and Schürhoff (2012), the manager owns a portion φ of equity, and any proceeds from debt issuance (after having paid the cost of exercising the growth option) go to equity holders in the form of a one-time dividend payment; therefore, maximizing shareholders' value is equivalent to maximizing firm value.[7]

We refer to κ as the post-tax compensation parameter since it allows our model to capture the well-established empirical fact that executive compensation increases with firm size. Also, the parameter κ captures the possibility for managerial empire-building preferences in our model. This definition of empire-building preferences is consistent with those used in Nikolov and Whited (2014). As in Nikolov and Whited (2014), we do not remove this portion that is paid out to managers from the gross income because the model parameters would not be identified as κ, and ϕ would have the same effects on the simulated moments discussed later. Therefore, we could not estimate the model, which is the main goal of this study. This is a simplification in the interest of identification, but it does not affect the results quantitatively and is likely to have a minor quantitative effect. Indeed, removing the compensation of the manager from gross income would decrease the amount of taxes paid, while this is not the case in our modeling choice. Therefore, the difference is only equal to the compensation multiplied by the marginal tax rate.

Next, we provide the closed-form solutions for the stage n claims (for $0 < n < N$); for a formal derivation, please see Appendix A. The value of a claim to net income at stage n is

$$\mathbf{NI}_n(Y) = \underbrace{n_n(Y)}_{\substack{\text{NPV of net income}\\ \text{over one stage}}} + p_n^i(Y)[\underbrace{\mathbf{NI}_{n+1}(Y_{n+1}^i)}_{\substack{\text{Net income claim}\\ \text{at stage } n+1}} - \underbrace{I_{n+1}}_{\substack{\text{Cost for exercising}\\ \text{the growth option}}}] \tag{11}$$

where

$$n_n(Y) = (1-\tau)\left[\frac{Z_n Y}{r-\mu} - \frac{C_n}{r} - p_n^i(Y)\left(\frac{Z_n Y_{n+1}^i}{r-\mu} - \frac{C_n}{r}\right) - p_n^D(Y)\left(\frac{Z_n Y_n^D}{r-\mu} - \frac{C_n}{r}\right)\right] \tag{12}$$

$n_n(Y)$ is the value of a claim over net income over one stage (i.e., before default and before exercising the next growth option), Y_{n+1}^i is the investment threshold at which the $n+1$-th growth option is exercised, Y_n^D is the default threshold at which the firm defaults conditional on not having exercised the $n+1$-th growth option, I_{n+1} is the cost incurred by the firm to exercise the $n+1$-th growth option, $p_n^D(Y)$ is the present value of \$1 to be received at the time of default, conditional on default occurring before the investment in the next growth opportunity, and $p_n^i(Y)$ is the present value of \$1 to be received when the next growth option is exercised, conditional on investment in the growth

[7] This is the same mechanism as in Leland (1994), where maximizing the value for shareholders is equivalent to maximizing the value of the firm.

option occurring before default. We provide the expressions for $p_n^D(Y)$ and $p_n^i(Y)$ in Appendix B. The value of a claim over the cash flows to the firm at stage n, $\mathbf{CF}_n(Y)$, can be easily obtained from Equation (11) by letting the coupon be equal to zero.

$$\mathbf{CF}_n(Y) = (1-\tau)\left(\frac{Z_n Y}{r-\mu} - p_n^i(Y)\frac{Z_n Y_{n+1}^i}{r-\mu} - p_n^D(Y)\frac{Z_n Y_n^D}{r-\mu}\right) + p_n^i(Y)\cdot(\mathbf{CF}_{n+1} - I_{n+1}) \tag{13}$$

The value of current debt at stage n is

$$\mathbf{D}_n(Y) = \frac{(1-\tau^d)C_n}{r}[1 - p_n^i(Y) - p_n^D(Y))] + p_n^D(Y)\cdot L_n(Y_n^D) + p_n^i(Y)\cdot P_n \tag{14}$$

where $L_n(Y_N^D)$ is the liquidation value of the firm at default and its expression is provided in Equation (4). The first term in Equation (14) represents the value of outstanding debt before either default or the next growth option exercise happens. The second term measures the net present value of what debt holders would receive at default, which is given by the product of the $p_n^D(Y)$ and the firm liquidation value $L_n(Y_n^D)$. The third term measures the net present value of the debt repayment at par (P_n) if the firm exercises the next growth option (conditional on default not having happened). Note that debt is issued at par, which implies that we can find an expression for P_n as a function of C_n:

$$P_n = \frac{(1 - p_n^i(Y_n^i) - p_n^D(Y_n^i))(1-\tau^d)\frac{C_n}{r} + p_n^D(Y_n^i)L_n(Y_n^D)}{1 - p_n^i(Y_n^i)} \tag{15}$$

The derivation of Equation (15) is provided in Appendix A.

The value of total debt, $\mathbf{TD}_n(Y)$, should include not only the current outstanding debt but also the debt that will be issued in the future. Its value is equal to

$$\mathbf{TD}_n(Y) = \frac{(1-\tau^d)C_n}{r}\left(1 - p_n^i(Y) - p_n^D(Y)\right) + p_n^D(Y)L_n(Y_n^D) + p_n^i(Y)\mathbf{TD}_{n+1}(Y_{n+1}^i). \tag{16}$$

The first term measures the value of total debt conditional on the firm not having exercised the next growth option or having defaulted. The second term measures the value of total debt when the firm defaults. The third term in Equation (16) measures the present value of total debt at the next investment threshold (i.e., when the next growth opportunity is exercised).

It follows that total firm value is

$$\mathbf{V}_n(Y) = (1-\phi)\mathbf{NI}_n(Y) + \mathbf{TD}_n(Y) - \kappa\mathbf{CF}_n(Y) \tag{17}$$

and the value of equity at stage n is

$$\mathbf{E}_n(Y) = \mathbf{V}_n(Y) - \mathbf{D}_n(Y) \tag{18}$$

Similar to stage N, the manager's claim consists of three components: she can divert a percentage ϕ of net income to her own private benefits, she owns a portion of the firm φ, and she receives compensation based on the size of the firm ($\kappa\mathbf{CF}_N(Y)$). The value of the manager's claim to cash flow at stage n is

$$\mathbf{M}_n(Y) = \varphi\mathbf{V}_n(Y) + \phi\mathbf{NI}_n(Y) + \kappa\mathbf{CF}_n(Y) \tag{19}$$

In stage 0, the firm has no assets in place and is fully financed with equity (i.e., it has no outstanding debt); therefore, it never defaults ($Y_0^D = 0$). The equity value $\mathbf{E}_0(Y)$ should solve the standard ODE for $Y \leq Y_1^i$:

$$\mu Y\mathbf{E}_0'(Y) + \frac{1}{2}\sigma^2 Y^2\mathbf{E}_0''(Y) - r\mathbf{E}_0(Y) = 0$$

subject to the value-matching conditions:

$$\mathbf{E}_0(Y_1^i) = \mathbf{V}_1(Y_1^i) - I_1$$
$$\mathbf{E}_0(0) = 0$$

The solution to this problem is

$$\mathbf{E}_0(Y) \equiv \mathbf{V}_0(Y) = \left(\frac{Y}{Y_1^i}\right)^{\beta_1}\left(\mathbf{V}_1(Y_1^i) - I_1\right) \tag{20}$$

where Y_1^i is the optimal investment threshold that is discussed in Section 1.2. Note that $\mathbf{V}_0(Y_1^i) \equiv \mathbf{E}_0(Y_1^i)$ since at time 0 the firm is fully financed with equity.

At time 0 the firm has no assets in place, and therefore, the value of a claim over net income is simply equal to a barrier option with threshold at Y_1^i:

$$\mathbf{NI}_0(Y) = \left(\frac{Y}{Y_1^i}\right)^{\beta_1}\mathbf{NI}_1(Y_1^i) \tag{21}$$

and

$$\mathbf{CF}_0(Y) = \left(\frac{Y}{Y_1^i}\right)^{\beta_1}\mathbf{CF}_1(Y_1^i) \tag{22}$$

It follows that the manager's claim at stage 0 is

$$\mathbf{M}_0(Y) = \varphi \mathbf{V}_0(Y) + \phi \mathbf{NI}_0(Y) + \kappa \mathbf{CF}_0(Y) \tag{23}$$

1.2 Optimal policies

In this section, we describe how the firm chooses the optimal policies for leverage as well as investment, default, and restructuring thresholds.

We assume that managers make both investment and financing decisions and that the firm is financially constrained and needs to issue debt to exercise its growth options. At any stage n, managers maximize $\mathbf{M}_n(Y)$. More specifically, at stage N (i.e., when there are no more growth options for the firm), managers simply choose the coupon C_N to maximize the value of their claim subject to the condition that the firm defaults as soon as the injection of an additional unit of equity in the firm has an NPV of zero.[8] Formally, the optimization problem faced by managers at this stage is the following:

$$C_N = \mathrm{argmax}_C \mathbf{M}_N(Y_N^i, C) \tag{24}$$

subject to the smooth-pasting condition:

$$\left\{ Y_N^D : \frac{\partial \mathbf{E}_N(Y, C_N)}{\partial Y} |_{Y = Y_N^D} = 0 \right\} \tag{25}$$

The solution to the maximization problem in Equation (24) and (25) can be attained using standard numerical procedures. Note that, as in Leland (1994), it is possible to find a closed-form expression for the default threshold using Equation (25):

$$Y_N^D = \frac{r - \mu}{r} \frac{\beta_2}{\beta_2 - 1} \frac{C_N}{Z_N} \tag{26}$$

where β_2 is the negative root of $\frac{1}{2}\sigma^2 x(x-1) + \mu x - r = 0$.

At any stage n such that $0 \leq n < N$, the firm still has unexercised growth options, and therefore managers choose the coupon C_n to maximize the value of their claim subject not only to the optimality of the default boundary but also to the optimality with respect to the investment threshold. Formally, the optimization problem faced by managers is the following:

$$C_n = \mathrm{argmax}_C \mathbf{M}_n(Y_n^i, C) \tag{27}$$

subject to the optimal investment and default thresholds that satisfy the following smooth-pasting conditions:

[8] This is the standard smooth-pasting condition described in Dumas (1991). For a textbook treatment, see Dixit and Pindyck (1994) and Stokey (2008).

$$\left\{ Y^i_{n+1} : \begin{array}{l} \left[\varphi \frac{\partial \mathbf{E}_n(Y, C_n)}{\partial Y} + \phi \frac{\partial \mathbf{NI}_n(Y, C_n)}{\partial Y} + \kappa \frac{\partial \mathbf{CF}_n(Y, C_n)}{\partial Y}\right]|_{Y=Y^i_{n+1}} = \\ \left[\varphi \frac{\partial \mathbf{V}_{n+1}(Y, C_{n+1})}{\partial Y} + \phi \frac{\partial \mathbf{NI}_{n+1}(Y, C_{n+1})}{\partial Y} + \kappa \frac{\partial \mathbf{CF}_{n+1}(Y, C_n)}{\partial Y}\right]|_{Y=Y^i_{n+1}} \end{array} \right\} \tag{28}$$

$$\left\{ Y^D_n : \frac{\partial \mathbf{E}_n(Y, C_n)}{\partial Y}|_{Y=Y^D_n} = 0 \right\} \tag{29}$$

Equation (28) can be derived from the following value-matching conditions:

$$\underbrace{\mathbf{E}_n(Y^i_{n+1}) + P_n}_{\mathbf{v}_n(Y^i_{n+1})} = \mathbf{V}_{n+1}(Y^i_{n+1}) - I_{n+1}$$

$$\mathbf{NI}_n(Y^i_{n+1}) = \mathbf{NI}_{n+1}(Y^i_{n+1}) - I_{n+1}$$

$$\mathbf{CF}_n(Y^i_{n+1}) = \mathbf{CF}_{n+1}(Y^i_{n+1}) - I_{n+1}$$

The first value-matching condition states that, when the firm reaches the investment threshold at stage n, its value should be equal to the value of the firm at stage $n+1$ immediately after the exercise of the growth option minus the investment cost (I_{n+1}). The second and third value-matching conditions immediately follow from Equation (11) and Equation (13). Note that the optimization described by Equations (27) to (29) is with respect to the manager's choices. In the absence of agency conflicts, shareholders would make different decisions that would lead to a higher firm value. While Equations (27) to (29) describe the optimal decisions of the manager, it is possible to derive the optimal decision for shareholders in the absence of agency conflicts by setting both ϕ and κ equal to zero.

