Aggregate Implication of Corporate Taxation over Business Cycle*

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Abstract

I examine the aggregate effects of corporate taxation using a quantitative dynamic stochastic general equilibrium model featuring firms subject to collateralized borrowing and idiosyncratic productivity shocks. In my model economy, two policies subsidize capital investment through corporate tax deductions. Firms that invest less than a threshold defined by the IRS enjoy lower user cost of capital, while others deduct their capital expenditure at a counter-cyclical bonus rate. Increasing the threshold is 50% more effective than raising the bonus rate in stimulating aggregate output while combining both policies reduces effectiveness by 13% compared to solely increasing the threshold. Although a higher bonus rate benefits more firms, unconstrained firms often distribute saved funds as dividends rather than reinvesting, diminishing policy efficacy per dollar of foregone government revenue. Conversely, raising the threshold empowers credit-constrained firms to overcome collateral limitations, thereby reducing capital misallocation due to financial frictions.

Keywords: Tax shields, Collateral constraint, Business cycle, Firm dynamics

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1 Introduction

To what extent can increasing corporate tax deductions stabilize the economy during recessions? Investment tax credits for corporate tax deductions are a commonly employed policy tool to stimulate investment, adopted by over 41 countries as of 2018[1]. Starting from 2002, there are two distinct policies to achieve such acceleration in the US: bonus depreciation and Section 179 deduction. Bonus depreciation offers all firms a fraction of the net present value of the total tax deduction during the year of investment, lowering the cost of capital. Section 179 deduction, on the other hand, is a targeted policy. It grants firms that invest below a threshold the entire tax deduction at the year of investment. Despite the wide impacts of these policies, quantitative assessments of their stabilization properties remain scarce.

This paper develops a dynamic stochastic general equilibrium model to quantitatively evaluate the efficacy of corporate tax deduction policies in attenuating aggregate fluctuations induced by real and financial shocks. Firms in the model are subject to corporate taxes based on taxable income, which is deductible by capital depreciation. Such deduction creates a gap between the purchasing and selling prices of the capital and yields the (S, s) investment decision rules for their capital. Section 179 deduction separates two groups of firms that pay different costs for investment, while the bonus rate defines the distance between two (S, s) boundaries. This tax-induced distortion in investment incentives interacts with persistent idiosyncratic productivity shocks and financial market imperfections, exacerbating the distortions caused by persistent declines in aggregate total factor productivity (TFP). I calibrate the model to match aggregate and micro-level data and use it as a laboratory to examine the distortion created by tax structure and quantify the mitigating effect of deduction policies.

I conduct both steady-state and dynamic policy experiments to quantitatively evaluate the effect of policies. I calibrate the baseline model to the 2015 Section 179 threshold and bonus depreciation rate in the US. To fairly compare the effectiveness of each policy, I conduct three experiments: raise the Section 179 threshold, raise the bonus rate, and raise both policy tools using the numbers from the previous two experiments. The cost of policies is fixed at 0.3% of the baseline output. From the experiments mentioned above, I have two main findings. First, raising the Section 179 threshold increases aggregate output by 1.61% and is 50% more effective than raising the bonus rate. Second, implementing both policies simultaneously results in a higher output boost but a 13% drop in marginal benefit of tax deductions compared to simply raising the Section 179 threshold, which aligns with the empirical evidence shown in Ohrn (2019). Later, I show that both policies are effective in mitigating the capital misallocation from

[1] See Steinmüller, Thunecke and Wamser (2018)

shocks to the availability of credit through the endogenous TFP channel. Temporary raising bonus rate mitigates trough in output by 0.37%, while raising Section 179 threshold mitigates that by 0.53%.

There are two mechanisms affecting firms' investment incentives: user cost effect and distributional effect. Firms with different financial conditions react differently to a lower user cost of capital. When the cost of capital is decreasing, small and credit-rationed firms raise their investment to boost future production, while large and resourceful firms utilize the saved funds on dividend payments rather than investment. The untargeted nature of bonus depreciation triggers the reaction from large firms, resulting in a moderate boost in aggregate output and investment despite large costs to the government. This qualitatively matches the empirical facts that firms that are not paying dividends have larger investment responses than dividend-paying firms[2]. On the other hand, Section 179 deduction targets median-sized firms and assists them in outgrowing their financial constraints without the adverse effects from large firms. This micro-level firm decision rule leads to macro-level impacts on the distribution of capital and the aggregate economy. Bonus depreciation increases the dispersion of capital investment, while Section 179 deduction mitigates this effect. As dispersion reflects misallocation, Section 179 deduction also improves the efficiency in the utilization of existing capital.

There is a large literature investigating how tax incentives influence aggregate investment. Hall and Jorgenson (1967) is the first to evaluate the response of a representative firm to tax credit through the change in the user cost of capital. My work follows this tradition in that the user costs associated with firms' binary investment choices are different. Firms that invest below the threshold enjoy lower user costs than those investing above the threshold, and the difference between two user costs is determined by the rate of bonus depreciation. Furthermore, Summers, Bosworth, Tobin and White (1981) proposed the tax-adjusted Tobin's q to evaluate how tax policies alter the valuation of the firms, providing another channel for fiscal policy to affect capital accumulation. In my model, both the corporate tax and the investment subsidy policies enter the value of the firms, allowing me to examine Tobin's q channel of tax credit. By unifying both channels in my model, I can identify the source heterogeneous response to tax credits and evaluate the corresponding aggregate implication.

