Optimal Corporate Taxation Under Financial Frictions[*]

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Abstract

This paper studies the optimal design of corporate taxes when firms have private information about future investment opportunities and face financial constraints. A government whose goal is to efficiently raise a given amount of revenue from its corporate sector should attempt to tax unconstrained firms, which value resources inside the firm less than financially constrained firms. We show that a corporate payout tax (a tax on dividends and share repurchases) can both separate constrained and unconstrained firms and raise revenue, and is therefore optimal. Our quantitative analysis implies that a revenue-neutral switch from profit taxation to payout taxation would increase the overall value of existing firms and new entrants by 7%. This switch could be implemented in the current U.S. tax system by making retained earnings fully deductible.

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1 Introduction

Virtually every developed country collects taxes from corporations. In this paper, we take as given that governments will tax firms, and ask how firms should be taxed. We consider economies with financial frictions, in which some firms are financially constrained, meaning that the marginal value of funds is higher inside the firm than outside the firm. We study the problem of a government that sets taxes to maximize the total value of the corporate sector subject to a revenue target, and observe that corporate taxes should be designed to minimize the tax burden faced by financially constrained firms. However, it is not easy for the government to determine whether a firm is financially constrained or not.[1] When firms have private information about their future investment opportunities, the government must design a tax mechanism that levies taxes primarily on unconstrained firms while ensuring that it is incentive-compatible for these firms to reveal that they are unconstrained. We consider a rich set of feasible corporate tax systems that includes both standard corporate profit taxes and more complex policies, and show that the optimal tax policy can be implemented by a *corporate payout tax* (a tax proportionally levied on dividends, share repurchases, and other payouts to firms' shareholders).[2]

We begin by illustrating the economic forces behind the optimality of payout taxation in the context of a stylized two-period model. A continuum of firms with private information about their future productivity make investment decisions. In this stylized model, we make the stark assumption that firms cannot raise external financing — an extreme form of financial frictions — and as a result some firms are financially constrained. We show that a constant linear corporate payout tax is a feasible and incentive-compatible mechanism that achieves constrained efficiency in production, and hence it is optimal.

Consistent with our assumption that firms cannot raise external financing, we assume that the government cannot subsidize firms, as otherwise the government would optimally choose to circumvent the financial frictions. As a result, optimal policy (the constant payout tax) achieves constrained efficiency in production but does not achieve first-best production. The key idea is that financially constrained firms will choose to make payouts only after production occurs, whereas unconstrained firms will be indifferent to the timing of payouts (because the payout tax is constant over time), and as a result make efficient investment decisions (Auerbach, 1979). In contrast, a profit tax limits investment by financially constrained firms and thereby exacerbates financial frictions, and hence is sub-optimal.

Subsequently, we derive the optimality of payout taxation — our main theoretical result — in the context of a general infinite-horizon model, which we use in the quantitative exercise that follows. In this general model, the productivity of a given firm is time-varying, and at each date the firm — but not the government — knows its next date productivity. This model allows for entry and exit of firms, accounts for the evolution of the distribution of firms, and gives the government the ability to borrow and save. Firms can now access financing, but are subject to a micro-founded financing constraint that features limited enforcement and no

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[1]The existence of a large literature (e.g., Fazzari, Hubbard and Petersen (1988) and Kaplan and Zingales (1997)) that seeks to identify financially constrained firms supports the premise that it is difficult for the government to determine whether a firm is financially constrained.

[2]Throughout the paper, we use the term corporate taxes to mean taxes collected from corporations. Our framework allows for conventional corporate profit taxes, which in practice take the form of a tax on firms' profits, adjusted for various credits and deductions. The optimal policy in our model is a corporate tax levied on payouts, as opposed to profits or other variables.

exclusion after default, as in Rampini and Viswanathan (2010). This constraint limits the ability of firms to raise financing and the ability of the government to raise taxes. In this general model, firms also have a more general production/depreciation technology, and face additional incentive-compatibility constraints that naturally emerge in a dynamic context.

We consider stationary Markov sub-game perfect equilibria, in which the government's policies are a function of the distribution of firms and the level of government debt. We purposely assume that the government cannot commit to future policies to prevent the use of its commitment ability to overcome the financial frictions. Although solving dynamic models with asymmetric information is challenging, building on the insights developed in the stylized model, we are able to conjecture and verify the optimal policies in the infinite-horizon setup. Formally, we show that the optimal sequence of mechanisms that solves the government's problem can be implemented by a constant corporate payout tax, following the logic outlined in our stylized model.

Since most countries use profit-based corporate taxes, we explore quantitatively the benefits of switching from profit taxes to payout taxes. To that end, we calibrate our model to the Li, Whited and Wu (2016) estimation of firms' productivity dynamics and financial frictions, and estimate the parameters relating to entry and exit to match several key moments documented by Lee and Mukoyama (2015) and Djankov et al. (2010). We find that a revenue-neutral switch from a profit tax to a payout tax increases the overall value of existing firms and future entrants by 7%. This switch redistributes the tax burden from financially constrained firms, who do not make payouts, to unconstrained firms, who do. It encourages entry, because many potential entrants would enter as constrained firms, but exacerbates distortions relating to the choice of debt vs. equity financing.

Before concluding, we describe how our results extend to alternative formulations of firms' financial frictions and discuss several conceptual and practical issues related to our results. Two practical implications of our results are worth highlighting. First, any corporate payout, and in particular dividends and share repurchases, should be taxed at the same rate.[3] Second, the optimal payout tax could be implemented in our current tax system by making all retained earnings fully deductible. That is, our results rationalize the tax deductibility of interest on debt as part of an optimal corporate tax policy.[4]

This paper is related to several literatures. There is an extensive literature on corporate taxation, surveyed by Auerbach and Hines Jr (2002) and Graham (2013). This literature, which studies the impact of corporate taxes on firms' decisions, largely takes as given the existing structure of corporate taxes. The literature closest to our work studies dividend taxation in the personal income tax system. The "old view" (e.g., Poterba and Summers (1984)) is that dividend taxes raise the cost of equity financing, distorting investment decisions. The "new view" (e.g., Auerbach (1979) and Korinek and Stiglitz (2009)) is that firms, except at the beginning of their life-cycle, do not actively issue equity, and as a result dividend taxes are not distortionary for existing firms. Our model embeds this second perspective into a setting with financial frictions and asymmetric information.

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[3]A corporate payout tax is different from a tax levied on dividends through the personal income tax system, both because the payout tax treats all payouts symmetrically (e.g., share repurchases and dividends) and because some shareholders do not pay personal income taxes (e.g., endowments). The clientele effects generated by dividend taxes in the personal income tax code as a result of this second difference (Allen and Gale, 2000) do not arise with a corporate payout tax.

[4]To our knowledge, only He and Matvos (2015) have provided a rationale for deducting interest on a firm's debt. In their model, deducting interest on debt is desirable because the laissez-faire level of firms' debt is too low to begin with, due to competitive distortions at the industry level.

A related literature argues that corporate taxes can be used to correct managerial distortions. This is the "agency view", recently analyzed in Chetty and Saez (2010). By assuming that firms maximize the expected value of dividends, we study optimal revenue-raising policies in an environment in which there is no role for corrective policies.[5] We find it useful to separately study corrective and revenue-raising taxes, given their additive nature (Sandmo, 1975; Kopczuk, 2003).

Our approach to corporate taxation has a strong analogy to the approach to personal taxation in Mirrlees (1971) and subsequent work, with three key differences. First, our results are not driven by the "incentives vs. equality" tradeoff, as in the personal income taxation literature, but rather by "plucking the goose as to obtain the largest possible amount of feathers with the smallest possible amount of hissing." In particular, when there are no revenue needs, optimal corporate taxes are zero regardless of the initial distribution of wealth across firms. Second, the financial frictions that firms face, which arise from their ability to default or restructure and cannot be circumvented by the government, endogenously restrict the revenue-raising capacity of the government. Third, the curvature of value functions in our model arises endogenously from financial frictions, instead of preferences.

The mechanism design approach we adopt builds on the modern optimal non-linear taxation literature recently surveyed in Golosov, Tsyvinski and Werquin (2016). The key difference between our paper and this body of work is our focus on firms and financial frictions. While dynamic Mirrleesian models focus on the behavior of households and treat firms as a veil, we emphasize how financial frictions create a meaningful distinction between corporate and personal taxes. Relatedly, even though we study a dynamic private information environment, an Inverse Euler Equation does not arise in our paper. Capital wedges in dynamic Mirrleesian models arise through a Jensen's inequality effect, which requires uncertainty about the household's future type or other relevant variables. Firms in our stylized model are perfectly informed about their future type (productivity).

Our formulation of financial frictions builds on the work of Kehoe and Levine (1993), Alvarez and Jermann (2000), and, most closely, Rampini and Viswanathan (2010). Like Li, Whited and Wu (2016), we study corporate taxation using a financial friction model of the firm. Our results also relate to the literature on dynamic contracting under financial frictions, which includes, among others, the work of Albuquerque and Hopenhayn (2004), Clementi and Hopenhayn (2006), and Cooley, Marimon and Quadrini (2004). There are two significant differences between our paper and this body of work. First, given our focus on corporate taxation, we work with a population of firms and a government budget constraint. In contrast, Albuquerque and Hopenhayn (2004) and Clementi and Hopenhayn (2006) are models of optimal contracts between an individual firm and its creditors.[6] More closely related is Cooley, Marimon and Quadrini (2004), who study a population of financially constrained firms interacting via general equilibrium effects. A key difference between our paper and Cooley, Marimon and Quadrini (2004) is our focus on optimal corporate taxation (as opposed to the interaction of financial frictions and the effects of new technologies). Second, a key idea that emerges in Albuquerque and Hopenhayn (2004) and Clementi and Hopenhayn (2006) is that optimal contracts delay payments to firm

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[5]The simplest case in which this is true is when the manager is paid in proportion to the dividends shareholders receive.

[6]That is, one could imagine studying optimal corporate taxation using Albuquerque and Hopenhayn (2004) or Clementi and Hopenhayn (2006) instead of Rampini and Viswanathan (2010) as the underlying model of individual firm behavior. See Section 6 for a discussion of how our results are affected by our assumptions on the nature of the financial frictions.

owners until the firm has grown out of being financially constrained. In our model, under optimal tax policies, the firm will choose to make payouts only after it has grown out of its financial constraints. These two results can be connected if one conceives of the government in our model as playing a role analogous to the creditors in Albuquerque and Hopenhayn (2004) or Clementi and Hopenhayn (2006). However, in those papers creditors can commit to long-term contracts, whereas in our model the government lacks commitment; the underlying financial frictions are also different. For these reasons, the two results are not directly comparable. Moreover, the fact that firms will choose to delay payouts until they perceive themselves to be financially unconstrained is an important ingredient in our paper but is not itself a central result, for the reason that it is likely true under a wide variety of tax systems. Our paper instead uses this ingredient as a building block to study optimal corporate taxation. In considering a government that chooses taxes, spending, and debt optimally, but lacks commitment, our approach follows Debortoli, Nunes and Yared (2017).

Because we assume that the government must raise revenues by taxing firms, we cannot address the question of whether taxing firms is optimal if there are other sources of revenue. Most, but not all (Straub and Werning, 2020), of the work on capital taxation under full information (Judd, 1985; Chamley, 1986; Chari and Kehoe, 1999) finds that long-run capital taxes should be zero. With asymmetric information, taxing capital is optimal, but the welfare gains of capital taxation might be small (Farhi and Werning, 2012). To our knowledge, there are no results on whether corporate taxes are optimal in a general equilibrium environment with asymmetric information and financial frictions. There is also a large literature on the incidence of corporate taxes, going back to Harberger (1962), and on the related issue of the choice of organizational form — see most recently Barro and Wheaton (2020). Our results can be thought of as a building block towards addressing the more general questions of whether corporate taxation is desirable at all, its incidence in general equilibrium, and its interactions with the taxation of households.

Lastly, the key insight behind the optimality of payout taxation — that constrained firms dislike paying dividends, while unconstrained firms do not — has been discussed at least implicitly in the literature on financial frictions. For example, Fazzari, Hubbard and Petersen (1988) argue that firms that consistently pay large dividends are not likely to be financially constrained, and Kaplan and Zingales (1997) provide direct evidence relating dividend payments to financial constraints. They show that firms that pay more dividends are less likely to report being financially constrained. Consistent with these ideas, the optimal corporate tax uses the payout policy of a firm to determine whether it should be taxed or not.

Section 2 presents a stylized two-period model that illustrates the optimality of a payout tax, highlighting the economic forces behind our more general results. Section 3 introduces our general infinite-horizon model, which we use to derive our main theoretical results in Section 4. Section 5 quantitatively assesses the benefits of switching from profit taxes to payout taxes. Section 6 discusses extensions of the model relating to the nature of the financial frictions and to equity issuance, and Section 7 discusses policy implications. Section 8 concludes. The Appendix contains all proofs and derivations, and additional details on our quantitative analysis.

2 Stylized Model

In this section, we present a stylized model to illustrate the economic forces behind our more general results introduced in Section 4. The two key simplifications of this model, relative to our general results, are that the model is a two-period model (as opposed to an infinite-horizon model) and that firms are completely unable to borrow or issue equity. Firms' inability to raise funds can be viewed as an extreme version of the financial frictions we study in our general framework.

2.1 Environment

We consider an environment with a continuum of firms and a government, who optimally sets taxes to fulfill a revenue-raising goal. There is a single consumption good (dollars), which serves as numeraire, and two dates, zero and one.

Firms are risk-neutral and do not discount cash flows between dates. In date zero, firms receive the profits of their past investments, $\theta_0 f(k_0)$, and must make an investment decision, k_1.[7] An investment of k_1 dollars at date zero yields $\theta f(k_1)$ dollars at date one, where the function $f(k_1)$ is continuously differentiable, increasing, and concave, with $f(0) = 0$, and $\theta \in (0,1]$ denotes the productivity of a firm. For simplicity, we have assumed that capital fully depreciates, and that, as highlighted above, firms cannot raise external funds.

Each firm privately knows its own date one productivity θ in date zero. In this sense, firms have private information about their future investment opportunities. In contrast, the government learns θ in date one, after production occurs. We denote the measure of firms with date one productivity θ by $\mu(\theta)$.

These assumptions ensure that our stylized model exhibits two key properties: that profit taxes are feasible, and that the government does not know which firms are financially constrained at date zero. For profit taxes to be feasible, the government must be able to observe past profits and investments. Firms must know if they are financially constrained; if the government cannot directly observe this, firms must have economically relevant private information. But since profit taxes are feasible, this private information cannot be about past profits. However, as Hayek (1945) and others have argued, firms may have better information than the government about their upcoming investment opportunities.[8]

We allow the government to collect taxes from firms in both date zero, τ_0, and date one, τ_1. Both τ_0 and τ_1 must be weakly positive; in particular, the government is not allowed to subsidize firms at date zero and thereby circumvent the financial frictions. The government does not discount cash flows, and must set taxes to raise a total of G dollars.

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[7]We assume that the initial resources available to firms take the form of profits generated by past investment because this allows us to compare payout taxes and profit taxes (the standard form of corporate taxes).

[8]An alternative approach would be to suppose that a firm's profits are influenced both by productivity and by "effort" that is unobservable to the government and carries a non-pecuniary cost (i.e., Mirrlees (1971) applied to firms). Reduced effort by firm owners is a plausible consequence of corporate taxation; however, inefficiency in the allocation of capital across firms is in our view a primary concern when considering how to allocate the corporate tax burden across firms.

2.2 Government's Problem

Given the description of the environment, we formally express the government's mechanism design problem as follows. The government chooses non-negative functions $k_1\left(\hat{\theta}\right)$, $\tau_0\left(\hat{\theta}\right)$, and $\tau_1\left(\theta,\hat{\theta}\right)$ to solve

$$\max_{k_1\left(\hat{\theta}\right),\tau_0\left(\hat{\theta}\right),\tau_1\left(\theta,\hat{\theta}\right)} \int_0^1 V\left(\theta,\theta\right)d\mu\left(\theta\right), \tag{1}$$

where $V\left(\theta,\hat{\theta}\right)$ denotes the net present value of a firm with a productivity θ that reports a productivity $\hat{\theta}$, given by

$$V\left(\theta,\hat{\theta}\right) = \underbrace{\theta_0 f\left(k_0\right) - k_1\left(\hat{\theta}\right) - \tau_0\left(\hat{\theta}\right)}_{\text{date zero payout}} + \underbrace{\theta f\left(k_1\left(\hat{\theta}\right)\right) - \tau_1\left(\theta,\hat{\theta}\right)}_{\text{date one payout}}, \tag{2}$$

subject to i) a set of incentive/truth-telling constraints, so that each firm reports its productivity θ truthfully, that is, $\theta = \arg\max_{\hat{\theta}\in(0,1]} V\left(\theta,\hat{\theta}\right)$; ii) the revenue-raising constraint, given by, for some government spending $G \geq 0$,

$$G \leq \int_0^1 \left(\tau_0\left(\theta\right) + \tau_1\left(\theta,\theta\right)\right)d\mu\left(\theta\right); \tag{3}$$

and iii) feasibility constraints that guarantee that firms' payouts are non-negative, given by $\theta f\left(k_1\left(\hat{\theta}\right)\right) \geq \tau_1\left(\theta,\hat{\theta}\right)$ and

$$\theta_0 f\left(k_0\right) - k_1\left(\hat{\theta}\right) - \tau_0\left(\hat{\theta}\right) \geq 0. \tag{4}$$

Note that the non-negativity of the date one payout (i.e., limited liability) prevents the government from assigning arbitrarily high taxes τ_1 to firms that falsely report their type ($\hat{\theta} \neq \theta$).

To characterize the solution to the government's problem, it is helpful to define the constrained efficient (i.e., second-best) capital investment for a firm with type θ, given by

$$k^{ce}\left(\theta\right) = \min\left\{\theta_0 f\left(k_0\right), k^*\left(\theta\right)\right\}, \tag{5}$$

where $k^*\left(\theta\right)$ corresponds to the efficient (i.e., first-best) level of capital investment, defined as the smallest solution to $\theta f'\left(k^*\left(\theta\right)\right) = 1$.[9]

2.3 Optimal Taxation

We structure our discussion of the optimal taxation results in three steps. First, we describe sufficient conditions for optimality. Next, we illustrate how a constant linear payout tax can implement an optimal mechanism. Finally, we explain why profit taxation is inferior to payout taxation and, in the Appendix, discuss the role of expensing of investment.

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[9]We assume $k^*(\theta)$ exists for all $\theta \in (0,1]$; necessary and sufficient conditions are $f'(0) = \infty$ and $f'(\infty) < 1$.

Sufficient Conditions for an Optimal Mechanism. Suppose, for the sake of argument, that a feasible and incentive-compatible mechanism achieves constrained efficiency in production,

$$k_1(\theta) = k^{ce}(\theta), \tag{6}$$

where $k^{ce}(\theta)$ is defined in Equation (5), and satisfies the revenue-raising constraint with equality. Such a mechanism maximizes date one production net of investment,

$$\int_0^1 (\theta f(k_1(\theta)) - k_1(\theta)) d\mu(\theta),$$

and collects the minimum possible total amount of taxes from firms. Consequently, it maximizes firm value on the set of feasible mechanisms that raise sufficient revenue. By assumption, it is incentive-compatible, and therefore optimal.

We next show that a payout tax satisfies these sufficient conditions, and hence is an optimal mechanism. A corollary of this fact is that the incentive-compatibility constraints do not bind, in the sense that granting the government knowledge of firms' date one productivity θ would not improve welfare. However, even in this case, incentive-compatibility limits the set of optimal mechanisms (i.e., there are feasible mechanisms that raise sufficient revenue and achieve the same welfare as a payout tax but are not incentive-compatible).

Optimality of a Payout Tax. In the environment considered here, a mechanism that features a constant linear payout tax $\tau_d \geq 0$ can be implemented by choosing:

$$k_1(\hat{\theta}) \in \arg\max_{k_1 \in [0, \theta_0 f(k_0)]} \frac{1}{1+\tau_d}(\theta_0 f(k_0) - k_1) + \frac{1}{1+\tau_d}\hat{\theta} f(k_1) \tag{7}$$

$$\tau_0(\hat{\theta}) = \frac{\tau_d}{1+\tau_d}(\theta_0 f(k_0) - k_1(\hat{\theta}))$$

$$\tau_1(\theta, \hat{\theta}) = \frac{\tau_d}{1+\tau_d}\theta f(k_1(\hat{\theta})).$$

This mechanism sets date zero taxes τ_0 equal to τ_d times the firms' date zero payout to its owners, $\frac{1}{1+\tau_d}(\theta_0 f(k_0) - k_1(\hat{\theta}))$, and likewise sets date one taxes τ_1 equal to τ_d times the firms' second period payout to its owners, $\frac{1}{1+\tau_d}\theta f(k_1(\hat{\theta}))$, while respecting the feasibility constraints (in particular, the upper bound on k_1). Here, τ_d is the ratio of taxes to payouts received by the firms' owners; $\frac{\tau_d}{1+\tau_d}$ is therefore the tax rate applied to the total (inclusive of taxes) payouts by firms. This mechanism assigns to firms the capital level $k_1(\hat{\theta})$ that maximizes firms' payouts (accounting for taxes) under a firm's reported productivity, in effect allowing a firm to choose its capital level subject to a constant payout tax.

The net present value function $V(\theta, \hat{\theta})$, introduced in Equation (2), for this mechanism is

$$V(\theta, \hat{\theta}) = \underbrace{\frac{1}{1+\tau_d}(\theta_0 f(k_0) - k_1(\hat{\theta}))}_{\text{date zero payout}} + \underbrace{\frac{1}{1+\tau_d}\theta f(k_1(\hat{\theta}))}_{\text{date one payout}}. \tag{8}$$

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It follows immediately that this mechanism is incentive-compatible: $k_1(\theta)$ maximizes the total payout to the firm on the set of feasible capital levels, and consequently $V(\theta, \theta) \geq V(\theta, \hat{\theta})$ for all $\hat{\theta} \in (0,1]$.

The capital level may or may not reach first-best. If $k^*(\hat{\theta}) \leq \theta_0 f(k_0)$, the firm is unconstrained, and the mechanism will set $k_1(\hat{\theta}) = k^*(\hat{\theta})$, as the constant payout tax does not distort intertemporal incentives. This follows from the first order condition associated with (7),

$$-\frac{1}{1+\tau_d} + \frac{1}{1+\tau_d}\hat{\theta}f'(k_1(\hat{\theta})) = 0.$$

If instead $k^*(\hat{\theta}) > \theta_0 f(k_0)$, the firm is constrained, the first-best capital level is infeasible, and the optimal capital in (7) is $k_1(\hat{\theta}) = \theta_0 f(k_0)$. Therefore, regardless of whether firms are constrained or unconstrained, firms' investment decisions are constrained efficient (given truthful reporting), $k_1(\hat{\theta}) = k^{ce}(\hat{\theta}), \forall \hat{\theta}$.

This argument generalizes the classic result of Auerbach (1979) (that constant payout taxes do not distort investment) to a simple setting with i) financial frictions and ii) asymmetric information. Payout taxes do not affect financially constrained firms, because those firms choose to payout later, when they are unconstrained. Payout taxes do not interfere with incentive-compatibility, because the firms' objective is a rescaled version of the firms' objective without taxes.

Consequently, a payout tax mechanism is feasible, incentive-compatible, and achieves constrained efficiency in production. It follows that the mechanism is optimal if it raises total taxes equal to G. The amount raised by the mechanism is

$$G_d(\tau_d) = \frac{\tau_d}{1+\tau_d} \int_0^1 [\theta_0 f(k_0) - k^{ce}(\theta) + \theta f(k^{ce}(\theta))] d\mu(\theta).$$

Therefore, if $G_d(\tau_d) = G$ for some value of $\tau_d \in [0, \infty)$, the payout tax can raise sufficient revenue, and hence is optimal.[10]

Note that the payout tax mechanism does not distinguish between firms with identical date one payouts based on whether or not their reports were truthful. That is, the government can achieve an optimal allocation without relying on its ability to observe and punish false reports (provided it can observe payouts). In our general model, we will assume the government cannot commit to future tax mechanisms; despite this lack of commitment, the government can sustain a constant payout tax, because doing so does not require committing to punish false reports.