Last, from the conditions described, it is possible to infer how the agency friction parameters ϕ and κ affect optimal policies. The manager would like to maximize $\mathbf{M}_0(Y) = \varphi\mathbf{V}_0(Y) + \phi\mathbf{NI}_0(Y) + \kappa\mathbf{CF}_0(Y)$. Using Equation (20), it is possible to show that shareholders would like to maximize

$$\mathbf{V}_0 = \mathbf{E}_0 = \left(\frac{Y}{Y^i_1}\right)^{\beta_1} \left(\underbrace{(1-\phi)\mathbf{NI}_1(Y^i_1) + \mathbf{TD}_1(Y^i_1) - \kappa\mathbf{CF}_1(Y^i_1)}_{\mathbf{v}_1(Y^i_1)} - I_1 \right)$$

For $\phi = \kappa = 0$, the objectives of the manager and shareholders are clearly aligned since both entail maximizing $\mathbf{V}_0$. However, this is not true any more as soon as either κ or ϕ (or both) are greater than zero.

Last, we note that in our model there are no conflicts of interest between shareholders and debtholders, consistent with the findings in Sundaresan, Wang, and Yang (2015). For a model that introduces agency conflicts between shareholders and debtholders in similar settings, we refer to Mauer and Sarkar (2005). Mauer and Sarkar (2005) show that shareholders overinvest (i.e., exercise the option earlier) compared to the "firm-maximizing" strategy, therefore showing a different mechanism through which underinvestment and overinvestment can influence firms' behavior. Differently from them, we show that agency conflicts of managers versus shareholders (and debtholders) can also lead to either overinvestment or underinvestment, depending on the degree of ϕ and κ.

2. Calibration and Comparative Statics

This section discusses the predictions of our model and provides a discussion of the effects that the consumption of private benefits, ϕ, and the post-tax compensation, κ, parameters have on the investment and financing decisions. Figure 1 provides a visualization of overinvestment and underinvestment in our model. For the rest of this paper, we use $N=2$ growth options, with the exception of Figure 1, which uses $N=1$ for illustrative purposes.

In the absence of agency conflicts between managers and shareholders ($\phi = \kappa = 0$), the manager would behave in the best interest of shareholders and would make decisions that maximize the value of the firm, which is equivalent to maximizing the value of equity since in our model there are no conflicts of interest between shareholders and debtholders. We refer to this strategy as the "equity-maximization" strategy. The investment threshold corresponding to the equity-maximization strategy is denoted with $Y^i_{EquityMax}$, and it corresponds to the case where both ϕ and κ are set equal to zero.[9] A strategy that leads to underinvestment corresponds to the case where managers invest later compared to what would be optimal for shareholders ($Y^i_{ManagerMaximization,Case1} > Y^i_{EquityMax}$ in Figure 1). Delaying investment is equivalent to underinvesting since investing later compared to what would be optimal for shareholders means that, on average, the firm invests less. Similarly, a strategy that leads to overinvestment entails the case where managers invest sooner compared to what would be optimal for shareholders ($Y^i_{ManagerMaximization,Case2} < Y^i_{EquityMax}$ in Figure 1). Investing early is equivalent to overinvestment since, on average, the firm invests more often compared to what would be optimal for shareholders.

[9] For simplicity, we discuss the case of a firm with one growth option. That is, we assume that $N = 1$ for the model discussed in Section 1.

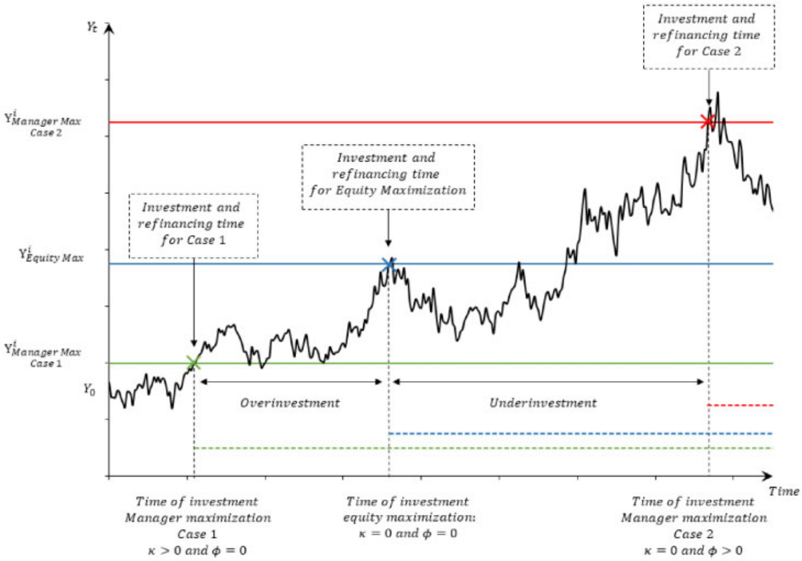

Figure 1
Visualization of overinvestment and underinvestment
This figure provides a visualization of overinvestment and underinvestment in the model. The horizontal line corresponding to $Y^i_{EquityMax}$ shows the investment threshold according to the equity-maximizing strategy; the horizontal dashed line that starts at the time of the investment depicts the endogenous default threshold. The horizontal line corresponding to $Y^i_{ManagerMaximization,Case1}$ shows the investment threshold according to a strategy that leads to underinvestment (e.g., $\kappa > 0$ and $\phi = 0$). Compared to the equity-maximization case, managers in Case 1 choose a higher investment threshold and wait to invest until the demand for the firm's products reaches a higher level. Similar to the equity-maximizing case, the horizontal dashed line that starts at the time of the investment depicts the endogenous default threshold. Last, the horizontal line corresponding to $Y^i_{ManagerMaximization,Case2}$ shows the investment threshold according to a strategy that leads to overinvestment (e.g., $\kappa = 0$ and $\phi > 0$). Compared to the equity-maximizing case, managers in Case 2 choose a lower investment threshold and invest sooner (i.e., when the demand for the firm's products reaches a lower level compared to the level chosen by the equity-maximization strategy).

2.1 Effect of agency conflicts on investment and leverage

We define agency conflicts very broadly in our model. Specifically, managers can take two types of actions that are not maximizing shareholders' value. They can either "shirk" by consuming private benefits (i.e., captured by a higher value of ϕ in our model), or they can overinvest by letting the company grow more than what would be optimal for shareholders if they derive utility from running larger firms (i.e., if their compensation grows with firm size).

Examples of the first type of agency conflicts (consumption of private benefits) include such actions as stealing from the company or hiring family and friends that are not qualified for the job. In this aspect, our model is close to Morellec, Nikolov, and Schürhoff (2012), who study the level of private benefits that make their model fit the observed financing decisions by the firm. We differentiate from them because we study the implications that the consumption of private benefits has on the joint determination of investment and leverage rather than leverage alone. As we will show, our model predicts that when managers consume private benefits, they not only use less leverage compared to the equity-maximization strategy—consistent with Morellec, Nikolov, and Schürhoff (2012)—but also invest less, thus underinvesting.

As for the agency conflict related to managers deriving utility from running larger firms, Nikolov and Whited (2014) show that making compensation more tightly linked to firm size leads managers to invest more than what would be optimal for shareholders, and they abstract from financing choices. Differently from theirs, our model analyzes both investment and financing choices. As will be shown, when managers' compensation is more tightly linked to firm size, managers invest more—consistent with Nikolov and Whited (2014)—while the effect on leverage is marginal. In other words, this second type of agency conflict has an effect on investment and only marginally affects leverage.

A summary of the model parameters is provided in Table 1. Table 2 reports the comparative statics describing the effects of the main parameters of the model on the firm's financing and investment decisions.

The values of the base case parameters have been chosen as follows. The risk-free rate, r, is set to 2.44%, which is the average yield for the three-month Treasury bill in the United States from January 1992 to December 2019. We set the corporate tax rate $\tau^c = 35\%$ calibrated to the highest marginal tax rate in the United States; we set the tax rate on dividends $\tau^e = 11.5\%$. Note that the tax rate on dividends is in line with the Reconciliation Act of 2003, which reduced the maximum tax rate on dividends from 38% to 15%. As for the corporate tax rate, the Tax Cuts and Jobs Act of 2017 prescribed a flat 21% corporate tax rate starting from January 1, 2018. Since this change affects only a very small portion of our sample (years 2018–2019), we applied the tax rate prevalent for the rest of our sample (1992–2019). The personal tax rate on interest income $\tau^d = 29.6\%$ according to the estimates in Graham (1999). The effective tax rate for the firm (including both corporate and personal taxes on dividend) is $\tau = 1 - (1 - \tau^c)(1 - \tau^e)$; τ is equal to 42.48% in our calibration, and it yields a tax advantage of debt over equity of $\tau - \tau^d = 12.875\%$, which is in line with the values used by other authors (see, for example, Hennessy and Whited, 2007). We calibrate the default loss rate for assets in place $\gamma_A = 25\%$ and the default loss rate for unexercised growth options $\gamma_G = 50\%$ as in Sundaresan, Wang, and Yang (2015). The managerial ownership $\varphi = 5.68\%$ is calibrated to the empirical values as described in Table 4 (see "Ownership including unexercisable options"). As in Hackbarth and Sun (2018), we normalize the initial value of the demand for the firm's products $Y_0 = \$5.00$. We normalize the costs for the exercise of the first and second growth options to \$100

Table 1
Descriptions of model parameters

Parameter	Definition
Y_t	Base cash flow process at time t
r	Risk-free rate
μ	Expected annual growth rate of Y_t
σ	Annual volatility of Y_t
τ^c	Corporate tax rate
τ^e	Personal tax rate on dividends
τ^d	Personal tax rate on interest income
γ_A	Loss rate for assets in place
γ_G	Loss rate for unexercised growth options
φ	Manager's equity stake in the firm including options
ϕ	Managerial consumption of private benefits (% of net income)
κ	Post-tax compensation (% of cash flows to the firm)
z_1, z_2	Production capacity for first and second growth options (i.e., rate at which output is created from assets in place generated by first and second growth options)
I_1, I_2	Investment cost for the first and second growth options (in \$)
Y_1^D, Y_2^D	Endogenous default thresholds in stage 1 and stage 2
Y_1^i, Y_2^i	Endogenous investment thresholds for the first and second growth options
C_1, C_2	Endogenous coupon payments in stage 1 and stage 2

(i.e., $I_1 = I_2 = \$100$).[10] We set the growth rate of the demand for the firm's products under the risk-neutral probability measure $\mu = 0.0\%$ as in Morellec, Nikolov, and Schürhoff (2012), which implies a growth rate of the cash flows under the physical probability equal to the average risk premium in the market.[11]

The volatility of cash flows, $\sigma = 14.1\%$, is calibrated to the observed average volatility of operating income (Compustat variable OIBDP). We normalize the production capacity for the first growth option $z_1 = 1$ as in Sundaresan, Wang, and Yang (2015). We set $z_2 = 0.85$, $\phi = 0.95\%$, and $\kappa = 0.5\%$ in line with the estimated values discussed in Section 4.2. The equity-maximization case corresponds to the case where $\phi = \kappa = 0$, while all other parameters are the same as in the base case.

Panel A of Table 2 shows that the leverage optimally chosen by managers decreases in ϕ (i.e. the consumption of private benefits decreases), consistent with Morellec, Nikolov, and Schürhoff (2012). Thus, our model is consistent with the cash-flow theory (Jensen, 1986, 1993), according to which debt acts as a disciplining device for managers.

[10] Calibrating the costs for the exercise of the growth option to $I_1 = I_2 = \$100$ has implications for the level of the investment threshold Y_1^i and Y_2^i, but it does not qualitatively affect the results of the paper since our interest is in the difference between investment with and without agency costs. In other words, reducing the costs for the exercise of the growth options will make all firms invest sooner. However, without agency conflicts, firms would invest even sooner, thus confirming that firms are underinvesting in the presence of agency conflicts (i.e., they are delaying investment).