Earlier empirical literature starts with data on public companies but oftentimes concludes that investment is not responsive to tax credits. Goolsbee (1998) uses data on the prices of capital by the Bureau of Economic Analysis (BEA) and concludes that the effect of the investment tax credit is offset by the increase in capital prices among public firms. Cummins, Hassett and Hubbard (1996) utilizes panel data among 14 OECD countries and identifies that the user cost of

[2] See Table 6 in Zwick and Mahon (2017)

capital and the adjustment costs can explain such unresponsiveness. House and Shapiro (2008) matches the BEA data with Internal Revenue Service (IRS) depreciation schedules and analyzes the 2001 to 2002 bonus depreciation. They claim that the intertemporal elasticity of investment is high under two assumptions: capital is long-lived and investment tax credit is temporary and unexpected. Even though the conclusion by House and Shapiro (2008) highlights the importance of intertemporal substitution, they assume all tax responses are temporary price effects and not income effects, which contradicts the evidence documented in corporate finance literature (e.g., Lamont (1997)). While these studies do not find heterogeneity in tax-term elasticity among public firms, evidence from subsequent studies shows that small and private firms are most responsive to these policies.

Recent empirical literature has utilized firm-level data and state-level policy compliance and found substantial heterogeneity in investment response. Zwick and Mahon (2017) is the first empirical research that exploits business tax data from the IRS to estimate the heterogeneity of investment response to the tax credit. They examine the impact of bonus depreciation by comparing industries that use long duration of capital to industries that use short duration. They found that bonus depreciation increases the investment of eligible capital by 10 to 16 percent compared to ineligible capital. Also, small firms respond 95 percent more than big firms. Ohrn (2018) further investigates the effect of corporate tax deductions and concludes that the investment raises by 4.7 percent for those states that comply with federal policies. In a subsequent study, Ohrn (2019) identifies potential conflicts between bonus depreciation and Section 179 deduction as mentioned before. These heterogeneous responses from small and young firms are the calibration targets for my model.

Theoretical exploration of response to fiscal policy has been studied through the representative firm models. Fernández-Villaverde (2010) build a dynamic stochastic general equilibrium (DSGE) model with representative firm and financial constraints to analyze the response to fiscal shocks. Occhino (2022) analyzes the aggregate effects of tax cuts and jobs act without dealing with the heterogeneous response to tax credit nor exploring the distortion created by Section 179 deduction. Later, Occhino (2023) evaluates the effect of corporate tax cuts with accelerated depreciation and assumes the bonus depreciation rate is an AR(1) process. This assumption ignores the countercyclical nature of these policies and may be subject to underestimation of the policy reaction. This paper is to my knowledge the first to examine the effectiveness of both investment subsidy policies through the lens of a heterogeneous firm model with tax wedges and financial frictions.

The remainder of the paper proceeds as follows. Section 2 introduces the quantitative model, and Section 3 provides useful analysis for numerical calculation. Section 4 exhibits and discusses the calibration strategies. Section 5 presents the quantitative results and policy experiments, and Section 6 concludes.

2 Model Environment

Time is discrete and infinite. In my model economy, there are three main agents: firms, households, and government. A continuum of heterogeneous firms produces homogeneous output using predetermined capital stock and labor. Whenever they invest, they accumulate tax capital stock, which is the level of capital for tax deduction purposes. Firms' investment and bond decision is distorted by corporate taxes and collateral constraints. Households are identical and infinitely lived. They supply labor, pay labor tax, lend risk-free loans, and own the firms. The government collects labor tax from households to fund exogenous government spending while undertaking corporate tax from the firms and rebates it back to the household as a lump sum. The government imposes a lump-sum tax on households whenever implementing bonus depreciation and Section 179 deduction.

2.1 Firms

The production function is $y = z\varepsilon F(k, n)$, where $F(k, n) = k^{\alpha} n^{\nu}$ with $\alpha < 1$, $\nu < 1$, and $\alpha + \nu < 1$. The variable z denotes the exogenous TFP shocks that are common among firms, while ε is firm-specific productivity shocks. I assume that ε is a Markov chain, i.e., $\varepsilon \in \mathbf{E} \equiv \{\varepsilon_1, \ldots \varepsilon_{N_\varepsilon}\}$, where $\Pr(\varepsilon' = \varepsilon_j | \varepsilon = \varepsilon_i) = \pi^{\varepsilon}_{ij}$, and $\sum_{j=1}^{N_\varepsilon} \pi^{\varepsilon}_{ij} = 1$. Following Khan and Thomas (2013), I assume each firm faces exogenous exit shock $\pi_d \in (0, 1)$ to prevent all firms from accumulating sufficient resources, and none are financially constrained.

At the beginning of each period, a firm is defined by four states: (1) its predetermined capital stock $k \in \mathbf{K} \subset \mathbb{R}_+$, (2) its level of one-period bond $b \in \mathbf{B} \subset \mathbb{R}$ issued one period ahead, (3) its tax capital from investment $\psi \in \mathbf{\Psi} \subset \mathbb{R}_+$, and (4) its realized idiosyncratic productivity $\varepsilon \in \mathbf{E}$. The distribution of firms μ over $(k, b, \psi, \varepsilon)$ is defined on a Borel algebra $\mathcal{S} = \mathbf{K} \times \mathbf{B} \times \mathbf{\Psi} \times \mathbf{E}$. Given all individual states, the firm maximizes the expected discounted value function by choosing current employment level n, future capital stock k', and next-period debt level b'. For each unit of labor employed, the firm pays competitive wage $w(\mu)$, which depends on the distribution of the firms. The firm can issue one-period debt at a risk-free price q but subject to collateral constraint. The amount of newly-issued debt, b', shall not exceed θ fraction firm's future capital choice k', i.e., $b' \leq \theta k'$. The forward-looking nature of collateral constraints follows the specification as in Kiyotaki and Moore (1997).