Given the similarities between the environment considered here and models of non-linear taxation in the Mirrlees tradition, it may seem surprising that the optimal tax is linear in payouts. The key driver of this result is the government's indifference to inequality across firms, in contrast to Mirrleesian models. The government cares only about the net present value of production, as in Equation (1), and the net present value of taxes, as in the right-hand side of Equation (3). Given the linearity of the government's objective in firms' payouts, any feasible mechanism that achieves constrained efficiency in production and raises sufficient revenue will

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[10]If $G > \lim_{\tau_d \to \infty} G_d(\tau_d)$, the government's problem is infeasible. So either a payout tax is optimal, or the government's problem has no solution.

be optimal, provided it is incentive-compatible.[11] A linear payout tax is one such mechanism; in our stylized two-period setting, there may be others.

Inferiority of Profit Taxation. We next explain why payout taxation is superior to profit taxation. Profits (π_0 and π_1) are defined as revenue minus depreciation; with full depreciation,

$$\pi_0 = \theta_0 f(k_0) - k_0, \quad \text{and} \quad \pi_1 = \theta f(k_1) - k_1. \tag{9}$$

We assume the inherited date zero profits π_0 are strictly positive. A mechanism equivalent to a constant linear profit tax at rate $\tau_p \in (0,1)$ that does not subsidize losses[12] can be implemented by

$$k_1\left(\hat{\theta}\right) \in \arg\max_{k_1 \in [0, (1-\tau_p)\theta_0 f(k_0) + \tau_p k_0]} (1-\tau_p)\left(\theta_0 f(k_0) - k_0\right) + (1-\tau_p)\left(\hat{\theta} f(k_1) - k_1\right), \tag{10}$$

$$\tau_0\left(\hat{\theta}\right) = \tau_p\left(\theta_0 f(k_0) - k_0\right),$$

$$\tau_1\left(\theta, \hat{\theta}\right) = \tau_p \max\left\{\theta f\left(k_1\left(\hat{\theta}\right)\right) - k_1\left(\hat{\theta}\right), 0\right\}.$$

In this mechanism, taxes are proportional to profits, and capital is chosen to maximize firms' profits taking taxes into account. This mechanism is feasible: at date one, taxes are bounded above by $\theta f\left(k_1\left(\hat{\theta}\right)\right)$; at date zero, (4) is satisfied due to the upper bound on k_1 in (10); and capital and taxes are all weakly positive.

We can reformulate $V\left(\theta, \hat{\theta}\right)$, introduced in Equation (2), as follows:

$$V\left(\theta, \hat{\theta}\right) = \underbrace{(1-\tau_p)\left(\theta_0 f(k_0) - k_0\right) + k_0 - k_1\left(\hat{\theta}\right)}_{\text{date zero payout}} + \underbrace{\hat{\theta} f\left(k_1\left(\hat{\theta}\right)\right) - \tau_p \max\left\{\hat{\theta} f\left(k_1\left(\hat{\theta}\right)\right) - k_1\left(\hat{\theta}\right), 0\right\}}_{\text{date one payout}}.$$

This mechanism appears almost identical to the payout tax mechanism, and is incentive-compatible for essentially the same reasons described above. However, it does not achieve constrained efficient production. Because date zero profits are positive ($\theta_0 f(k_0) > k_0$), k_1 is bounded above by

$$k_1 \leq (1-\tau_p)\theta_0 f(k_0) + \tau_p k_0 < \theta_0 f(k_0).$$

For any $\hat{\theta}$ such that $k^*\left(\hat{\theta}\right) > (1-\tau_p)\theta_0 f(k_0) + \tau_p k_0$, we will have $k_1\left(\hat{\theta}\right) < k^{ce}\left(\hat{\theta}\right)$. Consequently, the profit tax does not achieve constrained efficiency in production, and therefore achieves a lower level of welfare than a payout tax that raises the same amount of revenue.

The failure of the profit tax to achieve constrained efficiency in this case is caused by the financial frictions. If the upper bound on k_1 is not binding, the first order condition of Equation (10) is $\hat{\theta} f'(k_1) = 1$, which is to say that the firm will choose the first-best level of capital if possible. This feature of our stylized model is a consequence of assuming full depreciation; if we had instead assumed partial or no depreciation, the profit tax would also distort the firms' intertemporal tradeoffs, as discussed in, for example, Auerbach (1979) and

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[11] A government that wished to equalize the value of firms in the economy would have an objective of the form $\int_0^1 H\left(V(\theta, \theta)\right) d\mu(\theta)$, for some increasing and concave social welfare function H. In this case, the government would attempt to redistribute income beyond what the payout tax accomplishes, and in attempting to do so would face binding incentive-compatibility constraints.

[12] Our two-period setting is too simple to study concepts like tax loss carry-forwards.

Auerbach and Hines Jr (2002). This observation hints at another point, which we elaborate on in Appendix Section C: even if the profit tax were modified to allow for the full expensing of investment (which eliminates intertemporal distortions), there are circumstances in which the profit tax would not achieve constrained efficient production because it causes financial constraints to bind. These circumstances involve firms that are profitable and currently able to reach first-best production but are nevertheless financially constrained, because they anticipate increasing productivity in the future. Such possibilities are most naturally considered in the context of the dynamic model, which we present next.

3   General Model

We next describe a richer version of the stylized model discussed in the previous section. We derive our main theoretical results — Propositions 1 and 2 — in the context of this model, and use this model in our quantitative exercise. We begin by outlining the key differences between our general model and the stylized model of the previous section:

1. Our stylized model rules out borrowing; our general model features a micro-founded financing constraint that builds on Rampini and Viswanathan (2010).

2. Our stylized model is a two-period model with a fixed population of firms; our general model is an infinite-horizon model with entry and exit.

3. Related to the above two points, in our stylized model, whether the government can commit or not does not matter; our general model assumes that the government lacks commitment, to avoid the possibility of the government undoing the financial frictions.

4. Our stylized model uses a more specific production function, with full depreciation and zero discounting; our general model uses a more general production function, with neoclassical depreciation and discounting.

5. Our stylized model assumes that the date zero payout and date one capital are chosen simultaneously, implicitly allowing firms to commit to a payout policy when making investment decisions. Our general model allows firms to make investment and payout decisions separately within each period, breaking this commitment. As a result, in our stylized model there is a single condition required for incentive-compatibility, whereas in our general model there are two incentive-compatibility conditions in each date (one for investment and one for payouts).[13]

After introducing the model setup, we will discuss the role of each of these features in model detail.

We begin by describing the structure of a single date t. We consider an environment that now features three classes of agents: firms, governments, and outside investors. Both firms and outside investors are risk-neutral,

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[13]In our view, it is unrealistic to assume that firms commit to a payout policy when making investment decisions; however, it turns out that whether or not firms can commit in this way has essentially no impact on our results.

and discount cash flows at a predetermined gross real interest rate of $R > 1$.[14] Outside investors will lend resources to the firms.

Figure 1 illustrates the timeline of events within a date. At the beginning of date t, entry decisions are made, although the entering firms will not begin production until date $t + 1$. Next, the government designs the date t tax system. Once that tax system is designed, firms make financing and investment decisions. Production then occurs and depreciation materializes. Firms then make payout decisions, pay taxes, repay outside investors, and consider the possibility of defaulting or exiting. After payments, defaults, and exits are realized, date $t + 1$ begins.
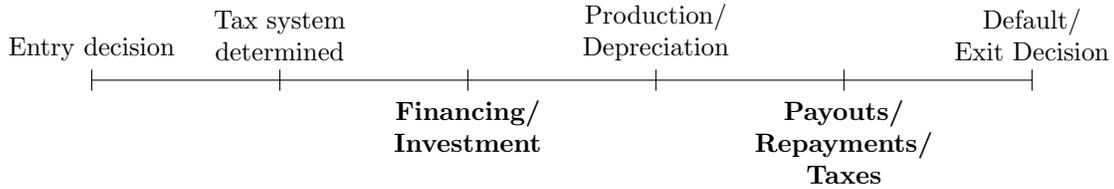

Figure 1: Single Date Timeline

We will first describe the two stages of existing firm decisions: financing/investment and payouts/repayments/taxes, and then step back and describe the government's problem and firm entry decisions.

3.1 Existing Firm Decisions

Financing/Investment stage. Firms are initially endowed with resources w_t and can raise additional funds $\ell_t \geq 0$ from outside investors. Firms invest these resources in capital k_t, broadly defined, satisfying the budget constraint

$$k_t \leq w_t + \ell_t. \tag{11}$$

An investment of k_t dollars at the beginning of date t yields $f(k_t, \theta_t)$ dollars when production occurs, where $\theta_t \in [0, 1]$ denotes the date t productivity of a firm. The function $f(k_t, \theta_t)$ is differentiable in both arguments, and increasing and concave in k_t. The marginal product of capital is increasing in a firm's productivity θ_t, and positive capital is essential for production. That is, $f_k(k_t, \theta_t)$ is weakly positive, decreasing in k_t, increasing in θ_t, and $f(0, \theta_t) = 0$. Capital depreciates at a rate $\delta \in [0, 1]$.

There exists a first-best level of capital, $k^*(\theta_t)$, which is the smallest level of capital such that

$$f_k(k^*(\theta_t), \theta_t) + 1 - \delta = R. \tag{12}$$

That is, the first-best level of capital for a firm of productivity θ_t at date t corresponds to the smallest solution to the problem: $\max_k f(k, \theta_t) + (1 - \delta)k - Rk$. Once capital exceeds the first-best level, we further assume that

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[14]Our assumption that the interest rate R is invariant to corporate tax policy (or, more generally, that the stochastic discount factor is invariant to corporate tax policy) is what makes our model a partial equilibrium model and allows us to study the problem of taxing firms separately from the problem of taxing households. A consideration of how the effects of corporate tax policy on the production of firms would in turn affect households and thereby influence discount rates is beyond the scope of the present paper.

$f(k_t, \theta_t)$ is such that the marginal product of capital remains constant and satisfies

$$f_k(k, \theta_t) + 1 - \delta = R, \quad \forall k > k^*(\theta_t).$$

This assumption mimics the ability of a firm, after reaching its optimal scale, to invest at the risk-free rate. Firms lose nothing by accumulating wealth (because they earn exactly the risk-free rate), but their productivity θ_t is bounded above. As a result, once firms accumulate sufficient resources to ensure first-best production, they will be willing to make positive payouts.[15] We discuss the importance of these assumptions in our remarks below.

Firms with the lowest type, $\theta_t = 0$, are a special type we will call "exiting." The level of first-best capital for these firms is zero, that is, $k^*(0) = 0$, and they earn a return on wealth equal to the risk-free rate. These firms have exhausted all of their profitable investment opportunities, and will choose to exit the economy in a manner described below.[16]

The following example provides an explicit illustration of firms' production technology. In this example, the production function is a standard decreasing returns to scale production function, augmented with the ability to earn the risk-free rate once the optimal scale has been reached.

Example. (Production function) In our quantitative analysis in Section 5, we assume the following functional form for firms' production technology:

$$f(k, \theta) - \delta k = \begin{cases} \theta A k^\alpha - \delta k & k \leq k^*(\theta) \\ \theta A (k^*(\theta))^\alpha - \delta k^*(\theta) + (R - 1)(k - k^*(\theta)) & k > k^*(\theta), \end{cases} \tag{13}$$

where $\alpha \in (0, 1)$, $A > 0$, and the first-best level of capital $k^*(\theta)$ is given by $k^*(\theta) = \left(\frac{\alpha \theta A}{R - 1 + \delta}\right)^{\frac{1}{1-\alpha}}$. Figure 2 illustrates this example production function for three different productivity levels.

Both outside investors and the government observe firms' initial wealth, financing and investment choices, and production outcomes, as well as firms' date t productivity, θ_t. We assume that each firm privately knows its own *future* investment opportunities. That is, at the beginning of date t, firms privately learn their future productivity, θ_{t+1}. However, outside investors and the government do not learn θ_{t+1} until the beginning of date $t + 1$. Because firms learn θ_{t+1} at the beginning of date t, they can condition all their date t choices on this information. Because repayments to outside investors and taxes depend on firms' decisions, these can be conditioned on θ_{t+1}, subject to incentive-compatibility conditions. That is, the future productivity parameter θ_{t+1} corresponds to a firm's "type" about which there is asymmetric information. In contrast, the government

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[15]This formulation contrasts with other models, e.g., DeMarzo and Sannikov (2006), in which firms always earn an above-risk-free rate of return but pay dividends because they discount cash flows at a higher rate than their creditors. Those authors view using a higher discount rate for firms as an approximation to considering a model with a risk-averse entrepreneur facing idiosyncratic risk that cannot be diversified. Our focus on corporate taxation leads us to consider instead firms owned by diversified shareholders, and hence to the assumption of a common discount rate.

[16]Note that when a firm becomes exiting, it does not "die" but instead remains in the population of firms until it has paid out all its wealth. Because an exiting firm earns the risk-free rate on its investments, the possibility of becoming exiting does not alter a firm's effective discount rate (which is equal to the risk-free rate).

Production Function
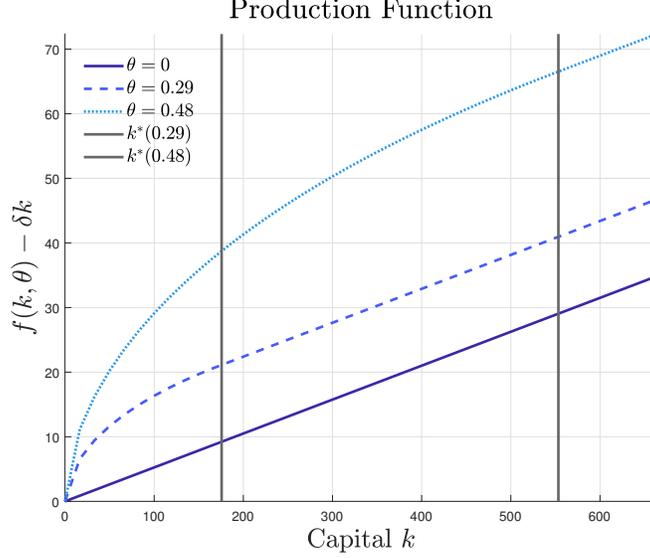
Note: Figure 2 shows the production function defined in Equation (13), using the parameters of our quantitative exercise (see Section 5 for details). The plot shows the production functions for firms with productivity $\theta = 0$, $\theta = 0.29$, and $\theta = 0.48$, productivity levels used in our quantitative exercise. The black vertical lines correspond to the first-best capital levels $k^*(0.29)$ and $k^*(0.48)$.

Figure 2: Production Functions

can condition date t taxes on θ_t without regard to incentive-compatibility; as discussed in the context of our stylized model, this assumption ensures that profit taxes are feasible.

Payouts/Repayments/Taxes stage. After production and depreciation take place, firms declare a weakly positive payout, $d_t \geq 0$. To simplify the exposition, we at times refer to this payout as a dividend. However, as discussed in the introduction, d_t also encompasses share repurchases and other discretionary transfers of funds to firms' owners. After the dividend is declared, firms must pay back $b_t \geq 0$ to outside investors and pay taxes $\tau_t \geq 0$ to the government.[17] At that point, the government/outside investors can block the proposed dividend, which prevents funds from leaving the firm, although it cannot prevent default. Firms then optimally decide whether or not to default and/or exit.

As in Rampini and Viswanathan (2010), we consider an environment with i) limited enforcement and ii) no exclusion after default. If a firm pays its obligations, its continuation wealth is given by w_{t+1}, where

$$w_{t+1} = f(k_t, \theta_t) + (1 - \delta) k_t - d_t - b_t - \tau_t. \tag{14}$$

If w_{t+1} is not weakly positive, repayment is not feasible and the firm is forced to default. If a firm defaults, its continuation wealth is given by its flow output and a fraction $1 - \varphi$ of the depreciated capital stock. The continuation wealth of a firm that defaults is $w^D(k_t, \theta_t)$, which can be expressed as a function of a firm's capital

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[17]The non-negativity constraint on τ_t implies that the government cannot subsidize firms, as discussed in more detail below.

choice, k_t, and its date t productivity, θ_t, as follows:

$$w^D(k_t, \theta_t) = f(k_t, \theta_t) + (1 - \varphi)(1 - \delta)k_t, \tag{15}$$

where $\varphi \in (0, 1]$. The value of φ captures a form of limited enforcement that restricts the amount of funds that outside investors and the government can receive from a firm. To prevent a firm from continuing with negative wealth, its declared dividend must be no larger than its continuation wealth in the event of default, so the constraint $d_t \leq w^D(k_t, \theta_t)$ must hold.

After defaulting, a firm cannot be excluded from starting a new firm with its same productivity. To ensure that the government cannot circumvent this friction, the government lacks commitment, which is to say that the government cannot condition its tax policy on firms' histories, only on firms' current wealth level and productivity. Otherwise, the government might treat new firms that have defaulted in the past differently, discouraging default.

As a consequence of firms' ability to re-enter, the value of a firm's dividend and continuation wealth, $d_t + w_{t+1}$, must be greater than the wealth following a default, $w^D(k_t, \theta_t)$, which leads to the no-default condition

$$b_t + \tau_t \leq \varphi(1 - \delta)k_t. \tag{16}$$

This constraint, which limits the amount of capital the firm can obtain, augments the constraint derived in Rampini and Viswanathan (2010) by treating taxes as additional debt payments. Taxes enter this condition because we have assumed that tax obligations, like debt obligations, are subject to default. We make this assumption to avoid a "chicken problem" in which the government but not outside investors can lend without risk of default.

In our model, it will be optimal without loss of generality to avoid default, and strictly optimal in the presence of deadweight losses associated with default. We therefore treat this no-default condition as a constraint that must be satisfied. We also assume that the government and outside creditors can block a firm's dividend, which prevents shareholders from looting the firm and then defaulting.

As discussed above, firms can also exit the economy. Exit does not necessarily imply default: a firm can choose to liquidate and pay off its taxes and outside investors. Because default will not occur in equilibrium in our model, exit is the only way in which firms leave the economy.[18] We will say that a firm exits when it chooses zero continuation wealth (which, by the equations above, would imply that it has zero capital and wealth at all future dates).

The possibility of a firm proposing a dividend that gets blocked and then defaulting creates an additional constraint in the government's mechanism design problem, as does the possibility of the firm voluntarily choosing to exit (with or without defaulting). However, these constraints will not bind in the equilibrium we construct, and for this reason we discuss these constraints only when formally describing the mechanism design problem.

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[18]The form of exit considered here involves shutting down the firm. One could also consider the possibility that firms may shift their activities to a different tax jurisdiction. This possibility might limit the taxes the government could collect but otherwise leaves the problem unchanged.

Firms' initial funding, ℓ_t, and the associated repayment, b_t, can be contingent on a firm's capital, k_t, initial wealth w_t, and current productivity, θ_t, but not on the firm's dividend payment. As a result,

$$\ell_t = R^{-1} b_t. \tag{17}$$

The simplest interpretation of this restriction is that firms only issue one-period debt. An alternative interpretation is that outside investors also know the firms' next date productivity, and hence must break-even for each productivity type.[19]

Remarks on the Environment. The environment considered here is meant to be the simplest one that allows for non-trivial financing, investment, and payout decisions — all of which are necessary to study corporate taxation — while incorporating financial constraints. The following remarks discuss our modeling choices in further detail.

Remark 1. *Additional uncertainty.* Our environment features no uncertainty, with the exception of the process that determines firms' productivity. Introducing observable shocks, under the assumption that both outside investors and the government can condition their payments/taxes on these shocks, does not affect our conclusions, as in Rampini and Viswanathan (2010). Including these shocks would allow us to discuss issues like security design in more detail, at the expense of additional notation.

Remark 2. *Trade-off Theory.* Our environment can be thought of as the zero-uncertainty limit of a model in which firms trade off the tax benefits of issuing debt against the deadweight costs of bankruptcy (trade-off theory) in the presence of non-contractable shocks. As non-contractable uncertainty vanishes, creditors will know ex-ante whether or not the firm will repay its debt, leading to a financing constraint along the lines of Equation (16). Focusing on this limit greatly simplifies our analysis. In this limit, the social cost of having too little wealth inside the firm is under-investment as opposed to the deadweight costs of bankruptcy.

Remark 3. *Marginal vs. average products.* The productivity parameter θ should be interpreted as controlling the marginal product of capital, not the average, since we assume that $f_{k\theta} \geq 0$ but make no assumption on f_θ. For simplicity, we consider a one-dimensional parameter space for θ, which links marginal and average products of capital, as in our example production function. Our results could be readily extended to, e.g., two-dimensional parameter spaces capable of distinguishing between average and marginal products.

Remark 4. *Payout interpretation.* In our environment, the agent that receives a firm's payouts is the one who controls the decisions made by that firm. Therefore, if firms maximize shareholder value, payouts in the model exactly correspond to payments to shareholders in reality, which include dividends and share repurchases. This is our preferred interpretation. Alternatively, if one assumes that firms are controlled by managers who maximize the value of their compensation independently of shareholder's value, one could interpret firms' payouts in our model as managerial compensation, which may include wages or in-kind benefits, and payments

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[19]In this case, there is no uncertainty for the firm or outside investors, and the claims of outsiders can be interpreted as either debt or equity. This interpretation requires that outside investors have an informational advantage over the government, but the government may be able to extract this information almost costlessly, along the lines of Crémer and McLean (1988).

to outside investors as debt or equity. We discuss this issue in more detail in Section 7.[20] The critical assumption under both interpretations is that the government can distinguish between payments to the agents controlling the firm and payments to outside investors.

Remark 5. *No equity issuance.* Throughout most of the paper, we assume that firms' payouts cannot be negative, so firms' shareholders cannot inject additional funds into the firm (except when entering the economy). In Section 6.2, we extend our results to a model in which negative dividends (equity issuance) are feasible but costly. If such issuance is feasible and not costly, firms will never be financially constrained.

Remark 6. *Symmetry between taxes and repayments to outside investors.* Taxes and repayments to outside investors enter symmetrically in the model, operating entirely through firms' continuation wealth w_{t+1}. This formulation ensures that the government cannot circumvent the financial frictions by assessing taxes that are not limited by the possibility of default. Higher taxes will tighten firms' financing constraint in the same way that higher promised repayments would, as implied by Equations (14) through (16).

Remark 7. *No government subsidies.* Since the government's objective is to find the best revenue-raising policy, we purposely restrict the ability of the government to subsidize firms by requiring non-negative tax payments. This restriction addresses the concern that, in models with financial frictions, the government may find it optimal to circumvent all financial frictions by taxing unconstrained firms and subsidizing constrained firms, even without a revenue-raising goal.

Our modeling choices are designed to ensure that the government cannot use taxes to circumvent financial frictions or correct other distortions in the economy. The only purpose of taxation in our model is to raise revenue. Therefore, if the government did not need to raise any revenue, the optimal policy would involve no taxation of any kind. Setting up our model in this way allows us to focus on the tradeoff between raising revenue and exacerbating financial frictions.

3.2   Evolution of Government Debt and The Population of Firms

The key state variables in our model are i) the level of government debt, B_t, and ii) the joint distribution of wealth and productivity across the population of firms, described by the measure μ_t. At each date t, the government inherits debt B_t and a measure of firms with wealth w and productivity θ, $\mu_t(w, \theta)$, and, through its policies, influences the debt B_{t+1} and measure μ_{t+1} that carry over to the next date. We study stationary Markov sub-game perfect equilibria, in which the government's policies are a function of μ_t and B_t.

Dynamics of Productivity.   Productivity evolves exogenously in our model; the Markov kernel $\Pi(\theta_{t+1}|\theta_t)$ characterizes the likelihood that a firm with productivity θ_t will have productivity θ_{t+1} in the next period. The "exiting" productivity level $\theta_t = 0$ is an absorbing state, meaning that $\theta_{t+1} = 0$ with probability one if $\theta_t = 0$. In contrast, firm wealth w_t evolves endogenously in our model. Recall that firms know θ_{t+1} at date t, and as a result w_{t+1} can be a function of w_t, θ_t, and θ_{t+1}. Let $w_{t+1}^*(\theta_{t+1}; w_t, \theta_t)$ be the function that describes the evolution of wealth under the government's equilibrium policies, and let $\tau_t^*(\theta_{t+1}; w_t, \theta_t)$ be the function describing the taxes collected under those policies. Recall that a firm exits once $w_{t+1}^*(\theta_{t+1}; w_t, \theta_t) = 0$.

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[20]We also discuss other theories of payout determination, e.g., signaling, in Section 7. All theories predict that more constrained firms are less likely to make payouts.