[11] Note that the growth rate of cash flows follows the same process as the demand for the firm's products, Y_t; hence, Equation (1) implies that the growth rate of cash flows is normally distributed with mean μ and volatility σ over the time interval dt under the risk-neutral probability measure. As in Morellec, Nikolov, and Schû¥rhoff (2012), this also implies that the mean growth rate of cash flows under the physical probability measure is $g \cdot dt = (\mu + \beta \times ERP) \cdot dt$, where β is the unlevered cash-flow beta and ERP is the equity risk premium.

Table 2
Comparative statics of the model

A. Comparative statics with respect to equity maximization case

	Y_1^i	Y_2^i	Y_1^D	Y_2^D	Lev_1	Lev_2
Equity maximization, $\phi = 0\%$ and $\kappa = 0\%$	7.350	9.385	0.975	2.730	0.920	0.515
$\phi = 0.5\%$ and $\kappa = 0\%$	7.073	10.661	2.377	2.013	0.612	0.421
$\phi = 0\%$ and $\kappa = 0.5\%$	6.924	6.585	0.959	2.465	0.086	0.565

B. Comparative statics with respect to base case

	Y_1^i	Y_2^i	Y_1^D	Y_2^D	Lev_1	Lev_2
Base, $\phi = 0.5\%$ and $\kappa = 0.5\%$	8.214	8.170	2.565	1.996	0.182	0.483
$\varphi = 5\%$	8.206	8.116	2.401	1.606	0.171	0.454
$\varphi = 10\%$	7.613	9.101	0.980	2.228	0.747	0.440
$\sigma = 12.5\%$	7.124	6.498	1.041	2.022	0.092	0.490
$\sigma = 16.5\%$	8.905	9.157	2.294	1.818	0.448	0.425
$\mu = -0.1\%$	8.293	8.421	2.587	1.985	0.508	0.472
$\mu = +0.1\%$	7.329	6.435	0.996	1.840	0.086	0.480
$\tau_c = 32.5\%$	7.460	6.580	0.961	1.438	0.083	0.386
$\tau_c = 37.5\%$	8.478	8.049	2.880	2.359	0.199	0.580
$\gamma_A = 35\%$	8.225	8.239	2.395	1.881	0.489	0.453
$\gamma_A = 15\%$	8.203	8.084	2.751	2.126	0.208	0.516
$\gamma_G = 45\%$	8.207	8.177	2.569	1.996	0.183	0.482
$\gamma_G = 55\%$	8.221	8.162	2.560	1.995	0.181	0.483

This table shows the comparative statics of the model. In the equity-maximization case (panel A), we set $\phi = \kappa = 0$ (i.e., no agency conflicts), while keeping all other parameters as in the base case, described here. The parameter values corresponding to the base case (panel B) are as follows: risk-free rate $r = 2.44\%$, growth rate of the cash-flow process $\mu = 0.0\%$, volatility of the cash-flow process $\sigma = 14.1\%$, corporate tax rate $\tau^c = 35\%$, dividend tax rate $\tau^e = 11.5\%$, personal tax rate on interest income $\tau^d = 29.6\%$, default loss rate for assets in place $\gamma_A = 25\%$, default loss rate for unexercised growth options $\gamma_G = 50\%$, initial value of demand for firm's products $Y_0 = \$5$, the managerial ownership $\varphi = 5.68\%$. We set $\phi = 0.5\%$ and $\kappa = 0.5\%$. The production capacities for the two growth options are $z_1 = 1$ and $z_2 = 0.9$. For a discussion of the choice of the base case parameters, see Section 2. Relative to the base case, we increase or decrease a parameter according to the value in column 1 (first from left) while keeping everything else the same.

However, contrary to the prediction that investment and leverage are negatively correlated, our model shows that as ϕ increases, managers not only reduce leverage but also delay investment, thus underinvesting compared to the equity-maximization case (Y_2^i is increasing sharply in ϕ, while Y_1^i is marginally affected). As we show later, once we calculate the investment rate in our simulation, this effect will be clearer. Since investment has to be funded with external funds (debt), managers prefer to delay investment and issue less debt in the future when the firm value has increased such that the growth option can be exercised without making the firm too levered.

In a model with no consumption of private benefits ($\phi = 0$ and $\kappa = 0$), it would never be optimal for managers to deviate from the equity-maximization case since doing so would decrease both firm value and the value of the manager's claim. However, if managers can consume private benefits, the decrease in the equity portion of the manager's total compensation is lower compared to the increase in consumption of private benefits managers can enjoy due to the firm having lower leverage.[12] This happens because, while managers own only a fraction of the company, they can consume the entirety of private benefits.

The effect of the post-tax compensation parameter, κ, on investment policy is the opposite of ϕ. Panel A of Table 2 shows that increasing κ leads to an early exercise of both growth options, meaning that firms are going to be investing more when κ increases. In our empirical analysis, we further analyze investment behavior through the lenses of investment rate, which is a close measure of how investment is measured empirically.

Panel B of Table 2 shows that the effects of volatility (σ), cash-flow growth (μ), corporate taxes (τ^c), and default costs (γ_A and γ_G) on leverage, investment, and default thresholds are similar to those reported previously in the literature (Hennessy, and Whited 2005; Strebulaev 2007; and Morellec, Nikolov, and Schürhoff 2012). Increasing μ makes the firm more profitable, which leads managers to issue more debt and invest earlier compared to the base case. Consistent with the trade-off theory of capital structure, leverage increases with the corporate tax rate; also, consistent with the literature that studies the effects of taxes on corporate investment (see, for example, Djankov et al., 2010), the model predicts an adverse effect of the corporate tax rate on investment (i.e., investment is delayed when the corporate tax rate increases). The effect of φ, the proportion of the firm owned by the manager, on the variables of interest is consistent with the intuition that if managers own a higher portion of the firm, they will act closer to the way they would in the equity-maximization case. For example, if the manager owned 100% of the firm, then maximizing the manager's claim would be equivalent to maximizing shareholders' value since there are no agency conflicts. When the manager owns less than 100% of the firm, she benefits entirely from any consumption of private benefits ($\phi > 0$), but she bears only a fraction φ of the costs. This intuition is captured in our model, as shown in panel B of Table 2. When φ increases to 10%, managers' choices are closer to the equity-maximization case presented in panel A as is shown by both investment thresholds moving toward the values of the equity-maximization case. The leverage taken by the firm at the exercise of the first and second growth options—which we define as Lev_1 and Lev_2, respectively—also move toward the values of the equity-maximization case.

[12] Managers are deriving their private benefits from net income as in Morellec (2004); decreasing leverage reduces coupon payments and increases the firm's net income, allowing managers to enjoy larger private benefits.

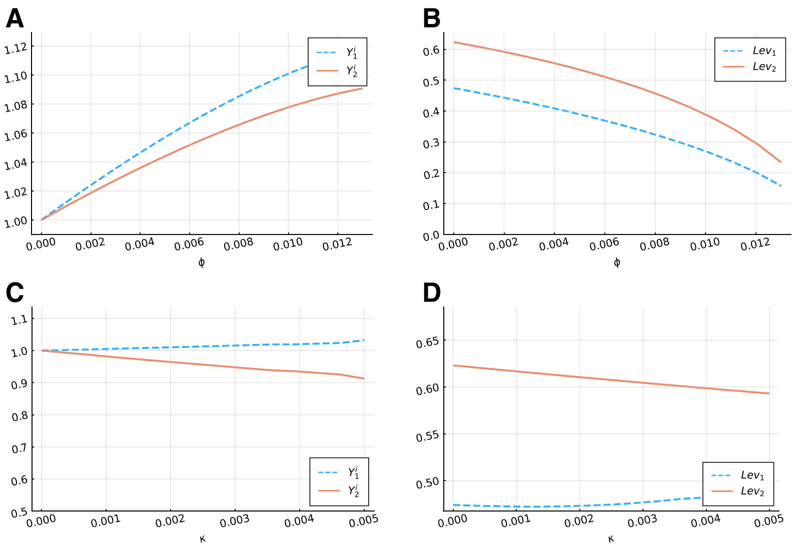

Figure 2
Effect of ϕ (panels A and B) and κ (panels C and D) on investment thresholds and leverage
Panels A and B show the effect that the consumption of private benefits parameter, ϕ, has on the investment thresholds (Y_1^i and Y_2^i) and leverage (Lev_1 and Lev_2). The parameters' values are the same as the base case described in the caption of Table 2 except that κ has been set to zero so that, for $\phi=0$, the level corresponds to the equity-maximization case (i.e., no agency conflicts, $\phi=\kappa=0$). Panel A shows the effect that ϕ has on the two investment thresholds: both Y_1^i (dashed line) and Y_2^i (solid line) increase (i.e., underinvestment becomes more severe) as ϕ increases. We normalize the value of investment thresholds for $\phi=0$ to 1 for ease of comparison. Panel B shows the decrease in quasi-market leverage at the first (Lev_1, dashed line) and second (Lev_2, solid line) investment thresholds as a function of ϕ. Panels C and D show the effect that the post-tax compensation parameter, κ, has on the investment thresholds and leverage. Similar to panel A, the parameters' values are the same as the base case described in Table 2 except that ϕ has been set to zero so that, for $\kappa=0$, the level corresponds to the equity-maximization case. Panel C shows the effect that κ has on the two investment thresholds. For ease of comparison, we normalize to 1 the value of the investment thresholds for $\kappa=0$. Panel D shows the effect of κ on quasi-market leverage at the first (Lev_1) and second (Lev_2) investment point as a function of κ.

2.2 Agency effects on corporate policies

Our model shows that the consumption of private benefits leads to underinvestment for both young firms (firms in stage 0) as well as firms with productive assets in place (firms in stage 1). Consistent with the findings of Morellec, Nikolov, and Schürhoff (2012), our model predicts that an increase in consumption of private benefits would lower the firm's leverage. Panel A of Figure 2 shows the relation between ϕ and the two investment thresholds. Both Y_1^i and Y_2^i increase in ϕ, thus showing that an increase in the consumption of private benefits leads managers to delay investment. Panel B of Figure 2 shows that leverage decreases with an increase in consumption of private benefits. Combined, panels A and B show that, as agency conflicts become more severe (i.e., ϕ increases), managers not only choose a lower level of leverage, consistent with the existing literature (Morellec, Nikolov, and Schürhoff, 2012), but also delay investment, causing underinvestment with respect to the equity-maximization case.

The post-tax compensation parameter, κ, also affects financing and investment decisions. Panel C of Figure 2 shows the effect that κ has on the two investment thresholds: while Y_1^i is almost unaffected by κ, Y_2^i decreases when κ increases, thus showing that an increase in the post-tax compensation parameter leads managers to invest earlier compared to the way they would in the equity-maximization case. Panel D shows that the effect of κ on leverage is modest compared to the effect that ϕ has on the same variable. Combined, panels C and D show that κ has a marginal effect on leverage, while it leads to overinvestment in firms with productive assets in place (Y_2^i decreases as κ increases for firms in stage 1).

Figure 3 shows the joint effect that ϕ and κ have on the investment thresholds (Y_1^i and Y_2^i). Panel A of Figure 3 shows that there exist combinations of ϕ and κ that lead to underinvestment, while some other values of ϕ and κ lead to overinvestment. There is also an indifference curve. For some combinations of ϕ and κ, the investment threshold is the same as the no-agency case ($\phi = \kappa = 0$). Increasing ϕ for any fixed κ leads managers to delay investment. Increasing κ for any fixed ϕ has the opposite effect, as managers invest sooner in the growth option. We also note that this indifference curve is only with respect to the investment threshold Y_2^i, while other moments, such as leverage, would have changed. That is, while we show an indifference curve with respect to Y_2^i for various values of ϕ and κ, we also point out that other moments will have changed, and this allows us to estimate the model as we discuss.

Panel B shows how the first investment threshold (Y_1^i) varies with ϕ and κ. Similar to panel A, increasing ϕ for any fixed κ leads managers to delay investment, albeit the effect is less strong compared to panel A. Differently than in panel A, increasing κ for any fixed ϕ only marginally changes the manager's strategy regarding the exercise of the first growth option. Note that in panel B, as soon as agency conflicts are present, there is underinvestment; hence, there is no indifference curve, contrary to panel A.

Figure 4 shows the joint effect of ϕ and κ on overall firm value at stage 0. We define overall firm value at stage 0 as the sum of firm value, V_0 (as defined in Equation (20)), and the manager's claim, M_0 (as defined in Equation (23)). For any given κ, increasing ϕ strongly decreases overall firm value, and the effect is exponential: for low values of ϕ, the drop in firm value is marginal, while for higher values of ϕ, the firm value drops by more than 10%. For any given ϕ, increasing κ slightly decreases overall firm value, thus showing that the consumption of private benefits is the main driver of the reduction in overall firm value.