The firm's capital decision, k', has two impacts on its value: production and tax deduction. The investment I is determined by the standard accumulation equation, $I = k' - (1-\delta)k$, where $\delta \in (0,1)$ is the depreciation rate of capital. As the investment corporate tax deduction only applies to equipment, I assume the firm's equipment-capital ratio is ω. Therefore, the firm gets ωI unit of deduction on taxable income for each unit of investment the firm undertakes. If the firm invests below or equal to the Section 179 threshold $\bar{I}$, i.e., $I \leq \bar{I}$, it gets the entirety of ωI deduction on taxable income at the year of investing. Otherwise, the firm gets ξ fraction of ωI tax deduction, where ξ is the bonus depreciation rate. The remaining tax deduction $(1-\xi)\omega I$ is added to the state ψ' following the law of motion

$$\psi' = (1-\delta^{\psi})\psi + (1-\xi)\omega I,$$

where δ^{ψ} is the tax depreciation rate. I assume $\delta^{\psi} > \delta$ to show the accelerated depreciation allowed by the government. For dis-investing firms, i.e., $I < 0$, their taxable income is going to increase due to the capital gain.

The government taxes the firms through corporate tax and rebates the revenue R back to households. The taxable income, $\mathcal{I}$, is defined as

$$\mathcal{I}(k',k,\psi) = \max\left\{z\varepsilon F(k,n) - wn - \mathcal{J}(k',k)\omega(k'-(1-\delta)k) - \delta^{\psi}\psi, 0\right\},$$

where $\mathcal{J}(k',k)$ is the indicator function with respect to Section 179 deduction $\bar{I}$. $\mathcal{J}(k,k) = 1$ if $I \leq \bar{I}$; $\mathcal{J}(k',k) = \xi$ if $I > \bar{I}$. The deduction from capital depreciation, $\mathcal{J}(k',k)\omega(k'-(1-\delta))k + \delta^{\psi}\psi$, alters the effective tax rate per unit of capital invested. In principle, the government does not subsidize firms when their taxable income is negative. When taxable income is nonpositive, i.e., $\mathcal{I}(k',k,\psi) \leq 0$, I derive the upper bound for k' choice such that firm is paying positive corporate tax,

$$k' < \bar{k}(k,\psi,\varepsilon) \equiv \frac{z\varepsilon f(k,n) - wn - \delta^{\psi}\psi}{\mathcal{J}(k',k)\omega} + (1-\delta)k.$$

Firms that invest higher than or equal to $\bar{k}$ are not paying corporate tax, and their capital and bond decisions are different from firms that pay corporate tax. The natural threshold $\bar{k}$ and the policy threshold $\bar{I}$ dissect the state space into three regions, as shown in figure 1. Solving $\bar{k} = (1-\delta)k + \bar{I}$ gives the intersection of two thresholds $\tilde{k}$,

$$\tilde{k} = \left(\frac{\delta^{\psi}\psi + \mathcal{J}(k',k)\omega\bar{I}}{A(w)z^{\frac{1}{1-\nu}}\varepsilon^{\frac{1}{1-\nu}}}\right)^{\frac{1-\nu}{\alpha}},$$

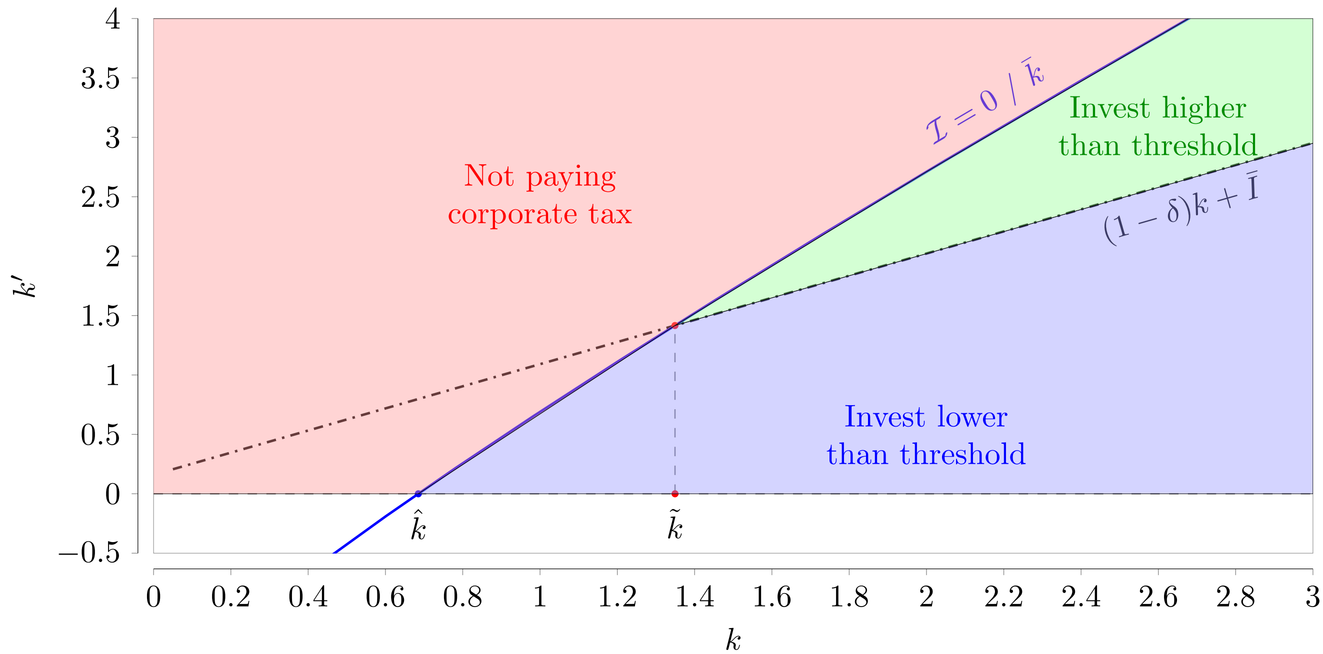


Figure 1: Capital choice state space

where $A(w) = \left[\left(\frac{\nu}{w(\mu)} \right)^{\frac{\nu}{1-\nu}} - w(\mu) \left(\frac{\nu}{w(\mu)} \right)^{\frac{\nu}{1-\nu}} \right]$. Firms with capital stock k lower than $\tilde{k}$ cannot choose to invest higher than threshold $\bar{I}$. Similarly, let $\hat{k}$ be the intersection between $\bar{k}$ and $k' = 0$. Firms with capital stock k lower than $\hat{k}$ cannot pay for corporate tax for all possible k' choices.

