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Tax policies and agency costs

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Abstract

We show that when large corporations are subject to a different tax system than smaller firms, the agency cost of under- and overinvestment is significantly altered. In contrast to the findings in the literature, the gap between the first- and second-best investment trigger prices do not move in lockstep with variations in the corporate tax rate, as in the case of a linear tax system. We show that the gap can either widen or shrink, depending on the tax policy design and regime. In addition, we find that the agency cost under a progressive tax regime is considerably larger than the agency cost under a regressive tax regime when equityholders have to bear all the investment costs. These results are reversed when managers have the ability to issue additional debt to finance the firm's expansion and transfer part of the investment costs to bondholders.

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G32, H25, H26

1 | INTRODUCTION

The seminal studies of Jensen and Meckling (1976) and Myers (1977) show that agency costs arising from the misalignment of interests between equityholders and bondholders ultimately affect the timing of investment and the balance between debt and equity used to fund these investment opportunities. Quantitatively, agency cost is typically measured as the difference between the (levered) firm value when managers follow the first-best policy (i.e., managers maximize the total value of the levered firm) and the second-best policy (i.e., managers maximize equity value instead of the total value of the firm).

The agency cost of underinvestment (see Mauer & Ott, 2000; Parrino & Weisbach, 1999, Pawlina, 2010) typically emerges when an equity-maximizer manager delays investment decisions relative to a firm-value-maximizer manager for bearing all the investment costs while sharing the benefits of investment with bondholders. In contrast, the agency cost of overinvestment (see Childs et al., 2005; Leland, 1998; Mauer & Sarkar, 2005; Morellec, 2001) can emerge when an equity-maximizer manager hastens her decision to invest relative to a firm-value-maximizer manager for being able to shift part of the investment cost to bondholders with additional debt issuance while preserving the upside potential gains of equity. In spite of the fact that researchers have been devoting a lot of effort to investigate potential factors affecting the capital structure and agency costs, such as debt restructuring (Goldstein et al., 2001), macroeconomic conditions (Hackbarth et al., 2006), managerial traits (Hackbarth, 2008), asymmetric information (Morellec & Schürhoff, 2011), and lack of coordination between the timing of investment and debt financing (Li & Mauer, 2016), it is still unclear how different tax regimes and their design affect the agency cost of under- and overinvestment of large corporations.

We fill this gap by investigating the implications for investment decisions, capital structure, and the agency costs of under- and overinvestment when large firms are subject to a different corporate tax rate. Our model builds on the real-option dynamic framework of Mauer and Ott (2000) and Hackbarth and Mauer (2012) and investigates the importance of tax heterogeneity and regimes to agency costs. Our theoretical model goes as follows. At the beginning, a young firm is endowed with a growth option that can be exercised at any point in time and its operating income is taxed at the rate of τ_1. Depending on the level of its operating income, the firm can either abandon its operations or mature (i.e., expand) by exercising the growth option. After expansion, if the mature firm's operating income becomes sufficiently large (i.e., above an exogenous threshold level that we label tax cutoff point L), a different marginal tax rate τ_2 is levied upon it and the overall effective tax rate is thus a weighted average between τ_1 and τ_2.

We consider two cases. First, the marginal corporate tax rate τ_2 levied on a large operating income is larger than the initial tax rate τ_1 (i.e., $\tau_1 < \tau_2$). We call this system the progressive tax regime. One can interpret this case as large firms drawing the attention of legislators that pass a targeted tax reform imposing a higher corporate tax rate on large firms. In the second case, we assume that the marginal tax rate τ_2 levied on large operating incomes is smaller than the initial tax rate τ_1 (i.e., $\tau_2 < \tau_1$). We label this system the regressive tax regime and interpret it as large firms hiring high-skilled accountants and lawyers that conduct aggressive tax avoidance. We benchmark our results against the case where operating income is subject to a linear (flat) tax rate.

Our main findings are as follows. First, we show that the agency cost of underinvestment under a progressive tax regime is considerably larger than under a regressive tax code when investment costs are all-equity financed. In our numerical analysis, the agency cost of underinvestment under a progressive tax code can be 2.6 times larger than the agency cost of underinvestment under a regressive tax code. The result follows from the fact that the tax policy terms ($\tau_1, \tau_1/\tau_2, L$) affect the first- and second-best investment trigger prices (i.e., the output price of the goods produced by the firm in which the total-firm-value-maximizer and equity-maximizer managers invest, respectively) in opposite directions. Different from the findings of Mauer and Ott (2000) that the first- and second-best investment trigger prices move in lockstep with variations in the linear tax rate in a flat tax system, we show that in the presence of tax heterogeneity, the underinvestment problem is aggravated under a progressive tax regime and alleviated under a regressive tax regime. These opposing effects on the investment trigger prices caused by the granularity of the tax policy design (i.e., two tax brackets instead of one) is carried out to other (partial) equilibrium quantities, such as the agency cost components (i.e., tax shield of debt and bankruptcy costs), equity betas, credit spreads, and leverage ratios.

Second, we find that the first-best policy investment trigger price is more sensitive to changes in the tax policy terms than the second-best investment trigger price when equityholders bear all the investment cost of the option exercise. The main reason is that tax dispersion, defined as $\Delta\tau = |\tau_2 - \tau_1|$, significantly distorts the trade-off between tax shield and bankruptcy cost, resulting in large variations in the trigger price that maximizes the total value of the firm (i.e., the first-best trigger price). However, when managers seek equity maximization (i.e., second-best policy), considerations of debt trade-off are only of second-order importance, which results in smaller variations in the second-best trigger price. Moreover, we find that equity valuation is significantly more sensitive to tax dispersion than debt valuation and that equity and debt valuations are larger under a regressive tax regime than under a progressive tax regime. In summary, we show that tax heterogeneity and regimes affect the trade-off within asset classes (by distorting the trade-off balance of tax shield of debt and bankruptcy costs) and across asset classes (by changing the blend between debt and equity).

Third, we investigate the effect of the tax policy design (τ_1, τ_1/τ_2, L) on the firm's first- and second-best equity betas. In the case where the investment cost is all-equity financed, we show that the first-best equity beta is more sensitive to the tax policy terms than the second-best equity beta. The reason is that the second-best equity value follows from equity-maximizer managers and, consequently, is at least as large as the first-best equity value, where managers maximize the total value of the levered firm. Thus, the smaller magnitude of the first-best equity becomes more sensitive to variations of the firm's good output price than the larger second-best equity price. In addition, we show that tax dispersion increases equity betas under a progressive tax code and decreases the betas under a regressive tax code, whereas the tax cutoff L has the opposite effect.

In a second analysis, we consider the case where the investment cost can be partially financed with additional debt issuance. As shown by Mauer and Sarkar (2005), additional financing opportunities can potentially drive equityholders to exercise the investment opportunity too early relative to the policy that maximizes the total value of the firm. To put it simply, it can lead managers to overinvest rather than underinvest. Essentially, by financing the cost of the option exercise with additional debt issuance, equityholders exploit the limited liability of equity to preserve upside potential gains while transferring the risk of premature investing to bondholders. In contrast to the previous analysis, we show that the agency cost of overinvestment under a regressive tax regime can be larger than under a progressive tax regime.

As important as stating what the model delivers is stating what the model does not address. First, because we do not solve a general equilibrium model, our framework is silent with respect to the optimality of the tax policies investigated.[1] The model does not provide any guidance regarding the optimality of the tax policy design. Second, we do not investigate the optimality of the debt coupon and take it as exogenously given. The reason is purely for the computational challenge it poses. As shown in Section 2, one of the intermediate steps in the model's characterization involves solving a high-dimensional nonlinear system with nine equations. Therefore, the numerical solution of this system is highly sensitive to the initial conditions. Adding an extra layer of complexity by optimizing the firm value over the debt coupon makes the numerical problem considerably more demanding.

Naturally, our article relates to the aforementioned studies that investigate the interaction between investment and financing decisions, and to research exploring the links between taxation and agency costs. For example, Mauer and Lewellen (1987) study the valuation of a tax-timing option that emerges when the firm issues long-term debt. The authors show that this option implies that leverage has a positive tax effect on total firm value. Sarkar (2008) investigates the impact of a convex tax schedule on corporate default and leverage decisions. The author concludes that tax convexity increases the optimal default boundary and reduces the optimal leverage ratio. Morellec and Schürhoff (2010) investigate how personal taxation affects the timing of investment decisions and affect the firm's capital structure. The authors show that because of the structure of realization-based capital gains taxes, the asymmetric taxation of gains and losses erodes the option value of waiting, leading firms owned by taxable high-basis investors to overinvest relative to firms owned by low-basis investors.

[1]For models on optimal taxation under a general equilibrium framework, see, for example, Chamley (1986), Slemrod et al. (1994), Turnovsky (1996), Aiyagari et al. (2002), and Oh and Reis (2012). None of these papers take into consideration the capital structure of firms.

2 | MODEL

Our setting is similar to Mauer and Ott (2000). We assume that a firm continuously produces a single good at a constant cost of C and sells it in a competitive market at the (stochastic) price of P_t. The commodity price P_t is assumed to satisfy the following stochastic differential equation (SDE):

$$\frac{dP_t}{P_t} = (r - \delta)dt + \sigma dZ_t,\ P_0 \text{ given},$$

where $r \in \mathbb{R}_+$ is the risk-free rate, $\delta \in \mathbb{R}_+$ is the convenience yield of the commodity, $\sigma \in \mathbb{R}_+$ is the commodity volatility, and Z_t is a standard Brownian motion under the risk-neutral measure. The output price P_t is the only state variable in our economy.

Similar to Dixit and Pindyck (1994), we assume that the firm initially has two operating options. The firm can either shut down its operations or pay a fixed cost I to scale up the production from 1 to $q > 1$ units of the good per year. We assume that the investment is irreversible once adopted, but the firm keeps the option of abandoning operations at any time.

We depart from previous studies by assuming that operating profits are subject to a tax system that takes into consideration the firm size (proxied by the firm's output price). In particular, we assume that if the firm's good output price is below a sufficiently large tax cutoff point L, the firm pays a tax rate of $\tau_1 \in (0, 1)$. Otherwise, the firm pays a tax rate of $\tau_1 \in (0, 1)$ up to L and a marginal tax rate $\tau_2 \in (0, 1)$ above L.[2]

At the initial date, the young firm is taxed at a constant tax rate τ_1 because the output price P is below the threshold L. The firm can expand its operations by paying a fixed cost of I at any time. If the firm eventually exercises its option to expand and grows large enough to reach the tax cutoff L, its operating profits are then taxed at a combination of tax rate $\tau_1 \in (0, 1)$ and tax rate $\tau_2 \in (0, 1)$. We loosely refer to the region where the output price has not reached the tax cutoff L as the "first tax bracket" and label the region of prices after the tax cutoff L is reached as the "second tax bracket." Thus, a tax system in our setting is described by the triplet $(\tau_1, \tau_1/\tau_2, L)$.

We say that a tax system is progressive if $\tau_1 < \tau_2$ and regressive if $\tau_2 < \tau_1$. A tax system is said to be flat or linear if $\tau_1 = \tau_2$, which is the case analyzed by Mauer and Ott (2000) and serves as the benchmark for our model. As stated in Section 1, the main purpose of our study is to investigate how different tax designs $(\tau_1, \tau_1/\tau_2, L)$ affect a firm's valuation, investment decisions, and agency costs of under- and overinvestment.