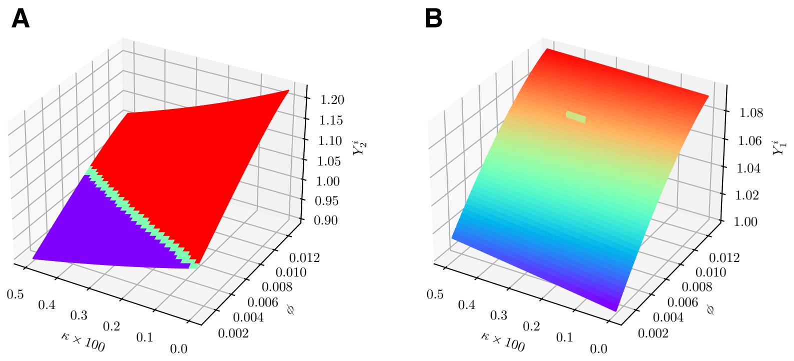

Figure 3
Effects of ϕ and κ have on the first investment threshold (panel A) and the second (panel B) investment thresholds
This figure shows the joint effects that ϕ and κ have on the first (Y_1^i) and the second (Y_2^i) investment thresholds. For ease of comparison, we normalize to 1 the value of the investment threshold corresponding to $\phi = \kappa = 0$. Panel A shows how the second investment threshold (Y_2^i) varies with ϕ and κ. The red/lighter area shows the underinvestment region: for these combinations of ϕ and κ, managers optimally choose a higher investment threshold. The green line shows the indifference curve: the line along which Y_2^i is the same as the no-agency case ($\phi = \kappa = 0$) for various combinations of ϕ and κ. The purple/darker area shows the overinvestment region: for these combinations of ϕ and κ, managers optimally choose a lower investment threshold. Panel B shows how the first investment threshold (Y_1^i) varies with ϕ and κ.

The results discussed show the thresholds as well as leverage levels at the refinancing/investment points. However, the model is dynamic, and a deeper assessment of its predictions should be conducted via simulations, which is the focus of the remaining sections.

3. Empirical Data

We get our financial data from Compustat. Following the literature (see, for example, Hennessy and Whited, 2007), we drop financial firms (SIC codes 6000–6999), utilities (4900–4999), and public administration firms (9000–9999). Observations with missing SIC codes, total assets, common shares outstanding, quasi-market leverage, total q, book equity, or closing price for the fiscal year are excluded. We also exclude firms with a negative book equity and companies for which managerial ownership is equal to 100%, consistent with Nikolov and Whited (2014). We match firms' financial characteristics with executive compensation data obtained from ExecuComp. As in Nikolov and Whited (2014), we consider compensation data only for the top five executives.[13] The resulting panel contains 2,049 firms for the period 1993–2019. A detailed definition of the variables is presented in Table 3.

[13] ExecuComp collects data for up to nine company executives for a given year; however, most companies only report data for the top five. Hence, we consider only the top five executives for all companies.

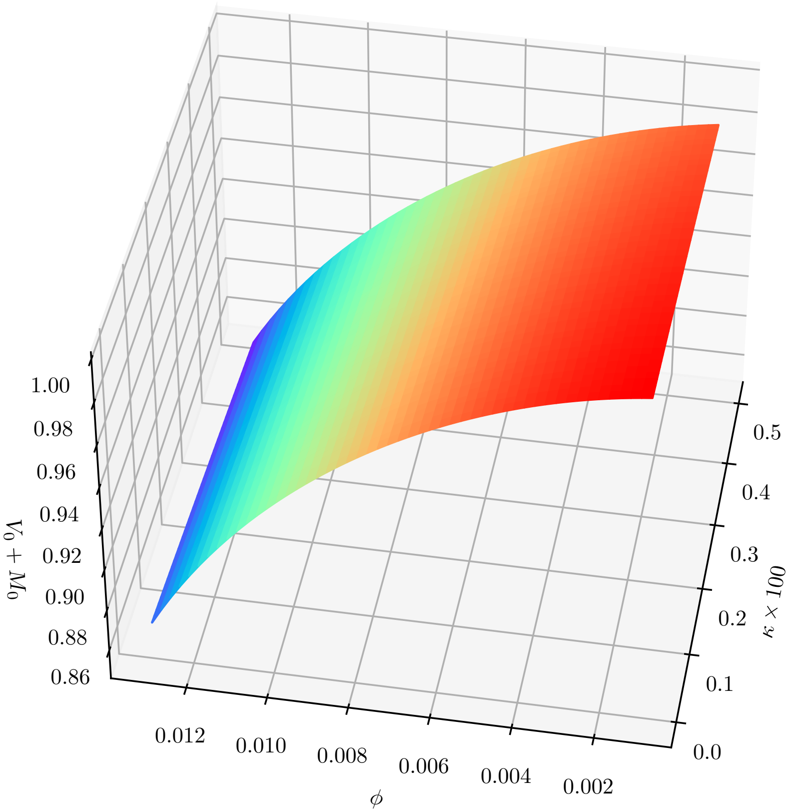

Figure 4
Effects of ϕ and κ on firm value at stage 0
This figure shows the effects that ϕ and κ have on overall firm value at stage 0. We define overall firm value at stage 0 as the sum of firm value, V_0 (as defined in Equation (20)), and the manager's claim, M_0 (as defined in Equation (23)). For ease of comparison, we normalize the value of $V_0 + M_0$ for $\phi = \kappa = 0$ to 1.

In Section 4.2 we sort firms based on CEO characteristics within the industry to check whether groups of firms sorted on these variables exhibit different estimates for the parameters of interest. Table 4 shows the summary statistics for the leverage, total q, book value of assets, managerial total compensation, and ownership share. For each variable, Table A1 shows the summary statistics for the full sample as well as for the sample splits based on CEO age, institutional ownership, as well as total compensation. Since the availability of compensation data is skewed toward large firms, it is not surprising that the median of firm assets in our full sample is \$1.125 billion. The distribution is also skewed as shown by the considerably larger mean of \$5.865 billion. We consider

Table 3
Descriptions of the empirical variables

Variable	Definition
Financial Data (Compustat)	
Book Equity	Stockholders Equity Total (SEQ) + Deferred Taxes and Investment Tax Credit (TXDITC) – Preferred/Preference Stock (Capital) Total (PSTK). If (PSTK) is missing then we use Preferred Stock Redemption Value (PSTKRV); if (PSTKRV) is missing, then we use Preferred Stock Liquidating Value (PSTKL).
Book Debt	Assets total (AT) – Book Equity
Market Value of Equity	Common Shares Outstanding (CSHO) × Price Close Annual Fiscal Year (PRCC_F)
Quasi-Market-Leverage (*Lev*)	Book Debt/(Assets total (AT) – Book equity + Market Value of Equity)
Total Q (Q)	As defined in Peters and Taylor (2017)
Investment Rate (*InvestmentRate*)	(Capital Expenditures (CAPX) + R&D Expense (XRD) + 0.3*(Selling, General, and Administrative Expense (XSGA)))/(Property, Plant, and Equipment Gross Total (PPEGT)+ Intangible Capital) as defined in Peters and Taylor (2017)
Executive Compensation (ExecuComp)	
Managerial Total Compensation (*Compensation*)	[Annual Bonus (BONUS) + Annual Salary (SALARY)]/Assets total (AT)
Managerial Ownership	Shares Owned Options Excluded (SHROWN_EXCL_OPTS)/Common Shares Outstanding (CSHO)
Managerial Ownership with options	(Shares Owned Options Excluded (SHROWN_EXCL_OPTS) + Unexercised Exercisable Options (OPT_UNEX_EXER_NUM))/Common Shares Outstanding (CSHO)
Managerial Ownership with options (alt.)	(Shares Owned Options Excluded (SHROWN_EXCL_OPTS) + Unexercised Exercisable Options (OPT_UNEX_EXER_NUM) + Unexercised Unexercisable Options (OPT_UNEX_UNEXER_NUM)/Common Shares Outstanding (CSHO)
Additional Data	
CEO Age	Age of the CEO (PAGE) as reported in the annual proxy statement in ExecuComp.
Institutional Ownership	Institutional Ownership is a ratio; first we calculate the quarterly ratio as the sum of all shares owned by institutional investors for each security for each quarter divided by total shares outstanding at quarter end. We then calculate the average of the four quarters for each fiscal year.

two compensation variables: managerial total compensation and managerial ownership. Consistent with the literature, we find that managers own only a small fraction (less than 10%) of the firm (Himmelberg, Hubbard, and Palia, 1999).

Table 4
Summary statistics for the main variables used in the structural estimation

	Mean	St.Dev.	25%	50%	75%	# of Obs.
Leverage	0.292	0.181	0.141	0.265	0.418	21,035
Q total	1.303	1.212	0.498	0.906	1.647	21,035
Book assets (in billions)	5.865	19.951	0.421	1.125	3.507	21,035
Investment rate	0.173	0.104	0.096	0.147	0.218	21,035
Compensation (bps)	0.335	0.329	0.090	0.219	0.464	21,035
Ownership	0.033	0.054	0.003	0.009	0.031	21,035
Ownership including exercisable options	0.047	0.058	0.011	0.024	0.056	21,035
Ownership including unexercisable options	0.057	0.061	0.016	0.034	0.071	21,035

This table presents the summary statistics for the main variables used in the structural estimation. We get our financial data from Compustat. We drop financial firms (SIC codes 6000–6999), utilities (4900–4999), and public administration firms (9000–9999). We match firms' financial characteristics with executive compensation data (from ExecuComp) for the top five executives. The resulting panel contains 10,528 observations for the period 1992–2019. A detailed definition of the variables (Leverage, Market to Book, etc.) is presented in Table 3.

4. Structural Estimation

We estimate our model using simulated method of moments (SMM).[14] Our parameters of interest are: the production capacity associated with the second growth option, z_2; the consumption of private benefits parameter, ϕ; and the post-tax compensation parameter, κ. We normalize to 1 the production capacity associated with the first growth option, $z_1 = 1$. Other parameters are calibrated as in the base case scenario, with a description of the calibration rationale provided in Section 2.

The SMM estimator is theoretically simple to implement. We generate a simulated panel of firms using the solution of our model for a given vector of parameters. We then calculate moments based on the simulated data and compare them to the empirical moments observed in the data described in the Section 3 sample. Intuitively, the SMM estimator chooses the vector of unknown structural parameters, $\theta = [z_2, \phi, \kappa]$, to "fit" the simulated moments to their empirical counterparts. We simulate $S = 5$ economies, each consisting of $N = 1,000$ firms for 20 years using the solution of our two-period model for a given θ. To keep the size of the simulated data sets constant over time, defaulting firms are replaced by new ones with the same characteristics.

We estimate the parameters of the model, z_2, ϕ, and κ using the simulated method of moments (SMM). The SMM searches for the vector of parameters, $\theta = [z_2, \phi, \kappa]$, to "fit" the simulated moments to their empirical counterparts. More specifically, we search for the vector of

[14] For a textbook treatment of the simulated method of moments estimator, please see Gourieroux and Monfort (1996). For further details on the use of SMM in dynamic structural models of corporate finance, see Strebulaev and Whited (2012).

parameters that minimizes the weighted distance between the simulated and empirical moments, $\Lambda(\theta)$:

$$\Lambda(\theta) = \left[\widehat{g} - \frac{1}{S}\sum_{i=1}^{S} g_i(\theta)\right]' \widehat{W} \left[\widehat{g} - \frac{1}{S}\sum_{i=1}^{S} g_i(\theta)\right] \tag{30}$$

where $\widehat{g}$ denotes the empirical moments, S is the number of simulated economies, θ is the vector of parameters, $g_i(\theta)$ is the vector of moments for the i-th simulated economy evaluated at θ, and $\widehat{W}$ is a positive definite weighting matrix. It is clear from Equation (30) that the function $\Lambda(\theta)$ is minimized for a a vector of parameters θ that makes the simulated moments ($g_i(\cdot)$) as close as possible to the empirical counterparts ($\widehat{g}$). The optimal weighting matrix is chosen as to place greater weights on more precisely estimated moments (i.e., moments with lower variance):

$$\widehat{W} = \frac{1}{\widehat{N}}[\mathrm{Var}(\widehat{g})]^{-1} \tag{31}$$

where $\widehat{N}$ is the sample size of our empirical data.