The firm's budget constraint under corporate tax is defined as

$$D = z\varepsilon F(k,n) - wn - b + qb' - (k' - (1-\delta)k) - \tau^c \mathcal{I}(k', k, \psi),$$

where τ^c is the corporate tax rate, and D is the dividend payment. When $\mathcal{I}(k', k, \psi)$ is positive, I combine the common terms and rewrite the budget constraint as

$$D = (1-\tau^c)(z\varepsilon F(k,n) - wn) - b + qb' - (1 - \tau^c \omega \mathcal{J}(k', k))(k' - (1-\delta)k) + \tau^c \delta^\psi \psi.$$

Notice that one unit of investment now costs $1 - \tau^c \omega \mathcal{J}(k', k)$ unit of final goods after deduction. Therefore, if the government decreases the corporate tax τ^c to zero, the model falls back to the ordinary business cycle model.

I now start to illustrate the problem solved by each firm in the model. Let $v^0(k, b, \psi, \varepsilon; \mu)$ denote the expected discounted value of a firm at the beginning of the period before the realization of the exogenous exit shock π_d. Upon exiting, the firm chooses labor demand n, sells capital, and repays debts. The function equations are defined as

$$
\begin{aligned}
v^0(k,b,\psi,\varepsilon;\mu) = \pi_d \max_n &\left\{ z\varepsilon F(k,n) - wn - b + (1-\delta)k - \tau^c \mathcal{I}(0,k,\psi) \right\} \\
&+ (1-\pi_d) v(k,b,\psi,\varepsilon;\mu)
\end{aligned} \tag{1}
$$

Conditional on survival, the continuation problem is stated as a discrete choice among three options,

$$
v(k,b,\psi,\varepsilon;\mu) = \max \left\{ v^H(k,b,\psi,\varepsilon;\mu), v^L(k,b,\psi,\varepsilon;\mu), v^N(k,b,\psi,\varepsilon;\mu) \right\}., \tag{2}
$$

where $v^L(k,b,\psi,\varepsilon;\mu)$ denotes the value to invest below threshold $\bar{I}$, $v^H(k,b,\psi,\varepsilon;\mu)$ represents the value to invest larger $\bar{I}$, and $v^N(k,b,\psi,\varepsilon;\mu)$ denotes the value if the firm is not paying tax.

In either case, the firm is maximizing the current dividend D and expected discounted future firm value. Let $Q(\mu)$ denote the stochastic discounting factor for firms' next-period value given the distribution μ. The dynamic problem for those firms that undertake investments larger than $\bar{I}$ is

$$
v^H(k,b,\psi,\varepsilon_i;\mu) = \max_{D,k',b',n} D + Q(\mu) \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} v^0(k',b',\psi',\varepsilon_j;\mu'), \tag{3}
$$

subject to

$$
\begin{aligned}
0 \le D = (1-\tau^c)&(z\varepsilon F(k,n) - wn) - b \\
&+ qb' - (1-\tau^c\omega\xi)(k' - (1-\delta)k) + \tau^c \delta^\psi \psi.
\end{aligned} \tag{4}
$$

$$
k' \in ((1-\delta)k + \bar{I}, \bar{k}) \text{ and } k > \hat{k} \tag{5}
$$

$$
b' \le \theta k' \tag{6}
$$

$$
\psi' = (1-\delta^\psi)\psi + (1-\xi)\omega(k' - (1-\delta)k) \tag{7}
$$

$$
\mu' = \Gamma(\mu) \tag{8}
$$

The counterpart for firms that undertake investment below the Section 179 deduction is

$$
v^L(k,b,\psi,\varepsilon_i;\mu) = \max_{D,k',b',n} D + Q(\mu) \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} v^0(k',b',\psi',\varepsilon_j;\mu'), \tag{9}
$$

subject to

$$
\begin{aligned}
0 \le D = (1-\tau^c)&(z\varepsilon F(k,n) - wn) - b \\
&+ qb' - (1-\tau^c\omega)(k' - (1-\delta)k) + \tau^c \delta^\psi \psi.
\end{aligned} \tag{10}
$$

$$k' < (1-\delta)k + \bar{I} \text{ and } k > \tilde{k} \tag{11}$$

$$b' \leq \theta k' \tag{12}$$

$$\psi' = (1-\delta^{\psi})\psi \tag{13}$$

$$\mu' = \Gamma(\mu) \tag{14}$$

If the firm has a nonpositive taxable income $\mathcal{I}(k', k, \psi)$ such that it is not paying corporate tax, then its capital decision is indirectly affected by the tax capital through the expected future value function.

$$v^N(k, b, \psi, \varepsilon_i; \mu) = \max_{D, k', b', n} D + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} V^0(k', b', \psi', \varepsilon_j; \mu'), \tag{15}$$

subject to

$$0 \leq D = z\varepsilon F(k, n) - wn - b + qb' - (k' - (1-\delta)k) \tag{16}$$

$$k' \geq \max(\bar{k}, 0) \tag{17}$$

$$b' \leq \theta k' \tag{18}$$

$$\psi' = (1-\delta^{\psi})\psi + (1 - \mathcal{J}(k', k))\omega(k' - (1-\delta)k) \tag{19}$$

$$\mu' = \Gamma(\mu) \tag{20}$$

Since there is no friction regarding the firm's employment decision, it pays the current wage bill after production, and the future capital decision does not affect current production. Therefore, the employment choice does not depend on the debt choice, remaining tax benefit, or continuation value. Denote the policy functions associate to firm's employment be $N(k, \varepsilon; \mu)$, capital be $K(k, b, \psi, \varepsilon; \mu)$, debt be $B(k, b, \psi, \varepsilon; \mu)$, dividend be $D(k, b, \psi, \varepsilon; \mu)$, and remaining tax benefit be $\Psi(\psi, K(k, b, \psi, \varepsilon; \mu), k; \mu)$. I characterize these policy functions in section 3.