The first step of the analysis is to characterize the unlevered value of the firm. Different from Mauer and Ott (2000), we have to consider the value of the unlevered value of the firm in two regions: before and after the tax bracket cutoff value.

2.1 | Unlevered firm value

First, we compute the value of the unlevered firm after the growth option is exercised. We use the subindex q to keep track of the postexercise quantities. In this unlevered case, we denote the price level differentiating the two tax brackets by L^U. Using the same strategy as in Mauer and Ott (2000) and moving backward in time, assume that the tax threshold L^U was reached and the firm's operating income is currently subject to a mix of corporate tax rates τ_1 and τ_2. Using standard risk-neutral valuation arguments and denoting the value of the

[2]Technically, describing the tax system in terms of the output price is equivalent to describing it in terms of the firm's pretax operating income because q and C are constants in our model. Thus, the region where the output price satisfies $P < L$ is equivalent to the region where $(P - C)q < \tilde{L}$, with $\tilde{L} = (L - C)q$. We opt to describe the tax policy in terms of the output price to ease notation. In addition, the precise definition of a sufficiently large tax cutoff L is formalized later in the text.

unlevered firm after the threshold L^U is reached by $V_q^{UAL}(P)$, the ordinary differential equation (ODE) satisfied by this function is[3]

$$\frac{\sigma^2}{2}P^2\partial_{PP}V_q^{UAL} + (r-\delta)P\partial_P V_q^{UAL} - rV_q^{UAL} + (L^U - C)q(1-\tau_1) + (P - L^U)q(1-\tau_2) = 0, \tag{1}$$

where the general solution of the ODE is given by

$$V_q^{UAL}(P) = \left(\frac{L^U - C}{r}\right)q(1-\tau_1) + \left(\frac{P}{\delta} - \frac{L^U}{r}\right)q(1-\tau_2) + A_1P^{\gamma_1} + A_2P^{\gamma_2},$$

with

$$\gamma_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} > 1,$$

$$\gamma_2 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} - \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} < 0.$$

The coefficients A_1 and A_2 are constants to be determined with the appropriate boundary conditions discussed later.

Next, consider the case where the growth option is exercised but the output price P has not reached the tax cutoff point L^U. Denoting the value of the unlevered firm before L^U is reached by $V_q^{UBL}(P)$, its ODE becomes

$$\frac{\sigma^2}{2}P^2\partial_{PP}V_q^{UBL} + (r-\delta)P\partial_P V_q^{UBL} - rV_q^{UBL} + (P - C)q(1-\tau_1) = 0, \tag{2}$$

with the general solution given by

$$V_q^{UBL}(P) = \left(\frac{P}{\delta} - \frac{C}{r}\right)q(1-\tau_1) + A_3P^{\gamma_1} + A_4P^{\gamma_2},$$

and coefficients A_3 and A_4 to be determined with the appropriate boundary conditions.

In this system, we need to determine five quantities: (1) four constant coefficients A_1, A_2, A_3, A_4, and (2) the price P_{A_q} at which the unlevered firm abandons its operations. Therefore, we use the following five boundary conditions to obtain these quantities:

$$\lim_{P\to\infty} V_q^{UAL}(P) = \left(\frac{L^U - C}{r}\right)q(1-\tau_1) + \left(\frac{P}{\delta} - \frac{L^U}{r}\right)q(1-\tau_2), \tag{3}$$

$$V_q^{UAL}(L^U) = V_q^{UBL}(L^U), \tag{4}$$

$$\partial_P V_q^{UAL}(L^U) = \partial_P V_q^{UBL}(L^U), \tag{5}$$

$$V_q^{UBL}(P_{A_q}) = 0, \tag{6}$$

$$\partial_P V_q^{UBL}(P_{A_q}) = 0, \tag{7}$$

[3]See Black and Cox (1976) and Moreno-Bromberg and Rochet (2018) for standard risk-neutral valuation arguments and discussions.

Boundary Condition (3) implies that $A_1 = 0$ (because $\gamma_1 > 0$), and (4) and (5) ensure the continuity and differentiability of the unlevered firm value function at the tax cutoff L^U. Boundary Condition (6) imposes that the all-equity-financed firm value is worth zero at the abandonment price and (7) ensures its smooth pasting at P_{A_q}.

The final step is characterizing the unlevered value of the firm before the growth option is exercised. Consider the case where the output price is between the price at which the unlevered firm abandon its operations before the growth option is exercised P_A and the investment trigger price P_I^U at which the firm exercise the growth option. By denoting the value of the unlevered firm before the growth option is exercised as $V^U(P)$, its ODE becomes

$$\frac{\sigma^2}{2}P^2\partial_{PP}V^U + (r - \delta)P\partial_P V^U - rV^U + (P - C)(1 - \tau_1) = 0,$$

with general solution given by

$$V^U(P) = \left(\frac{P}{\delta} - \frac{C}{r}\right)(1 - \tau_1) + A_5P^{\gamma_1} + A_6P^{\gamma_2}.$$

The quantities A_5, A_6, P_A, and the investment trigger price P_I^U are determined by the following four boundary conditions:

$$V^U(P_I^U) = V_q^{UBL}(P_I^U) - I, \tag{8}$$

$$\partial_P V^U(P_I^U) = \partial_P V_q^{UBL}(P_I^U), \tag{9}$$

$$V^U(P_A) = 0, \tag{10}$$

$$\partial_P V^U(P_A) = 0. \tag{11}$$

Boundary Condition (8) imposes that the unlevered firm value before the growth option is exercised matches the net unlevered firm value after the option is exercised at the investment trigger price, and (9) ensures its smooth pasting. Boundary Condition (10) imposes that an all-equity-financed firm value is worth zero at the abandonment price, and (11) guarantees its smooth pasting. This completes the characterization of the unlevered firm value.

2.2 | Levered firm value

Consider next the case where the firm is financed with debt and equity. Debt is modeled as a consol bond with a constant coupon payment of R per unit of time, and equity is modeled as a residual claim on the firm's cash flow after the payment of the coupon payment R. As a result, the coupon payment R represents an additional cost that reduces the profit base. To be consistent with the unlevered case where the tax bracket change is triggered by the firm's net profit reaching the threshold $(L^U - C)q$, the tax bracket change for the levered firm case must occur at the price level P satisfying $(P - C)q - R = (L^U - C)q$, or simply, when $P = L^U + R/q$. Intuitively, the fact that the price threshold level L^U has to be adjusted upward makes sense as it takes a higher price level P to achieve the same level of net profit when additional costs, such as the payment of debt coupons, are taken into consideration. Thus, we define the new tax threshold as $L = L^U + R/q$.

In a manner similar to the characterization of the unlevered firm value, we first compute the price of these contingent claims after the growth option is exercised. In this instance, the after-tax cash flow to equity is $((P - C)q - R))(1 - \tau_1)$ if the output price has not reached the tax cutoff *redL*, and

$((L - C)q - R))(1 - \tau_1) + (P - L)q(1 - \tau_2)$ otherwise. Denoting the equity value before and after the threshold L is reached by $E_q^{BL}(P)$ and $E_q^{AL}(P)$, respectively, the ODEs become

$$\begin{aligned} \frac{\sigma^2}{2}P^2\partial_{PP}E_q^{BL} + (r - \delta)P\partial_P E_q^{BL} - rE_q^{BL} + ((P - C)q - R))(1 - \tau_1) = 0, \\ \frac{\sigma^2}{2}P^2\partial_{PP}E_q^{AL} + (r - \delta)P\partial_P E_q^{AL} - rE_q^{AL} + ((L - C)q - R))(1 - \tau_1) + (P - L)q(1 - \tau_2) = 0. \end{aligned} \tag{12}$$

Denoting the value of debt before and after the tax cutoff *redL* is reached by $D_q^{BL}(P)$ and $D_q^{AL}(P)$, respectively, the ODEs satisfied by these functions are

$$\begin{aligned} \frac{\sigma^2}{2}P^2\partial_{PP}D_q^{BL} + (r - \delta)P\partial_P D_q^{BL} - rD_q^{BL} + R = 0, \\ \frac{\sigma^2}{2}P^2\partial_{PP}D_q^{AL} + (r - \delta)P\partial_P D_q^{AL} - rD_q^{AL} + R = 0. \end{aligned} \tag{13}$$

The general solution of the ODEs in (12) and (13) is given by

$$\begin{aligned} E_q^{BL}(P) &= \left(\left(\frac{P}{\delta} - \frac{C}{r}\right)q - \frac{R}{r}\right)(1 - red\tau_1) + E_1P^{\gamma_1} + E_2P^{\gamma_2}, \\ E_q^{AL}(P) &= \left(\left(\frac{L - C}{r}\right)q - \frac{R}{r}\right)(1 - red\tau_1) + \left(\frac{P}{\delta} - \frac{L}{r}\right)q(1 - \tau_2) + E_3P^{\gamma_1} + E_4P^{\gamma_2}, \\ D_q^{BL}(P) &= \frac{R}{r} + D_1P^{\gamma_1} + D_2P^{\gamma_2}, \\ D_q^{AL}(P) &= \frac{R}{r} + D_3P^{\gamma_1} + D_4P^{\gamma_2}, \end{aligned}$$

where the coefficients $E_1, E_2, E_3, E_4, D_1, D_2, D_3, D_4$, and the endogenous default price P_{D_q} at which the firm's manager defaults on the firm's debt are determined by the following nine boundary conditions:

$$E_q^{AL}(L) = E_q^{BL}(L), \tag{14}$$

$$\partial_P E_q^{AL}(L) = \partial_P E_q^{BL}(L), \tag{15}$$

$$D_q^{AL}(L) = D_q^{BL}(L), \tag{16}$$

$$\partial_P D_q^{AL}(L) = \partial_P D_q^{BL}(L), \tag{17}$$

$$E_q^{BL}(P_{D_q}) = 0, \tag{18}$$

$$\partial_P E_q^{BL}(P_{D_q}) = 0, \tag{19}$$

$$\lim_{P\to\infty} D_q^{AL}(P) = \frac{R}{r}, \tag{20}$$

$$\lim_{P\to\infty} E_q^{AL}(P) = \left(\left(\frac{L - C}{r}\right)q - \frac{R}{r}\right)(1 - \tau_1) + \left(\frac{P}{\delta} - \frac{L}{r}\right)q(1 - \tau_2), \tag{21}$$

$$D_q^{BL}(P_{D_q}) = (1 - b)V_q^{UBL}(P_{D_q}). \tag{22}$$

Boundary Conditions (14)–(17) impose continuity and differentiability conditions for debt and equity at the tax cutoff L, and (18)–(19) ensure equityholders limited liability and that the default price is chosen to maximize equity value, respectively. Boundary Condition (20) shows that when the output price is very high, the probability of default becomes irrelevant, risky debt becomes a riskless bond, and equity price converges to (21). Last, Boundary Condition (22) shows that debtholders receive the firm's liquidation value net of bankruptcy costs.