4.1 Identification

The selection of moments used in the SMM estimation is important to ensure that the parameters of interest are identified. We choose moments that are a priori informative about the unknown structural parameters. Intuitively, a moment is informative about an unknown parameter if that moment is sensitive to changes in the parameter. We choose four moments: leverage (*Lev*), total q (Q), the average total compensation paid to managers (*Compensation*), and the investment rate (*InvestmentRate*). The moment investment rate is defined as the average investment expenses over assets. More specifically, when the firm exercises growth option i, the investment rate at that time is the cost of growth option i divided by the value of assets. If the firm does not invest in a given period, the investment rate is zero. The average investment rate for a firm j is the average investment rate of such a firm over the 20 years of simulated data. This definition matches the empirical variable for investment rate.

As shown in Figure 5 and Table 5, these moments are informative about the structural parameters of interest in this study. The production capacity associated with the second growth option, z_2, is identified primarily by the investment rate *InvestmentRate*. As shown in panel A, κ negatively affects total q (Q), thus confirming that κ reduces the market value of the firm with respect to the book value of its assets. Panel B of Figure 5 shows that z_2 negatively affects the investment rate. The consumption of private benefits parameter, ϕ, is pinned down primarily by quasi-market leverage (*Lev*). Consistent with previous studies (Morellec,

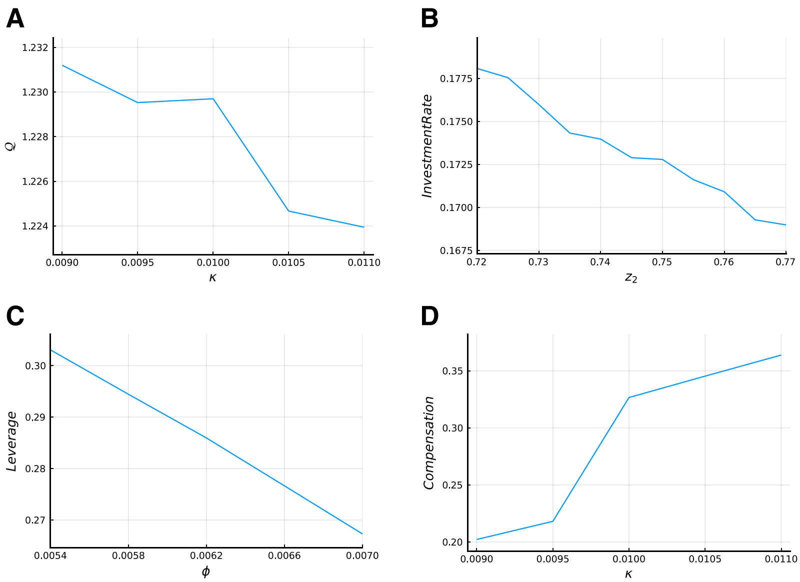

Figure 5
Effects of ϕ and κ on the first investment threshold (panel A) and the second (panel B) investment thresholds
This figure plots the simulated moments (*Leverage*, q, and *Compensation*) as a function of the structural parameters (z_2, ϕ, and κ). Panels A and B plot the market to book Q and the investment rate as a function of z_2. Panel C plots the quasi-market leverage as a function of ϕ, and panel D plots the manager's total compensation as a function of κ. For each plot, we let the structural parameter of interest vary on a fine grid; for each point on the fine grid, we simulate the model and calculate the simulated moments as explained in Section 4.2. All parameters are set to the base case described in the caption of Table 2 except for the parameter of interest in the chart, which is varying according to the x-axis.

Nikolov, and Schürhoff, 2012, 2018), ϕ has a strong negative impact on leverage. In our model, ϕ indeed has a strong effect on quasi-market leverage, as shown by both panel C of Figure 5 and the sensitivity of leverage with respect to ϕ shown in Table 5. Last, the post-tax compensation parameter, κ, is directly related to the average total compensation paid to managers (*Compensation*), as clearly shown in panel D of Figure 5.

4.2 Estimation and counterfactuals: Full sample

We first present the results for the estimation of our model on the full sample and then proceed to the analysis of different slices of the data based on CEO age and institutional ownership. We also present counterfactual experiments for the estimated models.

Table 6 contains estimation results for the full sample. We report the parameters' estimates in panel A, while panel B compares empirical moments with those from the simulated model for various specifications.

Table 5
The sensitivities of the moments used in the simulated method of moments (SMM) estimation

A. Sensitivity of moments (absolute values)

	Leverage	*Q*	*Compensation*	*InvestmentRate*
Base	0.2923	1.2297	0.3266	0.1729
$z_2 = 0.72$	0.2872	1.2307	0.3212	0.1781
$z_2 = 0.77$	0.2961	1.2296	0.3334	0.1690
$\phi = 0.7\%$	0.2673	1.2303	0.3271	0.1750
$\phi = 0.5\%$	0.4194	1.2283	0.2318	0.1661
$\kappa = 1.1\%$	0.2968	1.2239	0.3638	0.1714
$\kappa = 0.9\%$	0.4035	1.2312	0.2022	0.1567

B. Relative changes

	Leverage	*Q*	*Compensation*	*InvestmentRate*
Base				
$z_2 = 0.72$	–1.77%	0.08%	–1.66%	3.00%
$z_2 = 0.77$	1.31%	–0.01%	2.07%	–2.26%
$\phi = 0.7\%$	–8.56%	0.05%	0.15%	1.24%
$\phi = 0.5\%$	43.47%	–0.12%	–29.01%	–3.90%
$\kappa = 1.1\%$	1.52%	–0.47%	11.40%	–0.84%
$\kappa = 0.9\%$	38.03%	0.12%	–38.08%	–9.38%

This table presents the sensitivities of the moments used in the Simulated Method of Moments (SMM) estimation. We run one-dimensional sensitivity analyses on each estimated parameter and check that the selected moment conditions vary monotonically with changes in parameter values (see also Figure 5). The structural parameters estimated via SMM (as described in Section 4.2) are z_2, ϕ, and κ. Model parameters are defined in Table 1. Panel A presents the absolute values of the moments. Row 1 presents the model moments for the base case ($z_2 = 0.745, \phi = 0.59\%, \kappa = 1\%$); in the remaining rows, we change one parameter as outlined in column 1 while keeping everything else the same. Panel B shows the relative changes with respect to the base case.

First, as shown by the low t-statistics for the difference between model-implied and empirical moments, the model does a good job of matching the model moments, suggesting that the consumption of private benefits is sufficient to match the levels of both leverage and investment rate in a model where managers jointly determine financing and investment decisions. That is, the consumption of private benefits not only helps to explain the low leverage in a dynamic structural model, but also allows us to match the level of the investment rate when including irreversible investment.[15] Our estimation also shows that the model is able to match the compensation moment very well while also generating a reasonably high value for total q ($\mathcal{Q}$). The model-implied total q is still lower than the empirical counterpart, but the difference is not statistically different from zero, as shown by the t-statistic of 0.063. The fact that the model-implied moment is lower than the empirical counterpart is not surprising because, for tractability, we restrict our analysis to a model with two growth

[15] Morellec, Nikolov, and Schürhoff (2012) show that the consumption of private benefits helps solve the low-leverage puzzle in a model where managers make financing decisions only; our model considers the joint determination of both financing and investment decisions.

Table 6
Results for the estimation of the model on the full sample

A. Parameters' estimates

z_2	$\phi \times 100$	$\kappa \times 100$
0.745 (0.014)	0.587 (0.004)	1.019 (0.027)

B. Estimated moments

	Leverage	Q	Compensation	Investment rate
Empirical moments	0.292	1.303	0.335	0.173
Model moments	0.293	1.227	0.334	0.173
t-statistic	−0.006	0.063	0.002	0.000

C. Counterfactual for investment rate

	InvRate	Change (%)
Estimated	0.173	
Counterfactual	0.159	7.81%

D. Counterfactual for firm value ($\mathbf{V}_0$)

	V_0	% Change
Estimated	54.11	
Counterfactual	55.25	−2.12%

This table contains the results for the estimation of the model on the full sample. Panel A reports the estimated structural parameters. Panel B reports the empirical and simulated moments. Panel C shows the level of the estimated investment rate (*InvRate*) and their counterfactual value. We refer to the estimated investment rate as the value of *InvRate* that would be optimally chosen by managers given the estimated parameters in panel A. We calculate the counterfactual values setting both ϕ and κ to zero, while keeping the rest of the parameters as estimated in panel A. The "Change (%)" columns are calculated as estimated *InvRate* divided by counterfactual *InvRate* minus 1. Panel D shows firm value at stage 0 ($\mathbf{V}_0$, defined in Equation (20)) in the estimated model as well as in the counterfactual. Standard errors are in parentheses. In Panel B, *t*-statistics test the statistical difference between the empirical moments and model moments. Please see Section 4.2 for further details on the estimation methodology.

options. Empirically, firms are likely to have more opportunities, however, which would lead to a higher level for Q. Last, all parameters are statistically different from zero, which suggests that both ϕ and κ have tangible effects on the firm's investment and financing choices.

Panel C presents the estimated investment rate. We show both the estimated values ("Estimated" row) as well as their counterfactual values. We refer to the estimated investment thresholds as the values that would be optimally chosen by managers given the estimated parameters in panel A. We calculate the counterfactual values by setting both ϕ and κ to zero while keeping the rest of the parameters as estimated in Table 6. The question we would like to address is whether the average firm overinvests or underinvests compared to the equity-maximizing strategy (i.e., if there were no agency conflicts). To answer this question, we look at the investment rate (*InvRate*). The *InvRate* implied by our estimated model is 0.173, while the counterfactual *InvRate* (i.e., if there were no agency conflicts) is lower and equal to 0.159. This means that in the absence of agency conflicts, the average firm would have a lower investment rate; thus, we conclude that the average firm is overinvesting. Analyzing the effect on the investment rate is preferable to analyzing the effect that agency conflicts have on the investment thresholds. Since the firm makes both financing and investment decisions at the same time, it might delay one growth option (e.g., Y_1^i as shown in panel C) and exercise another one earlier (e.g., Y_2^i as shown in panel C). Overall, is the firm under-investing or overinvesting? We would not be able to answer this question by looking only at the investment thresholds, and this is why we calculate the investment rate (*InvRate*), which is able to capture intertemporal effects between the first and second growth options in our model.

Panel D of Table 6 shows the firm value at stage 0 (V_0) in the estimated model as well as in the counterfactual. We refer to the estimated firm value at stage 0 as the value that the firm would have at stage 0 given the parameters estimated in Table 6. As we did for panel C of Table 6, we calculate the counterfactual firm value by setting both ϕ and κ to zero while keeping the rest of the parameters as estimated in panel A of Table 6. The loss in firm value due to agency conflicts is approximately 2.12%. This loss is significant. The median firm size in terms of book assets is $\approx$\$1.1 billion, which implies an average loss in firm value of approximately \$23 million.

4.3 Estimation and counterfactuals: Subsamples

In this section, we study subsamples of our data to investigate variation in over- and underinvestment for various firms' characteristics. We begin with Tables 7 and 8, which contain the structural parameters, the estimated moments, and counterfactuals for the estimation of the model for the following sample splits: (i) firms sorted on the takeover index (Cain, McKeon, and Solomon, 2017), which proxies for the quality of corporate governance; (ii) data sorted on the beginning (1993–2006) versus the late (2006–2019) part of the sample, which allows us to understand the effects of improvements in corporate governance in the late part of the sample with respect to the beginning; and (iii) based on compensation of the top five executives, which allows us to evaluate whether managers whose compensation is more tightly linked to firm size invest more than the others. Since firms in the subsamples are likely to differ in terms of asset volatility, profitability, as well as managerial ownership, we estimate these parameters and recalibrate the models to such parameters for each subsample.[16] Therefore, we calibrate the values of σ, μ, and φ to the estimated values within the subsample following the same methodology described in Section 2 for the full sample. Since the parameter μ

[16] We would like to thank an anonymous referee for this suggestion.