2.2 Household

I assume there is a unit measure of identical households in the model. In each period, representative households maximize their lifetime utility by choosing consumption, c, labor supply, n^h, future firm shareholding, λ', and future bond holding, a':

$$
\begin{aligned}
V^h(\lambda, a; \mu) = \max_{c, n^h, a', \lambda'} & \left\{ u(c, 1-n^h) + \beta V^h(\lambda', a'; \mu') \right\} \\
\text{s.t.} \quad c + qa' + & \int \rho_1(k', b', \psi', \varepsilon') \lambda'(d[k' \times b' \times \psi' \times \varepsilon']) + T \qquad , \\
& \leq (1-\tau^n) w(\mu) n^h + a + \int \rho_0(k, b, \psi, \varepsilon) \lambda(d[k \times b \times \psi \times \varepsilon])
\end{aligned} \tag{21}
$$

where $\rho_0(k, b, \psi, \varepsilon)$ is the dividend-inclusive price of the current share, $\rho_1(k', b', \psi', \varepsilon')$ is the ex-dividend price of the future share, τ^n is the labor tax rate, and T is the lump-sum tax imposed by the government for policies change. I assume $T = 0$ in steady state. Let $C^h(\lambda, a; \mu)$ be the consumption demand function, and $N^h(\lambda, a; \mu)$ is the labor supply function. Similarly, let $A^h(\lambda, a; \mu)$ denote the households' decision for the bond, and $\Lambda(\lambda, a; \mu)$ is the choice of firm shares.

2.3 Government

In my model economy, the government collects corporate tax from firms and labor tax from households to fund exogenous government spending. The corporate tax revenue R is defined as

$$
\begin{aligned}
R = \int_{\mathcal{S}} \Bigg\{ & \tau^c \Big[z\varepsilon F(k, N(k, \varepsilon; \mu)) - w(\mu) N(k, \varepsilon; \mu) - \omega \mathcal{J}(K(k, b, \psi, \varepsilon; \mu), k) \\
& \times (K(k, b, \psi, \varepsilon; \mu) - (1-\delta)k) - \delta^\psi \psi \Big] \Bigg\} \mu(d[k \times b \times \psi \times \varepsilon]),
\end{aligned} \tag{22}
$$

The government balances its budget following the following formula,

$$
G = \tau^n w N^h(\lambda, a; \mu) + R + T, \tag{23}
$$

where T is the lump-sum tax on households to maintain the same level of government spending as in the baseline model. Notice that as firms face less corporate tax, they will hire more workers and raise wages, i.e., the labor tax revenue will increase. Therefore, the total cost of the policy, $\tilde{T}$, is the sum of two parts: the difference in labor tax revenue, and additional lump-sum tax,

$$
\tilde{T} = T + \tau^c \left(w N^h(\lambda, a; \mu) - w^* N^{h*}(\lambda, a; \mu) \right),
$$

where w^* is the wage in baseline model, while $N^{h*}(\cdot)$ is the employment. Another representation is the of $\tilde{T}$ is $R^* - R$, where R^* is the corporate tax revenue for baseline model. I normalize the cost of policies as zero in the baseline model.

2.4 Recursive Equilibrium

A *recursive competitive equilibrium* is a set of functions including prices $(p, w, q, \rho_0, \rho_1)$, quantities $\left(N, K, \Psi, B, D, C^h, N^h, A^h, \Lambda\right)$, a distribution $\mu(k, b, \psi, \varepsilon)$, and $\left(v^0, v^L, v^H, v, V^h\right)$ that solves firms' and households' optimization problems and clears the markets for assets, labor, and output in the following conditions.

1. v^0, v^L, v^H, and v solve (1), (2), (3), and (9). The associated policy functions for firms are (N, K, Ψ, B, D).
2. V^h solves (21), and the associated policy functions for households are (C^h, N^h, A^h, Λ)
3. Labor market clears, i.e., $N^h(\lambda, a; \mu) = \int_{\mathcal{S}} N(k, \varepsilon; \mu)\mu(d[k \times b \times \psi \times \varepsilon])$.
4. Goods market clears, i.e.,

$$\begin{aligned} C^h(\mu, a; \mu) = \int_{\mathcal{S}} \Big\{ & z\varepsilon F(k, N(k, \varepsilon; \mu) - wN(k, \varepsilon; \mu)) \\ & - (1 - \pi_d)\left[K(k, b, \psi, \varepsilon; \mu) - (1 - \delta)k\right] \\ & + \pi_d((1 - \delta)k - k_0) \Big\} \mu(d[k \times b \times \psi \times \varepsilon]) - G, \end{aligned}$$

   where k_0 is the capital endowment for entrants. I assume k_0 is a fixed fraction χ of the long-run aggregate capital stock,

$$k_0 = \chi \int k\tilde{\mu}(d[k \times b \times \psi \times \varepsilon]), \tag{24}$$

   where $\tilde{\mu}$ is the steady-state distribution.
5. Government uses labor tax to fund exogenous government spending G and imposes lump-sum tax T to fund policy changes.
6. The distribution of firms, $\mu(k, b, \psi, \varepsilon)$, is a fixed point of Γ function. $\Gamma(\mu)$ is consistent with policy functions (K, B, Ψ) and law of motion of ε.