Evolution of Government Debt. We first describe the evolution of government debt B_t. The government can borrow and save freely, and choose a level of spending G_t, without commitment. If the government chooses to spend G_t this date, the next date's debt level is

$$B_{t+1} = R(B_t + G_t) - \int_{0^+}^{\infty} \int_0^1 \int_0^1 \tau_t^* \left(\theta'; w, \theta\right) d\Pi \left(\theta'|\theta\right) d\mu_t(w, \theta). \tag{18}$$

We have adopted the convention that the spending G_t occurs at the beginning of date t, whereas the taxes τ_t^* are collected at the end of date t; for this reason, spending is multiplied by the gross interest rate R in this expression but taxes are not.

Evolution of Firm Population. We next describe the evolution of the firm population. Let $e_t(w', \theta'; \mu_t, B_t)$ denote the measure of firms that will enter the economy at date $t + 1$ with wealth w' and productivity θ'. This measure is endogenous, and we will describe how it is determined when we discuss entry. Under our assumed timing, the entry decision is made before the government chooses its policies at date t. As a result, the entry mass e_t depends on the state variables known at the beginning of date t (μ_t and B_t), but not on the specific policies adopted at date t.

The law of motion for the measure of firms at wealth $w' > 0$ and productivity θ' is

$$d\mu_{t+1}(w', \theta') = de_t(w', \theta'; \mu_t, B_t) + \int_{0^+}^{\infty} \int_0^1 \delta_{\text{dirac}} \left(w_{t+1}^*(\theta'; w, \theta) - w'\right) d\Pi \left(\theta'|\theta\right) d\mu_t(w, \theta), \tag{19}$$

where $\delta_{\text{dirac}}(\cdot)$ denotes the Dirac delta function.[21] Intuitively, the mass of firms with wealth w' and productivity θ' in the next period consists of the new firms entering at that wealth/productivity level and the existing firms who end up with that wealth/productivity level. Because of the timing of the entry decision, Equation (19) is not a fixed-point equation (entry decisions are a function of μ_t and B_t instead of μ_{t+1} and B_{t+1}), which simplifies our analysis. Note that these equations exclude firms with exactly zero wealth (the wealth integrals begin at 0^+).

3.3 Government's Problem

We denote the government's value function by $J_t(\mu_t, B_t)$ and the firms' value function, which corresponds to the net present value of dividends under the current and future optimal policies of the government, by $V_t(w, \theta; \mu_t, B_t)$. As mentioned above, the Markov nature of the equilibrium we consider implies that the government takes the continuation value functions $J_{t+1}(\mu_{t+1}, B_{t+1})$ and $V_{t+1}(w', \theta'; \mu_{t+1}, B_{t+1})$ as given. Given these, the government chooses policies to maximize its objective, which is to maximize the net present value of firm dividends and utility from government spending.

Government policy consists of a spending level G_t and a mechanism for each observable type (w, θ), which we denote $m_t(w, \theta)$. The set of admissible mechanisms for the observable type (w, θ) is $\mathscr{M}(w, \theta, V_{t+1})$; we define this set formally in the next subsection. For the purposes of this subsection, it is sufficient to note that the

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[21]The Dirac delta function can be heuristically defined as $\delta_{\text{dirac}}(x) = \begin{cases} \infty, & x = 0 \\ 0, & x \neq 0 \end{cases}$, with $\int_{-\infty}^{\infty} \delta_{\text{dirac}}(x) dx = 1$.

functions $w_{t+1}^*(\cdot; w, \theta)$ and $\tau_t^*(\cdot; w, \theta)$ described above are defined by the mechanism $m_t(w, \theta)$, as is the function describing equilibrium payouts, $d_t^*(\cdot; w, \theta)$. We include the continuation value function V_{t+1} as an argument of $\mathcal{M}$ to indicate that certain restrictions on the set of feasible mechanisms (such as incentive-compatibility) depend on the nature of firms' continuation values.

The government derives the following per date flow benefit/cost from spending an amount G_t:

$$u(G_t) = \begin{cases} G_t - \overline{G}, & \text{if } G_t \geq \overline{G} \\ -\overline{\chi}(\overline{G} - G_t), & \text{if } G_t < \overline{G}, \end{cases}$$

where $\overline{\chi} > 1$ and $\overline{G} > 0$. We interpret $\overline{G}$ as the level of socially useful government spending. Any spending beyond this target ($G_t > \overline{G}$) has a marginal value that is equal to the marginal value of firm payouts in the government's objective function. That is, government spending above $\overline{G}$ can be thought of as equivalent to lump sum transfers to firm owners, which explains why the government values this extra spending and payouts to the firms equally.[22] In contrast, the marginal value of government spending below $\overline{G}$ is $\overline{\chi} > 1$, meaning that this spending generates a higher social value than firm payouts. In most of the equilibria we study, the government sets G equal to $\overline{G}$ at all times, because it is socially useful for the government to tax firms so that it can spend $\overline{G}$, but it serves no social purpose to increase taxes beyond this point.[23] Allowing the government to adjust its spending level (instead of assuming a fixed spending $\overline{G}$) simplifies our analysis of off-equilibrium behavior and allows us to discuss what happens when a constant payout tax cannot raise sufficient revenue.

The government's value function in a Markov sub-game perfect equilibrium of the game between the current government and future governments can be expressed recursively as

$$J_t(\mu_t, B_t) = \max_{G_t, \{m_t(w, \theta) \in \mathcal{M}(w, \theta, V_{t+1})\}_{w \in (0, \infty), \theta \in [0,1]}} u(G_t)$$
$$+ R^{-1} \int_{0^+}^{\infty} \int_0^1 \int_0^1 d_t^*(\theta'; w, \theta) \, d\Pi(\theta'|\theta) \, d\mu_t(w, \theta)$$
$$+ R^{-1} J_{t+1}(\mu_{t+1}, B_{t+1}), \tag{20}$$

subject to Equations (18) and (19), which define μ_{t+1} and B_{t+1} as functions of government policy. The equilibrium must also satisfy no-Ponzi and transversality-type conditions, which we describe below.

The solution to this problem induces a value function for firms,

$$V_t(w, \theta; \mu_t, B_t) = R^{-1} \int_0^1 \left\{ d_t^*(\theta'; w, \theta, \mu_t, B_t) + V_{t+1}(w_{t+1}^*(\theta'; w, \theta, \mu_t, B_t), \theta'; \mu_{t+1}, B_{t+1}) \right\} d\Pi(\theta'|\theta).$$

Sub-game perfection requires that each government optimizes, meaning that $J_t(\mu, B) = J_{t+1}(\mu, B) = J(\mu, B)$. We study a stationary equilibrium in which the value function is also stationary, $V_t(w, \theta; \mu, B) =$

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[22]Note that this is not the same as making a lump sum transfer to the firm itself, which would circumvent financial frictions.

[23]The value of $\overline{\chi}$ also acts as an upper bound on the marginal cost to firms of raising a marginal dollar of tax revenue (the multiplier on Equation (18)). If the marginal cost of taxation reaches $\overline{\chi}$, the government will spend less than $\overline{G}$ instead of increasing taxes.

$V_{t+1}(w, \theta; \mu, B) = V(w, \theta; \mu, B)$.[24] The equilibrium must satisfy the transversality conditions

$$\lim_{s \to \infty} R^{-s} \mathbb{E}\left[J(\mu_{t+s}, B_{t+s}) \middle| \mu_t, B_t\right] = 0$$

$$\lim_{s \to \infty} R^{-s} \mathbb{E}\left[V(w_{t+s}, \theta_{t+s}; \mu_{t+s}, B_{t+s}) \middle| w_t, \theta_t, \mu_t, B_t\right] = 0,$$

which ensure that the value functions $J(\cdot)$ and $V(\cdot)$ are solutions to the corresponding sequence problems, and a no-Ponzi condition for the government,

$$\lim_{s \to \infty} R^{-s} \mathbb{E}\left[B_{t+s} \middle| \mu_t, B_t\right] \leq 0,$$

which arises from the requirement that the government repays its creditors. To sum up, we study equilibria in which Equations (18), (19), and (20) hold, the Bellman equation for the value function V and the stationarity restrictions are satisfied, the transversality-type equations and the no-Ponzi condition hold, policies are Markov, and expectations are consistent with those Markov policies.

Remark 8. *Markov structure/lack of commitment*. The problem that we study here is not equivalent to a single-agent optimization problem. Because the government lacks commitment, it does not internalize the effects that the current date mechanism has on previous governments, via the influence of V on the feasible set of mechanisms and on firms' entry decisions. A government with commitment would internalize these effects and in particular be able to circumvent financial frictions by punishing firms that attempt to default and re-enter.[25] We will demonstrate that, despite this lack of commitment, the government is able to refrain from attempting to completely expropriate firms.[26]

Remark 9. *Government's smoothing ability*. Allowing the government to borrow, save, and adjust spending is essential to guarantee that a constant payout tax is optimal whenever the population of firms does not start in a steady state. If the government were required to raise a particular amount of tax revenue each date, with no ability to smooth distortions across dates, the government would need to impose different payout tax rates in each date. Because firms can defer dividend payments at no cost by investing at the risk-free rate, if firms expect payout taxes to be lower in the future, the government will not be able to collect any payout taxes today. Consequently, a payout tax could not be optimal in this case. Because the government can borrow and save, and off-equilibrium adjust spending, today's government can leave tomorrow's government with a debt level that ensures tomorrow's government will implement the same payout tax rate that today's government implements. Consequently, it is possible for the government to maintain a constant payout tax rate. Relatedly, it should be clear that assuming that the government target level of spending $\overline{G}$ is time-invariant is not essential, since only the net present value of government spending matters.

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[24]This restriction is mild, but rules out equilibria in which the government oscillates between different policies that achieve the same value for the government but have different continuation values for specific firms.

[25]Studying optimal entry regulations would require breaking the lack of commitment assumption. Instead, we explore the impact of the tax policy on entry through our quantitative exercise.

[26]Even if the government with commitment could not observe the default history of an individual firm, it would be able to statistically discriminate between firms that had previously defaulted and firms that had not. We leave open the question of whether there are non-Markov "sustainable" equilibria (Chari and Kehoe, 1990) in which a government without commitment nevertheless punishes defaulting firms and circumvents the financial frictions. We thank Felipe Varas for pointing out this possibility.

3.4 Mechanism Design Problem

In this subsection, we define the mechanism design problem that characterizes government policy at each date. We start by defining a mechanism. We focus on direct revelation mechanisms in which each firm reports its private information (θ_{t+1}) twice: first at the financing/investment stage, and second at the payouts/repayments/taxes stage. This approach allows "double-deviations" to account for the possibility of a firm with future productivity θ_{t+1} acting as if it has future productivity θ' when investing, and then acting as if it has future productivity $\theta'' \neq \theta'$ when making payout decisions. The key economic assumption behind considering this possibility is that the firm, when making its investment decision, is not committing to a particular payout policy. If the government could punish firms to an arbitrary degree, such deviations would never present a concern. In our setting, governments are limited by the possibility of default and their own lack of commitment, and as a result it is potentially important to contemplate the possibility of such deviations.

Definition 1. (Mechanism) Given an observable initial wealth w and an observable initial productivity θ, a mechanism $m_t(w, \theta)$ is a collection of non-negative functions describing the levels of firms' debt, capital, continuation wealth, payouts, and taxes: $b_t(\theta'; w, \theta)$, $k_t(\theta'; w, \theta)$, $w_{t+1}(\theta', \theta''; w, \theta)$, $d_t(\theta', \theta''; w, \theta)$, and $\tau_t(\theta', \theta''; w, \theta)$, where the arguments of the functions are the first report θ' and second report θ''.

Note that the debt and capital functions depend only on the first report, as those values must be determined at the financing/investment stage. The functions d_t^*, w_{t+1}^*, and τ_t^* described previously are defined under the assumption of consistent reporting. That is, $d_t^*(\theta'; w, \theta) = d_t(\theta', \theta'; w, \theta)$, and likewise for w_{t+1}^* and τ_t^*.

We will restrict attention to mechanisms that satisfy budget constraints and the limit on dividends, avoid default, and are incentive-compatible. We define and discuss each of these properties in turn.

Definition 2. (Feasible mechanism) A mechanism $m_t(w, \theta)$ is feasible if the upper limit on dividends is satisfied,

$$d_t\left(\theta', \theta''; w, \theta\right) \leq w^D\left(k_t\left(\theta'; w, \theta\right), \theta\right), \forall \theta', \theta'',$$

the initial budget constraint is satisfied for each firm,

$$k_t\left(\theta'; w, \theta\right) \leq w + R^{-1}b_t\left(\theta'; w, \theta\right), \forall \theta',$$

and the continuation wealth is defined as in Equation (14),

$$
\begin{aligned}
w_{t+1}\left(\theta', \theta''; w, \theta\right) \leq {}& f\left(k_t\left(\theta'; w, \theta\right), \theta\right) + (1 - \delta)k_t\left(\theta'; w, \theta\right) \\
& - d_t\left(\theta', \theta''; w, \theta\right) - b_t\left(\theta'; w, \theta\right) - \tau_t\left(\theta', \theta''; w, \theta\right), \forall \theta', \theta''.
\end{aligned}
$$

Feasibility requires that the government respects the firms' budget constraints and the limits of the production technology. In the optimal mechanism, the initial budget constraint and continuation wealth equations will hold with equality, as the government will not wish to discard any output.

We next define mechanisms that avoid default. The incentives for a firm to default depend in part on the nature of the continuation value function, $V_{t+1}(\cdot; \mu_{t+1}, B_{t+1})$, which itself depends in our Markov equilibrium on the evolution of the state variables μ_{t+1} and B_{t+1}. In the definition that follows, we will take as given the

function V_{t+1}. This approach relies on the assumption that each firm is small, meaning that the firm's decision to default has no impact on μ_{t+1} and B_{t+1}. For this reason, in the definition below, we suppress the dependence of the value function on μ_{t+1} and B_{t+1}. We will also assume that the value function V_{t+1} does not create an incentive for voluntary exit, $V_{t+1}(w',\theta') \geq V_{t+1}(w',0)$ for all w',θ'. This property will hold under all of the policies we consider, and assuming it simplifies the definition below.

Definition 3. (Default-avoiding mechanism) A mechanism $m_t(w,\theta)$ is default-avoiding if it avoids default and re-entry after dividend payment,

$$V_{t+1}\left(w^D\left(k_t\left(\theta';w,\theta\right),\theta\right),\theta\right) - d_t\left(\theta',\theta'';w,\theta\right),\theta'''\right) \leq V_{t+1}\left(w_{t+1}\left(\theta',\theta'';w,\theta\right),\theta'''\right), \forall \theta',\theta'',\theta''',$$

avoids default and re-entry after a blocked/zero dividend,

$$V_{t+1}\left(w^D\left(k_t\left(\theta';w,\theta\right),\theta\right),\theta'''\right) \leq d_t\left(\theta',\theta'';w,\theta\right) + V_{t+1}\left(w_{t+1}\left(\theta',\theta'';w,\theta\right),\theta'''\right), \forall \theta',\theta'',\theta''',$$

and avoids firms disregarding the mechanism entirely and defaulting,

$$V_{t+1}\left(w^D\left(w,\theta\right),\theta'\right) \leq d_t\left(\theta',\theta';w,\theta\right) + V_{t+1}\left(w_{t+1}\left(\theta',\theta';w,\theta\right),\theta'\right), \forall \theta'.$$

The first two no-default constraints apply regardless of whether a firm's reports are truthful or consistent. That is, the government's mechanism must respect the firms' ability to default on and off the path of equilibrium play. The third constraint is an interim participation constraint that arises from the firms' ability to invest its own wealth without raising outside funds and then default; it will automatically be satisfied if the blocked-dividend no-default constraint is satisfied and the initial budget constraint of the firm binds. The no-default constraints could be classified as feasibility constraints; we present the no-default and feasibility constraints separately to emphasize that they arise for distinct economic reasons.

Before proceeding, note that under the (very mild) assumption that V_{t+1} is strictly increasing in firm wealth, a mechanism will avoid default and re-entry after dividend payment if and only if

$$w^D\left(k_t\left(\theta';w,\theta\right),\theta\right) - d_t\left(\theta',\theta'';w,\theta\right) \leq w_{t+1}\left(\theta',\theta'';w,\theta\right), \forall \theta',\theta''. \tag{21}$$

Using the definitions of $w^D(\cdot)$ and of continuation wealth, Equation (21) can be further simplified to

$$b_t\left(\theta';w,\theta\right) + \tau_t\left(\theta',\theta'';w,\theta\right) \leq \varphi\left(1-\delta\right)k_t\left(\theta';w,\theta\right), \forall \theta',\theta''. \tag{22}$$

This constraint is the binding constraint in the equilibrium we construct.

Lastly, we define incentive-compatibility. The government must account for two sets of incentive constraints. The first set of IC constraints applies to the payouts/repayments/taxes stage. These constraints prevent firms from deviating when payouts are determined and taxes are collected. The second set of IC constraints applies to the financing/investment stage. These constraints guarantee that firms find it optimal not to deviate when investment and financing from outside investors are determined.

Definition 4. (Incentive-compatible mechanism) A mechanism $m_t(w, \theta)$ is incentive-compatible if truth-telling is optimal at the payouts/repayments/taxes stage regardless of whether the firm reported truthfully initially at the financing/investing stage,

$$d_t\left(\theta', \theta''; w, \theta\right) + V_{t+1}\left(w_{t+1}\left(\theta', \theta''; w, \theta\right), \theta'''\right) \le d_t\left(\theta', \theta'''; w, \theta\right) + V_{t+1}\left(w_{t+1}\left(\theta', \theta'''; w, \theta\right), \theta'''\right), \forall \theta', \theta'', \theta''',$$

and if truth-telling is optimal at the financing/investing stage conditional on truth-telling at the payouts/repayments/taxes stage,

$$d_t\left(\theta', \theta'''; w, \theta\right) + V_{t+1}\left(w_{t+1}\left(\theta', \theta'''; w, \theta\right), \theta'''\right) \le d_t\left(\theta''', \theta'''; w, \theta\right) + V_{t+1}\left(w_{t+1}\left(\theta''', \theta'''; w, \theta\right), \theta'''\right), \forall \theta', \theta'''.$$

Combining these definitions, we define the set of feasible, incentive-compatible mechanisms that avoid default.

Definition 5. (Feasible, incentive-compatible, default-avoiding mechanisms) Given an observable initial wealth w_t and an observable initial productivity θ_t, and continuation value function $V_{t+1}(\cdot)$ for firms' values, $\mathcal{M}(w_t, \theta_t, V_{t+1})$ is the set of mechanisms (Definition 1) that are feasible (Definition 2), avoid default (Definition 3), and are incentive-compatible (Definition 4).

3.5 Firm Entry

We conclude our description of the model by discussing firm entry. At the beginning of date t, before the current government designs its mechanism, potential entrants with measure $e(\hat{w}, \theta')$ enter the economy with initial resources $F + \hat{w} > 0$ and next date type θ'.[27] Each potential entrant faces the same fixed cost of entry, $F > 0$, and can choose how many resources to put into the firm, $w_E \le \hat{w}$. If a potential entrant chooses to enter, it begins to produce in the next date with type θ' and entry wealth w_E.

Because a potential entrant begins operation in the next date, it makes its entry decision based on the continuation value $V_{t+1}(\cdot)$. This in turn implies that a firm's entry decision depends on the firm's expectations of μ_{t+1} and B_{t+1}. Because the entry decision occurs before the date t government designs its mechanism, these expectations are functions of the date t state variables μ_t and B_t. We define $w_E(\hat{w}, \theta'; \mu_t, B_t)$ as the level of entry wealth that maximizes a potential entrant's expected value conditional on entry,

$$w_E\left(\hat{w}, \theta'; \mu_t, B_t\right) \in \arg \max_{w \in [0, \hat{w}]} \mathbb{E}\left[V_{t+1}\left(w, \theta'; \mu_{t+1}, B_{t+1}\right) \big| \mu_t, B_t\right] - w.$$

In the equilibria that we consider, there is a single optimal level of entry wealth w_E for each $(\hat{w}, \theta')$. A potential entrant will decide to enter if the benefits of entry exceed the fixed cost, that is, if

$$\mathbb{E}\left[V_{t+1}\left(w_E\left(\hat{w}, \theta'; \mu_t, B_t\right), \theta'; \mu_{t+1}, B_{t+1}\right) \big| \mu_t, B_t\right] - w_E\left(\hat{w}, \theta'; \mu_t, B_t\right) \ge F.$$

---

[27]Assuming that the mass of potential entrants $e(\hat{w}, \theta')$ is the same each date simplifies the exposition but it is not necessary.

The measure of firms entering the economy during date t (i.e., starting operations at date $t+1$) with wealth w' and type θ' is therefore

$$de_t\left(w',\theta';\mu_t,B_t\right) = \int_0^\infty \mathbf{1}\{\mathbb{E}\left[V_{t+1}\left(w_E\left(\hat{w},\theta';\mu_t,B_t\right),\theta';\mu_{t+1},B_{t+1}\right)\big|\mu_t,B_t\right] - w_E\left(\hat{w},\theta';\mu_t,B_t\right) \geq F\}$$
$$\times \delta_{\text{dirac}}\left(w_E\left(\hat{w},\theta';\mu_t,B_t\right) - w\right)de\left(\hat{w},\theta'\right), \tag{23}$$

where $\delta_{\text{dirac}}\left(\cdot\right)$ denotes the Dirac delta function and $\mathbf{1}\{\cdot\}$ denotes the indicator function.

Entry adds an important channel through which future government policies matter. The date t government cannot affect entry at date t, because potential entrants have already made their decisions. However, through the impact of its policies on μ_{t+1} and B_{t+1}, the date t government might be able to affect the equilibrium values of μ_{t+2} and B_{t+2}, which will in turn affect the entry decisions made at date $t+1$. Intuitively, the date t government recognizes that by setting a policy that increases the debt burden of future governments, those governments will have to increase taxes in the future, which deters date $t+1$ potential entrants from entering.

Taxes distort entry in our model on both the extensive and intensive margins. Potential entrants with relatively low outside wealth $\hat{w}$ and productivity θ' might choose not to enter at all, if taxes lower the continuation value function V_{t+1} to the point that entry no longer justifies the fixed costs. More productive entrants, particularly those with high levels of outside wealth $\hat{w}$, will still choose to enter, but enter with lower levels of wealth w_E than they would have chosen in the absence of taxes (assuming that the marginal tax rate is positive). Our model is designed to tractably capture both of these margins.
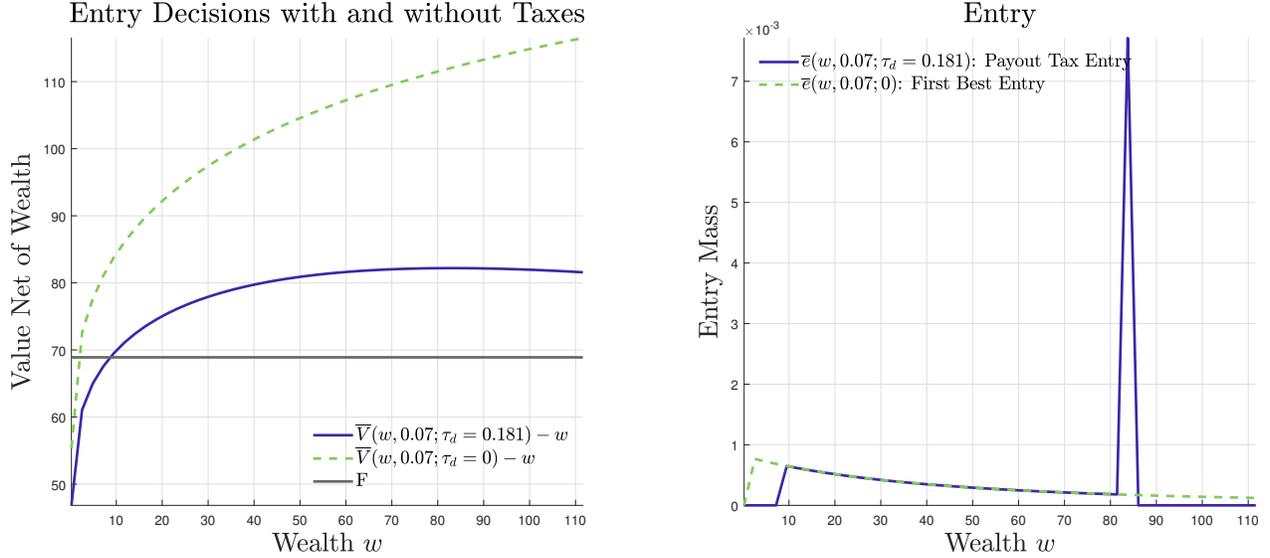
Figure 3 illustrates the extensive and intensive margins of entry distortion under payout taxation. The left panel of Figure 3 plots $V_{t+1}(w,\theta;\cdot) - w$ for one particular value of θ (a low one) from our quantitative analysis, assuming a constant payout tax rate ($\tau_d = 0$ or $\tau_d = 0.181$). The right panel of Figure 3 shows the corresponding distribution of entrants. We can observe both extensive and intensive margin distortions in Figure 3. At low levels of outside wealth $\hat{w}$, entry is deterred by taxation, meaning that some firms will choose not to enter due to taxation. This is the extensive margin distortion visible for low wealth in the right panel of Figure 3. At high levels of outside wealth, firms will choose to enter with less wealth than they would enter with in the absence of taxation, because payout taxes reduce the marginal returns on initial equity investment. This intensive margin distortion leads to the bunching visible at higher levels of wealth in the right panel of Figure 3. This effect captures the idea that taxing payouts to shareholders but not debt holders leads to debt crowding out equity.