2.3 | First-best investment policy

We now turn to the characterization of the debt and equity claims before the growth option is exercised. Managers adopting the first-best strategy exercise the growth option at the investment trigger price P_I^F to maximize the total value of the levered firm. In this case, the value of equity and debt satisfy, respectively,

$$\begin{aligned} 0 &= \frac{\sigma^2}{2}P^2\partial_{PP}E_F + (r-\delta)P\partial_P E_F - rE_F + (P-(C+R))(1-\tau_1), \\ 0 &= \frac{\sigma^2}{2}P^2\partial_{PP}D_F + (r-\delta)P\partial_P D_F - rD_F + R. \end{aligned} \tag{23}$$

The general solution of (23) is

$$\begin{aligned} E_F(P) &= \left(\frac{P}{\delta} - \frac{C+R}{r}\right)(1-\tau_1) + E_5P^{\gamma_1} + E_6P^{\gamma_2}, \\ D_F(P) &= \frac{R}{r} + D_5P^{\gamma_1} + D_6P^{\gamma_2}, \end{aligned} \tag{24}$$

where the coefficients E_5, E_6, D_5, D_6; the endogenous default price P_D; and the first-best investment trigger price P_I^F are determined by the following six boundary conditions:

$$D_F(P_D) = (1-b)V^U(P_D), \tag{25}$$

$$E_F(P_D) = 0, \tag{26}$$

$$\partial_P E_F(P_D) = 0, \tag{27}$$

$$E_F(P_I^F) = E_q^{BL}(P_I^F) - I, \tag{28}$$

$$V_F(P_I^F) = V_q^{BL}(P_I^F) - I, \tag{29}$$

$$\partial_P V_F(P_I^F) = \partial_P V_q^{BL}(P_I^F). \tag{30}$$

Here, the total value of the levered firm at the first-best policy is $V_F(P) = E_F(P) + D_F(P)$. The explanations for Boundary Conditions (25)–(28) are as before. Boundary Condition (29) ensures the continuity of the levered firm value function at the investment trigger price, and (30) guarantees that the investment trigger price maximizes the total value of the firm (i.e., managers follow the first-best policy).

2.4 | Second-best investment policy

When ensuring that the adoption of the first-best policy by contract is prohibitively expensive, managers may choose to deviate from the first-best policy and maximize the firm's equity value instead (i.e., managers follow the second-best policy). In this case, the second-best value of equity and debt satisfy, respectively,

$$0 = \frac{\sigma^2}{2}P^2\partial_{PP}E_S + (r-\delta)P\partial_P E_S - rE_S + (P-(C+R))(1-\tau_1),$$
$$0 = \frac{\sigma^2}{2}P^2\partial_{PP}D_S + (r-\delta)P\partial_P D_S - rD_S + R,$$

with the general solution given by

$$E_S(P) = \left(\frac{P}{\delta} - \frac{C+R}{r}\right)(1-\tau_1) + E_7P^{\gamma_1} + E_8P^{\gamma_2},$$
$$D_S(P) = \frac{R}{r} + D_7P^{\gamma_1} + D_8P^{\gamma_2}.$$

The coefficients E_7, E_8, D_7, D_8 and the second-best investment trigger price P_I^S are determined by the following five boundary conditions:

$$D_S(P_D) = (1-b)V^U(P_D), \tag{31}$$

$$E_S(P_D) = 0, \tag{32}$$

$$E_S(P_I^S) = E_q^{BL}(P_I^S) - I, \tag{33}$$

$$V_S(P_I^S) = V_q^{BL}(P_I^S) - I, \tag{34}$$

$$\partial_P E_S(P_I^S) = \partial_P E_q^{BL}(P_I^S), \tag{35}$$

where we define the second-best levered firm value as $V_S(P) = E_S(P) + D_S(P)$. Boundary Conditions (31)–(34) are similar to the first-best policy. The critical boundary condition here is (35), showing equity maximization and not total firm value maximization as in (30). This concludes the characterization of our model.[4]

After introducing the investment trigger prices P_I^U, P_I^F, and P_I^S, we can now formalize the concept of a sufficiently large tax cutoff L. In this context, L is said to be sufficiently large if $L \in (\max\{P_I^U, P_I^F, P_I^S\}, \infty)$. Naturally, a firm is said to be sufficiently large if it has reached L at some point in time. Given this assumption on L's domain, the young firm has to exercise the growth option before it can eventually become large enough to start being taxed at a combination of rates τ_1 and τ_2.

3 | NUMERICAL ANALYSIS

In this section, we investigate the agency cost of underinvestment under (1) a progressive tax policy ($\tau_1 < \tau_2$) and (2) a regressive tax policy ($\tau_2 < \tau_1$). First, we use the solution of the model of Mauer and Ott (2000) with a flat tax system ($\tau_1 = \tau_2$) to benchmark our results and illustrate how they differ from the authors' findings. Second, because of the high nonlinearity of the model presented in Section 2, the convergence of the algorithm is sensitive to the initial condition. However, setting the initial condition as the solution of the flat tax system makes the algorithm converge. Table 1 presents the parametrization used for our numerical analysis and follows Mauer and Ott (2000) closely. The bottom part of the table contains the tax policy design ($\tau_1, \tau_1/\tau_2, L$) for the progressive and regressive tax regimes that is exclusive in our study. The base unlevered L^U level is set at \$3.2, translating into a levered L level of \$3.78 (because $L = L^U + R/q$). We emphasize that the tax rate τ_2 in the second tax bracket is set symmetrically

[4]Although some steps of our analysis admit analytical expressions, the investment trigger prices can only be obtained numerically. For this reason, we prefer to present the model solution as a nonlinear system of equations to facilitate the implementation and replication of our results.

TABLE 1 Parameters.

Parameter	Symbol	Value
Production costs	C	\$1
Growth-option scale factor	q	3
Growth-option investment cost	I	\$20
Riskless interest rate	r	7%
Convenience yield	δ	7%
Output price volatility	σ	15%
Promised coupon payment	R	\$1.75
Bankruptcy costs	b	50%
Flat tax regime	(τ_1, τ_2)	(35%, 35%)
Progressive tax regime	(τ_1, τ_2, L)	(35%, 45%, \$3.78)
Regressive tax regime	(τ_1, τ_2, L)	(35%, 25%, \$3.78)

Note: This table reports the parameter values for the numerical exercise. The convenience yield, riskless interest rate, and output price volatility are reported in an annual frequency. The firm is assumed to have an initial annual rate of production of one unit per year.

TABLE 2 Investment trigger prices.

Tax code	Unlevered firm (P_I^U)	First best (P_I^F)	Second best (P_I^S)
Progressive	3.06	2.75	3.17
Flat	3.06	2.78	3.16
Regressive	3.06	2.80	3.16

Note: This table reports the investment trigger prices P_I^U, P_I^F, P_I^S for the progressive, flat, and regressive tax regimes.

relative to τ_1 in the progressive ($\tau_2 = \tau_1 + 10\%$) and regressive ($\tau_2 = \tau_1 - 10\%$) tax regimes on purpose. In this way, any differences in outcome are generated by the nonlinearities of the model and not by an artifact mechanically produced by asymmetric taxation.

Table 2 presents the investment trigger price for the progressive, flat, and regressive tax regimes. Our results indicate that the first-best trigger price is more sensitive relative to tax code changes, whereas the trigger price of the unlevered firm is essentially unresponsive to different tax regimes. Interestingly, despite setting the second tax rate symmetrically, the first-best trigger price in the progressive tax regime drops by \$0.03 (to \$2.75) relative to the benchmark trigger price of \$2.78, whereas the first-best trigger price under a regressive tax code only increases by \$0.02 (to \$2.80).

A second critical observation is that the underinvestment problem (i.e., the postponement of investment by an equity-maximizer manager) is more pronounced under a progressive tax regime not only because the first-best investment trigger price is lower but also because the second-best trigger price is higher than its counterpart in a flat tax regime. Under a progressive tax regime, an equity-maximizer manager waits until the price of \$3.17 is reached to exercise the option to grow, whereas the same manager exercises the growth option at \$3.16 under both flat and regressive tax codes.

To isolate the impact of the tax policy design $(\tau_1, \tau_1/\tau_2, L)$ on the first- and second-best investment trigger prices, we plot in Figure 1 the response of the first- and second-best investment trigger prices P_I^F (on the left y-axis) and P_I^S (on the right y-axis) to changes in the tax dispersion $\Delta\tau = |\tau_2 - \tau_1|$ (in the the first row) and to the unlevered tax

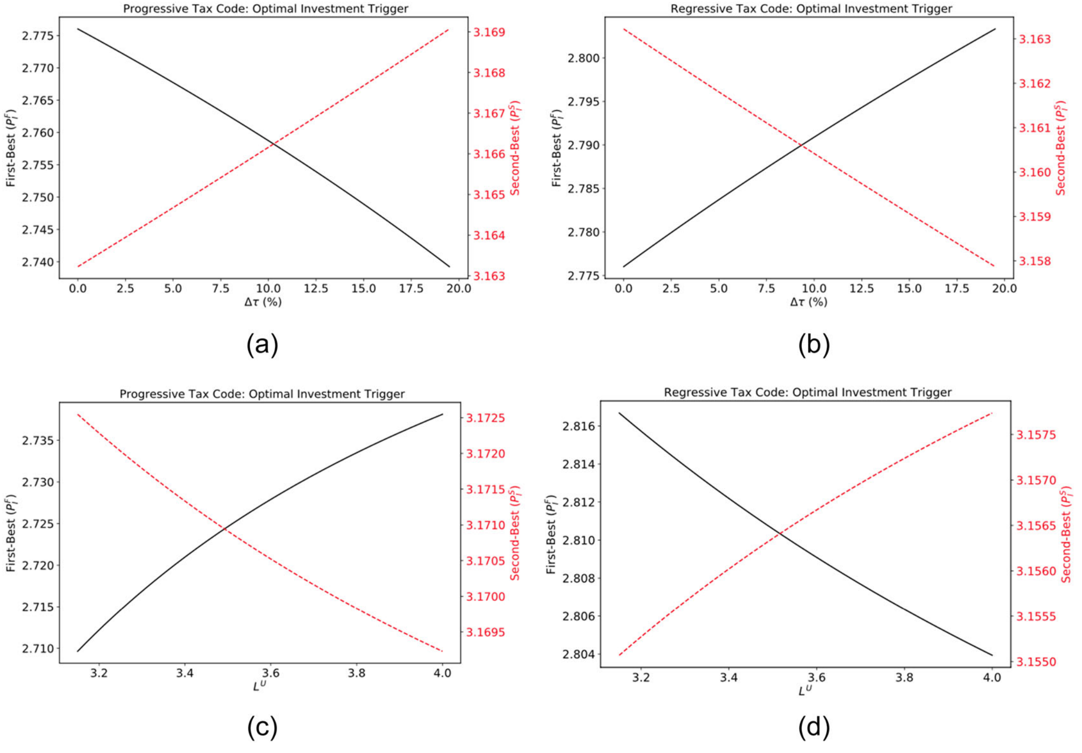

FIGURE 1 Sensitivities of the first- and second-best policies. This figure illustrates the effects of the tax policy terms (τ_1, τ_1/τ_2, L) on the first- and second-best investment policies. The first-best trigger price (in dollars) is represented on the left y-axis and the second-best trigger price (in dollars) is represented on the right y-axis. We vary the tax dispersion $\Delta\tau = |\tau_2 - \tau_1|$ in the interval [0, 0.1] and the tax cutoff L^U in [3.2, 4], both with step size of 0.005. The variations of the tax dispersion $\Delta\tau$ are represented in percentages in the x-axis, and L^U is shown in dollar terms. [Color figure can be viewed at wileyonlinelibrary.com]

bracket cutoff L^U (in the second row). Any change in L^U directly affects L by the same amount and in the same direction. The first column shows the effects under a progressive tax regime and the second column depicts the results for a regressive tax system. Each graph has two y-axes and the reader should be aware that the lines are not effectively crossing each other.[5]

A critical lesson from Figure 1 is that the terms of the tax policy (τ_1, τ_1/τ_2, L) act in opposite directions on the trigger prices. For instance, as illustrated in Figure 1a and 1c, whereas an increase in tax dispersion $\Delta\tau$ decreases (increases) the first-best (second-best) investment trigger price, an increase in L increases (decreases) the first-best (second-best) trigger price under a progressive tax regime. In other words, whereas an increase in the tax dispersion aggravates the underinvestment problem by decreasing the first-best policy trigger price and increasing the second-best policy trigger price, an increase in the threshold bracket L alleviates the underinvestment problem by reducing the distance between the first- and second-best policies. These results are reversed for the regressive tax code, depicted in Figure 1b and 1d.