3 Analysis

Before solving the recursive competitive equilibrium, I reformulate the firm's problem by exploiting the optimality conditions implied by the household's problem. In equilibrium, the wage w is pinned down by the marginal rate of substitution between consumption and leisure, that is,

$$w(\mu) = \frac{D_2 u(c, 1-n^h)}{(1-\tau^n) D_1 u(c, 1-n^h)}.$$

Similarly, the bond price q equals the inverse of the expected real interest rate. As there is no aggregate uncertainty in the economy, the expected real interest rate is $\frac{1}{\beta}$. The stochastic discounting factor $Q(\mu)$ equals to household's discounting factor,

$$Q(\mu) = \beta.$$

Without the loss of generality, I define $p(\mu)$ to be the marginal utility of consumption, $D_1 u(c, 1-n^h)$. The $p(\mu)$ represents the output price that is used to evaluate the firm's current dividend.

After incorporating the household's optimality condition into the prices that firms face, I define a new value V as the multiplication between $p(\mu)$ and v, and rewrite dynamic problem (1), (2), (3), and (9):

$$\begin{aligned} V^0(k, b, \psi, \varepsilon; \mu) = p(\mu)\pi_d \max_n \Big\{ z\varepsilon F(k, n) - wn - b + (1-\delta)k - \tau^c \mathcal{I}(0, k, \psi) \Big\} \\ + (1-\pi_d) v(k, b, \psi, \varepsilon; \mu) \end{aligned} \tag{25}$$

where

$$V(k, b, \psi, \varepsilon; \mu) = \max \Big\{ V^H(k, b, \psi, \varepsilon; \mu), V^L(k, b, \psi, \varepsilon; \mu), V^N(k, b, \psi, \varepsilon; \mu) \Big\}., \tag{26}$$

The dynamic problem for firms who invest larger than the Section 179 deduction is

$$V^H(k, b, \psi, \varepsilon_i; \mu) = \max_{D, k', b', n} p(\mu) D + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} V^0(k', b', \psi', \varepsilon_j; \mu'), \tag{27}$$

subject to constraints (4)-(8). The counterpart for firms that undertake investment below the Section 179 deduction is

$$V^L(k, b, \psi, \varepsilon_i; \mu) = \max_{D, k', b', n} p(\mu) D + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} V^0(k', b', \psi', \varepsilon_j; \mu'), \tag{28}$$

subject to constraints (10)-(14). Moreover, the value function for firms not paying corporate tax is

$$V^N(k,b,\psi,\varepsilon_i;\mu) = \max_{D,k',b',n} p(\mu)D + \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^{\varepsilon} V^0(k',b',\psi',\varepsilon_j;\mu') \tag{29}$$

subject to constraints (16)-(20).

I start my analysis by deriving the optimal labor choice $N(k,\varepsilon)$. Since there is no friction in the labor market, a firm's labor demand is independent of intertemporal choices. In other words, the optimal labor choice can be derived by solving $\pi(k,\varepsilon) \equiv \max_n z\varepsilon F(k,N(k,\varepsilon)) - wN(k,\varepsilon)$ and get

$$N(k,\varepsilon) = \left(\frac{\nu z \varepsilon k^{\alpha}}{w}\right)^{\frac{1}{1-\nu}}.$$

Thus, the flow profit $\pi(k,\varepsilon)$ is rewritten as

$$\pi(k,\varepsilon) = A(w) z^{\frac{1}{1-\nu}} \varepsilon^{\frac{1}{1-\nu}} k^{\frac{\alpha}{1-\nu}}, \tag{30}$$

where $A(w) = \left[\left(\frac{\nu}{w}\right)^{\frac{\nu}{1-\nu}} - w\left(\frac{\nu}{w}\right)^{\frac{1}{1-\nu}}\right]$.

To characterize a firm's intertemporal decision, I follow Khan and Thomas (2013) and Jo and Senga (2019) and separate firms into *unconstrained* and *constrained*. Unconstrained firms are those that have already accumulated enough financial savings such that the collateral constraints will never bind in all possible states. Thus, they are indifferent between paying dividends and financial savings. Following Khan and Thomas (2013), I resolve this indeterminacy by requiring unconstrained firms to adapt *minimum saving policy*, i.e., they prioritize dividend payment and accumulate the lowest financial saving b' to stay unconstrained.

Let W function be the value function for unconstrained firms. The start-of-period value before the realization of exit shocks, W^0, is

$$\begin{aligned} W^0(k,b,\psi,\varepsilon;\mu) = p(\mu)\pi_d \max_n \Big\{ z\varepsilon F(k,n) - wn - b + (1-\delta)k - \tau^c \mathcal{I}(0,k,\psi) \Big\} \\ + (1-\pi_d) W(k,b,\psi,\varepsilon;\mu). \end{aligned}$$

Upon survival, unconstrained firms undertake binary choice similar to (2),

$$W(k,b,\psi,\varepsilon;\mu) = \max \Big\{ W^H(k,b,\psi,\varepsilon;\mu), W^L(k,b,\psi,\varepsilon;\mu), W^N(k,b,\psi,\varepsilon;\mu) \Big\}.$$

As the capital decision of the unconstrained firm is orthogonal to its bond decision and the firm is indifferent about the bond choice, I express the firm's current value as $W(k,b,\psi,\varepsilon;\mu) = W(k,0,\psi,\varepsilon;\mu) - pb$ and the start-of-period value as $W^0(k,b,\psi,\varepsilon;\mu) = W^0(k,0,\psi,\varepsilon;\mu) - pb$.

Given these transformation, I rewrite (3), (9), and (15) as

$$\begin{aligned}
W^H(k,b,\psi,\varepsilon_i;\mu) &= p(1-\tau^c)\pi(k,\varepsilon) - pb + p(1-\tau^c\omega\xi)(1-\delta)k + \tau^c\delta^\psi\psi \\
&\quad + \max_{k'\in[(1-\delta)k+\bar{I},\bar{k})} \left\{ -p(1-\tau^c\omega\xi)k' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\}, \\
W^L(k,b,\psi,\varepsilon_i;\mu) &= p(1-\tau^c)\pi(k,\varepsilon) - pb + p(1-\tau^c\omega)(1-\delta)k + \tau^c\delta^\psi\psi \\
&\quad + \max_{k'\le\bar{I}+(1-\delta)k} \left\{ -p(1-\tau^c\omega)k' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\}, \\
W^N(k,b,\psi,\varepsilon_i;\mu) &= p\pi(k,\varepsilon) - pb + p(1-\delta)k \\
&\quad + \max_{k'\ge\max(\bar{k},0)} \left\{ -pk' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\},
\end{aligned}$$

where $\pi(k,\varepsilon)$ is defined by (30).