4 Theoretical Results

In this section, we present formal results for the general model. We first define the problem of a firm in the presence of payout taxes. We then construct an equilibrium in which the government optimally chooses to implement a payout tax in each period.

4.1 Firms' Problem

Before characterizing the optimal policy, we discuss the problem firms face and how the government's optimal mechanism can be implemented via taxes. Firms take the government's tax policies as given; these taxes

Note: Figure 3 illustrates the extensive and intensive margins of entry distortion under payout taxation for one particular productivity level ($\theta = 0.07$) from our quantitative analysis (see Section 5 for details). The left panel plots the firm value functions net of wealth under the constant payout taxes of $\tau_d = 0.181$ and $\tau_d = 0$, $\overline{V}(w, \theta; \tau_d = 0.181) - w$ and $\overline{V}(w, \theta; \tau_d = 0) - w$ (the functions $\overline{V}$ are formally defined in Section 4). The right panel plots the entering mass of firms under payout taxation and in the absence of taxation (first-best).

Figure 3: Entry with and without Payout Taxation

could be an arbitrary function of the observable state variables (w_t, θ_t) and the observable firm choices (b_t, k_t, d_t, w_{t+1}). Subject to these taxes, the firm must raise funds from outside investors, produce, and either pay its obligations and taxes or default. Firms have information (about the future productivity, θ_{t+1}) that the outside investors do not; at least in theory, this complicates the problem between a firm and its outside investors.

However, if the government implements a payout tax in the current date that is consistent with future payout taxes, unconstrained firms will be indifferent between paying dividends in the current date or retaining wealth for the future. Constrained firms will always prefer not to pay any dividends. As a result, both groups of firms' decisions to default will be as if they paid no dividends (and therefore no taxes). This observation can be used to show that the default decision does not depend on the future productivity θ_{t+1}.

Specifically, let us suppose that the only taxes a firm pays are in proportion to its dividends:

$$\tau_t (w_t, \theta_t, b_t, k_t, d_t, w_{t+1}) = \tau_d d_t.$$

Let $\overline{V}(w, \theta; \tau_d)$ be the firm value function under this constant payout tax τ_d at the very beginning of a date (before the firm learns its next date productivity). We will conjecture and verify that this value function satisfies certain properties. We use the notation $\overline{V}_{w^+}(w, \theta; \tau_d)$ to denote the right directional derivative with respect to w, recalling that such a derivative exists for all concave functions.

Conjecture 1. *(Value function under constant payout tax) We conjecture that, for all $\tau_d \geq 0$, there exists a weakly positive, continuous function $\overline{w}(\theta)$ such that*

    i) $\overline{V}(w, \theta; \tau_d)$ is concave in wealth w,

25

ii) $\overline{V}(w, \theta; \tau_d)$ satisfies, for all $w \geq \overline{w}(\theta)$, $\overline{V}_{w^+}(w, \theta; \tau_d) = \frac{1}{1+\tau_d}$,

iii) $\overline{V}(w, \theta; \tau_d)$ satisfies, for all $w < \overline{w}(\theta)$, $\overline{V}_{w^+}(w, \theta; \tau_d) > \frac{1}{1+\tau_d}$.

This definition can be understood in terms of the "payout boundary" $\overline{w}(\theta)$. Suppose that a firm faces a tax rate on payouts equal to τ_d, so that getting one dollar in payouts to its owners costs $1 + \tau_d$ dollars in continuation wealth. Such a firm would be willing to pay dividends once the firm's continuation wealth exceeded $\overline{w}(\theta)$, but would prefer not to pay dividends if the continuation wealth were less than $\overline{w}(\theta)$. Our conjecture is that the value function is concave and that a payout boundary exists.[28]

We first use this conjecture to observe that a firm's default decision does not depend on its private information.

Lemma 1. *(Default invariance) Suppose that the government implements a constant payout tax at rate $\tau_d \geq 0$ and that Conjecture 1 holds. Then a firm with capital k_t, debt b_t, and productivity θ_t will not default if and only if it will not default with $d_t = \tau_t = 0$,*

$$f(k_t, \theta_t) + (1 - \delta) k_t - b_t \geq w^D(k_t, \theta_t).$$

Proof. See the Appendix, Section A.1. □

Lemma 1 implies that outside investors have no particular reason to care about a firms' future type θ_{t+1} when the government implements this particular payout tax. Because a firm and its outside investors can contract on the level of capital, they will both know with certainty whether or not the firm will default, and the outside investors will limit the firm's borrowing to avoid default. That is, even though there is asymmetric information between firms and outside investors, it has no economic implications provided that the government implements this particular form of taxation. Profit taxation, the usual form of corporate taxation, also exhibits this property in our model; see Section 5 and Appendix Section B.1 for details.

Because a firm's default decision does not depend on its private information, we can consider the problem facing each firm separately.[29] Note that we write the no-default constraint as $w_{t+1} + d_t \geq w^D(k_t, \theta_t)$, taking advantage of the result above and the observation that, if this constraint binds in the firm's problem as we have written it, the firm will not pay dividends. This observation is part of the reason a constant payout tax is optimal: firms that are constrained will not pay dividends in the presence of a constant payout tax, whereas firms that are not constrained are willing to pay dividends in the presence of such a tax.

Definition 6. (Firms' problem) Fix some $w_t > 0$ and $\theta_t \in [0, 1]$, and suppose that the government implements a constant payout tax at rate $\tau_d \geq 0$ and that Conjecture 1 holds. The date t problem of the firm is

$$\overline{V}(w_t, \theta_t; \tau_d) = \int_0^1 \overline{V}(w_t, \theta_t, \theta_{t+1}; \tau_d) \, d\Pi(\theta_{t+1} | \theta_t), \tag{24}$$

---

[28]This conjecture is likely to hold under many government policies, not just a constant payout tax; however, one could imagine pathological tax policies that create convexities.

[29]If a firm's default decisions were influenced by its private information, an adverse selection problem would exist between outside investors and firms. In this case, optimal policy would address adverse selection problems in addition to attempting to raise revenue.

where $\overline{V}(w_t, \theta_t, \theta_{t+1}; \tau_d)$ is the value of a firm with wealth w_t, productivity θ_t, and future productivity θ_{t+1} under a constant payout tax,

$$\overline{V}(w_t, \theta_t, \theta_{t+1}; \tau_d) = \max_{b_t \geq 0, k_t \geq 0, w_{t+1} \geq 0, d_t \geq 0} R^{-1} \left\{ d_t + \overline{V}(w_{t+1}, \theta_{t+1}; \tau_d) \right\}$$

subject to

$$w_{t+1} \leq f(k_t, \theta_t) + (1 - \delta) k_t - (1 + \tau_d) d_t - b_t,$$
$$k_t \leq w_t + R^{-1} b_t,$$
$$w_{t+1} + d_t \geq w^D(k_t, \theta_t),$$
$$d_t \leq w^D(k_t, \theta_t).$$

Using this definition, we can verify our conjecture. It is indeed optimal for a firm to payout wealth to investors if and only if it reaches a payout threshold, and the firms' value function is in fact concave.

Lemma 2. *(Conjecture verified) Conjecture 1 holds for all $\tau_d \geq 0$ and some non-negative function $\overline{w}(\theta)$.*

Proof. See the Appendix, Section A.2. $\square$

We can in fact explicitly characterize the function $\overline{w}(\theta)$, which is the wealth level at which a firm chooses to make positive payouts under a constant payout tax. It is the level of wealth at which a firm knows that it can achieve first-best production regardless of the future evolution of its type, and satisfies the following functional equation:

$$\overline{w}(\theta) = \max \left\{ \left(1 - R^{-1} \varphi (1 - \delta)\right) k^*(\theta), R^{-1} \left(-f(k^*(\theta), \theta) - (1 - \delta - R) k^*(\theta) + \max_{\theta' \in supp(\Pi(\cdot|\theta))} \overline{w}(\theta') \right) \right\}. \tag{25}$$

Intuitively, financially unconstrained firms must have enough wealth to achieve first-best production in the current date — the first term in Equation (25) — and also have enough wealth to achieve first-best production in the future after including profits from the current date — the second term in Equation (25). Exiting types will always have $\overline{w}(0) = 0$, and all other types will have strictly positive $\overline{w}(\theta)$. In our numerical example, because it is always possible (although perhaps very unlikely) for non-exiting firms to reach the highest productivity level in the next date, this expression becomes

$$\overline{w}(\theta) = \max \left\{ \left(1 - R^{-1} \varphi (1 - \delta)\right) k^*(\theta), R^{-1} \left(-f(k^*(\theta), \theta) - (1 - \delta - R) k^*(\theta) + \left(1 - R^{-1} \varphi (1 - \delta)\right) k^*(1) \right) \right\}.$$

Note that the payout threshold $\overline{w}(\theta)$ does not depend on the tax rate τ_d. That is, the firm sets the payout threshold as if there were no taxes, implying that production occurs as if there were no taxes. Because the government cannot subsidize firms or circumvent the financial constraints, this level of production achieves the maximum feasible net present value of production, taking as given the firms' initial wealth.[30]

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[30]This last caveat is important since the firms' wealth on entry is endogenous and affected by payout taxes.

This expression for the payout threshold $\overline{w}(\theta)$ illustrates a key difference between payout taxes and profit taxes (including profit taxes with full expensing of investment). It is possible for firms to be profitable and achieve first-best levels of capital at the current date, and yet be financially constrained because they may not achieve first-best levels of capital at future dates. A profit tax, even one that allows for expensing of capital investment, would tax such a firm, thereby exacerbating financial constraints.[31] A payout tax, in contrast, would not tax this firm, because the firm would naturally choose not to make any payouts in the current date.

Under a constant payout tax at rate τ_d, a firm's value is simply a scaled-down version of its value in the absence of taxes, $\overline{V}(w, \theta; \tau_d) = \frac{1}{1+\tau_d}\overline{V}(w, \theta; 0)$. The net present value of taxes collected from the firm is $\frac{\tau_d}{1+\tau_d}\overline{V}(w, \theta; 0)$, and the total net present value of taxes and dividends is $\overline{V}(w, \theta; 0)$. Let $\bar{e}(w, \theta; \tau_d)$ be the measure of firms that choose to enter (see Equation (23)) under the assumption of a constant payout tax at rate τ_d (i.e., with the value function $\overline{V}(w, \theta; \tau_d)$ in the place of the continuation value).

4.2 Equilibrium with Payout Taxes

We next construct an equilibrium in which the government implements a constant payout tax.

We will first outline the basic logic, then present the formal result. The key ideas behind this result are essentially the same ideas illustrated in our stylized model. Suppose, for the sake of argument, that future governments, beginning with date $t+1$, will implement a payout tax at some rate $\tau_d \geq 0$ and spend at least $\overline{G}$ at each date if feasible. This may or may not in fact be feasible, but let us set this issue aside for the moment. In this case, the government's next period value function is

$$
\begin{aligned}
J_{t+1}(\mu_{t+1}, B_{t+1}) = & -B_{t+1} - \frac{\overline{G}}{1-R^{-1}} \\
& + \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0)\, d\mu_{t+1}(w, \theta) \\
& + \frac{1}{R-1} \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0)\, d\bar{e}(w, \theta; \tau_d).
\end{aligned} \tag{26}
$$

The first line in this expression is the net present value of the government's debt and target spending. The second is the net present value of taxes and dividends from the existing population of firms, and the third is the same for firms that will enter in the future. Taxes and dividends are valued equally, from the government's perspective, due to the assumption that the government is achieving its target spending level at each date.

Let us now use this J_{t+1} as the continuation value function in the government's problem at date t, Equation (20). Consider in particular when the government would like a firm to pay taxes, ignoring for a moment incentive-compatibility issues. Note first that collecting a marginal dollar of additional taxes from a firm reduces B_{t+1} by one dollar (see Equation (18)). It reduces firm continuation wealth w_{t+1} directly by one dollar (by Equation (14)), and by more than one dollar if the financing constraint (Equation (22)) binds. The

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[31]The key assumption here is that investment in capital is deductible but investment in cash or cash equivalents (retained earnings) is not. As discussed in Section 7, a payout tax can be thought of as a profit tax under which all retained earnings and interest expenses are deductible.

social value (including both future taxes and future dividends) of a dollar of continuation wealth is always at least one dollar ($\overline{V}_{w^+}(w_{t+1}, \theta_{t+1}; 0) \geq 1$), with equality if $w_{t+1} \geq \overline{w}(\theta_{t+1})$.

Consequently, to achieve what we will call constrained efficient production, tax policies must satisfy two conditions:

1. Constrained efficiency must hold in the current date, $k_t(\theta_{t+1}; w_t, \theta_t) = k^{ce}(w_t, \theta_t)$, and

2. Taxes must be paid only by firms that will be unconstrained at $t+1$ (those with $w^*_{t+1}(\theta_{t+1}; w_t, \theta_t) \geq \overline{w}(\theta_{t+1})$).

That is, constrained efficiency in production requires both that firms that are currently constrained are not taxed and that firms that might become constrained are not taxed. These two conditions are achieved under a constant payout tax: firms will only payout if their continuation wealth weakly exceeds the payout boundary, $w^*_{t+1}(\theta_{t+1}; w_t, \theta_t) \geq \overline{w}(\theta_{t+1})$, and will never pay out if doing so would constrain their production today.

Moreover, any mechanism that achieves constrained efficiency in production while satisfying the feasibility, incentive-compatibility, and no-default constraints is optimal. Today's government is indifferent to the level of taxation of unconstrained firms, because for these firms the marginal social value of wealth is exactly equal to the marginal social cost of debt. The payout tax mechanism with tax rate τ_d automatically satisfies the feasibility, no-default, and incentive-compatibility constraints, and consequently is optimal. We conclude that implementing a payout tax at rate τ_d is optimal for the date t government as the best response to future government's implementing a constant payout tax at rate τ_d.

Proposition 1. *(Implementation of optimal mechanism by a constant payout tax) Suppose that J_{t+1} satisfies Equation (26) for some $\tau_d \geq 0$, and that $V_{t+1}(\cdot; \mu_{t+1}, B_{t+1}) = \overline{V}(\cdot; \tau_d)$. Then there exists a set of optimal mechanisms $m^*(w, \theta)$ in the government's problem (20) that can be implemented by a constant payout tax at rate τ_d.*

Proof. See the Appendix, A.3. □

However, to formalize the argument, we must consider whether implementing a constant payout tax is feasible. If the government spends exactly its target $\overline{G}$ each date, and raises revenue from a constant payout tax, the net violation of the government's intertemporal budget constraint is

$$N(\mu, B, \tau_d) = \frac{\tau_d}{1 + \tau_d} \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0) \, d\mu(w, \theta) \tag{27}$$
$$+ \frac{\tau_d}{1 + \tau_d} \frac{1}{R-1} \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0) \, d\overline{e}(w, \theta; \tau_d)$$
$$- B - \frac{\overline{G}}{1 - R^{-1}}.$$

This equation illustrates the Laffer curve present in our model. The first term in this equation concerns the taxation of the existing stock of firms. The equity in these firms is "trapped," and taxing these firms more (increasing τ_d) always raises revenue. The second term in this equation is the net tax revenue from firms that will enter in the future. Increasing taxes raises more revenue from these firms holding entry constant, but will

reduce entry. In particular, increasing the tax rate τ_d both reduces the entering mass $\overline{e}$ (the extensive margin) and reduces wealth conditional on entry, shifting mass to lower wealth levels (the intensive margin). The last terms in this equation represent the net present value of the current debt and future government (target) spending. The government's intertemporal budget constraint is satisfied when $N(\mu, B, \tau_d) = 0$. Appendix Figure A1 illustrates the function N using the parameters of our quantitative analysis.

A constant payout tax can satisfy the intertemporal budget constraint if, given the initial measure of firms μ_0 and initial debt B_0, there exists a $\overline{\tau}_d \geq 0$ such that $N(\mu_0, B_0, \overline{\tau}_d) \geq 0$. We consider this case in Proposition 2, and discuss what happens when a constant payout tax is not feasible below. To simplify our exposition, we assume that the function $N(\mu_0, B_0, \tau_d)$ is continuous in τ_d in the interval $[0, \overline{\tau}_d]$.[32]

Formally, we characterize an equilibrium, in which, on the equilibrium path, the government i) implements a constant payout tax equal to $\tau_d \in [0, \overline{\tau}_d]$, and ii) sets government spending equal to $\overline{G}$ in all dates after the initial date.

Proposition 2. *(Equilibrium with constant payout tax) If there exists a $\overline{\tau}_d \geq 0$ such that $N(\mu_0, B_0, \overline{\tau}_d) \geq 0$, and $N(\mu_0, B_0, \tau)$ is continuous on $\tau \in [0, \overline{\tau}_d]$, then there exists an equilibrium characterized by a tax rate $\tau_d \in [0, \overline{\tau}_d]$ in which, on the equilibrium path, the government implements a constant payout tax rate equal to τ_d, and chooses a level of spending equal to its target, $G_t = \overline{G}, \forall t > 0$. If $B_0 + \frac{\overline{G}}{1 - R^{-1}} > 0$, then $\tau_d > 0$, $G_0 = \overline{G}$, and $N(\mu_0, B_0, \tau_d) = 0$.*

Proof. See the Appendix, Section A.4. □

Proposition 2 shows that there exists an equilibrium in which the optimal policy sets a constant payout tax rate. Provided that the government needs to raise some revenue ($B_0 + \frac{\overline{G}}{1 - R^{-1}} > 0$), this tax rate will be strictly positive and exactly satisfy the government's intertemporal budget constraint along the equilibrium path. The intuition behind this equilibrium is exactly as described above. Constrained firms prefer not to pay dividends, and it is socially optimal for them not to, whereas both unconstrained firms and the government are indifferent about whether the unconstrained firms pay dividends. A payout tax in the current date can efficiently separate constrained and unconstrained firms while raising revenue, and is therefore optimal if feasible. Appendix Figure A2 illustrates the optimal policies of firms in such an equilibrium, using the parameters of our quantitative analysis (Section 5).

To sustain this equilibrium, if the date t government improves the date $t+1$ government's fiscal position ($N(\mu_{t+1}, B_{t+1}, \tau_d) > 0$), the date $t+1$ government would respond by allowing firms to make higher payouts, or equivalently increasing government spending. In contrast, if the date t government worsens the $t+1$ fiscal position ($N(\mu_{t+1}, B_{t+1}, \tau_d) < 0$), "something bad" happens, but our proof of Proposition 2 is silent about exactly what occurs in this case. Instead, the proof uses a bound on the value function on this domain to show that the government would never choose to enter it. We discuss this situation heuristically below. Note that this discussion also applies if a constant payout tax cannot satisfy the intertemporal budget constraint given the initial conditions, meaning that $N(\mu_0, B_0, \tau_d) < 0, \forall \tau_d \in [0, \infty)$.

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[32]This assumption could be derived from more primitive assumptions (i.e., finiteness and continuity in the appropriate sense) on the population of initial firms and of potential entrants.

Let χ_t denote the multiplier on the constraint, Equation (18), in the government's problem, Equation (20). Assuming differentiability, the first order condition for government debt and optimal government spending yields

$$\overline{\chi} \geq \chi_t = -J_B\left(\mu_{t+1}, B_{t+1}\right) \geq 1.$$

In the equilibrium described in Proposition 2, $\chi_t = -J_B\left(\mu_t, B_t\right) = 1$ along the equilibrium path. Now consider what happens when $N\left(\mu_0, B_0, \tau_d\right)$ is close to but less than zero at its maximum on $\tau_d \in [0, \infty)$. In this case, it may be possible for the government at date zero to raise additional taxes from strictly unconstrained firms ($w > \overline{w}(\theta)$) in such a way that it creates no distortions and satisfies $N\left(\mu_1, B_1, \tau_d\right) = 0$. If this holds, the equilibrium will be the one described in Proposition 2 from date one onwards, with additional taxation at date zero and with $\chi_t = 1$. If this outcome is not possible, then $\chi_t > 1$, which leads to the government engaging in distortionary taxation, meaning that it will tax firms that are financially constrained. We speculate in this case that the government will use distortionary taxation for one or more dates, with χ_t decreasing over time, until it is able to reach $\chi_t = 1$. At that point, it will use a constant payout tax as described in Proposition 2. What makes this case difficult to characterize is that, with distortionary taxation, the incentive-compatibility constraints bind, which means the set of feasible mechanisms is influenced by the value function V, which is in turn influenced by whatever distortionary taxes will occur in the future. There is, however, an upper bound to the amount of distortionary taxation the government will implement. The multiplier χ_t is bounded above by $\overline{\chi}$, due to the government's ability to cut spending. If the cost of additional distortionary taxation is high enough, the government will choose to cut spending and then use distortionary taxation to eventually reach $\chi_t = 1$. Summarizing, we conjecture that, regardless of initial conditions, the conclusions of Proposition 2 will hold starting from some date $t \geq 0$.

These equilibria capture the key result of our stylized model, which is that a constant payout tax rate can efficiently separate constrained and unconstrained firms. In the next section, we attempt to quantify the benefits of switching from the usual form of corporate taxation to payout taxation. In the subsequent section, we discuss the connections between two key assumptions of the model (the form of the financial frictions and the limit on equity issuance) and our results.

5   Quantitative Analysis

Our theoretical results show that payout taxation emerges as an optimal policy in our model. In practice, most countries use profit-based corporate taxation (henceforth, profit taxation). In this section, we explore quantitatively the magnitude of the gains of switching from profit taxation to payout taxation, as well as the effects on entry, which the government in our theoretical model does not internalize. We find that a revenue-neutral switch from a profit tax to a payout tax would increase the overall value of existing firms and future entrants by 7%.

Comparing Profit and Payout Taxes.   A profit-based corporate tax in our model takes the form

$$\tau_t\left(w_t, \theta_t, b_t, k_t, d_t, w_{t+1}\right) = \tau_c\left[f\left(k_t, \theta_t\right) - \delta k_t - \left(1 - R^{-1}\right)b_t\right],$$

where τ_c is the tax rate. This tax applies to profits net of depreciation and includes a deduction for interest paid on debt. Deductions for depreciation and interest payments are features of the existing tax code in the United States and many other countries. In Appendix Section B.1 we explicitly describe the problem of a firm in our model facing this profit-based corporate tax.

Let us compare a profit tax at rate τ_c with a payout tax at rate τ_d that raises the same revenue. It is useful to separately consider the impact of switching from a profit tax to a payout tax on incumbent firms and on entry decisions. Beginning with incumbent firms, the value of each incumbent firm can be thought of as consisting of two parts: the value of the wealth w inside the firm and the value of the future profits. A payout tax taxes these two components at the same rate, when they are paid out. A profit tax taxes the value of future profits more than the value of wealth inside the firm.[33] As a result, firms whose value consists mostly of future profits (constrained firms) would prefer the payout tax, whereas firms whose value comes more from wealth inside the firm (unconstrained firms) would prefer the profit tax.

If the tax rates τ_c and τ_d raise the same amount of tax revenue, switching from a profit tax to a payout tax creates winners (constrained firms) and losers (unconstrained firms). But because the constrained firms that benefit from this switch endogenously have better investment opportunities than the unconstrained firms, switching to a payout tax increases overall output and the total value of all firms in the economy.

Switching to a payout tax also affects entry. Marginal entrants — those for whom the benefits of entry are close to the fixed costs of entry — will enter the economy as constrained firms and hence benefit from a switch to payout taxation. Switching to payout taxation therefore reduces the extensive margin distortions caused by taxing firms. However, payout taxation can induce well-capitalized potential entrants to reduce their wealth on entry. Switching to payout taxation can therefore exacerbate the intensive margin distortions caused by taxation. In total, a switch from profit taxation to payout taxation will increase the number of firms entering but reduce their average size, and have ambiguous effects on the total value of entering firms.