Our results significantly contrast with the findings of Mauer and Ott (2000, p. 168) who report that as τ decreases, *"both the first- and second-best policymakers are encouraged to exercise the growth option sooner"* and

[5]We opt to represent the first- and second-best in the same figure for the sake of compactness. Naturally, these curves can be displayed separately but this will encompass eight different graphs just for this single analysis.

conclude that *"the difference between the two growth option trigger prices remains relatively constant."* As Table 2 reveals, when we take into consideration a more granular system with design (τ_1, τ_1/τ_2, L), the difference between the two trigger prices can either increase or decrease, depending on the tax regime under consideration. For instance, consider a young firm facing a progressive tax regime. Before the growth option is exercised, the firm enjoys a smaller tax shield because $\tau_1 < \tau_2$. A manager maximizing the total value of the firm (i.e., following the first-best policy) has incentives to exercise the growth option earlier (i.e., P_I^F is lower) and collect the benefits of higher future production. With a higher production level, as the firm reaches the second tax bracket, it benefits from a higher tax shield of debt. Conversely, the underinvestment problem for an equity-maximizer manager is aggravated under a progressive tax regime. The reason is that equityholders bear the full cost of the investment (when exercising the growth option), and although they benefit from higher subsequent cash flow and a higher tax shield, they do not capture the entire benefit of that higher cash flow nor do they benefit from the lower expected bankruptcy costs resulting from the lower probability of default. It is the bondholders who benefit the most from the lower probability of default and expected bankruptcy costs despite not receiving a direct tax benefit on the coupon received (taxed at their personal marginal income tax rate and thus independent of the firm's marginal tax rate). As a result, equity-maximizer managers postpone the growth option exercise even further (i.e., P_I^S increases). The combined effects result in a larger gap between P_I^F and P_I^S, ultimately aggravating the underinvestment problem, as shown in Figure 1a.

The situation is reversed under a regressive tax regime where $\tau_2 < \tau_1$. In this case, the young firm enjoys a higher tax shield value of debt. To extract the maximum tax shield benefits, managers following the first-best policy delay the exercise of the growth option relative to the benchmark case. Conversely, managers following the second-best policy exercise the growth option earlier to extract the gains from the higher expected payoffs generated by the higher scale factor (because $q > 1$) and lower operating income tax rate τ_2. These gains outweigh the tax shield benefits provided by the initial (higher) tax rate. As a result, the gap between P_I^F and P_I^S reduces and the underinvestment problem is alleviated under a regressive tax regime, as shown in Figure 1b.

Table 3 presents the default and abandonment triggers for each of the tax regimes. Whereas the abandonment triggers are apparently insensitive to the tax system in place, the young firm's default price P_D under a progressive tax regime is $1.53/1.50 - 1 = 2\%$ and $1.53/1.48 - 1 = 3.38\%$ higher than the flat and regressive tax codes, respectively. The firm also displays a lower default price of \$1.06 under a regressive tax code after expansion. The reason is that although the higher tax τ_2 is only levied once the firm is sufficiently large and far from the default threshold P_{Dq}, the expected operating cash flow received if the firm surpasses L is larger, making the opportunity cost of liquidating the firm under a regressive tax regime larger relative to a progressive tax code.

Table 4 presents the effect of the different tax regimes on the valuation of debt and equity when managers follow the first- and second-best policies. As reported, firms' valuations are the highest under the

TABLE 3 Abandonment and default prices.

	Before growth option is exercised		After growth option is exercised	
Tax code	Abandonment price (P_A)	Default price (P_D)	Abandonment price (P_{Aq})	Default price (P_{Dq})
Progressive	0.65	1.53	0.67	1.07
Flat	0.64	1.50	0.67	1.06
Regressive	0.64	1.48	0.67	1.06

Note: This table reports the abandonment and default triggers P_A, P_{Aq}, P_D, P_{Dq} for the progressive, flat, and regressive tax codes.

TABLE 4 Equity and debt values under the first- and second-best policies.

	First-best policy						Second-best policy					
	Progressive tax code		Flat tax code		Regressive tax code		Progressive tax code		Flat tax code		Regressive tax code	
Output price (I)	Equity $E_F\ (P)$	Debt $D_F\ (P)$	Equity $E_F\ (P)$	Debt $D_F\ (P)$	Equity $E_F\ (P)$	Debt $D_F\ (P)$	Equity $E_S\ (P)$	Debt $D_S\ (P)$	Equity $E_S\ (P)$	Debt $D_S\ (P)$	Equity $E_S\ (P)$	Debt $D_S\ (P)$
1.50					0.01	4.21					0.01	4.20
1.60	0.07	5.71	0.14	6.36	0.21	6.93	0.11	5.64	0.18	6.28	0.26	6.85
1.70	0.39	8.16	0.53	8.72	0.69	9.20	0.50	7.99	0.63	8.56	0.78	9.05
1.80	0.93	10.25	1.16	10.72	1.39	11.13	1.10	9.98	1.31	10.47	1.52	10.91
1.90	1.66	12.06	1.97	12.45	2.28	12.79	1.90	11.67	2.18	12.11	2.47	12.50
2.00	2.55	13.64	2.96	13.96	3.36	14.25	2.86	13.14	3.22	13.53	3.59	13.87
2.10	3.59	15.05	4.09	15.30	4.59	15.53	3.98	14.42	4.43	14.76	4.88	15.06
2.20	4.76	16.31	5.38	16.50	5.97	16.68	5.24	15.55	5.78	15.85	6.32	16.12
2.30	6.07	17.46	6.79	17.59	7.50	17.72	6.63	16.56	7.27	16.82	7.91	17.06
2.40	7.49	18.52	8.34	18.59	9.16	18.68	8.15	17.47	8.89	17.70	9.64	17.90
2.50	9.03	19.51	10.01	19.53	10.96	19.57	9.80	18.29	10.65	18.50	11.51	18.67
2.60	10.68	20.45	11.81	20.41	12.89	20.40	11.56	19.05	12.54	19.23	13.51	19.38
2.70	12.45	21.35	13.72	21.25	14.95	21.19	13.45	19.76	14.55	19.91	15.66	20.04
2.80							15.45	20.42	16.69	20.54	17.94	20.65
2.90							17.57	21.04	18.97	21.14	20.36	21.23
3.00							19.81	21.64	21.37	21.71	22.92	21.78
3.10							22.17	22.21	23.90	22.26	25.63	22.30

Note: This table reports the first- and second-best policy debt and equity values under the progressive, flat, and regressive tax regimes for different levels of the output price P in the range [1.50, 3.10]. The blank spaces represent instances where the output price is either below the default price or above the investment trigger price, and immediate exercise is optimal. The parameter values are as in Table 1.

regressive tax regime and the lowest under the progressive tax regime. The higher expected payoffs with lower tax rate under a regressive tax regime outweighs the higher tax shield provided by the upper tax bracket under a progressive tax system, leading to higher valuations of debt and equity under a regressive tax code. Despite the fact that both debt and equity levels are higher under the regressive tax code, our numerical results indicate that equity is clearly more sensitive than debt to changes in the tax system, which confirms that the benefits of lower operating income taxation of large firms exceeds the tax shield gains provided by higher tax rates.

Another interesting observation is that the complexity of the tax system does not change the fact that the adoption of a second-best policy represents a burden to debtholders who pay less for the debt at issuance. Consequently, the resulting higher bond yield represents an additional cost to managers, which ultimately reduces equity value. As a result, similar to the findings of Mauer and Ott (2000), equity valuation in the second-best policy is always higher than in the first-best policy, whereas the second-best debt level is always smaller than the first-best debt level, independent of the tax regime in place.

With trigger prices and contingent claims fully determined, we turn to the characterization of the agency cost of underinvestment. Following the literature, we define the dollar agency cost as the difference between the value of the levered firm under the first- and second-best policies, that is,

$$AC = V_F(P) - V_S(P),$$

and the percentage agency cost as

$$AC_{\%} = \frac{V_F(P) - V_S(P)}{V_S(P)}.$$

Figure 2 shows the percentage agency costs for the three tax regimes. The progressive tax code (dashed line) displays the largest agency cost and the regressive tax code (dotted line) the lowest. Note that different from the findings of Mauer and Ott (2000), the inclusion of a more complex tax system can significantly amplify (in the case of a progressive tax system) or dampen (in the case of a regressive tax policy) the agency costs of underinvestment. Our numerical example shows that the percentage agency cost under the progressive tax code can be 1.5 times larger than its counterpart under a regressive tax regime. Whereas the first ranges from 0 to 1.82%, the percentage agency cost under a flat and regressive tax system ranges from 0 to 1.54% and from 0 to 1.32%, respectively.

To isolate the impact of each of the tax policy terms (τ_1, τ_1/τ_2, L) on the agency cost of underinvestment, we show in Figure 3 the sensitivity of the percentage agency cost under a progressive tax regime with respect to these quantities. Figure 4 contains the same analysis for a regressive tax regime. First, we observe that the agency cost on both tax regimes is more sensitive to variations on the tax dispersion $\Delta\tau$ than the unlevered tax cutoff L^U. Second, the counteracting effects exerted by the tax dispersion $\Delta\tau$ and the unlevered tax cutoff L^U on the investment trigger prices (i.e., P_I^F and P_I^S) are carried out to the percentage agency cost. Interestingly, these effects are not monotonic on the output price. For instance, in Figure 3a and 3b the agency cost is decreasing on the tax dispersion $\Delta\tau$ for output prices near to the default price and increasing when the output price is close to the first-best investment trigger. A reverse pattern is observed in Figure 3c.

Although Figures 3 and 4 are informative with respect to the effect on the total agency cost, they do not tell us which components of the total agency cost are moving the most with the changes in the tax policy terms.