To search for the target capitals that solve the above two problems, it is necessary to find conditional expected start-of-period value function $W^0(k',0,\psi',\varepsilon_j;\mu)$. Yet, the future tax benefit ψ' is a function of current tax benefit ψ and current capital stock k. Therefore, all target capital are functions of k, ψ, and ε. To be specific, let $k_H^*(k,\psi,\varepsilon)$ denotes the target capital for firms invest higher than threshold, $k_L^*(k,\psi,\varepsilon)$ be that for firms invest lower than threshold, and $k_N^*(k,\psi,\varepsilon)$ be that for firms not paying corporate tax,

$$\begin{aligned}
k_H^*(k,\psi,\varepsilon) &= \arg\max_{k'\in[(1-\delta)k+\bar{I},\bar{k})} \left\{ -p(1-\tau^c\omega\xi)k' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\}, \\
k_L^*(k,\psi,\varepsilon) &= \arg\max_{k'\le(1-\delta)k+\bar{I}} \left\{ -p(1-\tau^c\omega)k' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\}. \\
k_N^*(k,\psi,\varepsilon) &= \arg\max_{k'\ge\max(\bar{k},0)} \left\{ -pk' + \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^\varepsilon W^0(k',0,\psi',\varepsilon_j;\mu') \right\}.
\end{aligned} \tag{31}$$

Thus, the capital decision rule for unconstrained firms, $K^w(k,\psi,\varepsilon)$, follows *(S, s)* policies,

$$K^w(k,\psi,\varepsilon)=\begin{cases} k_L^*(k,\psi,\varepsilon) & \text{if } k \geq \frac{k_L^*(k,\psi,\varepsilon)-\bar{I}}{1-\delta} \\ & \quad \text{and } W^L(\cdot)=\max\left\{W^H(\cdot),W^L(\cdot),W^N(\cdot)\right\} \\ (1-\delta)k+\bar{I} & \text{if } k < \frac{k_L^*(k,\psi,\varepsilon)-\bar{I}}{1-\delta} \\ & \quad \text{and } W^L(\cdot)=\max\left\{W^H(\cdot),W^L(\cdot),W^N(\cdot)\right\} \\ k_H^*(k,\psi,\varepsilon) & \text{if } k \in \left(\tilde{k}, \frac{k_H^*(k,\psi,\varepsilon)-\bar{I}}{1-\delta}\right] \\ & \quad \text{and } W^H(\cdot)=\max\left\{W^H(\cdot),W^L(\cdot),W^N(\cdot)\right\} \\ \bar{k} & \text{if } k \in \left(\frac{k_N^*(k,\psi,\varepsilon)-\bar{I}}{1-\delta}, \tilde{k}\right] \\ & \quad \text{and } W^N(\cdot)=\max\left\{W^H(\cdot),W^L(\cdot),W^N(\cdot)\right\} \\ k_N^*(k,\psi,\varepsilon) & \text{if } k < k_N^*(k,\psi,\varepsilon) \\ & \quad \text{and } W^N(\cdot)=\max\left\{W^H(\cdot),W^L(\cdot),W^N(\cdot)\right\} \end{cases}.$$

I follow two traditions to illustrate how policies affect firms' investment incentive: the user cost of capital from Jorgenson (1963), and q-theory approach from Summers, Bosworth, Tobin and White (1981). The user cost of capital is the rental rate in the frictionless market per period. The rental rate is observably equivalent to the price difference between purchasing capital at date t and resale it at date $t+1$ after discounting. Assume that a firm stay at type N across date t and $t+1$. This firm buys one unit of capital for 1, produces one unit of output, and can resale the remaining $1-\delta$ fraction at the same price with discounting, i.e.,

$$c^N = 1-\beta(1-\delta).$$

If this firm is L-type, then the cost and benefit of one unit of capital purchase is distorted by the corporate tax. It purchases one unit of capital costs $1-\tau^c\omega$, produces $1-\tau^c$ unit of output, and after-tax resale price of the capital is $(1-\tau^c\omega)\beta(1-\delta)$,

$$c^L = \frac{1-\tau^c\omega}{1-\tau^c}(1-\beta(1-\delta)).$$

For a H-type firm, the purchase of one unit of capital brings more taxable income deduction to date $t+1$ through the tax capital ψ. It acquires one unit of capital at cost $1-\tau^c\omega\xi$, produces $1-\tau^c$ unit of output, and the after-tax resale price is the same as L-type firms. However, as only ξ fraction of the tax benefit has been deducted, $1-\xi$ fraction of the remaining benefit is accumulated in the tax capital ψ as in (7). As a result, the firm gain additional $\beta\delta^{\psi}(1-\xi)\tau^c\omega$

amount of deduction on its taxable income at date $t+1$, and the corresponding user cost of capital is

$$c^H = \frac{1-\tau^c\omega\xi}{1-\tau^c} - \beta\delta^\psi(1-\xi)\frac{\tau^c\omega}{1-\tau^c} - \beta(1-\delta)\frac{1-\tau^c\omega}{1-\tau^c}.$$

When the bonus rate ξ increases, the current cost ("down payment") of capital $1-\tau^c\omega\xi$ is lower, while the benefit from future taxable income deduction is smaller. The shrink in current cost dominates, and c^H will be lower when the bonus rate ξ increases. As a result, raising the bonus rate will lead to a boost in investment for all firms. The story is the same in the case of raising Section 179 threshold $\bar{I}$, and this policy only applies to medium-sized firms experiencing a transition from H-type to L-type.