Table 7
Subsample analysis

A. Parameters' estimates

Specification	z_2	$\phi \times 100$	$\kappa \times 100$	σ	μ	φ
Full	0.745	0.587	1.019	0.141	0.000	0.057
	(0.014)	(0.004)	(0.027)			
Takeover Index	0.748	0.279	0.402	0.134	−0.013	0.047
High	(0.015)	(0.036)	(0.013)			
Takeover Index	0.699	0.507	1.112	0.155	0.026	0.073
Low	(0.029)	(0.007)	(0.046)			
2007–2017	0.873	0.678	0.803	0.138	−0.009	0.048
	(0.015)	(0.006)	(0.016)			
1993–2006	0.762	0.554	0.869	0.149	0.013	0.066
	(0.013)	(0.005)	(0.023)			
Comp. High	0.879	0.385	1.182	0.175	0.002	0.080
	(0.000)	(0.000)	(0.013)			
Comp. Low	0.150	1.000	1.057	0.096	−0.001	0.034
	(0.005)	(0.014)	(0.089)			

B. Estimated moments

		Leverage	Q	Compensation	*InvRate*
Full	Empirical	0.292	1.303	0.335	0.173
	Simulated	0.293	1.227	0.334	0.173
T-stat		−0.006	0.063	0.002	0.000
Takeover Index	Empirical	0.314	1.084	0.281	0.150
High	Simulated	0.367	1.269	0.121	0.187
T-stat		−0.302	−0.185	0.540	−0.480
Takeover Index	Empirical	0.264	1.516	0.433	0.208
Low	Simulated	0.290	1.248	0.420	0.173
T-stat		−0.142	0.192	0.036	0.294
2007–2017	Empirical	0.296	1.207	0.276	0.152
	Simulated	0.295	1.240	0.273	0.152
T-stat		0.005	−0.030	0.007	−0.008
1993–2006	Empirical	0.288	1.401	0.397	0.195
	Simulated	0.303	1.259	0.321	0.172
T-stat		−0.084	0.108	0.222	0.200
Comp. High	Empirical	0.244	1.397	0.572	0.203
	Simulated	0.231	1.481	0.671	0.175
T-stat		0.073	−0.062	−0.313	0.257
Comp. Low	Empirical	0.340	1.209	0.098	0.143
	Simulated	0.461	1.013	0.097	0.155
T-stat		−0.689	0.187	0.015	−0.139

This table contains the structural parameters (panel A) and estimated moments (panel B) for the structural estimation of the model for various sample splits. A detailed definition of the variables is presented in Table 3. Standard errors are in parentheses.

represents the risk-neutral growth rate, we set it equal to the subsample average minus the average in the entire sample. The intuition is that μ should capture the growth rate in excess of what is expected by the average firm. Overall, Table 7 shows that our model does a good job at matching the moments for different splits. For φ, we set it equal to the average value for the subsample, which we calculated in Table 4.

The first question we address is whether corporate governance affects managerial behavior. In other words, are managers in firms with "bad" corporate governance deviating more from maximizing shareholders'

Table 8
Counterfactual analysis

		InvRate	Change (%)	V_0	Change (%)
Full	Estimated	0.173		54.11	
	Counterfactual	0.159	7.81%	55.25	−2.12%
Takeover Index	Estimated	0.187		54.52	
High	Counterfactual	0.126	32.96%	54.90	−0.71%
Takeover Index	Estimated	0.173		54.91	
Low	Counterfactual	0.136	21.46%	56.09	−2.16%
2007–2017	Estimated	0.152		61.22	
	Counterfactual	0.163	−7.19%	62.36	−1.86%
1993–2006	Estimated	0.172		57.67	
	Counterfactual	0.156	9.43%	58.70	−1.78%
Compensation High	Estimated	0.175		54.34	
	Counterfactual	0.145	16.82%	55.75	−2.60%
Compensation Low	Estimated	0.155		19.03	
	Counterfactual	0.108	30.01%	19.49	−2.42%

This table presents the counterfactual results for the various models estimated in Table 7. We refer to the "estimated" investment rate (*InvRate*) and firm value ($\mathbf{V}_0$) as the values that would be optimally chosen by managers given the estimated parameters in Table 7. We calculate the "counterfactual" values setting both ϕ and κ to zero, while keeping the rest of the parameters as estimated in Table 7. The "Change (%)" columns show the percentage between estimated and counterfactual values. A detailed definition of the variables is presented in Table 3.

value? Analyzing the results in Table 8 shows that both high- and low-takeover-index (Cain, McKeon, and Solomon, 2017) firms exhibit over-investment, as shown by the fact that the counterfactual investment rates are lower than the estimated ones. Consistent with the intuition that better governance is associated with fewer agency conflicts, high-takeover-index firms experience a lower loss in firm value (–0.71% for high- vs. –2.16% for low-takeover-index firms). This intuition that firms with a high takeover index exhibit lower agency conflicts is also captured by the lower estimated values of ϕ and κ (our agency costs parameters). Both ϕ and κ for high-takeover-index firms are lower than the parameters estimated for low-takeover-index firms, as shown in Table 7. For example, we find that the estimated ϕ is 0.279% for high versus 0.507% for low takeover index. As for the investment behavior, our results show that high-takeover-index firms exhibit a higher level of overinvestment (counterfactual investment rate is 32.96% lower than the estimated one) compared to low-takeover-index firms (counterfactual investment rate is 21.46% lower than the estimated one). This result can be explained by analyzing the difference in φ between the two samples. As shown in Table 7, φ is considerably higher in low-takeover-index than high-takeover-index firms (0.073 vs. 0.047). This result shows that, when making investment decisions, managers that have a greater "skin in the game" (i.e., higher φ) make decisions closer to the equity-maximizing case.

The next question we address is whether there are differences in agency conflicts over time. That is, do agency conflicts vary between the early and the late part of our sample? Table 7 shows that there are small differences in ϕ and κ. Our results show that ϕ—which proxies for consumption of private benefits—is slightly higher in the late part of the sample (0.678% late vs. 0.554% early), while κ—which proxies for managerial preferences for empire-building—is marginally higher in the early part of our sample (0.803% late vs. 0.869% early). The counterfactual analysis in Table 8 shows that firms in the early part of our sample exhibit overinvestment, as shown by the investment rate that is 9.43% smaller under the equity-maximizing strategy. For the later part of our sample, firms exhibit an underinvestment behavior as shown by the investment rate that is –7.19% under the counterfactual of equity-maximizing strategy. Next, we analyze firms based on how tightly linked to firm size their compensation is. We split our sample into "Compensation High" ("Compensation Low") firms, which pay their top five executives more (less) than the median firm. Our results show that firms with high compensation have a considerably lower value of ϕ compared to firms with low compensation. This suggests that when compensation is more tightly linked to firm size, managers exhibit a lower consumption of private benefits. We also find that firms with high compensation exhibit a slightly higher value of κ. This higher value of κ does not translate into a higher investment rate for firms with high compensation, showing that the effect of the differential in ϕ between the two groups of firms is more important than the differential in κ.

In Tables 9 and 10, we present results for additional subsamples. We split firms by CEO age, institutional ownership and firm size (market value of equity), and CEO tenure. Specifically, "Age High" ("Age Low") firms are those with a CEO with above (below) median age; "IO High" ("IO Low") firms are those with higher (lower) institutional ownership compared to the median; "ME high" ("ME low") firms are those with market value of equity above (below) median; last, "Tenure High" ("Tenure Low") firms are those with CEO tenure measured as in Pan, Wang, and Weisbach (2016) above (below) median.

There is evidence that young CEOs manage firms with higher return volatility (Serfling, 2014), which is confirmed by our results in Table 9. Firms with young CEOs (Age Low) have an average volatility of 15.1%, while those with older CEOs have an average volatility of 12.8%. Our analysis also shows that older CEOs exhibit higher values for both ϕ and κ, meaning that agency conflicts are larger than in firms managed by younger CEOs. Table 10 confirms this by showing that the loss in firm value for high-age firms is higher (2.62%) than that of low-age firms (2.19%), thus confirming that firms with older CEOs are subject to larger agency conflicts. As for investment behavior, low-age firms exhibit an overinvestment behavior, while high-age firms show a slight

Table 9
Additional subsample analysis

Panel A—Parameters' estimates

Specification	z_2	$\phi \times 100$	$\kappa \times 100$	σ	μ	φ
Full	0.745	0.587	1.019	0.141	0.000	0.057
	(0.014)	(0.004)	(0.027)			
Age High	0.736	0.582	1.267	0.128	0.006	0.057
	(0.016)	(0.006)	(0.023)			
Age Low	0.672	0.491	1.127	0.151	−0.011	0.057
	(0.013)	(0.009)	(0.041)			
IO High	0.669	0.720	0.789	0.170	−0.008	0.042
	(0.006)	(0.004)	(0.009)			
IO Low	0.708	0.640	1.362	0.126	0.006	0.072
	(0.014)	(0.008)	(0.049)			
ME High	0.766	0.766	0.650	0.124	0.015	0.037
	(0.000)	(0.000)	(0.010)			
ME Low	0.614	0.255	1.546	0.161	−0.017	0.076
	(0.003)	(0.008)	(0.017)			
Tenure High	0.691	0.608	1.106	0.141	0.015	0.071
	(0.016)	(0.005)	(0.033)			
Tenure Low	0.811	0.583	0.933	0.143	−0.022	0.040
	(0.007)	(0.073)	(0.008)			

Panel B—Estimated moments

		Leverage	Q	Compensation	*InvRate*
Full	Empirical	0.292	1.303	0.335	0.173
	Simulated	0.293	1.227	0.334	0.173
t-statistic		−0.006	0.063	0.002	0.000
Age High	Empirical	0.307	1.202	0.299	0.155
	Simulated	0.284	1.182	0.330	0.167
t-statistic		0.129	0.017	−0.101	−0.132
Age Low	Empirical	0.276	1.410	0.372	0.191
	Simulated	0.286	1.237	0.392	0.177
t-statistic		−0.053	0.134	−0.057	0.124
IO High	Empirical	0.291	1.308	0.263	0.163
	Simulated	0.318	1.248	0.232	0.149
t-statistic		−0.155	0.052	0.120	0.145
IO Low	Empirical	0.293	1.297	0.407	0.182
	Simulated	0.296	1.199	0.400	0.181
t-statistic		−0.013	0.078	0.018	0.014
ME High	Empirical	0.278	1.587	0.146	0.160
	Simulated	0.292	1.232	0.137	0.173
t-statistic		−0.084	0.281	0.056	−0.134
ME Low	Empirical	0.306	1.018	0.524	0.186
	Simulated	0.292	1.251	0.600	0.178
t-statistic		0.073	−0.215	−0.220	0.075
Tenure High	Empirical	0.277	1.406	0.353	0.183
	Simulated	0.280	1.229	0.350	0.181
t-statistic		−0.019	0.139	0.010	0.015
Tenure Low	Empirical	0.313	1.165	0.311	0.159
	Simulated	0.309	1.237	0.322	0.160
t-statistic		0.022	−0.064	−0.034	−0.014

This table contains the structural parameters (Panel A) and estimated moments (Panel B) for the structural estimation of the model for various sample splits. A detailed definition of the variables is presented in Table 3. Standard errors are in parentheses.

Table 10
Additional counterfactual analysis

		InvRate	Change (%)	V_0	Change (%)
Full	Estimated	0.173		54.11	
	Counterfactual	0.159	7.81%	55.25	−2.12%
Age High	Estimated	0.167		49.78	
	Counterfactual	0.184	−10.46%	51.08	−2.62%
Age Low	Estimated	0.177		52.72	
	Counterfactual	0.133	24.93%	53.88	−2.19%
IO High	Estimated	0.149		56.29	
	Counterfactual	0.113	24.25%	57.30	−1.79%
IO Low	Estimated	0.181		47.24	
	Counterfactual	0.153	15.31%	48.63	−2.94%
ME High	Estimated	0.173		40.70	
	Counterfactual	0.164	5.31%	41.47	−1.88%
ME Low	Estimated	0.178		50.50	
	Counterfactual	0.155	12.78%	51.79	−2.56%
Tenure High	Estimated	0.181		50.63	
	Counterfactual	0.161	11.33%	51.78	−2.27%
Tenure Low	Estimated	0.160		56.88	
	Counterfactual	0.149	6.96%	57.95	−1.88%

This table presents the counterfactual results for the various models estimated in Table 9. We refer to the "estimated" investment rate (*InvRate*) and firm value ($\mathbf{V}_0$) as the values that would be optimally chosen by managers given the estimated parameters in Table 9. We calculate the "counterfactual" values setting both ϕ and κ to zero, while keeping the rest of the parameters as estimated in Table 9. The "Change (%)" columns show the percentage between estimated and counterfactual values. A detailed definition of the variables is presented in Table 3.

underinvestment, confirming the results in Serfling (2014) that younger CEOs invest more than older ones.