Description of Quantitative Exercise. We study these tradeoffs in our quantitative exercise. First, we calibrate our model of firms to the estimated parameters of Li, Whited and Wu (2016), using a corporate tax rate of $\tau_c = 20\%$. We then estimate the parameters of our model that govern entry and exit dynamics to match relevant facts documented by Lee and Mukoyama (2015) and the elasticity of entry with respect to corporate tax rates estimated by Djankov et al. (2010).

Armed with our quantitative model, we can calculate how much revenue the corporate profit tax $\tau_c = 20\%$ raises, and find the steady state population of firms, μ_c^*. We can then compute the payout tax rate τ_d that would be required to raise the same amount of revenue (in a net-present-value sense), assuming that the initial population of firms is equal to μ_c^*. The payout tax rate τ_d is the tax rate required to implement a revenue-neutral switch from a profit tax to a payout tax in our calibrated model. Comparing the two taxes, we study how the total value of entering and continuing firms is affected by the switch to payout taxation.

We start by describing our functional form assumptions, then discuss our calibration, and lastly present the results of our quantitative analysis. Appendix Section B contains a more detailed description of our functional form assumptions and calibration procedure.

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[33]The value of wealth inside the firm is taxed by a profit tax due to the taxation of the risk-free net return $R-1$, but this effect is smaller than the effect on the value of future profits.

Functional Forms. Our model requires functional forms for the production function $f(k,\theta)$, transition kernel $\Pi(\theta_{t+1}|\theta_t)$, and potential entry mass $e(\hat{w},\theta')$. For $f(k,\theta)$, we use the decreasing returns to scale production function, augmented with the cash-like investment option, described in Equation (13). For the transition probabilities, we assume that log productivity (conditional on not exiting) follows a discrete approximation of an AR(1) process. We use the Tauchen (1986) approximation, with 14 non-zero log productivity levels spanning two standard deviations in both directions. The parameters ρ (persistence) and σ (standard deviation of shocks) describe the properties of the AR(1) process being discretized.

We define the exit probabilities $\Pi(0|\theta_t)$ using the parameters $\Pi(0|1)$ and $\Pi(0|\theta_L)$, where θ_L is the lowest non-zero productivity level. We log-linearly interpolate between the log values of these two parameters. That is, $\ln(\Pi(0|\theta_t))$ is linear in $\ln(\theta_t)$ and varies between $\ln(\Pi(0|\theta_L))$ and $\ln(\Pi(0|1))$. These exit probabilities, plus the discretized AR(1) process, fully determine the transition probabilities $\Pi(\theta_{t+1}|\theta_t)$.

The total potential entry mass will scale the steady state mass μ_c^* up and down, but will not affect any of our calculations. We therefore normalize the total potential entry mass to one. We assume that the outside wealth $\hat{w}$ and productivity θ' are independently distributed. For productivity θ', we assume that entrant productivity is drawn from the steady state of the AR(1) process,[34] with the mean shifted by the parameter μ_z^e. This parameter controls the relative productivity of entrants and existing firms. For outside wealth $\hat{w}$, we use a shifted Pareto (Lomax) distribution with a tail parameter of $\frac{3}{2}$.[35] We use the scale parameter ξ_w to control the fraction of potential entrants with low wealth as opposed to high wealth, which influences the relative size of entrants and existing firms.

Calibration. The starting point for our calibration is the estimated results of Li, Whited and Wu (2016). The model employed by Li, Whited and Wu (2016) is close to ours (and in particular uses the same Rampini and Viswanathan (2010) financial friction), with a few differences. Li, Whited and Wu (2016) estimate the parameters of their model using simulated method of moments on the population of Compustat firms, with a sample period of 1965–2012. Because our model and theirs are so similar, we are able to calibrate all of the parameters relating to firms (as opposed to entry/exit) using their results.

However, we should note that our model differs from theirs in ways that are important for our theoretical exercise. We assume that future productivity is privately known to the firm and that firms finance themselves using debt, whereas Li, Whited and Wu (2016) assume productivity shocks are contractable. We also assume that taxes are subject to default, whereas Li, Whited and Wu (2016) assume that taxes are not subject to default.[36] We calibrate our parameters to their estimation results, acknowledging that estimating our model on their dataset would likely result in a somewhat different set of parameters. Appendix Table A1 lists both the

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[34]Note that this is not the same as the steady state distribution of our productivity parameter, because of the different rates of exit across productivity levels.

[35]This tail parameter is close to the value of the tail parameter for the 2005 wealth distribution in the United States estimated by Atkinson, Piketty and Saez (2011), although it is not obvious that the distribution of potential entrant wealth should be similar to the distribution of total wealth. Fixing the tail parameter and controlling the scale parameter allow us to vary between distributions that are close to uniform and distributions that are highly concentrated at low wealth levels, and our results are not very sensitive to the choice of tail parameter.

[36]There are a few other differences relating to timing, and Li, Whited and Wu (2016) estimate a productivity process that does not account for exit. Li, Whited and Wu (2016) also assume that the corporate tax does not include a deduction for depreciation.

parameters we calibrate from Li, Whited and Wu (2016) and the parameters relating to entry and exit that we estimate, described next.

There are five parameters relating to entry and exit that we estimate, $\left(\Pi(0|1), \Pi(0|\theta_L), \mu_z^e, \xi_w, F\right)$. We follow Clementi and Palazzo (2016) and target several moments regarding the entry and exit of manufacturing plants documented by Lee and Mukoyama (2015). Specifically, we attempt to match the exit rate, relative TFP of exiting and continuing firms, relative TFP of entering and continuing firms, and relative size of entering and continuing firms, under the steady state distribution μ_c^*. These four moments help us pin down the five parameters above.

The fifth moment we use is the semi-elasticity of entry to corporate tax rates estimated by Djankov et al. (2010) using a cross-section of countries. Calibrating our model to this elasticity ensures that the extensive margin response to tax changes in the model is consistent with empirical evidence. As discussed above, switching from profit taxation to payout taxation will affect the extensive margin of entry, which is why we target this particular moment. Note that this moment is about changes in the rate of profit taxation, and not directly about what would happen under a switch to payout taxation. We are using the structure of our model to translate what is known about how profit taxation affects entry into a prediction about how a switch to payout taxation would affect entry. Appendix Table A2 summarizes the targeted moments, our interpretation of these moments within the model, and our model fit of those moments.

Quantitative Results. Armed with our calibrated model, we first calculate the steady state distribution μ_c^* and the total value of the taxes raised each period in that steady state, which are by definition equal to $\tau_c = 20\%$ of the profits after deductions for the population of firms. Because we have normalized the mass of entering firms each period to one, the total value of the taxes raised each period has by itself little meaning.

It becomes more meaningful when we consider a switch to payout taxation, and answer the question: what payout tax rate is required to raise this amount of revenue (in an NPV sense)? We estimate this value to be $\tau_d = 18.1\%$, and note that it is not a priori obvious whether this tax rate should be larger or smaller than the corresponding profit tax rate. Since this value of τ_d raises the desired amount of revenue, it characterizes optimal policy in a Markov equilibrium (according to Proposition 2).

We next consider the effects of switching to payout taxation. Our theoretical results show that this switch will increase the value of existing firms, but are silent on the net effects of such a switch on entry. We therefore begin by discussing the effects on entry. With a profit tax of $\tau_c = 20\%$, the total mass of entrants is 74.6% of what entry would be in the absence of taxation (i.e., if $\tau_c = \tau_d = 0$). Our model is calibrated to match this number (i.e., to match the semi-elasticity of Djankov et al. (2010)). With a payout tax rate of $\tau_d = 18.1\%$, the total mass of entrants is 98.0% of entry in the absence of taxation. That is, switching to payout taxation increases entry by 31%.

This increase occurs because marginal entrants are constrained, and payout taxation is preferable for constrained firms. However, because these entrants are marginal, they are not very valuable from a private perspective (this echoes a point made by Jaimovich and Rebelo (2017)). Moreover, because payout taxation is worse for firms with more wealth, and some potential entrants could choose to enter with higher wealth,

payout taxation can exacerbate intensive margin distortions. Nevertheless, we find that the total private value of entering firms increases by 10.2% when switching to payout taxation.

Figure 4 shows the value functions net of wealth and resulting entry measures for three different productivity levels, under profit taxation and payout taxation. It is immediately apparent from the left panel that switching from profit taxation to payout taxation benefits low-wealth firms and harms high-wealth firms. As a result, this switch reduces extensive margin distortions (the profit tax shuts down entry completely for the lowest productivity type) and exacerbates intensive margin distortions.

We can decompose the increase in entrant value into two parts: the increase due to changing entry patterns, holding fixed the value of each firm at its value with the profit tax $\tau_c = 20\%$, and the increase due to the change in value for each firm type (w, θ) under the new entry patterns. The effect due to changing entry patterns, holding fixed the value function, is -4.0%. That is, although 31% more firms enter, the increase in the intensive margin distortion is such that the overall value of entering firms would shrink, if the value of each firm were held fixed. However, this value is not fixed; in particular, constrained firms become much more valuable under a payout tax. This change increases the total value of firms by 14.7%. The 10.2% increase in firm value mentioned above is the product of these two effects.

Switching to payout taxation also increases the value of incumbent firms (a result that is implied by Proposition 2). This increase is smaller than the increase for entrants, because entrants are more constrained than incumbents. We find that switching to payout taxation increases the value of incumbent firms by 4.7%. If we restrict attention to the set of incumbent firms in the top five percent of the firm size distribution (measured by capital under the profit tax regime), we observe a small decrease in firm value.

This might seem counterintuitive, in light of our discussion about how payout taxation is worse for firms with high levels of wealth. To understand this result, observe that with profit taxation, firms will pay out wealth before they have enough wealth to achieve first-best production. Even though they are unconstrained in the sense that they have equated their internal and external value of funds, they are still constrained in the sense that they are not achieving production efficiency. As a result, in the steady state distribution under profit taxation, almost all firms will either benefit or be close to indifferent to a switch to payout taxation. Firms wealthy enough to be substantially harmed by a switch to payout taxation are rare in the steady state because they would have found it optimal to pay out their wealth earlier.

Combining the effects on entry with the effects on incumbent firms, we find that the total value of all firms (the value of incumbents plus the net present value of all future entrants) increases by 7.0%. This estimate is of course influenced by all of the parameters of our model, but is particularly sensitive to the magnitude of the entry semi-elasticity. If we re-calibrate our model using an entry semi-elasticity twice as large, we estimate a total value increase for all firms of 16.9%. This increase is driven primarily by a larger increase in the value of new firms under payout taxation as opposed to profit taxation, and to a lesser extent by a reduction in the payout tax rate required from $\tau_d = 18.1\%$ to $\tau_d = 16.7\%$. If instead we calibrate our model with zero entry semi-elasticity, we find that switching to a payout tax reduces the total value of firms by 1.4%. The switch still increases the current value of the existing stock of firms (by slightly less, because the required payout tax rate is $\tau_d = 19.9\%$), but this effect is overwhelmed by negative effects on the intensive margin of entry, and there are no offsetting positive effects on the extensive margin of entry in this case.
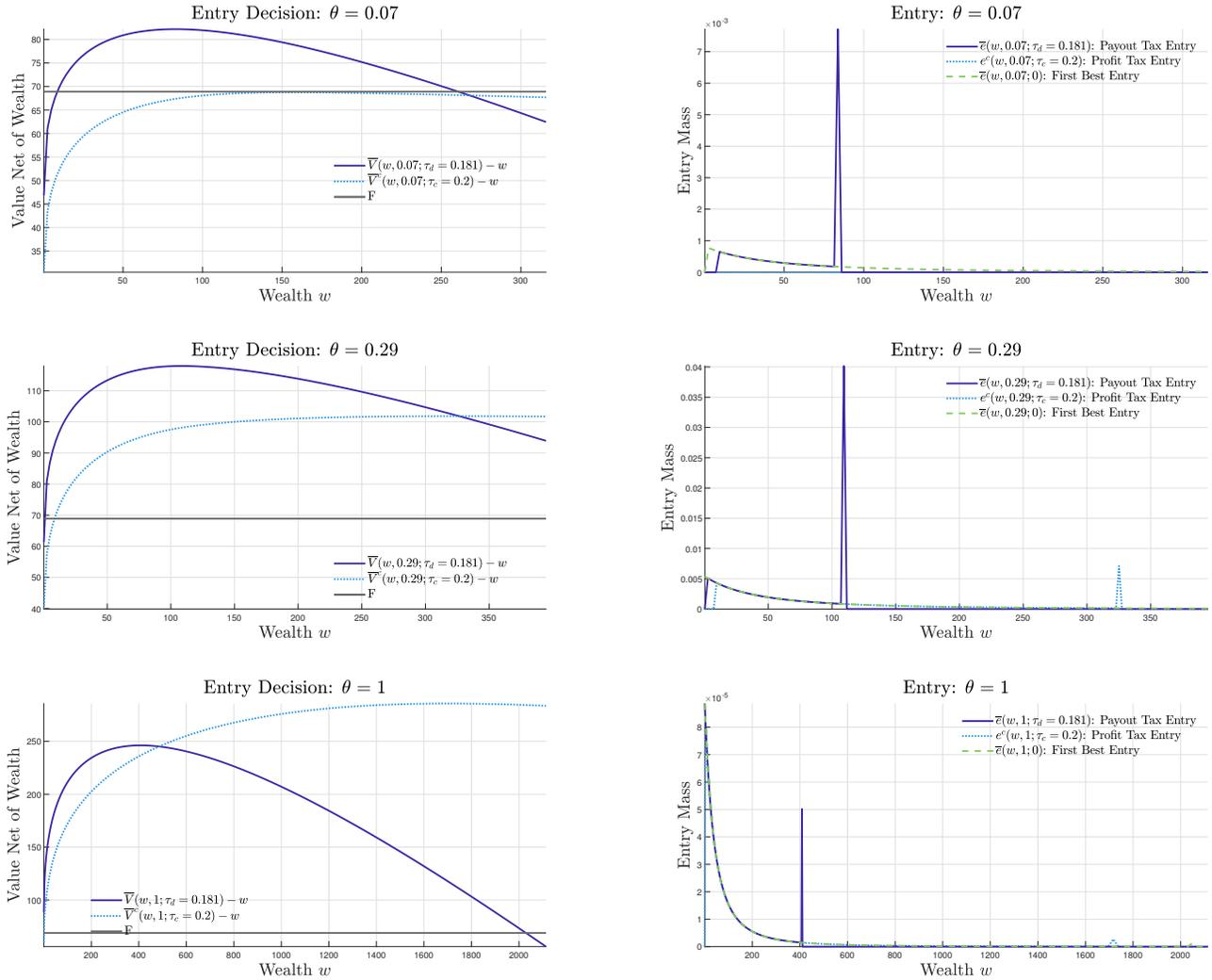
Note: Figure 4 illustrates the extensive and intensive margins of entry distortion under payout taxation and profit taxation from our quantitative analysis. Each row of the figure uses a different productivity level ($\theta = 0.07, \theta = 0.29, \theta = 1$). The left panel plots the private value functions under payout and profit taxation net of wealth, $\overline{V}(w, \theta; \tau_d = 0.181) - w$ and $\overline{V}^c(w, \theta; \tau_c = 0.2) - w$ (for details on $\overline{V}^c$, see Appendix Section B.1). The right panel plots the entering mass of firms under payout taxation, profit taxation, and in the absence of taxation (first-best). Note that each row uses a different scale on both axes.

Figure 4: Entry under Payout Taxation and Profit Taxation

These results reinforce our core conclusions: switching to payout taxation increases the value of existing firms and increases entry by new firms, but reduces the size of new entrants. Overall, a revenue-neutral switch to payout taxation would substantially increase the total value of all firms in our calibrated model.

Note, however, that such a switch would require the government to borrow. Tax revenues will fall after the switch to payout taxation, as firms accumulate wealth to reach first-best production levels. The government can borrow to maintain its target spending levels, and eventually as firms reach the optimal scale and make payouts, tax revenue will rise to cover both target spending and the interest payments on the government's extra debt.

6 Extensions

We next discuss how our results extend when relaxing two critical modeling assumptions. First, we describe how the functional form of the financial frictions that firms face affects our results. Second, we describe how to introduce equity issuance by existing firms.

6.1 Financial Frictions

As in Rampini and Viswanathan (2010), our model assumes that firms' financial contracts face limited enforcement and that there is no exclusion after default. While the option to re-enter after default is important, the exact formulation of limited enforcement, which determines the functional form of $w^D(\cdot)$ in Equation (15), is not, as we explain here.

Let us begin by incorporating an option for the defaulting firm to re-enter, rather than explicitly requiring re-entry, as in Definition 3. In particular, suppose that a defaulting firm can liquidate and consume a fraction $1 - \lambda$ of its wealth, instead of re-entering. This assumption, which makes liquidation less efficient than continuation, leads to an additional constraint

$$d_t + V_{t+1}(w_{t+1}, \theta_{t+1}; \mu_{t+1}, B_{t+1}) \geq (1 - \lambda) w^D(k_t, \theta_t). \tag{28}$$

This constraint will not bind under a constant payout tax provided that the tax rate $\frac{\tau_d}{1+\tau_d}$ is less than λ. Under a constant payout tax, the left-hand side of this expression is (weakly) maximized with $d_t = 0$: this is the logic of Lemma 1. In this case, the continuation wealth w_{t+1} will be weakly greater than the wealth given default for any levels of capital and debt that satisfy Equation (16). Moreover, for all firms under a constant payout tax, $\overline{V}(w_{t+1}, \theta_{t+1}; \tau_d) \geq \frac{1}{1+\tau_d} w_{t+1}$. Consequently, Proposition 2 will hold for equilibrium tax rates $\tau_d \in \left[0, \frac{\lambda}{1-\lambda}\right]$.

The conclusion is different when firms face the default-and-liquidate constraint of Equation (28), but cannot re-enter after default. In this case, which maps to Kehoe and Levine (1993), the constraint depends on the private information of the firm, θ_{t+1}. As a result, even in the absence of taxes, there is an asymmetric information problem between outside investors and the firm, and no simplification along the lines of Lemma 1 applies. Because of this asymmetric information problem, the government will find it optimal to use corrective taxes to improve allocations, even if it has no revenue-raising objective (Greenwald and Stiglitz, 1986). Consequently, the optimal policy in this case will have both corrective and revenue-raising objectives,

which will non-trivially depend on assumptions about the structure of the market between firms and creditors. We leave an exploration of this case to future work.

More generally, the key to our analysis is that the financial frictions that a firm faces can be written as a function of a firm's current productivity, but not its future productivity. This restriction applies to the limited enforcement assumption of Rampini and Viswanathan (2010), but also to many other forms of financial constraints, including those that restrict repayment in terms of firms' cash flows.[37] In the context of our model, assuming that $f(k_t, \theta_t)$ corresponds to a firm's date t EBITDA, we can require that

$$f(k_t, \theta_t) - \tau_t \geq \vartheta b_t, \tag{29}$$

that is, that either the EBITDA to repayment ratio (net of taxes) exceeds a constant $\vartheta > 1$ or that the repayment is zero.[38] To incorporate this cash flow lending friction, we allow the continuation wealth of a firm after default $w^D(\cdot)$ to depend on current productivity θ_t, capital k_t, and repayment b_t (the last of these does not enter into the Rampini and Viswanathan (2010) specification). Combining this constraint with Equation (14), we can rewrite Equation (29) as

$$\begin{aligned} w_{t+1} + d_t &\geq w^D(k_t, b_t, \theta_t), \\ w^D(k_t, b_t, \theta_t) &= (\vartheta - 1)b_t + (1 - \delta)k_t. \end{aligned} \tag{30}$$

We can further rewrite this equation as requiring

$$d_t + V_{t+1}(w_{t+1}, \theta_{t+1}; \mu_{t+1}, B_{t+1}) \geq d_t + V_{t+1}(w^D(k_t, b_t, \theta_t) - d_t, \theta_{t+1}; \mu_{t+1}, B_{t+1}),$$

and interpret the constraint in the style of Rampini and Viswanathan (2010) as arising from firm owners' ability to re-enter with wealth $w^D(k_t, b_t, \theta_t)$. This specification will also include a blocked-dividend no-default constraint, but our proof shows that this constraint will not bind. Our point here is not that the continuation wealth on default implied by this interpretation is sensible, only that this particular $w^D(\cdot)$ generates an earnings-based constraint of the type that appears common in practice. The proofs of Lemma 2 and Proposition 1, which are the key steps of our results, assume only that $\forall k, b, \theta$, $\frac{\partial}{\partial k}w^D(k, b, \theta) < f_k(k, \theta) + 1 - \delta$, which ensures that the initial budget constraint binds, and that $\frac{\partial}{\partial k}w^D(k, b, \theta) > \varepsilon$ for some $\varepsilon > 0$, which ensures that a maximum feasible capital level exists. To have a binding financial friction under some circumstances, it suffices to have $\frac{\partial}{\partial k}w^D(k, b, \theta) + R\frac{\partial}{\partial b}w^D(k, b, \theta) > 0$, so that debt-financed capital accumulation increases the temptation to default. The Rampini and Viswanathan (2010) specification in Equation (15), the "earnings-based" specification in Equation (30), and many other constraints share these properties, and our results apply to all of these cases.

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[37] A growing literature — see e.g., Lian and Ma (2021) — shows that earnings-based covenants are commonly used. We would like to thank Ludwig Straub for suggesting that we consider such constraints.

[38] Firms' covenants typically take the form of restrictions on the ratio of earnings (commonly EBITDA) to debt or to interest payments. Treating a constraint on the EBITDA/debt ratio as structural is problematic from the perspective of optimal taxation, since this constraint is meant to ensure that firms have enough earnings to service their obligations, including their taxes. For this reason, we use EBITDA net of taxes as the earnings measure in Equation (29).

6.2 Equity Issuance

So far, firms have only been able to issue equity at entry. In this subsection, we discuss how to accommodate equity issuance by existing firms in a manner similar to how we treat entry. Introducing equity issuance in this way does not change our main results, in particular Proposition 2.

In the infinite-horizon environment, entering firms decide whether to enter and if so how much wealth to enter with in the beginning of the period, before the government designs its mechanism. We now assume that, at the same time and before learning their next date productivity, existing firms can raise equity at a cost of $1 + \kappa$ per unit of wealth raised. For simplicity, we assume that this cost is borne by the existing firms' shareholders, as opposed to the firm itself.[39]

We denote the measure of existing firms before and after equity raising and entry by, respectively, μ_t^{pre} and μ_t^{post}. The law of motion of firms' wealth can be split into two equations:

$$d\mu_{t+1}^{\text{pre}}\left(w', \theta'\right) = de_t\left(w', \theta'; \mu_t^{\text{pre}}, B_t\right)$$
$$+ \int_{0^+}^{\infty} \int_0^1 \delta_{\text{dirac}}\left(w_{t+1}^*\left(\theta'; w, \theta\right) - w'\right) d\Pi\left(\theta'|\theta\right) d\mu_t^{\text{post}}\left(w, \theta\right),$$

$$d\mu_t^{\text{post}}\left(w', \theta\right) = \int_{0^+}^{\infty} \int_0^1 \delta_{\text{dirac}}\left(w' - w - x_t\left(w, \theta; \mu_t^{\text{pre}}, B_t\right)\right) d\mu_t^{\text{pre}}\left(w, \theta\right).$$

The first of these equations is the analog of Equation (19). Entering firms that decide to enter at date t appear as new firms at date $t+1$, which is why entry appears in the first equation and why the relevant expectations are based on μ_t^{pre}. The second equation describes the impact of equity issuance. Here, $x_t\left(w, \theta; \mu_t^{\text{pre}}, B_t\right)$ is the equity issuance decision of a firm with wealth w and type θ at the beginning of date t, before the firm knows θ_{t+1} and before the government designs its mechanism. The firm will choose $x_t\left(w, \theta; \mu_t^{\text{pre}}, B_t\right)$ to solve

$$x_t\left(w, \theta; \mu_t^{\text{pre}}, B_t\right) \in \arg\max_{x \geq 0} \mathbb{E}\left[V_t\left(w + x, \theta; \mu_t^{\text{post}}, B_t\right) \middle| \mu_t^{\text{pre}}, B_t\right] - (1 + \kappa)x. \tag{31}$$

Because each firm is small, it treats μ_t^{post} as exogenous when forming expectations. The measure μ_t^{post} takes the place of μ_t as the relevant state variable in the government's objective and budget constraint, introduced in Equations (20) and (18). Combining these equations, the evolution of μ_{t+1}^{post} depends on $\mathbb{E}\left[V_{t+1}\left(\cdot; \mu_{t+1}^{\text{post}}, B_{t+1}\right)\right]$, which in the equilibrium described in Proposition 2 is based on the presumption of a constant payout tax. As a result, the proof of Proposition 2 applies almost un-modified, except that the social value of a firm is no longer equal to $\overline{V}\left(w, \theta; 0\right)$, but instead to

$$\overline{V}\left(w + x\left(w, \theta; \tau_d\right), \theta; 0\right), \quad \text{where} \quad x\left(w, \theta; \tau_d\right) \in \arg\max_{x \geq 0} \overline{V}\left(w + x, \theta; \tau_d\right) - (1 + \kappa)x.$$

This social value continues to satisfy Conjecture 1 (it is concave and has a payout boundary), and therefore Proposition 1, which is the critical result, still applies.