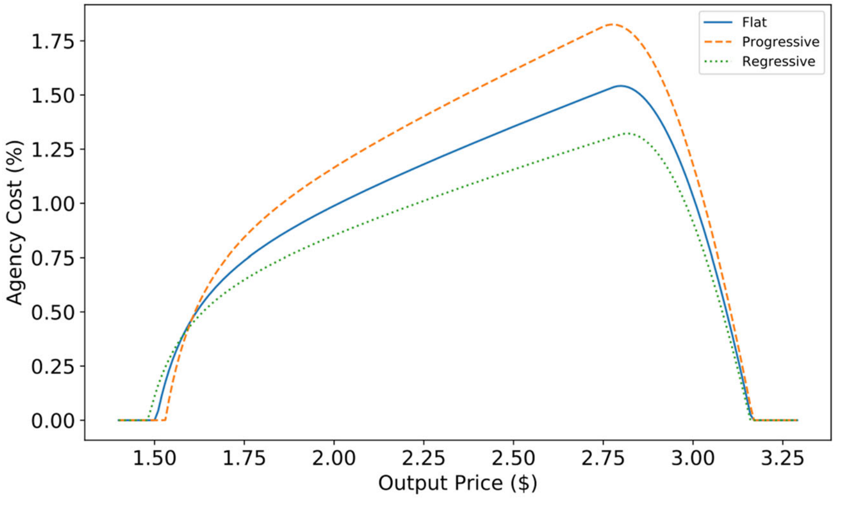

FIGURE 2 Agency cost of underinvestment. This figure shows the percentage agency cost as a function of the output price (in dollars). The solid line represents the percentage agency cost under a flat tax code, the dashed line the percentage agency cost under a progressive tax code, and the dotted line the percentage agency cost under a regressive tax code. The parameter values are provided in Table 1. [Color figure can be viewed at wileyonlinelibrary.com]

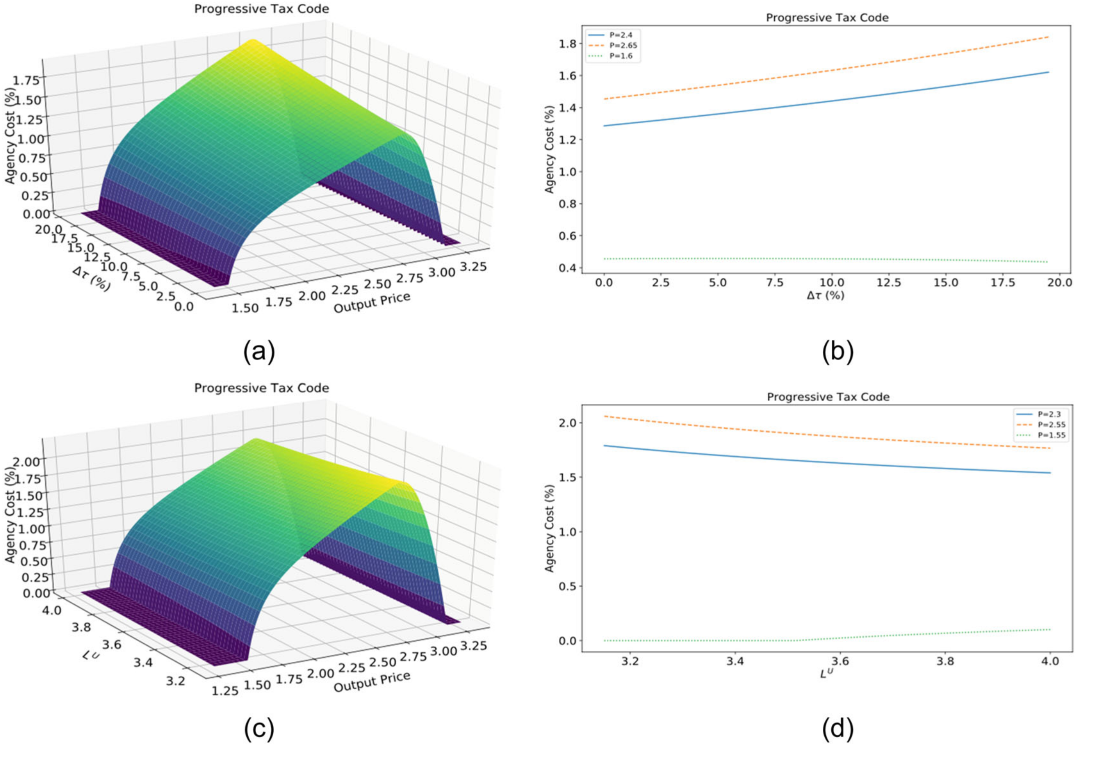

FIGURE 3 Effects of tax policy terms on total agency cost under a progressive tax code. This figure illustrates the effects of the tax policy terms (τ_1, τ_1/τ_2, L) on the percentage agency cost of underinvestment under a progressive tax regime. Figure 3a shows the joint effect of the output price P (x-axis) and the tax dispersion $\Delta\tau$ (y-axis) on the percentage agency cost (z-axis). Figure 3b shows three slices of 3(a) to highlight the effect of the tax dispersion on the agency cost. The dotted line represents the slice for P = \$1.60, the solid line the slice for P = \$2.40, and the dashed line the slice for P = \$2.65. We vary $\Delta\tau$ from 0% to 10% with step size of 0.5%. Figure 3c shows the joint effect of the output price P (x-axis) and the tax cutoff L^U (y-axis) on the percentage agency cost (z-axis). Figure 3d shows three slices of 3(c) to highlight the effect of the tax cutoff L^U on the agency cost. The dotted line represents the slice for P = \$1.55, the solid line the slice for P = \$2.30, and the dashed line the slice for P = \$2.55. We vary L^U in the interval [3.2, 4] with a step size of 0.005. [Color figure can be viewed at wileyonlinelibrary.com]

To answer this question, we decompose the total percentage agency cost into three parts: (1) unlevered firm component, (2) tax shield of debt, and (3) bankruptcy costs. Formally, we write

$$AC_{\%} = \frac{V_F^U(P) - V_S^U(P)}{V_S(P)} + \frac{TS_F(P) - TS_S(P)}{V_S(P)} + \frac{BC_S(P) - BC_F(P)}{V_S(P)}.$$

Table 5 presents the decomposition of levered firm value and the total agency cost for the progressive, flat, and regressive tax regimes. First, bankruptcy costs are only larger than the tax shield of debt when the firm is in distress (i.e., for output prices that are near default price P_D). Because the firm has the largest default price of \$1.53 under a progressive tax regime, there is a wider range of output values where bankruptcy costs outweighs the tax shield of debt in comparison to the regressive tax regime. Second, observe that the agency cost as a percentage of the second-best debt service (last column in Table 5) is considerably larger under a progressive tax code than under a regressive tax code. This indicates that a substantial portion of the additional agency cost emerging under the progressive tax regime comes from the variations in the financing components of the agency cost (i.e., $TS_F - TS_S$ and $BC_S - BC_F$).

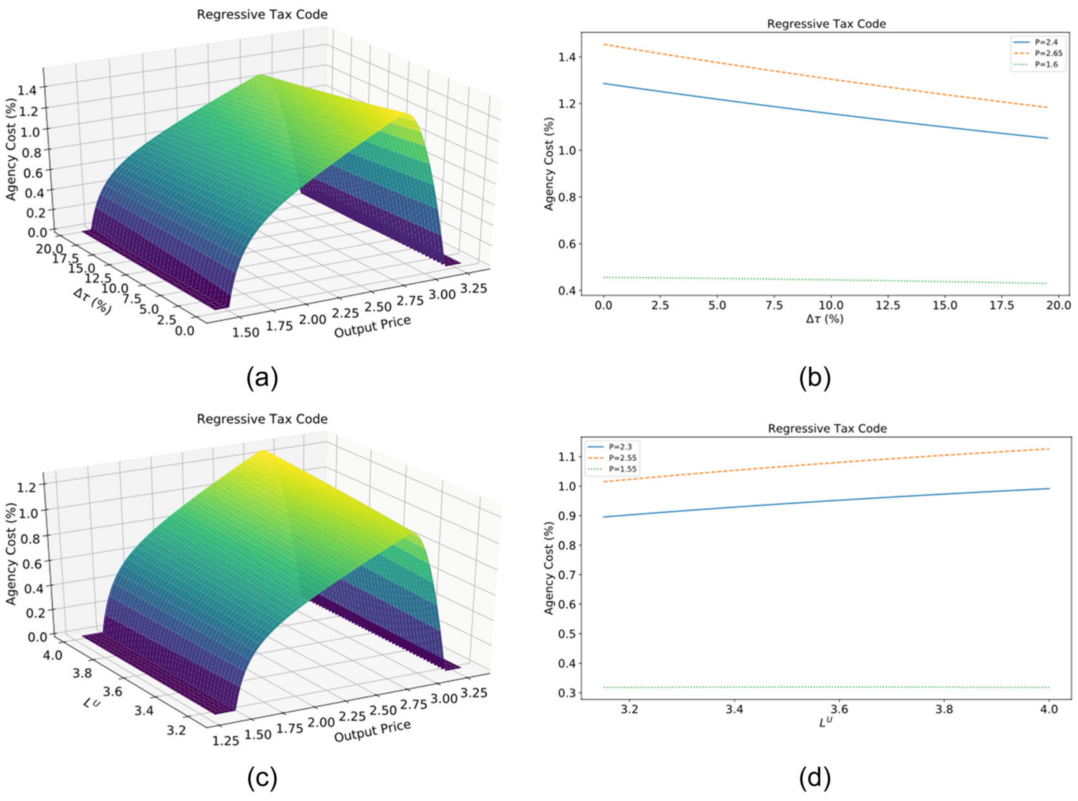

FIGURE 4 Effects of tax policy terms on total agency cost under a regressive tax code. This figure illustrates the effects of the tax policy terms (τ_1, τ_1/τ_2, L) on the percentage agency cost of underinvestment under a regressive tax regime. Figure 4a shows the joint effect of the output price P (x-axis) and the tax dispersion $\Delta\tau$ (y-axis) on the percentage agency cost (z-axis). Figure 4b shows three slices of 4(a) to highlight the effect of the tax dispersion on the agency cost. The dotted line represents the slice for P = \$1.50, the solid line the slice for P = \$2.30, and the dashed line the slice for P = \$2.55. We vary $\Delta\tau$ from 0% to 10% with step size of 0.5%. Figure 4c shows the joint effect of the output price P (x-axis) and the tax cutoff L^U (y-axis) on the percentage agency cost (z-axis). Figure 4d shows three slices of 4(c) to highlight the effect of the tax cutoff L^U on the agency cost. We vary L^U in the interval [3.2, 4] with a step size of 0.005. [Color figure can be viewed at wileyonlinelibrary.com]

In fact, whereas the dollar value of the first- and second-best tax shields TS_F and TS_S decrease with tax dispersion, the dollar tax shield component of the agency cost (i.e., $\Delta TS = TS_F - TS_S$) increases with $\Delta\tau$. The reason is that the second-best tax shield TS_S is much more sensitive to variations in $\Delta\tau$ and decreases faster relative to the first-best tax shield TS_F. This can be readily observed in Table 5 by comparing the first- and second-best tax shields under the progressive tax code (where $\Delta\tau$ = 10%) and flat tax code (where $\Delta\tau$ = 0%) for any output price. Intuitively, the larger the tax dispersion, the sooner a firm-value-maximizer manager invests to exploit the tax shield of debt provided by a higher tax rate in the event the firm reaches the tax cutoff L, and the later an equity-maximizer manager exercises the growth option to postpone the wealth transfer to bondholders from bearing all the investment cost. As a result, the gap between the first- and second-best trigger prices widens and the deviation from the first-best policy is priced by bondholders that ultimately are willing to pay less for risky debt. The substantial reduction in the firm's debt valuation is accompanied by a large reduction of the tax shield value of debt.