Our results also show that firms with high institutional ownership (IO High), on average, invest more compared to those with lower institutional ownership (IO Low). Indeed, firms with high institutional ownership exhibit an overinvestment of 24.25% (i.e., estimated investment rate is 24.25% higher than its counterfactual), while firms with low institutional ownership exhibit an overinvestment of 15.31%. However, firms with low institutional ownership exhibit a larger loss of firm value due to agency conflicts, as shown by the decrease in firm value of 2.94%, which is larger than the 1.79% measured for firms with high institutional ownership. These results show that institutional ownership is an intuitive proxy for understanding the level of agency conflicts in a firm: high institutional ownership is linked to better governance, which in turn leads to lower agency conflicts. However, this is not true for investment. Higher institutional ownership might be related to better governance, but we do not find evidence that this translates into an investment behavior that is more aligned with shareholders.

When we sort firms based on their market value (ME High vs. ME Low), we also observe differences in agency conflicts. Our results show that larger firms have slightly higher values of ϕ, thus showing that managers in larger firms can exploit higher consumption of private benefits. However, smaller firms exhibit a higher value of κ, thus showing that managers in smaller firms are likely to invest more than what would be optimal for shareholders. This intuition is confirmed by our analysis in Table 10: (i) small firms exhibit a considerable overinvestment, as shown by the fact that under the counterfactual scenario, *InvRate* is 12.78% lower than the estimated *InvRate*, while larger firms have a much milder overinvestment (5.31% lower than counterfactual); and (ii) the loss in firm value is larger (2.56%) for ME Low firms compared to large (ME High) firms, which exhibit a loss in firm value of 1.88%. Last, we estimate the model on subsamples sorted by CEO tenure, which is an indicator for CEO entrenchment. Our findings show that CEOs with a high tenure invest considerably more than those with lower tenure. For firms with high tenure, the investment rate in the counterfactual scenario is 11.33% smaller than the estimated one, thus showing strong overinvestment behavior. For firms with low tenure, we estimate only a slight overinvestment, as shown by the fact that the counterfactual investment rate is 6.96% lower than the estimated one. These results confirm the evidence in Pan, Wang, and Weisbach (2016).

5. Conclusion

We study how agency conflicts affect firms' financing and investing decisions in a dynamic capital structure model with irreversible investment and conflicts between managers and shareholders. We also include the possibility for managerial empire-building preferences in our model following Nikolov and Whited (2014). Our model predicts that when managers consume a percentage of net income as private benefits, they optimally choose (i) lower values of leverage compared to what would be optimal for shareholders and (ii) to delay the exercise of investment opportunities, thus underinvesting compared to the equity maximizing strategy, even with lower optimal leverage.

We estimate our model using simulated method of moments. Our estimation shows that a small consumption of private benefits allows the model to match not only the leverage ratio but also the total q. Our counterfactual analysis shows that the average firm slightly overinvests compared to what would be optimal for shareholders, and that there is heterogeneity in investment when we consider samples of firms sorted on various characteristics: firms with better corporate governance are more aligned with shareholders' objectives, firms with younger CEOs invest more than those with older CEOs, and firms with a higher proportion of institutional ownership exhibit a lower loss in firm value due to agency conflicts.

Appendix A: Proof of the Pricing

A.1 Net Income

After the exercise of the last growth option, the firm net income is equal to $(1-\tau)(Z_N Y_t - C_N)dt$ where $\tau = 1-(1-\tau^c)(1-\tau^e)$. Note that τ represents the total tax rate that takes into account both the corporate (τ^c) and personal (τ^e) tax rates. Let $T_N^D = \inf\{t : Y_t = Y_N^D\}$ be the first time that the demand for the firm's products reaches the default threshold Y_N^D.

The value of the firm's net income can be calculated as follows:

$$\begin{aligned}\mathbf{NI}_N(Y) &= \mathbf{E}[\textstyle\int_0^{T_N^D} e^{-rs}(1-\tau)(Z_N Y_s - C_N)ds | Y_0 = Y] \\ &= \mathbf{E}[\textstyle\int_0^{\infty} e^{-rs}(1-\tau)(Z_N Y_s - C_N)ds | Y_0 = Y] - \\ &\quad \mathbf{E}[\textstyle\int_{T_N^D}^{\infty} e^{-rs}(1-\tau)(Z_N Y_s - C_N)ds | Y_{T_N^D} = Y_N^D] \\ &= (1-\tau)\left[\frac{Z_N Y}{r-\mu} - \frac{C_N}{r} - p_N^D(Y,r)\left(\frac{Z_N Y_N^D}{r-\mu} - \frac{C_N}{r}\right)\right]\end{aligned} \tag{A.1}$$

We now analyze the value of net income at stage n for $0 < n < N$. Without loss of generality, assume that $t=0$ immediately after exercising the n-th growth option. Let $T_{n+1}^i = \inf\{t : Y_t = Y_n^i\}$ be the first time that the demand for the firm's products reaches the investment threshold Y_{n+1}^i and $T_n^D = \inf\{t : Y_t = Y_n^D\}$ be the first time that the demand for the firm's products reaches the default threshold Y_n^D. Let $T = \inf\{T_{n+1}^i, T_n^D\}$ be the minimum between T_{n+1}^i and T_n^D. Similar to the derivation of $\mathbf{NI}_N(Y)$, for any $Y_n^D \leq Y \leq Y_{n+1}^i$, the value of $\mathbf{NI}_n(Y)$ is:

$$\begin{aligned}\mathbf{NI}_n(Y) &= \mathbf{E}[\textstyle\int_0^{T} e^{-rs}(1-\tau)(Z_N Y_s - C_N)ds | Y_0 = Y] \\ &= n_n(Y) + p_n^i(Y,r)\mathbf{NI}_{n+1}(Y_{n+1}^i)\end{aligned} \tag{A.2}$$

where

$$\begin{aligned}n_n(Y) &= \mathbf{E}[\textstyle\int_0^{T} e^{-rs}(1-\tau)(Z_n Y_s - C_n)ds | Y_0 = Y] \\ &= (1-\tau)\left[\frac{Z_n Y}{r-\mu} - \frac{C_n}{r} - p_n^i(Y)\left(\frac{Z_n Y_n^i}{r-\mu} - \frac{C_n}{r}\right) - p_n^D(Y)\left(\frac{Z_n Y_n^D}{r-\mu} - \frac{C_n}{r}\right)\right]\end{aligned}$$

where $p_n^D(Y)$ and $p_n^i(Y)$ are defined in Appendix B.

A.2 Debt

If the firm defaults at stage N, the debt holders receive the right to claim a fraction $1-\gamma_A$ of the (after tax) firm's cash flows. If the firm continues its operations, the continuous cash flows accruing to debt holders are equal to C_N. For, $Y_N^D < Y$, the value of $D_N(Y)$ can be written as

$$\begin{aligned}\mathbf{D}_N(Y) &= \underbrace{\int_0^{T_N^D} e^{-rt}(1-\tau^d)C_N dt}_{\text{Value over one business cycle}} + \underbrace{\int_{T_N^D}^{\infty} e^{-rt}(1-\gamma_A)(1-\tau)\frac{Z_N Y_t}{r-\mu}}_{\text{PV of cash}-\text{flows to debtholders at default}} dt \\ &= \left(1-p_N^D(Y)\right)\frac{(1-\tau^d)C_N}{r} + p_N^D(Y)(1-\gamma_A)(1-\tau)\frac{Z_N Y_N^D}{r-\mu}\end{aligned} \tag{A.3}$$

From Equation (4), we have that $L_N(Y_N^D) = (1-\gamma_A)(1-\tau)\frac{Z_N Y_N^D}{r-\mu}$; substituting it in Equation (A.3), we obtain Equation (7).

Table A1
Summary statistics for main variables

		Mean	St.Dev.	25%	50%	75%	# of Obs.
Leverage	Full	0.292	0.181	0.141	0.265	0.418	21,035
	Takeover Index High	0.314	0.176	0.170	0.291	0.440	8,770
	Takeover Index Low	0.264	0.182	0.106	0.225	0.387	8,788
	2007–2017	0.296	0.177	0.151	0.271	0.418	10,703
	1993–2006	0.288	0.184	0.131	0.259	0.417	10,310
	Compensation High	0.244	0.173	0.100	0.200	0.350	10,517
	Compensation Low	0.340	0.175	0.204	0.320	0.468	10,517
	Age High	0.307	0.177	0.162	0.286	0.432	10,301
	Age Low	0.276	0.182	0.121	0.242	0.400	10,311
	IO High	0.291	0.175	0.145	0.267	0.413	10,517
	IO Low	0.293	0.186	0.136	0.263	0.423	10,517
	ME High	0.278	0.164	0.146	0.259	0.386	10,506
	ME Low	0.306	0.195	0.137	0.275	0.455	10,506
	Tenure High	0.277	0.180	0.123	0.246	0.397	9,931
	Tenure Low	0.313	0.180	0.167	0.288	0.441	8,726
Q total	Full	1.303	1.212	0.498	0.906	1.647	21,035
	Takeover Index High	1.084	0.996	0.449	0.800	1.364	8,770
	Takeover Index Low	1.516	1.395	0.529	1.011	2.009	8,788
	2007–2017	1.207	1.099	0.479	0.880	1.543	10,703
	1993–2006	1.401	1.312	0.515	0.936	1.785	10,310
	Compensation High	1.397	1.351	0.440	0.924	1.846	10,517
	Compensation Low	1.209	1.048	0.542	0.894	1.493	10,517
	Age High	1.202	1.117	0.487	0.854	1.494	10,301
	Age Low	1.410	1.296	0.513	0.976	1.838	10,311
	IO High	1.308	1.165	0.528	0.938	1.647	10,517
	IO Low	1.297	1.259	0.462	0.882	1.647	10,517
	ME High	1.587	1.263	0.716	1.156	2.011	10,506
	ME Low	1.018	1.087	0.324	0.666	1.248	10,506
	Tenure High	1.406	1.272	0.541	0.976	1.816	9,931
	Tenure Low	1.165	1.114	0.444	0.822	1.454	8,726
Book assets (in billions)	Full	5.865	19.951	0.421	1.125	3.507	21,035
	Takeover Index High	8.091	23.785	0.573	1.652	5.197	8,770
	Takeover Index Low	2.026	6.105	0.286	0.666	1.717	8,788
	2007–2017	7.863	25.370	0.537	1.527	4.664	10,703
	1993–2006	3.796	11.640	0.342	0.838	2.506	10,310
	Compensation High	0.575	0.616	0.232	0.423	0.726	10,517
	Compensation Low	11.156	27.199	1.792	3.448	8.798	10,517
	Age High	7.834	24.571	0.522	1.488	4.656	10,301
	Age Low	3.885	13.720	0.349	0.880	2.526	10,311
	IO High	4.271	9.759	0.640	1.504	3.847	10,517
	IO Low	7.459	26.378	0.283	0.761	3.001	10,517
	ME High	11.072	27.243	1.634	3.388	8.788	10,506
	ME Low	0.664	0.761	0.234	0.440	0.805	10,506
	Tenure High	5.199	19.174	0.395	1.016	2.992	9,931
	Tenure Low	6.708	20.930	0.466	1.324	4.165	8,726
Investment rate	Full	0.173	0.104	0.096	0.147	0.218	21,035
	Takeover Index High	0.150	0.079	0.093	0.134	0.186	8,770
	Takeover Index Low	0.208	0.119	0.114	0.178	0.280	8,788
	2007–2017	0.152	0.090	0.086	0.131	0.188	10,703
	1993–2006	0.195	0.112	0.110	0.166	0.254	10,310
	Compensation High	0.203	0.111	0.120	0.175	0.263	10,517
	Compensation Low	0.143	0.086	0.081	0.122	0.177	10,517
	Age High	0.155	0.090	0.090	0.135	0.192	10,301
	Age Low	0.191	0.112	0.104	0.163	0.250	10,311
	IO High	0.163	0.096	0.092	0.141	0.205	10,517
	IO Low	0.182	0.110	0.101	0.152	0.233	10,517