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[39]The most straightforward interpretation of the cost κ is as a transaction cost, and note that our results hold even if $\kappa = 0$. Transaction costs do not introduce new inefficiencies that can be addressed by government policy. If instead the cost κ is associated with distortions, for instance due to adverse selection problems, our approach should be interpreted as either assuming optimal regulation in the background or abstracting from the corrective benefits of the tax policy.

Because the government designs its mechanism after the equity issuance/entry decisions are made at a given date, the government does not internalize the effects of its mechanism on equity issuance and entry decisions. If instead equity issuance decisions were made after the mechanism is designed, in effect allowing the government to have a single period of commitment, the government would want firms to raise more equity than they would choose on their own. This follows from Equation (31), which involves the private, not social, value of the firm. By threatening to force firms to their outside option if they do not raise sufficient equity, the government could induce firms to raise more equity. The remainder of the problem would remain the same, so the optimal policy in this case would be a constant payout tax plus an equity-raising mandate.

7   Implications for Policy

Before concluding, we discuss several conceptual and practical issues related to our results. First, at various times in the United States and other countries, the tax code has treated dividends and share repurchases differently. In this paper, firms' payouts include all payments to the agents controlling the firm, and hence include both dividends and share repurchases under our preferred interpretation. Under the optimal policy characterized in this paper, dividends and share repurchases are taxed at the same rate.[40]

Second, in the United States and most other countries, corporate taxes are assessed on firms' earnings, net of various deductions. Our results imply that this is a desirable way to structure corporate taxation as long as these deductions account for all retained earnings, since earnings less retained earnings is, by definition, equal to dividends plus share repurchases.[41] This conclusion is reminiscent of the "new view" of dividend taxation (Auerbach and Hines Jr, 2002), but is applied to a model with financial frictions. Perhaps more importantly, interpreting the payments to outside investors in the model as debt, our results justify exempting interest payments on debt. The key distinction between equity and debt financing, from the model's perspective, is control. A time-invariant tax on payments to the agents controlling the firm does not distort firms' intertemporal decisions, except when issuing equity; see Korinek and Stiglitz (2009) for more on this point. Our results show that any other tax would distort both intertemporal decisions and equity issuance decisions. Therefore, even though firms issue less equity when they face higher payout taxes, payout taxes are still optimal.

Third, the optimality of a payout tax is sensitive to how payout policies are determined. As discussed in Section 2, if there is managerial entrenchment (Zwiebel, 1996) or conflicts of interest between shareholders and managers and the latter control the firm, our results can be reinterpreted to justify a tax on managerial compensation. If managers and shareholders can optimally contract, and there is no scope for corrective policies by the government, then it does not matter which agent is taxed and our results continue to hold. If instead there is scope for corrective policies, but these corrective policies can be implemented using non-tax

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[40]The global rise in corporate saving (see, e.g., Chen, Karabarbounis and Neiman (2017)) makes this observation particularly relevant. For instance, Apple Inc., the world's largest company by market capitalization in 2015, has experienced a large increase in profits, but not dividends, over the last few decades. At the same time — prior to the reforms of the Tax Cuts and Jobs Act of 2017 — it has accumulated large holdings of cash and repurchased its equity. The optimal payout tax that we characterize implies that these equity repurchases should be taxed.

[41]One could argue that the current tax system, modified to have full expensing of investment, is not too far from this policy. In fact, Barro and Furman (2018) estimate that a switch to full expensing would increase output per worker by 8.1%, which is comparable to our estimate that a switch to payout taxation would increase the total value of firms in our model by 7%. However, as discussed previously, there are situations in which a profit tax with full expensing of investment exacerbates financial frictions.

instruments, our results should also still apply.[42] Similar points apply to issues related to signaling or catering through dividend policy, which may also be important for how payouts are determined.

Finally, we should highlight that France in 2012 implemented a 3% corporate dividend tax that resembles the optimal tax we have characterized, in addition to more traditional corporate taxes.[43] A recent analysis of a different set of dividend tax changes in France (Boissel and Matray, 2021) finds, consistent with our model, that possibly temporary dividend tax changes induced significant "intertemporal arbitrage" with respect to the timing of dividend payments. Likewise, consistent with our model, (Yagan, 2015) finds that changes in the rate of personal dividend taxation in the United States has relatively large effects on payout policy but small effects on real investment.

8   Conclusion

This paper provides a normative analysis of the design of corporate taxes when firms are financially constrained. We show that a government whose goal is to efficiently raise a given amount of revenue from its corporate sector finds it optimal to tax unconstrained firms, which value resources inside the firm less than financially constrained firms. When firms have private information about their future productivity, the government must use a mechanism to elicit which firms are financially constrained in an incentive-compatible way. We show that a corporate payout tax (a tax on dividends and share repurchases) can both separate constrained and unconstrained firms and raise revenue, and is therefore optimal. Our quantitative analysis implies that a revenue-neutral switch from profit taxation to payout taxation could increase the total value of current and future firms by 7%. This switch could be implemented in the current U.S. tax system by making retained earnings fully deductible.

Even though there are well-developed literatures that explore the optimal determination of personal taxation, including income, capital, and commodity taxation, to our knowledge, this paper is the first to address the question of how corporate taxes should be structured in an environment in which firms have private information about future investment opportunities, face financial constraints, and in which any feasible non-negative tax instrument can be employed. Future work taking into account manager-shareholder conflicts, security design, interactions between personal and corporate taxation, and general equilibrium considerations should lead to a deeper understanding of optimal corporate taxation.

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[42]Regardless of who controls the firm, it might also be possible for the agent controlling the firm to extract value from the firm through in-kind benefits, such as markups for goods or services provided, or disguised as payments to unrelated parties. If these payments destroy value relative to dividend payments (along the lines of, e.g., DeMarzo and Urošević (2006)), then the possibility of such payments will limit the payout tax rate the government can implement but otherwise leave our results unchanged.

[43]Court rulings eventually declared the tax to be unconstitutional, due to double taxation issues. It was repealed in 2017.

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APPENDIX

The Appendix contains all proofs referenced in the paper, additional information about our quantitative analysis, including an explicit formulation of the firms' problem under a profit tax, and discussion of expensing of investment within the stylized model.

A   Proofs

A.1   Proof of Lemma 1 (Default invariance)

Here we prove that a firm will not default for given b_t, k_t, θ_t, θ_{t+1}, and a payout tax of rate $\tau_d \geq 0$ if and only if

$$f(k_t, \theta_t) + (1-\delta) k_t - b_t \geq w^D(k_t, \theta_t).$$

The wealth accumulation constraint (which will bind) states that continuation wealth as a function of the dividend d is

$$w_{t+1}(d) = f(k_t, \theta_t) + (1-\delta) k_t - (1+\tau_d) d - b_t.$$

The firm will not default if and only if there is a dividend d_t^* such that the payoff of declaring that dividend exceeds both the payoff of defaulting post-dividend and the payoff of paying a zero/blocked dividend and then defaulting,

$$d_t^* + \overline{V}(w_{t+1}(d_t^*), \theta_{t+1}; \tau_d) \geq d_t^* + \overline{V}(w^D(k_t, \theta_t) - d_t^*, \theta_{t+1}; \tau_d),$$
$$d_t^* + \overline{V}(w_{t+1}(d_t^*), \theta_{t+1}; \tau_d) \geq \overline{V}(w^D(k_t, \theta_t), \theta_{t+1}).$$

Note that the first of these constraints holds (by the fact that $\overline{V}$ is strictly increasing) if and only if

$$w_{t+1}(d_t^*) + d_t^* \geq w^D(k_t, \theta_t),$$

and that

$$\frac{\partial}{\partial d}(w_{t+1}(d) + d) \leq 0.$$

Moreover, under our conjecture,

$$\frac{\partial}{\partial d}\left[d + \overline{V}(f(k_t, \theta_t) + (1-\delta) k_t - (1+\tau_d) d - b_t, \theta_{t+1}; \tau_d)\right] \leq 0,$$

and consequently both constraints can hold for some $d_t^* \geq 0$ if and only if they hold with $d_t^* = 0$, which yields

$$f(k_t, \theta_t) + (1-\delta) k_t - b_t \geq w^D(k_t, \theta_t).$$

A.2 Proof of Lemma 2 (Conjecture verified)

The Bellman equation defining the firms' problem is

$$\overline{V}(w_t, \theta_t; \tau_d) = \max_{\substack{b_t(\theta_{t+1}) \geq 0, k_t(\theta_{t+1}) \geq 0, \\ w_{t+1}(\theta_{t+1}) \geq 0, d_t(\theta_{t+1}) \geq 0}} R^{-1} \int_0^1 \left\{ d_t(\theta_{t+1}) + \overline{V}(w_{t+1}(\theta_{t+1}), \theta_{t+1}; \tau_d) \right\} d\Pi(\theta_{t+1}|\theta_t),$$

subject to

$$w_{t+1}(\theta_{t+1}) \leq f(k_t(\theta_{t+1}), \theta_t) + (1-\delta)k_t(\theta_{t+1}) - (1+\tau)d_t(\theta_{t+1}) - b_t(\theta_{t+1}),$$
$$k_t(\theta_{t+1}) \leq w_t + R^{-1}b_t(\theta_{t+1}),$$
$$w_{t+1}(\theta_{t+1}) + d_t(\theta_{t+1}) \geq w^D(k_t(\theta_{t+1}), \theta_t),$$
$$d_t(\theta_{t+1}) \leq w^D(k_t(\theta_{t+1}), \theta_t).$$

It is immediately apparent that $\overline{V}(w_t, \theta_t; \tau_d)$ is increasing in w_t, and hence that the initial budget constraint and production constraints bind. We can therefore rewrite the problem as

$$\overline{V}(w_t, \theta_t; \tau_d) = \max_{k_t(\theta_{t+1}) \geq 0, d_t(\theta_{t+1}) \geq 0}$$
$$R^{-1} \int_0^1 \left\{ d_t(\theta_{t+1}) + \overline{V}(y(k_t(\theta_{t+1}), \theta_t) + Rw_t - (1+\tau)d_t(\theta_{t+1}), \theta_{t+1}; \tau_d) \right\} d\Pi(\theta_{t+1}|\theta_t),$$

where

$$y(k, \theta_t) = f(k, \theta_t) + (1-\delta)k - Rk,$$

subject to

$$k_t(\theta_{t+1}) \geq w_t,$$
$$y(k_t(\theta_{t+1}), \theta_t) + Rw_t - \tau d_t(\theta_{t+1}) \geq w^D(k_t(\theta_{t+1}), \theta_t),$$
$$d_t(\theta_{t+1}) \leq w^D(k_t(\theta_{t+1}), \theta_t),$$
$$(1+\tau)d_t(\theta_{t+1}) \leq \pi(k_t(\theta_{t+1}), \theta_t) + Rw_t.$$

Note that the feasible set of policies is always non-empty — since $k_t(\theta_{t+1}) = w_t$ and $d_t(\theta_{t+1}) = 0$ is always feasible — and that the flow payoff is bounded from below by zero.

The firms' value function is also bounded from above via the intertemporal budget constraint and first-best production,

$$\overline{V}(w_t, \theta_t; \tau_d) = \mathbb{E}_t \left[\sum_{j=0}^{\infty} R^{-j} d_{t+j}^* \right] \leq \frac{1}{1+\tau_d} \left(w_t + \sum_{j=0}^{\infty} R^{-j} \mathbb{E}_t \left[y(k^*(\theta_{t+j}), \theta_{t+j}) \right] \right).$$

Define the maximum possible profit

$$\bar{y} = \max_{\theta \in [0,1]} y(k^*(\theta), \theta),$$

and observe that

$$\overline{V}(w_t, \theta_t; \tau_d) \leq \frac{1}{1 + \tau_d} \left(w_t + \sum_{j=0}^{\infty} R^{-j} \bar{y} \right).$$

We will guess and verify that a solution to the firms' problem exists and satisfies Conjecture 1. Let $\mathcal{V}$ be the set of functions on $w \in [0, \infty)$ and $\theta \in [0, 1]$ with range $\left[0, \frac{\bar{y}}{1+\tau_d} \frac{R}{R-1} \right]$. Define the Bellman operator $T : \mathcal{V} \to \mathcal{V}$ by

$$
T(V; \tau_d)(w_t, \theta_t) = \max_{k_t(\theta_{t+1}) \geq 0, d_t(\theta_{t+1}) \geq 0} R^{-1} \int_0^1 \left\{ \frac{1}{1+\tau_d} y(k_t(\theta_{t+1}), \theta_t) \right\} d\Pi(\theta_{t+1}|\theta_t)
$$
$$
+ R^{-1} \int_0^1 V(y(k_t(\theta_{t+1}), \theta_t) + Rw_t - (1+\tau_d)d_t(\theta_{t+1}), \theta_{t+1}) d\Pi(\theta_{t+1}|\theta_t),
$$

subject to the constraints above. This Bellman operator corresponds to the Bellman equation of the firms' problem with V redefined as the firm value function less $\frac{1}{1+\tau_d} w_t$. Note that, by $0 \leq y(k, \theta) \leq \bar{y}$, this operator indeed maps $\mathcal{V}$ to $\mathcal{V}$, preserving the bounds on the range of the functions.

It is immediate that this Bellman operator satisfies Blackwell's sufficient conditions, and hence that the contraction mapping theorem holds and thus a unique fixed point exists. Let V^* denote this fixed point. By the boundedness of V^* (which ensures that the transversality condition is satisfied), the non-emptiness of the set of feasible policies, and the fact that the flow payoff is bounded from below, Stokey, Lucas and Prescott (1989) Theorem 9.2 applies, and consequently

$$\overline{V}(w_t, \theta_t; \tau_d) = V^*(w_t, \theta_t) + \frac{1}{1+\tau_d} w_t$$

is the solution to the firms' problem.

Let us now take an arbitrary function $\hat{V}$ satisfying the properties of Conjecture 1, and define

$$V(w, \theta) = \hat{V}(w, \theta) - \frac{1}{1+\tau_d} w_t.$$

Consider $\tilde{V} = T(V; \tau_d)$, and conjecture that the only potentially binding constraint is the no-default constraint.

Observe immediately by the envelope theorem that the directional derivative exists and satisfies

$$\tilde{V}_{w^+}(w_t, \theta_t) \geq 0.$$

Note also that we must have either $k_t(\theta_{t+1}) \geq k^*(\theta_t)$ or $k_t(\theta_{t+1}) < k^*(\theta_t)$ and $d_t(\theta_{t+1}) = 0$, and that the former is always preferable to the latter if feasible (as this maximizes $y(k_t, \theta_t)$). In the latter case,

$$
\tilde{V}(w_t, \theta_t) = \frac{1}{1+\tau_d} y(k_{\max}(w_t, \theta_t), \theta_t) + R^{-1} \int_0^1 \{ V(y(k_{\max}(w_t, \theta_t), \theta_t) + Rw_t, \theta_{t+1}) \} d\Pi(\theta_{t+1}|\theta_t)
$$

where $k_{\max}(w_t, \theta_t)$ is defined implicitly as the largest capital level such that

$$y(k_{\max}(w_t, \theta_t), \theta_t) + Rw_t = w^D(k_{\max}(w_t, \theta_t), \theta_t).$$

For our specific functional form, an explicit expression is

$$k_{\max}(w_t, \theta_t) = \frac{w_t}{1 - R^{-1}\varphi(1-\delta)},$$

but nothing in this proof will use this explicit functional form (we assume only the existence of a $k_{\max}(w_t, \theta_t)$ and that $0 < \frac{\partial w^D}{\partial k}$).

It follows immediately by the concavity of V and of the production function that $\tilde{V}$ is concave in wealth on the domain $k_{\max}(w_t, \theta_t) < k^*(\theta_t)$, and its directional derivative satisfies

$$\tilde{V}_{w^+}(w_t, \theta_t) > 0.$$

Let us now consider the possibility that $k_{\max}(w_t, \theta_t) \geq k^*(\theta_t)$. In this case, it is without loss of generality to suppose that

$$k_t(\theta_{t+1}) = \max\{k^*(\theta_t), w_t\}$$

and therefore does not depend on θ_{t+1}. Note that $y(k, \theta_t) = y(k^*(\theta_t), \theta_t)$ for all $k \geq k^*(\theta_t)$. It is always weakly optimal to suppose that $d_t(\theta_{t+1}) = 0$, and therefore

$$\tilde{V}(w_t, \theta_t) = \frac{1}{1+\tau_d}y(k^*(\theta_t), \theta_t) + R^{-1}\int_0^1 \{V(y(k^*(\theta_t), \theta_t) + Rw_t, \theta_{t+1})\}\,d\Pi(\theta_{t+1}|\theta_t)$$

It follows immediately that $\tilde{V}(w_t, \theta_t)$ is concave on this domain, and $\tilde{V}_{w^+}(w_t, \theta_t) = 0$ if and only if

$$y(k^*(\theta_t), \theta_t) + Rw_t \geq \max_{\theta \in supp(\Pi(\cdot|\theta_t))} \overline{w}(\theta),$$

where $\overline{w}(\theta)$ is defined as in Conjecture 1 for $\hat{V}$. Consequently, we can define

$$w^+(\theta_t) = \max\left\{\left(1 - R^{-1}\varphi(1-\delta)\right)k^*(\theta_t), R^{-1}\left(-y(k^*(\theta_t), \theta_t) + \max_{\theta \in supp(\Pi(\cdot|\theta_t))} \overline{w}(\theta)\right)\right\},$$

and note that the function $V^+(w_t, \theta_t)$ defined by

$$V^+(w_t, \theta_t) = \tilde{V}(w_t, \theta_t) + \frac{1}{1+\tau_d}w_t$$

satisfies Conjecture 1 for the payout threshold w^+. We also observe that proposed policies in this relaxed problem (zero dividends, $k_{t+1}(\theta_{t+1})$ described above) are feasible in the original problem, and hence optimal.

We conclude that if V satisfies the properties of Conjecture 1, $T\left(V - \frac{w}{1+\tau_d}\right) + \frac{w}{1+\tau_d}$ will share these properties. By the contraction mapping theorem, $\overline{V}(w_t, \theta_t; \tau_d) = V^*(w_t, \theta_t) + \frac{1}{1+\tau_d}w_t$ must also share these properties (see e.g., Rockafellar (1970) Theorem 24.5 regarding the convergence of the directional derivative).

A.3 Proof of Proposition 1 (Implementation of optimal mechanism by a constant payout tax)

Let us first rewrite the conjectured government value function as

$$J_{t+1}(\mu_{t+1}, B_{t+1}) = \bar{J} - B_{t+1} + \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0) \, d\mu_{t+1}(w, \theta)$$

for some constant $\bar{J}$. Now let us plug this into the government's problem, Equation (20):

$$J_t(\mu_t, B_t) = \max_{G_t, \{m_t(w,\theta) \in \mathcal{M}(w,\theta,V_{t+1})\}_{w \in \mathbb{R}_+, \theta \in [0,1]}} u(G_t) + R^{-1} \int_{0^+}^{\infty} \int_0^1 \int_0^1 d_t^*(\theta'; w, \theta) \, d\Pi(\theta'|\theta) \, d\mu_t(w, \theta)$$

$$+ R^{-1} \bar{J} - R^{-1} B_{t+1} + R^{-1} \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; 0) \, d\mu_{t+1}(w, \theta),$$

and then plug in the flow budget constraint, Equation (18), and the evolution of the firm distribution, Equation (19),

$$J_t(\mu_t, B_t) = \max_{G_t, \{m_t(w,\theta) \in \mathcal{M}(w,\theta,V_{t+1})\}_{w \in \mathbb{R}_+, \theta \in [0,1]}} u(G_t) - G_t - B_t + R^{-1} \bar{J}$$

$$+ R^{-1} \int_{0^+}^{\infty} \int_0^1 \int_0^1 \left(d_t^*(\theta'; w, \theta) + \tau_t^*(\theta'; w, \theta) \right) d\Pi(\theta'|\theta) \, d\mu_t(w, \theta)$$

$$+ R^{-1} \int_{0^+}^{\infty} \int_0^1 \int_0^1 \overline{V}(w_{t+1}^*(\theta'; w, \theta), \theta'; 0) \, d\Pi(\theta'|\theta) \, d\mu_t(w, \theta)$$

$$+ R^{-1} \int_{0^+}^{\infty} \int_0^1 \overline{V}(w', \theta'; 0) \, de_t(w', \theta'; \mu_t, B_t).$$

The last line in this expression is unaffected by the current government's choice variables, and the optimality of $G_t = \overline{G}$ is immediate. Consequently, it is sufficient to prove that the mechanism $m^*(w, \theta)$ that is equivalent to a payout tax at rate τ_d maximizes

$$m^*(w, \theta) \in \arg\max_{m_t(w,\theta) \in \mathcal{M}(w,\theta,V_{t+1})} \int_0^1 \left(d_t^*(\theta'; w, \theta) + \tau_t^*(\theta'; w, \theta) \right) d\Pi(\theta'|\theta)$$

$$+ \int_0^1 \overline{V}(w_{t+1}^*(\theta'; w, \theta), \theta'; 0) \, d\Pi(\theta'|\theta)$$

for each $(w, \theta) \in supp(\mu_t)$.

We prove this result by considering a larger set of mechanisms, $\mathcal{M}^+(w_t, \theta_t) \supset \mathcal{M}(w, \theta, V_{t+1})$. Importantly, the definition of this set does not depend on V_{t+1}. We will then show that the optimal mechanism within this larger set can be implemented by a payout tax and is contained in $\mathcal{M}(w, \theta, V_{t+1})$ under the assumption that $V_{t+1}(w, \theta; \mu_{t+1}^*, B_{t+1}^*) = \overline{V}(w, \theta; \tau_d)$.

We begin by defining the set of allocations $\mathcal{M}^+(w_t, \theta_t)$.

Definition 7. *(Relaxed-feasible direct revelation mechanism)* Given an observable initial wealth w_t and an initial type θ_t, a relaxed-feasible direct revelation mechanism m is a collection of weakly positive functions

$\{b_t(\theta'), k_t(\theta'), w_{t+1}(\theta', \theta''), d_t(\theta', \theta''), \tau_t(\theta', \theta'')\}$ such that the following constraints are satisfied:

Upper Limit on Dividends:
$$d_t(\theta', \theta'') \leq w^D(k_t(\theta'), \theta_t), \forall \theta', \theta'',$$

Initial Budget Constraint (with free disposal):
$$k_t(\theta') \leq w_t + R^{-1}b_t(\theta'), \forall \theta',$$

Production Function (with free disposal):
$$w_{t+1}(\theta', \theta'') \leq f(k_t(\theta'), \theta_t) + (1-\delta)k_t(\theta')$$
$$- d_t(\theta', \theta'') - b_t(\theta') - \tau_t(\theta', \theta''), \forall \theta', \theta'',$$

Simplified No-Default:
$$w^D(k_t(\theta'), \theta_t) - d_t(\theta', \theta'') \leq w_{t+1}(\theta', \theta''), \forall \theta', \theta'',$$

Let $\mathcal{M}^+(w_t, \theta_t)$ be the set of all such mechanisms.

By feasibility (Definition 2) and the post-dividend no-default condition (Definition 3), $\mathcal{M}(w_t, \theta_t, V_{t+1}) \subseteq \mathcal{M}^+(w_t, \theta_t)$ for all value functions V_{t+1} that are strictly increasing in wealth (and hence in particular for $\overline{V}(\cdot; \tau_d)$).

Let us now consider the mechanism design problem

$$m^* \in \arg\max_{m \in \mathcal{M}^+(w_t, \theta_t)} \int_0^1 \left\{ d_t(\theta, \theta) + \tau_t(\theta, \theta) + \overline{V}(w_{t+1}(\theta, \theta), \theta; 0) \right\} d\Pi(\theta|\theta_t).$$

Observe that there are no interactions across firms of different types, because $\mathcal{M}^+$ has no IC constraints. We can therefore solve this problem firm-by-firm.