The results are reversed for a regressive tax regime. For large tax dispersions under a regressive tax code, managers following the first-best policy postpone the investment opportunity to keep extracting higher tax benefits, whereas equity-maximizer managers anticipate the investment to increase production and eventually pay

TABLE 5 Agency cost.

Output price (P)	First-best components			Second-best components			Agency cost components			Total agency cost		
	V_F^U	TS_F	BC_F	V_S^U	TS_S	BC_S	$V_F^U - V_S^U$	$TS_F - TS_S$	$BC_S - BC_F$	AC	AC % of V_S	AC % of D_S
Panel A: Progressive tax code												
1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.60	8.30	0.84	3.36	8.31	0.81	3.37	−0.01	0.03	0.01	0.03	0.45	0.53
1.70	9.60	1.87	2.92	9.65	1.80	2.96	−0.05	0.07	0.04	0.06	0.75	0.75
1.80	10.96	2.76	2.54	11.05	2.64	2.61	−0.09	0.12	0.07	0.10	0.92	1.00
1.90	12.41	3.53	2.22	12.51	3.36	2.30	−0.10	0.17	0.08	0.14	1.05	1.20
2.00	13.91	4.21	1.93	14.05	3.99	2.04	−0.14	0.22	0.11	0.19	1.17	1.45
2.10	15.48	4.82	1.67	15.66	4.55	1.81	−0.18	0.27	0.14	0.23	1.26	1.60
2.20	17.13	5.38	1.44	17.36	5.04	1.61	−0.23	0.34	0.17	0.28	1.36	1.80
2.30	18.86	5.89	1.22	19.13	5.49	1.43	−0.27	0.40	0.21	0.34	1.45	2.05
2.40	20.67	6.36	1.02	20.98	5.90	1.26	−0.31	0.46	0.24	0.39	1.53	2.23
2.50	22.57	6.81	0.83	22.92	6.28	1.11	−0.35	0.53	0.28	0.45	1.61	2.46
2.60	24.55	7.24	0.65	24.95	6.64	0.97	−0.40	0.60	0.32	0.52	1.70	2.73
2.70	26.61	7.66	0.47	27.07	6.97	0.83	−0.46	0.69	0.36	0.59	1.78	2.99
2.80	28.96	7.93	0.37	29.29	7.29	0.71	−0.33	0.64	0.34	0.65	1.82	3.18
2.90	31.53	8.06	0.35	31.60	7.60	0.59	−0.07	0.46	0.24	0.62	1.62	2.95
3.00	34.08	8.18	0.32	34.02	7.90	0.47	0.06	0.28	0.15	0.49	0.49	2.26
3.10	36.61	8.31	0.30	36.55	8.19	0.36	0.06	0.12	0.06	0.24	0.54	1.08
Panel B: Flat tax code												
1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.60	8.61	1.1 0	3.22	8.64	1.07	3.24	−0.03	0.03	0.02	0.03	0.46	0.48
1.70	9.98	2.07	2.8	10.03	2.0 0	2.84	−0.05	0.07	0.04	0.06	0.66	0.70
1.80	11.42	2.9 0	2.44	11.49	2.79	2.50	−0.07	0.11	0.06	0.09	0.80	0.86
1.90	12.94	3.61	2.13	13.03	3.47	2.21	−0.09	0.14	0.08	0.13	0.90	1.07
2.00	14.55	4.23	1.86	14.66	4.05	1.96	−0.11	0.18	0.10	0.17	0.99	1.26
2.10	16.22	4.79	1.62	16.37	4.56	1.74	−0.15	0.23	0.12	0.21	1.07	1.42
2.20	17.99	5.29	1.40	18.17	5.01	1.55	−0.18	0.28	0.15	0.25	1.14	1.58
2.30	19.84	5.74	1.19	20.05	5.41	1.37	−0.21	0.33	0.18	0.29	1.22	1.72
2.40	21.79	6.16	1.01	22.03	5.77	1.21	−0.24	0.39	0.20	0.34	1.29	1.92
2.50	23.82	6.55	0.83	24.12	6.1 0	1.07	−0.30	0.45	0.24	0.39	1.35	2.11
2.60	25.97	6.91	0.66	26.29	6.40	0.93	−0.32	0.51	0.27	0.45	1.42	2.34
2.70	28.21	7.26	0.50	28.57	6.69	0.8 0	−0.36	0.57	0.30	0.51	1.49	2.56
2.80	30.64	7.54	0.37	30.97	6.95	0.68	−0.33	0.59	0.31	0.57	1.54	2.78

(Continues)

2.90	33.39	7.62	0.34	33.48	7.2 0	0.57	−0.09	0.42	0.23	0.56	1.41	2.65
3.00	36.14	7.70	0.32	36.10	7.44	0.46	0.04	0.26	0.14	0.45	1.03	2.07
3.10	38.90	7.77	0.30	38.84	7.67	0.35	0.06	0.10	0.05	0.21	0.46	0.94
Panel C: Regressive tax code												
1.50	7.57	0.22	3.58	7.58	0.21	3.58	−0.01	0.01	0.00	0.00	0.11	0.00
1.60	8.93	1.31	3.10	8.95	1.28	3.12	−0.02	0.03	0.02	0.03	0.44	0.44
1.70	10.36	2.23	2.70	10.41	2.16	2.74	−0.05	0.07	0.04	0.06	0.59	0.66
1.80	11.88	3.00	2.36	11.93	2.91	2.41	−0.05	0.09	0.05	0.09	0.70	0.82
1.90	13.49	3.66	2.07	13.55	3.54	2.13	−0.06	0.12	0.06	0.12	0.78	0.96
2.00	15.16	4.24	1.80	15.26	4.08	1.89	−0.10	0.16	0.09	0.15	0.85	1.08
2.10	16.95	4.74	1.57	17.08	4.54	1.68	−0.13	0.20	0.11	0.18	0.92	1.20
2.20	18.82	5.19	1.36	18.97	4.95	1.49	−0.15	0.24	0.13	0.22	0.98	1.36
2.30	20.80	5.59	1.17	20.97	5.31	1.32	−0.17	0.28	0.15	0.26	1.04	1.52
2.40	22.88	5.95	0.99	23.09	5.62	1.17	−0.21	0.33	0.18	0.30	1.10	1.68
2.50	25.06	6.29	0.82	25.30	5.91	1.03	−0.24	0.38	0.21	0.35	1.16	1.87
2.60	27.37	6.59	0.67	27.63	6.16	0.90	−0.26	0.43	0.23	0.40	1.21	2.06
2.70	29.78	6.88	0.51	30.08	6.39	0.78	−0.30	0.49	0.27	0.45	1.27	2.25
2.80	32.32	7.15	0.37	32.65	6.60	0.66	−0.33	0.55	0.29	0.51	1.32	2.47
2.90	35.25	7.19	0.34	35.34	6.80	0.55	−0.09	0.39	0.21	0.51	1.23	2.40
3.00	38.22	7.21	0.32	38.18	6.97	0.45	0.04	0.24	0.13	0.41	0.91	1.88
3.10	41.19	7.23	0.30	41.14	7.14	0.35	0.05	0.09	0.05	0.19	0.39	0.85

Note: This table presents the first- and second-best components of the levered firm value for the progressive, flat, and regressive tax regimes. The agency cost components are formed as the difference between the first- and second-best values, with the exception of the bankruptcy cost component that is measured as the second-best value minus the first-best value to capture the increase in the expected bankruptcy costs. The last three columns report the dollar agency cost, percentage agency cost, and agency cost as a percentage to the second-best debt value. The parameters are provided in Table 1.

a lower corporate tax rate. As a result, the gap between the first- and second-best trigger prices are reduced, which generates a smaller agency cost than the other tax regimes and leads to higher debt valuations. The higher levels of debt make this contingent claim less sensitive to tax dispersion, resulting in a decline in the tax shield component of the agency cost (i.e., ΔTS) as $\Delta\tau$ increases.

3.1 | Betas, credit spreads, and leverage

In this section, we analyze the impact of the tax policy design on equity beta. Following Gomes and Schmid (2010) and Li and Mauer (2016), we proxy the equity beta by the elasticity of equity with respect to the output price P. Formally, we define the first- and second-best equity beta as[6]

[6]As explained in Gomes and Schmid (2010), under the assumption of a constant risk premium λ, the expected return on equity in a one-factor asset pricing model is given by $\mathbb{E}_t[R_{t+1}] = r + \beta_t \sigma \lambda$, where β_t is given in (36).

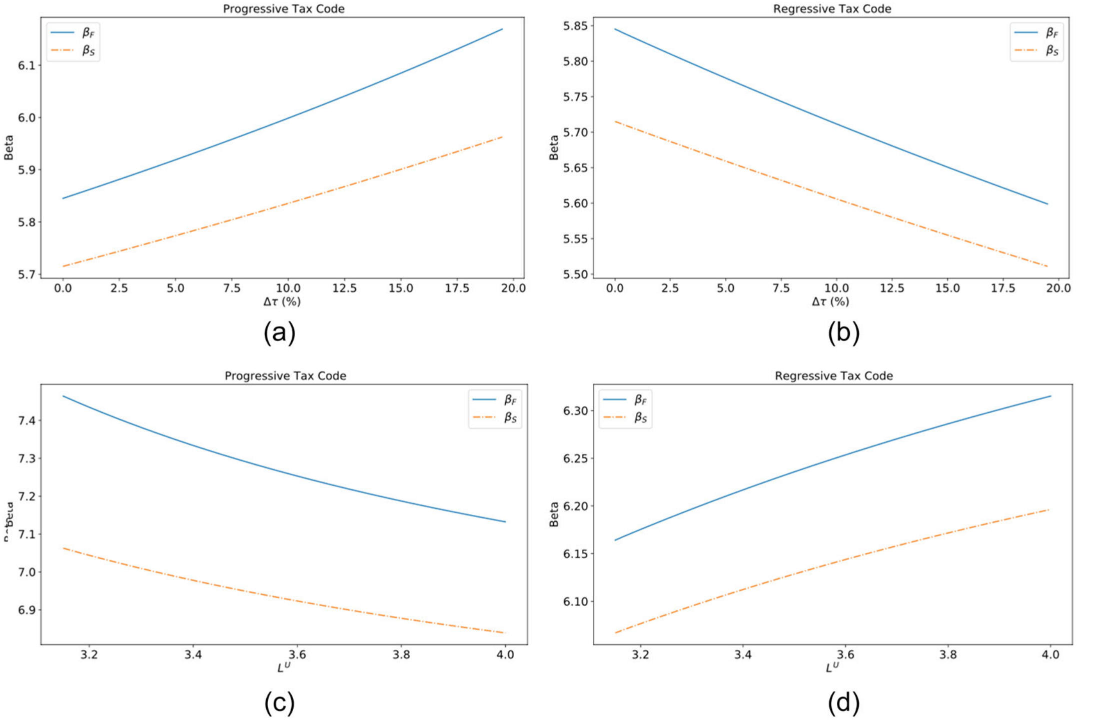

FIGURE 5 Equity betas. This figure shows the effect of the tax dispersion $\Delta\tau$ (first row) and the tax cutoff L^U (second row) on the first- and second-best equity beta under the progressive (first column) and regressive (second column) tax regimes. The solid line represents the first-best equity beta and the dashed line the second-best equity beta. The parametrization is the same as in Table 1, and the output pice is fixed at $P = \$2.05$. [Color figure can be viewed at wileyonlinelibrary.com]

$$\beta_F = \frac{d\log E_F}{d\log P} \quad \text{and} \quad \beta_S = \frac{d\log E_S}{d\log P}. \tag{36}$$

Figure 5 shows the effect of the tax policy terms ($\tau_1, \tau_1/\tau_2, L$) on the firm's first- and second-best equity betas. First, observe that the first-best beta is always above the second-best beta, indicating that the first-best equity value is more sensitive to the changes in the output price than the second-best equity value. This result follows from the fact that the second-best equity $E_S(P)$ is obtained by an equity-maximizer manager, and consequently, this equity value is at least as large as the first-best equity value $E_F(P)$, where managers maximize the total value of the firm (i.e., debt plus equity). Thus, it is expected that the lower levels of the first-best equity price are more sensitive to variations in the output price than the higher levels of the second-best equity. Intuitively, the larger the corporate tax rate τ_2, the larger the asset substitution effect across asset classes because managers rely more on equity than on debt to finance the firm, especially when managers follow a first-best policy and equity maximization is not the objective function. As a result, the first-best equity becomes more sensitive than the second-best equity to variations in the output price, and the gap between the equity betas increase with the tax dispersion, as shown in Figure 5a.