(continued)

Table A1
Continued

		Mean	St.Dev.	25%	50%	75%	# of Obs.
	ME High	0.160	0.098	0.089	0.135	0.198	10,506
	ME Low	0.186	0.107	0.106	0.159	0.239	10,506
	Tenure High	0.183	0.108	0.101	0.156	0.235	9,931
	Tenure Low	0.159	0.096	0.090	0.136	0.197	8,726
Compensation (bps)	Full	0.335	0.329	0.090	0.219	0.464	21,035
	Takeover Index High	0.281	0.297	0.069	0.176	0.376	8,770
	Takeover Index Low	0.433	0.354	0.156	0.320	0.609	8,788
	2007–2017	0.276	0.303	0.064	0.159	0.365	10,703
	1993–2006	0.397	0.343	0.136	0.286	0.554	10,310
	Compensation High	0.572	0.316	0.317	0.464	0.753	10,517
	Compensation Low	0.098	0.060	0.044	0.090	0.146	10,517
	Age High	0.299	0.308	0.074	0.188	0.413	10,301
	Age Low	0.372	0.345	0.110	0.251	0.528	10,311
	IO High	0.263	0.257	0.082	0.177	0.352	10,517
	IO Low	0.407	0.374	0.104	0.278	0.604	10,517
	ME High	0.146	0.166	0.045	0.095	0.183	10,506
	ME Low	0.524	0.343	0.254	0.426	0.720	10,506
	Tenure High	0.353	0.333	0.101	0.239	0.494	9,931
	Tenure Low	0.311	0.322	0.078	0.192	0.423	8,726
Ownership	Full	0.033	0.054	0.003	0.009	0.031	21,035
	Takeover Index High	0.026	0.047	0.002	0.007	0.022	8,770
	Takeover Index Low	0.042	0.061	0.005	0.013	0.048	8,788
	2007–2017	0.029	0.050	0.003	0.009	0.026	10,703
	1993–2006	0.036	0.057	0.003	0.009	0.037	10,310
	Compensation High	0.046	0.062	0.006	0.017	0.055	10,517
	Compensation Low	0.019	0.040	0.002	0.005	0.014	10,517
	Age High	0.035	0.056	0.003	0.010	0.034	10,301
	Age Low	0.030	0.051	0.003	0.009	0.028	10,311
	IO High	0.019	0.033	0.003	0.008	0.018	10,517
	IO Low	0.046	0.065	0.003	0.013	0.059	10,517
	ME High	0.022	0.044	0.002	0.005	0.014	10,506
	ME Low	0.044	0.060	0.006	0.016	0.051	10,506
	Tenure High	0.044	0.061	0.005	0.016	0.054	9,931
	Tenure Low	0.019	0.040	0.002	0.005	0.014	8,726
Ownership including exercisable options	Full	0.047	0.058	0.011	0.024	0.056	21,035
	Takeover Index High	0.039	0.052	0.008	0.019	0.044	8,770
	Takeover Index Low	0.061	0.064	0.017	0.034	0.078	8,788
	2007–2017	0.042	0.054	0.009	0.021	0.047	10,703
	1993–2006	0.054	0.061	0.012	0.028	0.067	10,310
	Compensation High	0.066	0.065	0.021	0.041	0.086	10,517
	Compensation Low	0.028	0.043	0.006	0.013	0.028	10,517
	Age High	0.049	0.060	0.010	0.024	0.058	10,301
	Age Low	0.046	0.056	0.011	0.025	0.055	10,311
	IO High	0.033	0.039	0.010	0.020	0.040	10,517
	IO Low	0.062	0.070	0.011	0.031	0.086	10,517
	ME High	0.031	0.048	0.006	0.014	0.030	10,506
	ME Low	0.064	0.063	0.020	0.039	0.082	10,506
	Tenure High	0.062	0.065	0.017	0.036	0.083	9,931
	Tenure Low	0.031	0.044	0.007	0.015	0.033	8,726
Ownership including unexercisable options	Full	0.057	0.061	0.016	0.034	0.071	21,035
	Takeover Index High	0.047	0.054	0.013	0.028	0.057	8,770
	Takeover Index Low	0.073	0.067	0.025	0.049	0.096	8,788
	2007–2017	0.048	0.057	0.012	0.027	0.058	10,703
	1993–2006	0.066	0.064	0.020	0.043	0.085	10,310
	Compensation High	0.080	0.066	0.032	0.056	0.104	10,517
	Compensation Low	0.034	0.046	0.009	0.019	0.037	10,517
	Age High	0.057	0.063	0.014	0.032	0.072	10,301

(continued)

Table A1
Continued

	Mean	St.Dev.	25%	50%	75%	# of Obs.
Age Low	0.057	0.059	0.017	0.036	0.072	10,311
IO High	0.042	0.042	0.015	0.028	0.052	10,517
IO Low	0.072	0.072	0.017	0.044	0.102	10,517
ME High	0.037	0.050	0.009	0.019	0.040	10,506
ME Low	0.076	0.065	0.030	0.053	0.098	10,506
Tenure High	0.071	0.068	0.023	0.046	0.096	9,931
Tenure Low	0.040	0.047	0.011	0.024	0.048	8,726

This table presents the summary statistics for the main variables used in the structural estimation. We get our financial data from Compustat. We drop financial firms (SIC codes 6000–6999), utilities (4900–4999), and public administration firms (9000–9999). We match firms' financial characteristics with executive compensation data (from ExecuComp) for the top five executives. The resulting panel contains 10,528 observations for the period 1992–2019. We split firms by age, competition, institutional ownership, and total compensation (salary + bonus) as follows: "Age High" ("Age Low") firms are those with a CEO with above (below) median age; "IO High" ("IO Low") firms are those with higher (lower) institutional ownership compared to the median; "Compensation High" ("Compensation Low") firms pay their top five executives more (less) than the median firm. A detailed definition of the variables (Leverage, Market to Book, etc.) is presented in Table 3.

At stage $n<N$, there will be a difference between the value of outstanding debt and the value of total debt; the latter is the value of debt that includes changes in leverage due to the exercise of the future growth options.

Recalling that $T=\inf\{T_n^i, T_n^D\}$ and letting P_n be the principal of the outstanding debt, $D_n(Y)$ follows a derivation very similar to Equation (A.3):

$$\begin{aligned}\mathbf{D}_n(Y) &= \underbrace{\int_0^T e^{-rt}(1-\tau^d)C_n dt}_{\text{Value over one business cycle}} + \underbrace{\int_{T_n^D}^{\infty} e^{-rt}(1-\gamma_A)(1-\tau)\frac{Z_N Y_t}{r-\mu}dt}_{\text{PV of cash-flows to debtholders at default}} + \underbrace{\mathbf{E}[e^{-rT_n^i}]P_n}_{\substack{\text{PV of Principal repayment}\\ \text{at investment threshold}}} \\ &= \frac{(1-\tau^d)C_n}{r}[1-p_n^D(Y)-p_n^i(Y)] + p_N^D(Y)(1-\gamma_A)(1-\tau)\frac{Z_N Y_N^D}{r-\mu} + p_n^i(Y)P_n \\ &= \frac{(1-\tau^d)C_n}{r}[1-p_n^D(Y)-p_n^i(Y)] + p_N^D(Y)L_n(Y_n^D) + p_n^i(Y)P_n \end{aligned} \tag{A.4}$$

Since debt is issued at par, it must be that at the time of issuance its value is equal to the par value, $\mathbf{D}_n(Y_n^i)=P_n$. By equating the right-hand side of Equation (A.4) for $Y=Y_n^i$ to P_n, we have:

$$\frac{(1-\tau^d)C_n}{r}[1-p_n^D(Y_n^i)-p_n^i(Y_n^i)] + p_N^D(Y_n^i)L_n(Y_n^D) + p_n^i(Y_n^i)P_n = P_n \tag{A.5}$$

which can easily be rearranged to obtain an expression for P_n as shown in Equation (15).

The total value of corporate debt, $\mathbf{TD}_n(Y)$, includes not only the value of outstanding debt, $\mathbf{D}_n(Y)$, but also the new debt that will be issued when the next growth option is exercised. The value of $\mathbf{TD}_n(Y)$ is

$$
\begin{aligned}
\mathbf{TD}_n(Y) &= \underbrace{\int_0^T e^{-rt}\left(1-\tau^d\right)C_n dt}_{\text{Value over one business cycle}} + \underbrace{\int_{T_n^D}^{\infty} e^{-rt}(1-\gamma_A)(1-\tau)\frac{Z_N Y_t}{r-\mu}dt}_{\text{PV of cash-flows to debtholders at default}} + \underbrace{\mathbf{E}[e^{-rT_n^i}]\mathbf{TD}_{n+1}\left(Y_{n+1}^i\right)}_{\substack{\text{PV of } \mathbf{TD}_{n+1}(Y) \\ \text{at investment threshold}}} \\
&= \frac{\left(1-\tau^d\right)C_N}{r}\left[1-p_n^D(Y)-p_n^i(Y)\right] + p_N^D(Y)(1-\gamma_A)(1-\tau)\frac{Z_N Y_N^D}{r-\mu} \\
&\quad + p_n^i(Y)\mathbf{TD}_{n+1}\left(Y_{n+1}^i\right) \\
&= \frac{\left(1-\tau^d\right)C_N}{r}\left[1-p_n^D(Y)-p_n^i(Y)\right] + p_N^D(Y)L_n\left(Y_n^D\right) + p_n^i(Y)\mathbf{TD}_{n+1}\left(Y_{n+1}^i\right)
\end{aligned}
\tag{A.6}
$$

which proves Equation (16).

Appendix B: Value of $p_n^i(Y)$ and $p_n^D(Y)$

For any integer n such that $0 \le n \le N$, $p_n^i(Y,r)$ is the present value of \$1 to be received at the time of investment, conditional on investment occurring before default, and $p_n^D(Y)$ is the present value of \$1 to be received at the time of default, conditional on default occurring before investment.

The derivation of $p_n^i(Y,r)$ and $p_n^D(Y,r)$ can be found in Stokey (2008, 82), Proposition 5.3. We report the solutions here:

$$
p_n^i(Y) = \frac{Y^{\beta_1} - \left(Y_n^D\right)^{\beta_1-\beta_2} Y^{\beta_2}}{\left(Y_{n+1}^i\right)^{\beta_1} - \left(Y_n^D\right)^{\beta_1-\beta_2}\left(Y_{n+1}^i\right)^{\beta_2}} \tag{B.1}
$$

$$
p_n^D(Y) = \frac{Y^{\beta_1} - \left(Y_{n+1}^i\right)^{\beta_1-\beta_2} Y^{\beta_2}}{\left(Y_n^D\right)^{\beta_1} - \left(Y_{n+1}^i\right)^{\beta_1-\beta_2}\left(Y_n^D\right)^{\beta_2}} \tag{B.2}
$$

where β_1 and β_2 are the positive and negative roots of the equation $\frac{1}{2}\sigma^2 x(x-1)+\mu x - r = 0$; the expressions for β_1 and β_2 are as follows:

$$
\beta_1 = \frac{-(\mu-0.5\sigma^2)+\sqrt{(\mu-0.5\sigma^2)^2+2r\sigma^2}}{\sigma^2} > 0
$$

$$
\beta_2 = -\frac{(\mu-0.5\sigma^2)+\sqrt{(\mu-0.5\sigma^2)^2+2r\sigma^2}}{\sigma^2} < 0
$$

At stage 0, the firm has no debt therefore it would never default, $Y_0^D = 0$. It is easy to show that

$$
\lim_{Y_0^D \to 0} p_0^i(Y) = \lim_{Y_0^D \to 0} \frac{Y^{\beta_1} - \left(Y_0^D\right)^{\beta_1-\beta_2} Y^{\beta_2}}{\left(Y_1^i\right)^{\beta_1} - \left(Y_0^D\right)^{\beta_1-\beta_2}\left(Y_1^i\right)^{\beta_2}} = \left(\frac{Y}{Y_1^i}\right)^{\beta_1},
$$

which explains why the term $\left(\frac{Y}{Y_1^i}\right)^{\beta_1}$ that appears in Equations (20) to (22).

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