We begin by observing that the production function constraint must bind with equality because $\overline{V}(w_{t+1}(\theta, \theta), \theta; 0)$ is strictly increasing in wealth. By similar logic, because

$$0 < \frac{\partial}{\partial k} w^D(k, \theta_t) \leq f_k(k, \theta_t) + (1-\delta),$$

increasing capital holding debt fixed increases the objective and relaxes all constraints. Therefore, the initial budget constraint must bind. Note by the non-negativity of debt that this implies $k_t(\theta) \geq w$.

Because these constraints bind, we can rewrite the no-default constraint under truth-telling as

$$w^D(k_t(\theta), \theta_t) \leq f(k_t(\theta), \theta_t) + (1-\delta-R)k_t(\theta) + Rw_t - \tau_t(\theta, \theta),$$

and the objective for this firm as

$$d_t(\theta, \theta) + \tau_t(\theta, \theta) + \overline{V}(f(k_t(\theta), \theta_t) + (1-\delta-R)k_t(\theta) + Rw_t - \tau_t(\theta, \theta) - d_t(\theta, \theta), \theta; 0).$$

It follows immediately that $d_t(\theta, \theta) > 0$ only if $\overline{V}_{w^-}(\cdot; 0) = 1$, where $\overline{V}_{w^-}(\cdot; 0)$ is the directional derivative of $\overline{V}(\cdot; 0)$ with respect to reducing wealth, which exists by concavity (Lemma 2). This requires, by Lemma 2,

$$f(k_t(\theta), \theta_t) + (1-\delta-R)k_t(\theta) + Rw_t > \overline{w}(\theta).$$

The same logic applies to $\tau_t(\theta, \theta) > 0$, as reducing taxes might also relax the no-default constraint. Moreover, if the no-default constraint binds, we must have $\tau_t(\theta, \theta) = 0$ regardless of whether the above condition is satisfied. Therefore, if $f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + w_t \leq \overline{w}(\theta)$, we must have $d_t(\theta, \theta) = \tau_t(\theta, \theta) = 0$. If $f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + w_t > \overline{w}(\theta)$, any choice of taxes and dividends are optimal provided that

$$f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + Rw_t - \tau_t(\theta, \theta) - d_t(\theta, \theta) \geq \overline{w}(\theta).$$

We are therefore free to suppose that $\tau_t(\theta, \theta) = \tau_d d_t(\theta, \theta)$. Under this assumption, the no-default constraint requires

$$\tau_d d_t(\theta, \theta) \leq f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + Rw_t - w^D(k_t(\theta), \theta_t).$$

Capital will be chosen to maximize $f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta)$ if this is feasible, which is to say achieving at least $k_t(\theta) \geq k^*(\theta_t)$, and otherwise the no-default constraint will bind and capital will be maximal.

Define $k_{\max}(w_t, \theta_t)$ implicitly by

$$f(k_{\max}(w_t, \theta_t), \theta_t) + (1 - \delta - R) k_{\max}(w_t, \theta_t) + Rw_t = w^D(k_{\max}(w_t, \theta_t), \theta_t).$$

Observe under the functional form of Equation (15) that this value exists and is strictly greater than w_t, and that for all $k < k_{\max}(w_t, \theta_t)$,

$$f(k, \theta_t) + (1 - \delta - R) k + Rw_t \geq w^D(k, \theta_t).$$

It remains to select a level of $d_t(\theta, \theta)$ so that the no-default and dividend limits are satisfied, and $d_t(\theta, \theta) = 0$ if this is strictly optimal. The following allocation $m^* \in \mathcal{M}^+(w_t, \theta_t)$ chooses the maximum possible dividend satisfying these constraints, and ignores the report on the first date by assigning all types the same level of capital:

$$k_t(\theta) = \max\{w_t, \min\{k^*(\theta_t), k_{\max}(w_t, \theta_t)\}\},$$

$$d_t(\theta, \theta') = \max\left\{0, \min\left\{\frac{1}{1 + \tau_d}\left(f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + Rw_t - \overline{w}(\theta')\right),\right.\right.$$

$$\left.\left. w^D(k_t(\theta), \theta_t), \frac{1}{\tau_d}\left(f(k_t(\theta), \theta_t) + (1 - \delta - R) k_t(\theta) + Rw_t - w^D(k_t(\theta), \theta_t)\right)\right\}\right\},$$

$$\tau_t(\theta, \theta') = \tau_d d_t(\theta, \theta'),$$

$$b_t(\theta) = R(k_t(\theta) - w_t),$$

$$w_{t+1}(\theta, \theta') = f(k_t(\theta), \theta_t) + (1 - \delta) k_t(\theta) - d_t(\theta, \theta') - b_t(\theta) - \tau_t(\theta, \theta').$$

If $\tau_d = 0$, we will treat τ_d^{-1} as infinite and ignore the term with τ_d^{-1} in the min function that defines dividends.

Let us next consider the firm problem with the payout tax τ_d (Definition 6), and observe that the constraints are identical to the constraints of the relaxed mechanism design problem. Because V_{t+1} is strictly increasing in wealth, our arguments that the initial budget constraint and production function bind continue to hold.

Consequently, the firms' objective is

$$d_t + V_{t+1}(f(k_t, \theta_t) + (1 - \delta - R) k_t + Rw_t - (1 + \tau_d) d_t, \theta),$$

subject to the constraints

$$k_t \geq w_t,$$
$$0 \leq d_t \leq w^D\left(k_t\left(\theta\right),\theta_t\right),$$

and

$$\tau_d d_t \leq f\left(k_t,\theta_t\right) + \left(1 - \delta - R\right)k_t + Rw_t - w^D\left(k_t,\theta_t\right).$$

It follows immediately that $d_t > 0$ implies

$$f\left(k_t,\theta_t\right) + \left(1 - \delta - R\right)k_t + Rw_t > \overline{w}\left(\theta\right),$$

and that the firm is indifferent to all dividend levels provided this condition holds. If this condition is violated, the firm will set $d_t = 0$.

These are the exact same conditions as the ones in the government's mechanism design problem, and therefore the allocation that solves the mechanism design problem described above is also a solution to the firms' problem.

To complete the proof, we must show that these allocations are contained in $\mathcal{M}\left(w_t,\theta_t,V_{t+1}\right)$ under the assumption that $V_{t+1} = \overline{V}\left(\cdot;\tau_d\right)$. Let us observe first that in the proposed allocation, $k_t \geq w_t$, and therefore the interim participation constraint of Definition 3 will be satisfied provided that the blocked-dividend no-default constraint is satisfied. The financing/investment IC constraint of Definition 4 is automatically satisfied, as there is only a single capital/debt level shared by all firms with the observable type $\left(w_t,\theta_t\right)$. By the fact that V_{t+1} is strictly increasing in wealth and that the simplified no-default constraint of Definition 7 holds, the post-dividend no-default constraint of Definition 3 is satisfied. Feasibility (Definition 2) holds by construction. It therefore remains to show that the dividend/payout/taxes IC constraint of Definition 4 and the blocked-dividend no-default constraint of Definition 3 are satisfied.

Consider the blocked-dividend no-default constraint of Definition 3, under the assumption that the dividend/payout/taxes IC constraint of Definition 4 holds. Note that the initial report is irrelevant under the proposed mechanism, and that due to the assumed IC constraint holding it is sufficient to consider the blocked-dividend no-default constraint under truth-telling.

Note that $k_t\left(\theta\right) \leq k_{\max}\left(w_t,\theta_t\right)$, either because $k_t\left(\theta\right) = \min\{k^*\left(\theta_t\right), k_{\max}\left(w_t,\theta_t\right)\}$ or because $k_t\left(\theta\right) = w_t < k_{\max}\left(w_t,\theta_t\right)$. If $d_t\left(\theta,\theta\right) = 0$,

$$f\left(k_t\left(\theta\right),\theta_t\right) + \left(1 - \delta - R\right)k_t\left(\theta\right) + Rw_t \geq w^D\left(k_t\left(\theta\right),\theta_t\right),$$

implying that the blocked-dividend no-default constraint is satisfied. But $d_t\left(\theta,\theta\right) > 0$ only if $w_{t+1}\left(\theta,\theta\right) \geq \overline{w}\left(\theta\right)$, and in that case

$$
\begin{aligned}
d_t\left(\theta,\theta\right) + V_{t+1}\left(w_{t+1}\left(\theta,\theta\right),\theta\right) &= V_{t+1}\left(w_{t+1}\left(\theta,\theta\right) + \left(1 + \tau_d\right)d_t\left(\theta,\theta\right),\theta\right) \\
&= V_{t+1}\left(f\left(k_t\left(\theta\right),\theta_t\right) + \left(1 - \delta - R\right)k_t\left(\theta\right) + w_t,\theta\right) \\
&\geq V_{t+1}\left(w^D\left(k_t\left(\theta\right),\theta_t\right),\theta\right),
\end{aligned}
$$

and therefore the constraint is satisfied.

To conclude, we show that the dividend/investment IC constraint of Definition 4 is satisfied. Observe that in the proposed allocation,

$$w_{t+1}\left(\theta,\theta'\right) = f\left(k_t\left(\theta\right),\theta_t\right) + (1-\delta-R)k_t\left(\theta\right) + Rw_t - (1+\tau_d)d_t\left(\theta,\theta'\right).$$

Let us suppose first that type θ' has a lower dividend, $d_t\left(\theta,\theta'\right) < d_t\left(\theta,\theta\right)$. This implies $d_t\left(\theta,\theta\right) > 0$, implying $w_{t+1}(\theta,\theta') > w_{t+1}\left(\theta,\theta\right) \geq \overline{w}(\theta)$, and therefore

$$d_t\left(\theta,\theta\right) + V_{t+1}(w_{t+1}\left(\theta,\theta\right),\theta) = d_t\left(\theta,\theta'\right) + V_{t+1}(w_{t+1}(\theta,\theta'),\theta),$$

and hence the dividend/investment IC constraint is satisfied in this case (noting that the initial report does not affect allocations).

Now suppose that type θ' has a higher dividend, $d_t\left(\theta,\theta'\right) > d_t\left(\theta,\theta\right)$. In this case, $w_{t+1}(\theta,\theta') < w_{t+1}\left(\theta,\theta\right)$. By the fact that $V_{t+1,w^-}(\cdot) \geq \frac{1}{1+\tau_d}$ (the directional derivative again exists by concavity),

$$V_{t+1}(w_{t+1}\left(\theta,\theta\right),\theta) - \frac{1}{1+\tau_d}(w_{t+1}\left(\theta,\theta\right) - w_{t+1}(\theta,\theta')) \geq V_{t+1}(w_{t+1}\left(\theta,\theta\right),\theta),$$

which immediately implies

$$V_{t+1}(w_{t+1}\left(\theta,\theta\right),\theta) + (d_t\left(\theta,\theta\right) - d_t(\theta,\theta')) \geq V_{t+1}(w_{t+1}\left(\theta,\theta\right),\theta),$$

and therefore the dividend/investment IC constraint is satisfied in this case as well.

We conclude that the proposed mechanism m^* is contained in $\mathcal{M}(w_t,\theta_t,V_{t+1})$ and is implemented by a payout tax at rate τ_d.

A.4   Proof of Proposition 2 (Equilibrium with constant payout tax)

We begin by observing that it is without loss of generality to suppose that, for all $\tau_d \in [0,\overline{\tau}_d]$, for some $\overline{\tau}_d$,

$$N(\mu_0,B_0,\overline{\tau}_d) \geq N(\mu_0,B_0,\tau_d).$$

That is, if $N(\mu_0,B_0,\tau_d) > N(\mu_0,B_0,\overline{\tau}_d) \geq 0$ for some $\tau_d \in [0,\overline{\tau}_d]$, we can redefine $\overline{\tau}_d$ to be equal to this value.

By the positivity of the value function $\overline{V}$ (which follows from the non-negativity of dividends), for all $\tau_d \in [0,\overline{\tau}_d]$,

$$N(\mu_0,B_0,\tau_d) \geq N(\mu_0,B_0,0).$$

If $N(\mu_0,B_0,0) \geq 0$, define $\tau_d = 0$. Otherwise, by our assumption that $N(\mu_0,B_0,\tau_d)$ is continuous and the intermediate value theorem, we can define $\tau_d \in [0,\overline{\tau}_d]$ as a root,

$$N(\mu_0,B_0,\tau_d) = 0.$$

Observe that $N(\mu_0,B_0,0) \geq 0$ requires

$$B_0 + \frac{\overline{G}}{1-R^{-1}} \leq 0,$$

which is to say that the government has no net financing need. If this quantity is strictly negative, the government will set $G_0 > \overline{G}$ and $\tau_d = 0$ (we prove this below). If this quantity is strictly positive, then $\tau_d > 0$.

We conjecture and verify that, on the domain of (μ, B) such that $N(\mu, B, \tau_d) \geq 0$, $V(w, \theta; \mu, B) = \overline{V}(w, \theta; \tau_d)$ and

$$
J(\mu, B) = u\left(N(\mu, B, \tau_d) + \overline{G}\right) + \int_{0^+}^{\infty} \int_0^1 \overline{V}(w, \theta; \tau_d) \, d\mu(w, \theta) + \frac{1}{R-1} \int_0^{\infty} \int_0^1 \overline{V}(w, \theta; \tau_d) \, d\overline{e}(w, \theta; \tau_d),
$$

and most importantly that if $N(\mu_t, B_t, \tau_d) \geq 0$, then $N(\mu_{t+1}, B_{t+1}, \tau_d) \geq 0$. Since τ_d is defined so that $N(\mu_0, B_0, \tau_d) \geq 0$, by induction $N(\mu_t, B_t, \tau_d) \geq 0$ for all $t \geq 0$.

We will show that, under the policies associated with these value functions, the equilibrium tax rate and government spending are constant and equal to τ_d and $\overline{G}$ respectively (except that $G_0 = N(\mu_0, B_0, \tau_d) + \overline{G}$). On this path, by construction, the no-Ponzi condition holds (due the satisfaction of the intertemporal budget constraint) and the transversality-type conditions hold due the transversality condition associated with $\overline{V}(w, \theta; \tau_d)$. Stationarity holds by construction, the policies are Markov by construction, and expectations are consistent with a constant payout tax rate. Moreover, by definition, the value function V satisfies the Bellman equation, provided that the optimal mechanism is indeed a constant payout tax.

Therefore, to prove the existence of an equilibrium, it suffices to show that the Bellman equation of the government is satisfied under the evolution equations for the population of firms and for government debt (Equations (18), (19), and (20)), and that the optimal mechanism is implemented with a constant payout tax.

We will do this without explicitly characterizing the value function $J(\mu, B)$ on the domain with $N(\mu, B, \tau_d) < 0$. Instead, we will bound from above $J(\mu, B)$ on this domain, and then show that if $N(\mu_t, B_t, \tau_d) \geq 0$, the government will always choose to set $N(\mu_{t+1}, B_{t+1}, \tau_d) \geq 0$ (that is, to not enter the domain $N(\mu, B, \tau_d) < 0$).

Define $B^*(\mu, \tau_d)$ as the solution to $N(\mu, B^*(\mu, \tau_d), \tau_d) = 0$, which exists by the linearity of N in B. For any $B > B^*(\mu, \tau_d)$, we must have $N(\mu, B, \tau_d) < 0$. In this case, the government with debt $B^*(\mu, \tau_d)$ could always choose to spend $B - B^*(\mu, \tau_d)$ more than the government with debt B would choose to spend, and otherwise replicate that government's policies. As a result, we must have

$$
J(\mu, B^*(\mu, \tau_d)) \geq J(\mu, B) + B - B^*(\mu, \tau_d).
$$

Therefore, using Equation (20), the government's value function must satisfy

$$
\begin{aligned}
J_t(\mu_t, B_t) \leq \max_{B_{t+1}, G_t, \{m_t(w, \theta) \in \mathcal{M}(w, \theta, V_{t+1})\}_{w \in \mathbb{R}_+, \theta \in [0,1]}} & \, u(G_t) - R^{-1} \max\{B_{t+1} - B^*(\mu_{t+1}, \tau_d), 0\} \\
& + R^{-1} \int_{0^+}^{\infty} \int_0^1 \int_0^1 d_t(\theta', \theta'; w, \theta) \, d\Pi(\theta'|\theta) \, d\mu_t(w, \theta) \\
& + R^{-1} J_{t+1}(\mu_{t+1}, \min\{B_{t+1}, B^*(\mu_{t+1}, \tau_d)\}),
\end{aligned}
$$

with equality if the optimal policy sets $B_{t+1} \leq B^*(\mu_{t+1}, \tau_d)$ (which is to say, $N(\mu_{t+1}, B_{t+1}, \tau_d) \geq 0$).

Let us now turn to our conjecture, and observe that, on the domain $N(\mu, B, \tau_d) \geq 0$,

$$
u(N(\mu, B, \tau_d) + \overline{G}) = N(\mu, B, \tau_d).
$$

Using the definition of N and the fact that $\tau_d \overline{V}(w,\theta;0) + \overline{V}(w,\theta;\tau_d) = \overline{V}(w,\theta;0)$, our conjecture is

$$J(\mu,B) = -B - \frac{\overline{G}}{1-R^{-1}} + \int_{0+}^{\infty}\int_0^1 \overline{V}(w,\theta;0)\,d\mu(w,\theta) + \frac{1}{R-1}\int_{0+}^{\infty}\int_0^1 \overline{V}(w,\theta;0)\,d\bar{e}(w,\theta;\tau_d).$$

Define the constant

$$J_E = \frac{1}{R-1}\int_{0+}^{\infty}\int_0^1 \overline{V}(w,\theta;0)\,d\bar{e}(w,\theta;\tau_d)$$

and note that

$$J_E = R^{-1}\int_{0+}^{\infty}\int_0^1 \overline{V}(w,\theta;0)\,d\bar{e}(w,\theta;\tau_d) + R^{-1}J_E.$$

Now consider the Bellman inequality above using this conjectured function as the continuation value and suppose that firms conjecture a constant payout tax rate τ_d beginning in the next date:

$$J_t(\mu_t,B_t) = \max_{B_{t+1},G_t,\{m_t(w,\theta)\in\mathcal{M}(w,\theta,\overline{V}(\cdot;\tau_d))\}_{w\in\mathbb{R}_+,\theta\in[0,1]}} u(G_t)$$

$$-R^{-1}\max\{B_{t+1}-B^*(\mu_{t+1},\tau_d),0\} - R^{-1}\min\{B_{t+1},B^*(\mu_{t+1},\tau_d)\} - \frac{R^{-1}\overline{G}}{1-R^{-1}}$$

$$+R^{-1}\int_{0+}^{\infty}\int_0^1\int_0^1 \{d_t(\theta',\theta';w,\theta) + \overline{V}(w_{t+1}(\theta',\theta';w,\theta),\theta';0)\}\,d\Pi(\theta'|\theta)\,d\mu_t(w,\theta)$$

$$+R^{-1}J_E + R^{-1}\int_0^{\infty}\int_0^1 \overline{V}(w,\theta;0)\,d\bar{e}(w,\theta;\tau_d).$$

This simplifies to

$$J_t(\mu_t,B_t) = \max_{B_{t+1},G_t,\{m_t(w,\theta)\in\mathcal{M}(w,\theta,\overline{V}(\cdot;\tau_d))\}_{w\in\mathbb{R},\theta\in[0,1]}} u(G_t) - R^{-1}B_{t+1} - \frac{R^{-1}\overline{G}}{1-R^{-1}} + J_E$$

$$+R^{-1}\int_{0+}^{\infty}\int_0^1\int_0^1 \{d_t(\theta',\theta';w,\theta) + \overline{V}(w_{t+1}(\theta',\theta';w,\theta),\theta';0)\}\,d\Pi(\theta'|\theta)\,d\mu_t(w,\theta)$$

Now plug in the flow government budget constraint, in Equation (18),

$$R^{-1}B_{t+1} = (B_t+G) - R^{-1}\int_{0+}^{\infty}\int_0^1\int_0^1 \tau_t(\theta',\theta';w,\theta)\,d\Pi(\theta'|\theta)\,d\mu_t(w,\theta),$$

to eliminate the choice variable B_{t+1} and simplify to

$$J_t(\mu_t,B_t) = \max_{G_t,\{m_t(w,\theta)\in\mathcal{M}(w,\theta,\overline{V}(\cdot;\tau_d))\}_{w\in\mathbb{R},\theta\in[0,1]}} u(G_t) - B_t - G_t - \frac{R^{-1}\overline{G}}{1-R^{-1}} + J_E$$

$$+R^{-1}\int_{0+}^{\infty}\int_0^1\int_0^1 \{d_t(\theta',\theta';w,\theta) + \tau_t(\theta',\theta';w,\theta) + \overline{V}(w_{t+1}(\theta',\theta';w,\theta),\theta';0)\}\,d\Pi(\theta'|\theta)\,d\mu_t(w,\theta)$$

Observe immediately that it is weakly optimal to set $G_t = \overline{G}$, and $\overline{G} + \frac{R^{-1}\overline{G}}{1-R^{-1}} = \frac{\overline{G}}{1-R^{-1}}$. Now observe that firms will never voluntarily become exiting, by $\overline{V}(w,\theta;\tau_d) \geq \overline{V}(w,0;\tau_d)$. We can invoke Proposition 1 to show that a constant payout tax at rate τ_d implements the optimal mechanism.

Observe in this case that

$$
\begin{aligned}
d_t\left(\theta',\theta';w,\theta\right)+\tau_t\left(\theta',\theta';w,\theta\right)+\overline{V}\left(w_{t+1}\left(\theta',\theta';w,\theta\right),\theta';0\right)= \\
(1+\tau_d)d_t\left(\theta',\theta';w,\theta\right)+\overline{V}\left(w_{t+1}\left(\theta',\theta';w,\theta\right),\theta';0\right)= \\
(1+\tau_d)d_t\left(\theta',\theta';w,\theta\right)+(1+\tau_d)\overline{V}\left(w_{t+1}\left(\theta',\theta';w,\theta\right),\theta';\tau_d\right),
\end{aligned}
$$

and consequently

$$
\begin{aligned}
\int_0^1\left\{d_t\left(\theta',\theta';w,\theta\right)+\tau_t\left(\theta',\theta';w,\theta\right)+\overline{V}\left(w_{t+1}\left(\theta',\theta';w,\theta\right),\theta';0\right)\right\}d\Pi\left(\theta'|\theta\right)= \\
(1+\tau_d)\overline{V}(w,\theta;\tau_d)= \\
\overline{V}(w,\theta;0).
\end{aligned}
$$

It follows that the conjectured form of the value function J holds if the Bellman inequality is an equality. By the definition of N, if $N(\mu_t,B_t,\tau_d)\geq 0$, under the constant payout tax rate τ_d, the intertemporal budget constraint will continue to hold,

$$
N(\mu_{t+1},B_{t+1},\tau_d)\geq 0,
$$

verifying our conjecture and concluding the proof.

B   Quantitative Analysis: Additional Details

B.1   Firms' Problem with a Profit Tax

In this section, we describe the firms' problem in the presence of a corporate tax

$$
\tau_t\left(w_t,\theta_t,b_t,k_t,d_t,w_{t+1}\right)=\tau_c\left[f\left(k_t,\theta_t\right)-\delta k_t-(1-R^{-1})b_t\right].
$$

In our model, because taxes are subject to default, the profit tax can induce default. Defaults occur for firms that are productive but have very little wealth. These defaults are predictable (because taxes depend on capital and debt and not dividends), in the sense that lenders will know with certainty whether a firm will default or not. As a result, lenders will not lend to defaulting firms.

Let $\xi_t\in\{0,1\}$ be an indicator for whether the firm chooses to default. We will assume in the event of default that the government collects the maximum taxes possible (that is, there is no deadweight loss due to default). This can also be interpreted as a cap on the profit tax so as to avoid default. This assumption (as opposed to assuming positive deadweight loss due to default) makes the profit tax look better relative to the payout tax in our quantitative exercise.

The firms' problem with a profit tax, which parallels Definition 6, is given below.