Second, in the progressive tax regime, both equity betas are decreasing in the tax cutoff L. Once again, this effect can be understood by checking the effect of L on equity valuation. In particular, consider the intuitive case where the tax cutoff L is extremely large (i.e., $L \to \infty$). In this instance, the two-bracket tax system essentially becomes a flat tax system. As indicated in Table 4, equity valuation is larger under a flat tax regime than under a progressive system and less sensitive to output price variations. Thus, the larger the tax cutoff L, the smaller the equity betas, as shown in Figure 5c. The reasoning for the regressive tax regime follows from the reverse logic.[7]

The economic intuition for this result goes as follows. Consider the case of the first-best beta under a progressive tax regime. There are two factors contributing to the increase in the equity beta. First, a higher corporate tax rate for sufficiently large firms induces managers to anticipate the option exercise (see Table 2), making the expansion more likely and, consequently, the growth option more valuable. Because of the convex structure of equity, beta increases. Second, as revealed by Table 4, equity declines more than debt for an increase in the tax dispersion, ultimately increasing the firm's leverage. As pointed out by Hong and Sarkar (2007), this increase in the leverage ratio can be interpreted as a shift in additional risk bearing to equityholders that results in higher equity beta.

In contrast, these two effects on the second-best equity beta are not reinforcing each other as in the case of the first-best equity but, rather, are competing. The reason is that an increase in the tax dispersion under a progressive tax code induces managers to postpone investment because they bear all the investment costs and share the benefits with bondholders (see Table 2). This effect reduces the likelihood of the expansion and, consequently, the relevance of the growth option, driving the second-best equity downward. In our analysis, the first effect dominates the second, which culminates in an increase of the second-best equity beta.

In fact, the interaction of these two effects can be readily observed in Figure 5a. As shown, the reason the first-best equity beta has a larger growth rate than the second-best equity beta is that the two effects act in tandem on the first-best equity beta and in opposition in the second-best equity beta.

Similar to Leland (1994), we define credit spreads and leverage, respectively, as

$$CS_j(P) = \frac{R}{D_j(P)} - r, \text{ and } \ell_j(P) = \frac{D_j(P)}{V_j(P)}, \text{ with } j \in \{F, S\}. \tag{37}$$

Figure 6 presents the results for the first- and second-best credit spread (first row) and leverage (second row) under progressive (dashed line), flat (solid line), and regressive (dotted line) tax regimes. First, as Figure 6a and 6b illustrate, credit spreads are decreasing functions of the output price for all tax regimes because an increase in output price always increases the debt valuation and therefore decreases credit spreads according to (37). It is worth mentioning again that we do not optimize over the debt coupon in our analysis and that R is exogenously given. If one were to optimize over R, the debt coupon would become a function of the output price itself and could, in theory, have a larger growth rate than debt, resulting in an increase in credit spreads.

Second, firms under a progressive tax policy present overall higher credit spreads because the valuation is the lowest under this tax regime, as shown in Table 4. In addition, yield spreads are considerably larger in periods of distress, when the output price is close to the default price. In these instances, as equity valuation approaches zero, the firm is mainly financed through debt, which is also priced at a discount. The substantial decline in the price of risky debt makes credit spreads spike. As the output price deviates from the default prices and approaches the investment trigger price, credit spreads decline with the increase in debt valuation. Moreover, the difference between spreads under different tax regimes disappears.

The effect of output price and tax regimes on the firm's leverage is slightly more subtle because, different from the credit spread expression, variations in the output price and taxation affect both the numerator and denominator of the leverage ratio presented in (37). As Table 4 shows, equity is considerably more sensitive to changes in the output price than debt. As a result, the increase in output price changes the balance between debt and equity toward equity, resulting in smaller leverage ratios. In addition, because equity valuation is the highest under a regressive tax regime, the leverage ratio under this tax system is the lowest.

[7]The parametrization of Mauer and Ott (2000) that we follow generates large values for equity betas. Because our main objective is understanding the sensitivity of equity betas to the tax policy design, the fact that the beta levels are off does not affect our analysis.

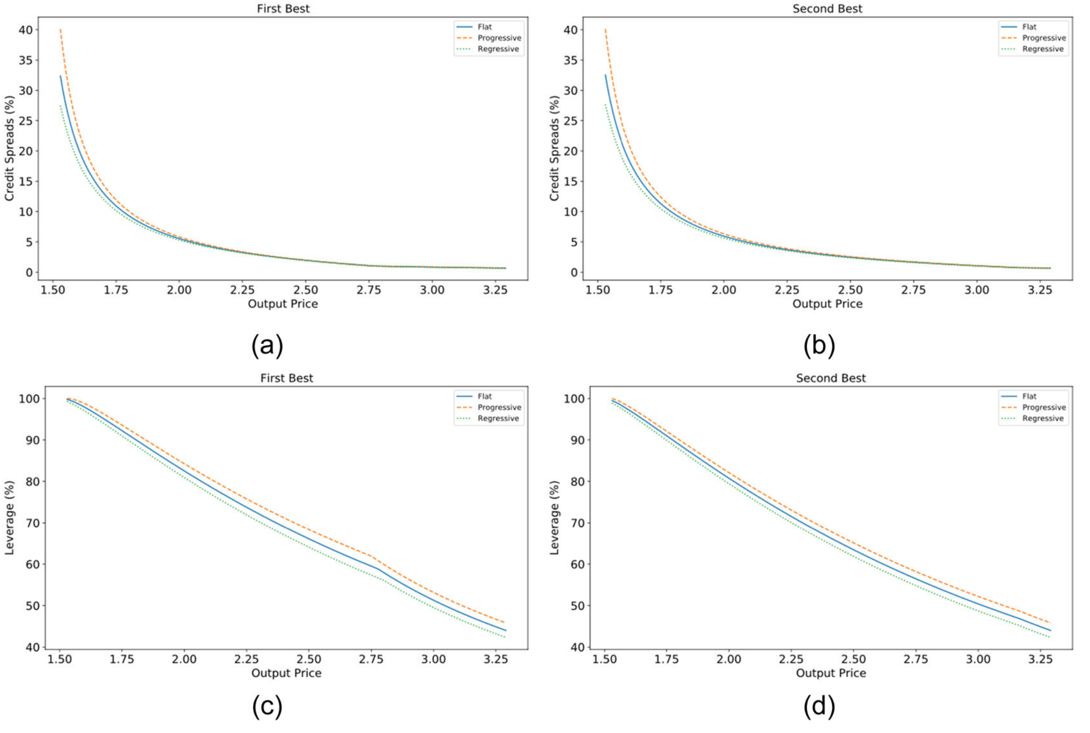

FIGURE 6 Credit spreads and leverage. The figure shows the effect of the output price on credit spreads (first row) and the leverage ratio (second row) under the progressive (dashed line), flat (solid line), and regressive (dotted line) tax regimes. The first column displays the first-best quantities and the second column the second-best. The parametrization is the same as in Table 1. [Color figure can be viewed at wileyonlinelibrary.com]

An interesting observation is that in contrast to credit spreads, the gap between the leverage ratios under different tax systems does not converge to zero as the output price increases. In fact, the distance between the leverage ratio under progressive and regressive tax regimes fluctuates and can either increase or decrease with the output price, as shown in Figure 6c and 6d. The reason is that changes in the output price simultaneously affect equity and debt (i.e., the numerator and denominator of the leverage ratio), and these are highly sensitive around the default and the investment trigger prices. When firms are in distress and the output price is in the vicinity of the default price, leverage approaches 100%, independent of the tax regime in place. Note that this is the region where the gap between the first-best progressive and regressive leverages is the lowest. As output approaches the first-best investment trigger price, the gap widens and subsequently shrinks after the first-best investment trigger under a regressive regime is reached. In contrast to the first-best leverage, Figure 6d shows that the gap between the second-best progressive and regressive leverage appears to be monotonically increasing in the output price.

4 | FINANCING THE GROWTH OPTION WITH ADDITIONAL DEBT ISSUANCE

As argued by Myers (1977) and Mauer and Ott (2000), the nature of the underinvestment problem emerges from the fact that managers have to cover the full cost of the investment but share the benefits with debtholders. Mauer and Sarkar (2005) show that when managers have the ability to finance the growth opportunity with additional debt issuance and share the investment cost with debtholders, the problem of overinvestment might emerge. In this case, instead of delaying the growth option exercise, equity-maximizer managers exercise the growth option too soon relative to total-value-firm-maximizer managers.

To investigate the interactions between the tax policy terms and the additional debt financing of the growth option, we extend our model by building on Hackbarth and Mauer (2012) and allowing the firm to issue additional debt at the exercise time to finance its expansion. We assume that the additional issued debt has equal priority (*pari passu*) in the case of bankruptcy. Thus, if the firm defaults after the investment is made, new debtholders receive a fraction of the firm's liquidation value proportional to the new coupon.

Whereas the problem for the unlevered firm remains identical, the levered firm problem differs in a few dimensions with the introduction of the additional debt issuance at the time of exercise. Nevertheless, the solution strategy remains the same; we first characterize the value of debt and equity after the investment is made, and then price the contingent claims before the growth option is exercised, assuming that managers follow the first- and second-best policy.

4.1 | Levered firm value after investment

After the expansion, we need to price equity and two (classes) of debt: debt issued at the initial date and the additional debt issued at the exercise date to finance the growth option. As in Section 2.2, the tax cutoff must be adjusted to take the additional coupon R_l into account; thus, we now have $L = L^U + (R + R_l)/q$. In addition, we restrict our analysis to the case where the firm's net profit can cover the firm's debt service. In other words, we assume the parametrization restriction $R + R_l < (L - C)q$ to guarantee that the firm operates at a positive net profit level.