Definition 8. (Firms' problem with a profit tax) Fix some $w_t>0$ and $\theta_t\in[0,1]$, and suppose that the government implements a constant profit tax with interest and depreciation deductibility,

$$
\tau_t\left(w_t,\theta_t,b_t,k_t,d_t,w_{t+1}\right)=\tau_c[f\left(k_t,\theta_t\right)-\delta k_t-(1-R^{-1})b_t],\ \forall j\geq 0.
$$

Then the current-date problem of a firm with future type θ_{t+1} is

$$V^c(w_t, \theta_t, \theta_{t+1}) = \max_{b_t \geq 0, k_t \geq 0, w_{t+1} \geq 0, d_t \geq 0, \xi_t \in \{0,1\}} R^{-1} \xi_t \left\{ d_t + \int_0^1 V^c(w_{t+1}, \theta_{t+1}, \theta_{t+2}) \, d\Pi(\theta_{t+2}|\theta_{t+1}) \right\}$$

$$+ (1 - \xi_t) R^{-1} \left\{ d_t + \int_0^1 V^c\left(w^D(k_t, \theta_t) - d_t, \theta_{t+1}, \theta_{t+2}\right) d\Pi(\theta_{t+2}|\theta_{t+1}) \right\}$$

subject to

$$w_{t+1} \leq f(k_t, \theta_t) + (1 - \delta)k_t - d_t - b_t - \tau_c \left[f(k_t, \theta_t) - \delta k_t - (1 - R^{-1})b_t \right],$$

$$k_t \leq w_t + R^{-1} \xi_t b_t,$$

$$d_t \leq w^D(k_t, \theta_t).$$

We can solve for the optimal debt, capital, and default choices in this problem without explicitly characterizing the value function, and simplify the firms' problem of choosing dividends. The following lemma summarizes these results. We assume that the firm does not default if it is indifferent between defaulting and not defaulting.

Lemma 3. *(Firms' default with a profit tax) In the firms' problem with a profit tax (Definition 8), the firm will default if and only if*

$$\tau_c[f(w_t, \theta_t) - \delta w_t] > \varphi(1 - \delta) w_t.$$

If the firm defaults, $k_t = w_t$ and $b_t = 0$. If the firm does not default, $b_t = R(k_t - w_t)$ and $k_t \geq w_t$ is maximal and solves

$$(R - \varphi(1 - \delta))k_t + \tau_c[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] = R\left(1 - \tau_c(1 - R^{-1})\right) w_t.$$

In both cases, the firm will choose $d_t \in [0, w^D(k_t, \theta_t)]$ to maximize

$$d_t + \int_0^1 V^c\left(w^D(k_t, \theta_t) - d_t, \theta_{t+1}, \theta_{t+2}\right) d\Pi(\theta_{t+2}|\theta_{t+1}).$$

Proof. See below. □

This lemma simplifies the firms' problem in several ways. First, it shows that the firm will not default unless forced to by the profit tax. This will occur for low-wealth, high-productivity firms. Second, it shows that either the firm will default or that capital will be maximal, meaning that the firm exhausts its borrowing capacity. This implies that a firm's dividend d_t plus continuation wealth w_{t+1} will be equal to wealth given default $w^D(k_t, \theta_t)$, hence leading to our simplification of the choice of dividend. We use these simplifications when computing the firms' value function and optimal payout policy under a profit tax in our quantitative exercise.

Because the choice of capital and default decision does not depend on the future type θ_{t+1}, we can rewrite the problem in terms of the value function

$$\overline{V}^c(w_t, \theta_t) = \int_0^1 V^c(w_t, \theta_t, \theta_{t+1}) \, d\Pi(\theta_{t+1}|\theta_t)$$

as

$$\overline{V}^c(w_t, \theta_t) = \max_{d_t \in [0, w^D(k(w_t, \theta_t), \theta_t)]} R^{-1} \left\{ d_t + \int_0^1 \overline{V}^c\left(w^D\left(k\left(w_t, \theta_t\right), \theta_t\right) - d_t, \theta_{t+1}\right) d\Pi\left(\theta_{t+1}|\theta_t\right) \right\},$$

where $k(w_t, \theta_t)$ is the optimal policy described in Lemma 3. We use this formulation in the numerical procedures underlying our quantitative exercise.

Proof of Lemma 3

It is immediate that the value function is non-decreasing in wealth, and therefore that the problem can be simplified by observing that the wealth accumulation and initial budget constraint bind. Therefore,

$$w_{t+1} + d_t = (1 - \tau_c)[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] + R\left(1 - \tau_c(1 - R^{-1})\right)w_t.$$

Default will only be beneficial if $w_{t+1} + d_t < w^D(k_t, \theta_t)$. Consider first the case in which default is beneficial. In this case, $b_t = 0$, and therefore we must have

$$\tau_c[f(w_t, \theta_t) - \delta w_t] > \varphi(1 - \delta)w_t.$$

Now suppose not defaulting is optimal. In this case, we must have

$$(1 - \tau_c)[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] + R(1 - \tau_c(1 - R^{-1}))w_t \geq f(k_t, \theta_t) + (1 - \varphi)(1 - \delta)k_t,$$

which simplifies to

$$(R - \varphi(1 - \delta))k_t + \tau_c[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] \leq R\left(1 - \tau_c(1 - R^{-1})\right)w_t.$$

The left-hand side is increasing in k_t, and therefore a necessary condition for no-default is

$$\tau_c[f(w_t, \theta_t) - \delta w_t] \leq \varphi(1 - \delta)w_t.$$

It follows the firm will not default if and only if this condition is satisfied.

If the firm defaults, $k_t = w_t$, and it will set dividends to solve

$$d_t \in \arg\max_{d \in [0, w^D(w_t, \theta_t)]} d_t + \int_0^1 V^c\left(w^D(k_t, \theta_t) - d_t, \theta_{t+1}, \theta_{t+2}\right) d\Pi(\theta_{t+2}|\theta_{t+1}).$$

If the firm does not default, it is weakly optimal to set k_t to its maximal value if possible (either because this increases production or because it relaxes the maximum dividend constraint). It follows in this case that

$$\tau_c[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] + (R - \varphi(1 - \delta))k_t = w_t R(1 - \tau_c(1 - R^{-1})).$$

In this case, the firm sets dividends to solve

$$d_t \in \arg\max_{d \in [0, w^D(k_t, \theta_t)]} d_t + \int_0^1 V^c(w_{t+1}, \theta_{t+1}, \theta_{t+2}) d\Pi(\theta_{t+2}|\theta_{t+1}),$$

where

$$w_{t+1} + d_t = (1 - \tau_c)[f(k_t, \theta_t) + (1 - \delta)k_t - Rk_t] + R\left(1 - \tau_c(1 - R^{-1})\right)w_t = w^D(k_t, \theta_t).$$

B.2 Functional Forms

In this subsection, we provide more details on the functional forms used in our quantitative analysis. The productivity parameter transition kernel $\Pi(\theta_{t+1}|\theta_t)$ is defined using the Tauchen (1986) approximation of an AR(1) process for log productivity. That is, define an AR(1) process

$$z_{t+1} = \rho z_t + \sigma \varepsilon_{t+1},$$

with $\varepsilon_{t+1} \sim N(0, 1)$. Let $\Pi_z(z_{t+1}|z_t)$ be the transition matrix associated with the discrete approximation of this process. We define $\theta_t = A^{-1}\exp(z_t)$ for all productive types ($\theta_t > 0$), scaling the parameter A to ensure the highest productivity level is $\theta_t = 1$. The production function we employ and the AR(1) approximation for productivity both follow Li, Whited and Wu (2016).

We incorporate the exiting type, $\theta_t = 0$, by assuming that the probability of exiting next period is

$$\Pi(0|\theta_t) = \Pi(0|1) \times \theta_t^{\frac{\ln(\Pi(0|\theta_L)) - \ln(\Pi(0|1))}{\ln(\theta_L)}},$$

where θ_L is the smallest non-zero productivity level. This can also be written as

$$\ln(\Pi(0|\theta_t)) = \ln(\Pi(0|1)) + (\ln(\Pi(0|\theta_L)) - \ln(\Pi(0|1))) \times \frac{\ln(1) - \ln(\theta_t)}{\ln(1) - \ln(\theta_L)},$$

which is to say $\ln(\Pi(0|\theta_t))$ is linear in $\ln(\theta_t)$. The parameters $\Pi(0|1)$ and $\Pi(0|\theta_L)$ control the exit probabilities of the highest and lowest productivity types; this functional form smoothly interpolates the transition probability between them for other values of θ_t. The final transition matrix is

$$\Pi(\theta_{t+1}|\theta_t) = \begin{cases} 1 & \theta_{t+1} = \theta_t = 0, \\ 0 & \theta_{t+1} \neq 0, \theta_t = 0, \\ \Pi(0|\theta_t) & \theta_{t+1} = 0, \theta_t \neq 0, \\ (1 - \Pi(0|\theta_t))\Pi_z(\ln(A\theta_{t+1})|\ln(A\theta_t)) & \theta_{t+1} \neq 0, \theta_t \neq 0. \end{cases}$$

This final transition matrix is a function of the parameters $(\rho, \sigma, \Pi(0|\theta_L), \Pi(0|1))$.

The last functional form required is the distribution of potential entrant wealth and type. We assume that outside wealth and productivity are independent. For productivity, we use $\ln(A\theta') \sim N\left(\mu_z^e, \frac{\sigma^2}{1-\rho^2}\right)$. For potential entrant wealth, the exact functional form of the shifted Pareto (Lomax) distribution is

$$f(\hat{w}|\xi_w) = \frac{3}{2\xi_w}\left(1 + \frac{\hat{w}}{\xi_w}\right)^{-\frac{5}{2}}.$$

B.3 Calibration

Table A1 lists both the parameters that we calibrate to the results of Li, Whited and Wu (2016) and the parameters that we estimate to match the moments described in Lee and Mukoyama (2015) and Djankov et al. (2010). The estimates from Li, Whited and Wu (2016) come from Panel B of Table 1 in that paper, under the assumption of a 20% tax rate.

Table A1: Calibrated Parameter Values

Parameter Name	Symbol	Value	Source
Risk-Free Rate	R	1.0525	1965-2012 Avg. 3-mo T-bill rate (FRED), following Li, Whited and Wu (2016)
Depreciation Rate	δ	0.038	Li, Whited and Wu (2016) Estimation, $\tau_c = 20\%$
Decreasing Returns	α	0.572	
Collateral Haircut	φ	0.369	
Productivity Persistence	ρ	0.530	
Productivity Volatility	σ	0.458	
Low-Prod. Exit Rate	$\Pi(0\|\theta_L)$	8.3%	Estimated, Table A2
High-Prod. Exit Rate	$\Pi(0\|1)$	3.55%	
Potential Entrant Prod. Mean	μ_z^e	0.006	
Potential Entrant Wealth Shape	ξ_w	0.042	
Fixed Cost of Entry	F	68.9	

Note: The time interval assumed in the calibration is one year.

Table A2 describes the moments from Lee and Mukoyama (2015) and Djankov et al. (2010) that we use to estimate our other parameters. Because our model is exactly identified by these moments, the (very small) differences between the target moments and fitted values are due to the limitations of our numerical procedures. We use the notation $e_c^*(w, \theta; \tau_c)$ to denote the entering mass under the tax rate $\tau_c = 20\%$, and $k_c(w, \theta)$ to denote the optimal capital choice of a firm facing that tax rate. Note that, by definition, the total entering mass is equal to the exit rate times the steady state mass of firms, which is to say

$$\int_0^1 \int_{0^+}^\infty de_c^*(w, \theta; \tau_c) = \int_{0^+}^1 \int_{0^+}^\infty \Pi(0|\theta) d\mu_c^*(w, \theta).$$

Table A2: Target Moments and Fit

Moment	Model Formula	Calib. Value	Target Value	Source
Exit Rate	$\dfrac{\int_{0+}^{1}\int_{0+}^{\infty}\Pi(0|\theta)d\mu_c^*(w,\theta)}{\int_{0+}^{1}\int_{0+}^{\infty}d\mu_c^*(w,\theta)}$	0.0550	0.0550	Lee and Mukoyama (2015), Table 2
Relative TFP, Exiters vs. Stayers	$\dfrac{(1-\text{ExitRate})\int_{0+}^{1}\int_{0+}^{\infty}\theta\Pi(0|\theta)d\mu_c^*(w,\theta)}{\text{ExitRate}\int_{0+}^{1}\int_{0+}^{\infty}\theta(1-\Pi(0|\theta))d\mu_c^*(w,\theta)}$	0.8596	0.8600	Lee and Mukoyama (2015), Table 1
Relative TFP, Entrants vs. Existing Firms	$\dfrac{(1-\text{ExitRate})\int_{0+}^{1}\int_{0+}^{\infty}\theta de_c^*(w,\theta)}{\text{ExitRate}\int_{0+}^{1}\int_{0+}^{\infty}\theta(d\mu_c^*(w,\theta)-de_c^*(w,\theta))}$	0.9590	0.9600	
Relative Size, Entrants vs. Existing Firms	$\dfrac{(1-\text{ExitRate})\int_{0+}^{1}\int_{0+}^{\infty}\min\{k_c(w,\theta),k^*(\theta)\}de_c^*(w,\theta)}{\text{ExitRate}\int_{0+}^{1}\int_{0+}^{\infty}\min\{k_c(w,\theta),k^*(\theta)\}(d\mu_c^*(w,\theta)-de_c^*(w,\theta))}$	0.6000	0.6000	
Semi-Elasticity of Entry to Tax Rates	$\left(\dfrac{\int_{0+}^{1}\int_{0+}^{\infty}d\bar{e}(w,\theta;0)}{\int_{0+}^{1}\int_{0+}^{\infty}de_c^*(w,\theta;\tau_c)}-1\right)\dfrac{10\%}{\tau_c}$	0.1700	0.1700	Djankov et al. (2010), Table 5

Note that we define the relative TFP of exiters vs. stayers based on the prior period's TFP. In our model, currently exiting firms earn the risk-free rate on their investments. In the data, after a plant exits its TFP is not observed. We therefore compare the prior period's TFP of firms that subsequently exit to the prior period's TFP of firms that do not exit.

For entrants, the timing is different. Entrant TFP is not observed in the data until after entry, which is to say after the first period of operation. We therefore compare the TFP of firms that begin operations at the current date to firms that begin operations at a prior date (and are not currently exiting). For both of these measures, we use the relative TFP moments from Table 1 of Lee and Mukoyama (2015), using those authors' TFP measure (as opposed to their average labor productivity measure).

Entrant relative size is defined like entrant TFP, but with capital in the place of productivity. We exclude cash from this capital measure, which is why we use the minimum of the broadly defined capital $k_c(w,\theta)$ and the first-best capital level $k^*(\theta)$. We compare this to the relative size measure in Table 1 of Lee and Mukoyama (2015), which is based on the number of workers at a manufacturing plant (those authors do not provide a size comparison based on capital).

For the entry semi-elasticity, we solve the model both under a 20% profit tax rate and under zero taxes, and then calculate the increase in the mass of entrants. Recall that $\bar{e}(w,\theta;0)$ is entry under a payout tax of zero, which is identical to entry under a profit tax of zero, hence the notation in Table A2. We compare this value to the point estimate in Table 5 of Djankov et al. (2010) for the effect of the five-year effective tax rate on the average entry rate in their sample period. We use the average entry rate (8%) described by those authors in the text below their Table 5 to convert their point estimate of a 1.36 percent increase in the entry rate given a 10% change in the tax rate to an elasticity ($0.17 = \frac{1.36}{8}$).

B.4 Numerical Methods

Our numerical procedure uses a grid of 15 productivity levels by 200 wealth levels to solve for the value function under a profit tax. The size of our wealth grid is based on the first-best capital level of the most productive type, $k^*(1)$. The first 100 wealth levels span from $k^*(1)/1000$ to $k^*(1)/5$ in equally spaced intervals, and the second 100 span from $k^*(1)/5$ to $2k^*(1)$ in equally spaced intervals. We oversample low wealth levels to more accurately capture the curvature of the value function in that region.

We pre-compute many variables in the firms' problem (in particular, b, k) that can be solved for analytically without knowing the value function or the optimal payout boundary in the firms' problem. We then use value function iteration to solve for the value function and for the optimal payout policy.

Note that solving for the value function requires knowing the transition matrix $\Pi(\theta_{t+1}|\theta_t)$, and therefore the value function depends on the parameters $\Pi(0|\theta_L)$ and $\Pi(0|1)$. However, the value function does not depend on the parameters (μ_z^e, ξ_w, F) that affect entry. After computing the value function, we solve for the values of (μ_z^e, ξ_w, F) that minimize the percentage deviation between our model moments and their target values. We repeat this procedure (solve for the value function, and solve for (μ_z^e, ξ_w, F)) over a grid of possible values for $\Pi(0|\theta_L)$ and $\Pi(0|1)$, and choose the values for those two parameters that result in the best fit.

B.5 Additional Figures
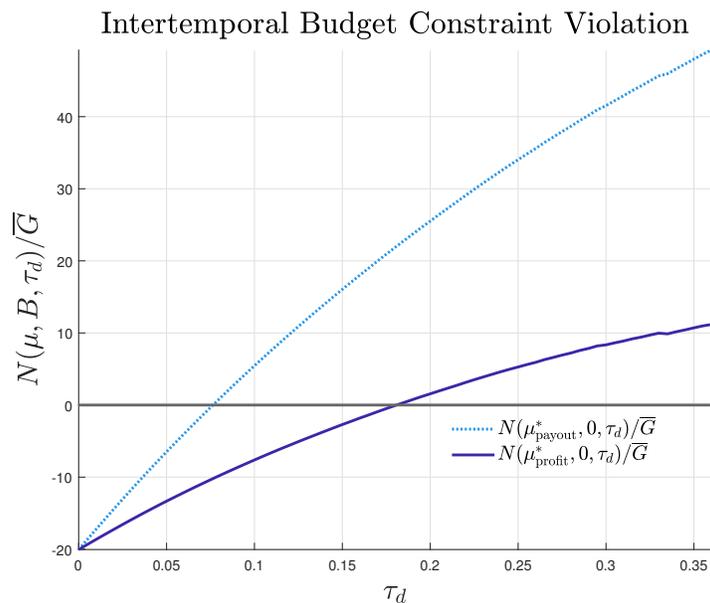
Note: Figure A1 shows the Laffer curve present in our model, plotting the net violation of the intertemporal budget, normalized by the target spending $\overline{G}$, from our quantitative exercise (see Section 5 for details). The horizontal axis varies the rate of payout taxation (assumed to be constant from date zero onward), and the vertical axis shows $N(\mu, 0, \tau_d)$ as defined in Equation (27). The figure plots these curves for two values of μ, the steady state under a constant payout tax rate of $\tau_d = 0.181$, μ_{payout}^*, and the steady state under a constant rate of profit taxation $\tau_c = 0.2$, μ_{profit}^*. In our quantitative exercise, the latter is the initial measure of firms in the economy, and the former is the eventual steady state after switching from profit taxation to payout taxation. In that exercise, $\overline{G}$ is assumed to be equal to the steady state annual revenue from a profit tax of $\tau_c = 0.2$. The units of the vertical axis can therefore be interpreted as multiples of annual tax revenue.

Figure A1: Intertemporal Budget Constraint Violation vs. Tax Rate
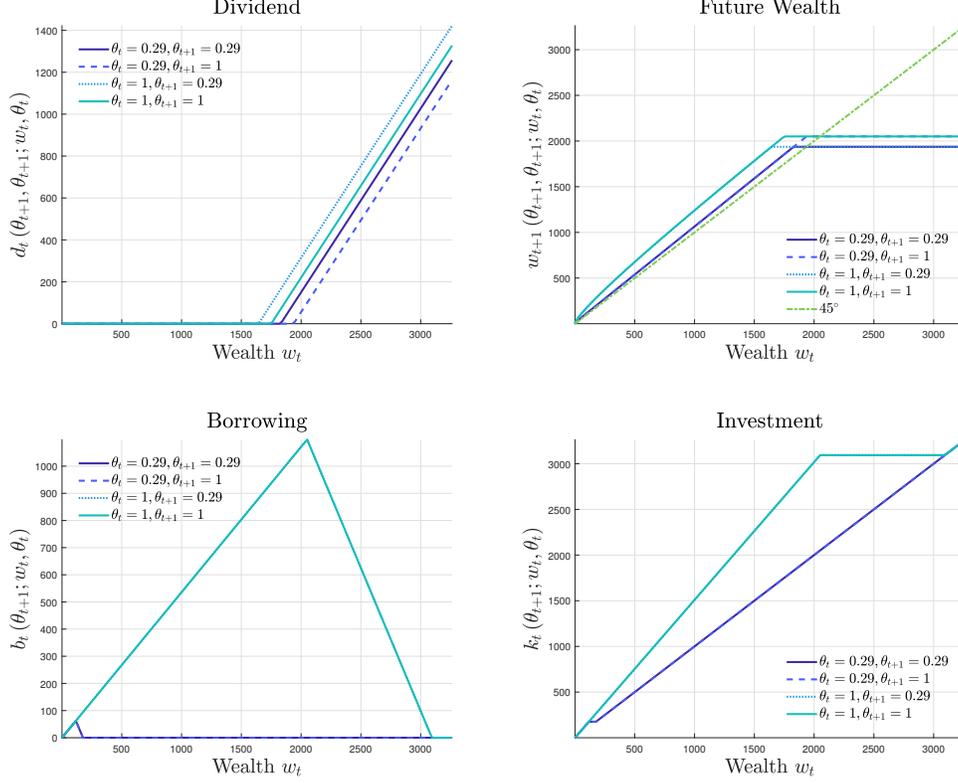
Note: Figure A2 illustrates the optimal policies for (d_t, w_{t+1}, b_t, k_t) in our quantitative exercise (see Section 5 for details), as a function of w_t, under four different assumptions about current and future productivity: $(\theta_t, \theta_{t+1}) \in \{(0.29, 0.29), (0.29, 1), (1, 0.29), (1, 1)\}$. Note that b_t and k_t do not depend on a firm's future productivity under the optimal policies.

Figure A2: Optimal Policies in the Dynamic Model

C   Stylized Model: Expensing of Investment

In this section, we illustrate in the context of our stylized model how a firm might be accumulating cash or paying down debt and yet still be financially constrained, in the sense of having a marginal value of wealth inside the firm that exceeds the value of wealth outside the firm. In this scenario, which emerges naturally in the full dynamic model introduced in Section 3, a profit tax with full expensing of investment would not achieve constrained efficient production because it causes financial constraints to bind.

For simplicity, here we suppose that firms must repay some initial debt, b_0, but cannot borrow. To further simplify the argument, we assume that interest on that debt is zero. In this case, the counterpart of Equation (4) (the feasibility constraint) becomes

$$\theta_0 f(k_0) - k_1(\hat{\boldsymbol{\theta}}) - b_0 - \tau_0(\hat{\boldsymbol{\theta}}) \geq 0, \tag{A1}$$

and the definition of constrained efficient investment, $k^{ce}(\boldsymbol{\theta})$, originally introduced in Equation (5), now must account for debt repayment,

$$k^{ce}(\boldsymbol{\theta}) = \min\left\{k^*(\boldsymbol{\theta}), \theta_0 f(k_0) - b_0\right\}.$$

The arguments for the optimality of payout taxes made in Section 2 remain unchanged. But now we consider a profit tax with full expensing of investment. In this case, taxable profits under full expensing are now defined as:

$$\pi_0 = \theta_0 f(k_0) - k_1, \quad \text{and} \quad \pi_1(k_1, \theta) = \theta f(k_1),$$

which implies that Equation (A1) takes the form:

$$\theta_0 f(k_0) - \frac{b_0}{1 - \tau_p} \geq k_1(\hat{\theta}).$$

Consequently, a mechanism equivalent to a constant linear profit tax with full expensing of investment can be implemented by

$$k_1(\hat{\theta}) \in \arg \max_{k_1 \in [0, \theta_0 f(k_0) - \frac{b_0}{1 - \tau_p}]} -b_0 + (1 - \tau_p)\theta_0 f(k_0) + (1 - \tau_p)(\hat{\theta} f(k_1) - k_1)$$

$$\tau_0(\hat{\theta}) = \tau_p(\theta_0 f(k_0) - k_1)$$

$$\tau_1(\theta, \hat{\theta}) = \tau_p \theta f(k_1(\hat{\theta})).$$

However, this mechanism does not achieve constrained efficiency, as $k_1(\hat{\theta}) < k^{ce}(\hat{\theta})$ for all $\hat{\theta}$ with $k^*(\hat{\theta}) > f(k_0) - \frac{b_0}{1 - \tau_p}$. Note that, as discussed in the main text, the inefficiency of a profit tax with full expensing of investment arises not because of an intertemporal distortion (full expensing eliminates intertemporal distortions), but because firms can be profitable in the current period and yet might fail to achieve first-best production in the future.