Although the ODEs for the initial debt claims before and after the tax cutoff L is reached remain identical, we need to (1) adjust the general solution for equity to include the cost of new (exogenous) debt coupon *red*R_l and (2) include the ODEs satisfied by the new debt before and after the tax cutoff L is reached. Denoting the equity value before and after the threshold L is reached by $E_q^{BL}(P)$ and $E_q^{AL}(P)$, respectively, the ODEs become

$$\frac{\sigma^2}{2}P^2\partial_{PP}E_q^{BL} + (r - \delta)P\partial_P E_q^{BL} - rE_q^{BL} + ((P - C)q - (R + R_l))(1 - \tau_1) = 0,$$
$$\frac{\sigma^2}{2}P^2\partial_{PP}E_q^{AL} + (r - \delta)P\partial_P E_q^{AL} - rE_q^{AL} + ((L - C)q - (R + R_l))(1 - \tau_1) + (P - L)q(1 - \tau_2) = 0,$$

with the general solution given by

$$\begin{aligned} E_q^{BL}(P) &= \left(\left(\frac{P}{\delta} - \frac{C}{r}\right)q - \frac{R + R_l}{r}\right)(1 - \tau_1) + E_1 P^{\gamma_1} + E_2 P^{\gamma_2}, \\ E_q^{AL}(P) &= \left(\left(\frac{L - C}{r}\right)q - \frac{R + R_l}{r}\right)(1 - \tau_1) + \left(\frac{P}{\delta} - \frac{L}{r}\right)q(1 - \tau_2) + E_3 P^{\gamma_1} + E_4 P^{\gamma_2}. \end{aligned}$$

Denoting the value of the additional debt before and after the tax cutoff L is reached by $D_{l,q}^{BL}(P)$ and $D_{l,q}^{AL}(P)$, respectively, their ODEs become

$$\frac{\sigma^2}{2}P^2\partial_{PP}D_{l,q}^{BL} + (r - \delta)P\partial_P D_{l,q}^{BL} - rD_{l,q}^{BL} + R_l = 0,$$
$$\frac{\sigma^2}{2}P^2\partial_{PP}D_{l,q}^{AL} + (r - \delta)P\partial_P D_{l,q}^{AL} - rD_{l,q}^{AL} + R_l = 0,$$

with the general solution given by

$$\begin{aligned} D_{l,q}^{BL}(P) &= \tfrac{R_l}{r} + D_9 P^{\gamma_1} + D_{10} P^{\gamma_2}, \\ D_{l,q}^{AL}(P) &= \tfrac{R_l}{r} + D_{11} P^{\gamma_1} + D_{12} P^{\gamma_2}. \end{aligned} \tag{38}$$

Although Boundary Conditions (14)–(20) remain the same, we adapt Boundaries (21) and (22) to incorporate the additional cost to equityholders of the new coupon payment and to reflect that both classes of debt have equal priority in the case of bankruptcy. Thus, under this new framework, when the firm becomes extremely large, the value of equity is

$$\lim_{P\to\infty} E_q^{AL}(P) = \left(\left(\frac{L-C}{r}\right)q - \frac{R+R_l}{r}\right)\left(1-\tau_1\right) + \left(\frac{P}{\delta} - \frac{L}{r}\right)q\left(1-\tau_2\right). \tag{39}$$

Conversely, at the default price P_{D_q}, debtholders receive a fraction of the firm's liquidation value, proportional to the debt's coupon payment, that is,

$$D_q^{BL}(P_{D_q}) = \left(\frac{R}{R+R_l}\right)\left(1-b\right)V_q^{UBL}(P_{D_q}). \tag{40}$$

In addition to (14)–(20) and (39)–(40), the following four boundary conditions determine D_9, D_{10}, D_{11}, and D_{12} in (38):

$$\lim_{P\to\infty} D_{l,q}^{AL}(P) = \frac{R_l}{r},$$

$$D_{l,q}^{AL}(L) = D_{l,q}^{BL}(L),$$

$$\partial_P D_{l,q}^{AL}(L) = \partial_P D_{l,q}^{BL}(L),$$

$$D_{l,q}^{BL}(P_{D_q}) = \left(\frac{R_l}{R+R_l}\right)\left(1-b\right)V_q^{UBL}(P_{D_q}).$$

This concludes the characterization of all contingent claims after the growth option is exercised.

4.2 | First- and second-best investment policy

Before the expansion, there are only two contingent claims to price: initial debt and equity. Although the ODEs and the general solution for the first-best policy are identical to (23) and (24), we adapt Boundary Conditions (28)–(30) to reflect the fact that the investment cost is now partially financed with additional debt issuance. These three boundary conditions now become

$$E_F(P_I^F) = E_q^{BL}(P_I^F) - \left(I - D_{l,q}^{BL}(P_I^F)\right),$$

$$V_F(P_I^F) = V_q^{BL}(P_I^F) - \left(I - D_{l,q}^{BL}(P_I^F)\right),$$

$$\partial_P V_F(P_I^F) = \partial_P V_q^{BL}(P_I^F) + \partial_P D_{l,q}^{BL}(P_I^F).$$

TABLE 6 Investment trigger prices.

Tax code	Unlevered firm (P_I^U)	First best (P_I^F)	Second best (P_I^S)
Progressive	3.06	2.81	2.79
Flat	3.06	2.80	2.78
Regressive	3.06	2.80	2.77

Note: This table reports the investment trigger prices P_I^U, P_I^F, P_I^S for the progressive, flat, and regressive tax codes.

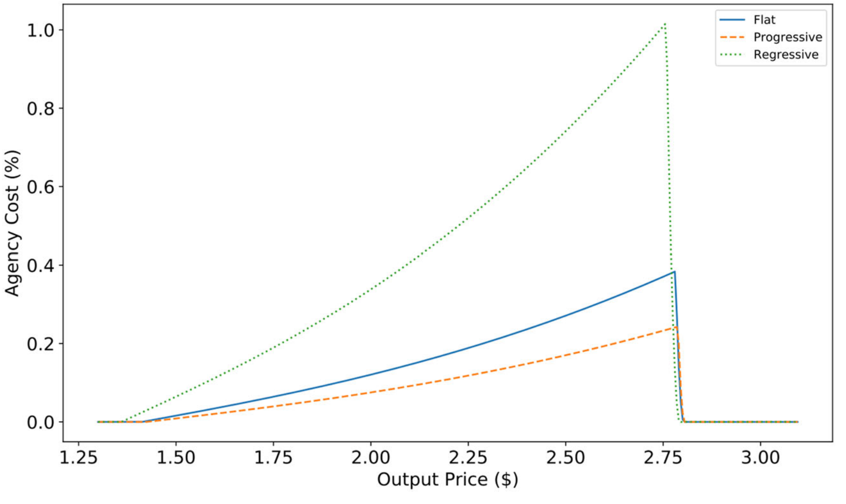

FIGURE 7 Agency cost of overinvestment. This figure shows the percentage agency cost of overinvestment as a function of the output price (in dollars). The solid line represents the percentage agency cost under a flat tax code, the dashed line the percentage agency cost under a progressive tax code, and the dotted line the percentage agency cost under a regressive tax code. The parameter values are shown in Table 1 and the additional debt coupon is set at $R_I = 1.75$. [Color figure can be viewed at wileyonlinelibrary.com]

Similarly, to obtain the second-best contingent claim prices, we simply modify Boundary Conditions (33)–(35) to

$$E_S(P_I^S) = E_q^{BL}(P_I^S) - \left(I - D_{I,q}^{BL}(P_I^S)\right),$$

$$V_S(P_I^S) = V_q^{BL}(P_I^S) - \left(I - D_{I,q}^{BL}(P_I^S)\right),$$

$$\partial_P E_S(P_I^S) = \partial_P E_q^{BL}(P_I^S) + \partial_P D_{I,q}^{BL}(P_I^S),$$

which concludes the model's characterization.

Table 6 presents the results for the first- and second-best investment trigger prices using the same parametrization of Table 1. We assume the value of the new debt coupon is the same as the initial debt coupon. The results indicate that when the firm can finance part of its growth option with the additional debt that pays a coupon of R_I = 1.75, the problem of overinvestment emerges under all three tax policy regimes. Interestingly, both the first- and second-best trigger prices are much less sensitive to changes in the tax policy than the all-equity-financed growth option case.

Figure 7 shows the percentage agency cost under the three tax regimes. First, in contrast to the all-equity-financed option case, when managers have the opportunity to finance the investment opportunity with additional debt, the percentage agency cost is the lowest under a progressive tax regime and the largest under a regressive tax system. The reason is that managers following the second-best policy (i.e., maximizing equity) exercise the option too soon relative to the first-best policy, which increases the firm's risk of bankruptcy. In essence, the limited liability of equity allows equityholders to shift default risk to bondholders. Moreover, the lower marginal tax rate levied on large firms under a regressive tax regime induces equity-maximizer agents to anticipate the exercise even earlier to collect the benefits of higher future production and after-tax cash flow to equity. Second, we observe that the magnitude of the percentage agency cost of overinvestment for the three tax regimes is smaller than the case studied in Section 2. Third, the percentage agency cost moves in lockstep with the changes in the upper bracket tax rate τ_2. The reason is that now the tax dispersion $\Delta\tau$ affects the first- and second-best trigger prices not in opposite ways as before but rather in the same direction. As a result, the gap between the two policies scales with τ_2.

5 | CONCLUSION

We present a comprehensive analysis of the impact of tax policies on the agency cost of under- and overinvestment. We show that depending on the tax policy design (τ_1, τ_1/τ_2, L), some important results in the literature do not hold true any longer. For instance, different from the findings of Mauer and Ott (2000) where the first- and second-best investment trigger prices move in lockstep with variations of the (unique) corporate tax rate, we show that in the presence of a more refined tax system, the underinvestment problem can be either aggravated or alleviated, depending on the tax regime in place. The reason is that the tax policy terms (τ_1, τ_1/τ_2, L) have opposite effects on the equilibrium quantities. This counteracting force has a ripple effect on all (partial) equilibrium quantities, such as investment trigger prices, agency cost components, equity betas, credit spread, and leverage ratios. In addition, we report that the agency cost under a progressive tax regime is considerably larger than the agency cost under a regressive tax regime when managers have to bear all the investment costs.

We also investigate the interactions between the tax policy terms and the agency cost of overinvestment. We show that in contrast to the case where the investment is all equity financed, the agency cost of overinvestment is the largest under a regressive tax regime and the lowest under a progressive tax regime. Moreover, the agency cost appears to scale with variations of the corporate tax rate affecting large firms. The reason is that tax dispersion affects the first- and second-best triggers in the same direction in this case.

Our article opens up several possibilities for future work. A natural first extension is trying to overcome the challenging numerical problem of finding the optimal debt coupon that maximizes the total value of the firm and investigating the potential impact on credit spreads. A second interesting extension is investigating whether the interaction between the risky debt maturity as in Leland and Toft (1996), Goldstein et al. (2001), and Ju and Ou-Yang (2006) and different tax policies can significantly alter the timing of investment, ultimately affecting the first- and second-best policies. A third potential fruitful study is investigating the effects on agency costs when the corporate tax rates are subject to economic policy uncertainty as in Baker et al. (2016). In this case, the additional layer of uncertainty generated by the tax system can potentially aggravate agency costs. Finally, the model can be extended to incorporate other types of taxes, such as personal tax, sales tax, and value-added tax, to understand how their interaction with corporate tax can affect the firm's investment decisions. Naturally, empirical work is needed to shed more light on all of these models.

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