On the other hand, Tobin's q tradition indicates that large firms will aim for a lower efficiency unit of capital when raising either policy. To derive this result, let's ignore the discontinuity in the value function and focus on the case in which a firm remains H-type at the end of the period. One can derive the first-order derivative of this firm by the Benveniste-Scheinkman condition,

$$\frac{\partial W(k',0,\psi',\varepsilon_j;\mu')}{\partial\psi'} = \tau^c\delta^\psi > 0,$$

That is, firms' value function $W(k',0,\psi',\varepsilon_j;\mu')$ increases with the future tax capital ψ'. As bonus rate ξ increases, the accumulation of tax capital ψ stops, leading to lower firm value. From the solutions for target capital (31), firms aim for lower efficiency units of capital as their firm value decreases. This effect induces unconstrained firms to pay out more dividends, leading to an inefficient usage of taxpayers' money.

The *minimum saving policy*, $B^w(k,\psi,\varepsilon)$, can be recursively calculated by the following two equations with both policy functions for labor, $N(k,\varepsilon)$, and capital, $K^w(k,\psi,\varepsilon)$,

$$\begin{aligned}
B^w(k,\psi,\varepsilon) &= \min_{\varepsilon_j}\left(\tilde{B}(K^w(k,\psi,\varepsilon_i),\psi',\varepsilon_j)\right) \\
\tilde{B}(k,\psi,\varepsilon_i) &= (1-\tau^c)\pi(k,\varepsilon_i) + \tau^c\delta^\psi\psi \\
&\qquad - \left(1-\tau^c\omega\mathcal{J}\left(K^w(\cdot),k\right)\right)\left(K^w(k,\psi,\varepsilon_i)-(1-\delta)k\right) \\
&\qquad + q\min\left\{B^w(k,\psi,\varepsilon_i),\theta K^w(k,\psi,\varepsilon_i)\right\} \text{ if } \mathcal{I}(k',k,\psi)>0 \\
\tilde{B}(k,\psi,\varepsilon_i) &= \pi(k,\varepsilon_i) - \left(K^w(k,\psi,\varepsilon_i)-(1-\delta)k\right) \\
&\qquad + q\min\left\{B^w(k,\psi,\varepsilon_i),\theta K^w(k,\psi,\varepsilon_i)\right\} \text{ if } \mathcal{I}(k',k,\psi)\leq 0
\end{aligned}$$

where $\tilde{B}(k,\psi,\varepsilon)$ represents the minimum level of saving (negative debt) that an unconstrained firm needs to put aside to remain unconstrained given the realization of ε_j. $B^w(k,\psi,\varepsilon)$, therefore, is the minimum of $\tilde{B}(K^w(\cdot),\psi',\varepsilon_j)$ over all possible ε_j to guarantee the unconstrained status of the firm for all possible future. Notice that the accumulation of remaining tax benefit, ψ' enters this recursive definition, and thus firm's binary investment choice will affect the threshold that distinguishes constrained and unconstrained firms. The current dividend D^w that unconstrained firms pay is

$$\begin{aligned}
D^w(k,b,\psi,\varepsilon) = &(1-\tau^c)\pi(k,\varepsilon) + \tau^c\delta^\psi\psi \\
&- (1-\tau^c\omega\mathcal{J}(K^w(k,\psi,\varepsilon)-(1-\delta)k))(K^w(k,\psi,\varepsilon)-(1-\delta)k) \\
&- b + q\min\left\{B^w(k,\psi,\varepsilon), \theta K^w(k,\psi,\varepsilon)\right\} \text{ if } \mathcal{I}(k',k,\psi) > 0 \\
D^w(k,b,\psi,\varepsilon) = &\pi(k,\varepsilon) - (K^w(k,\psi,\varepsilon)-(1-\delta)k) \\
&- b + q\min\left\{B^w(k,\psi,\varepsilon), \theta K^w(k,\psi,\varepsilon)\right\} \text{ if } \mathcal{I}(k',k,\psi) \le 0
\end{aligned}$$

Constrained firms, on the other hand, are paying negative dividends $D^w(\cdot)$ if they are adopting both unconstrained capital and bond decision rules. Their bond decision is implied by binding collateral constraints, i.e., $B^c(k,b,\psi,\varepsilon) = \theta K^c(k,b,\psi,\varepsilon)$, and the capital decision $K^c(k,b,\psi,\varepsilon)$ has to be determined recursively. Let $J(k,b,\psi,\varepsilon;\mu)$ be the value function for constrained firms. They undertake the same binary choice between investing higher or lower than the Section 179 threshold:

$$J(k,b,\psi,\varepsilon;\mu) = \max\Big\{J^H(k,b,\psi,\varepsilon;\mu), J^L(k,b,\psi,\varepsilon;\mu), J^N(k,b,\psi,\varepsilon;\mu)\Big\},$$

where J^H, J^L and J^N are the value function for H-type, L-type, and N-type firms.

For firms that invest higher than the threshold, their value function after exogenous death shock is

$$\begin{aligned}
J^H(k,b,\psi,\varepsilon;\mu) = &\max_{k'\in\Omega_H(k,b,\psi,\varepsilon)} \beta\sum_{j=1}^{N_\varepsilon}\pi_{ij}^{\varepsilon}V^0(k',b_H(k'),\psi',\varepsilon_j;\mu'), \\
&\text{subject to} \\
&b_H(k') = \frac{1}{q}\Big(-(1-\tau^c)\pi(k,\varepsilon) + b - \tau^c\delta^\psi\psi + (1-\tau^c\omega\xi)(k'-(1-\delta)k)\Big), \\
&\psi' = (1-\delta^\psi)\psi + (1-\xi)(k'-(1-\delta)k),
\end{aligned} \tag{32}$$

The choice sets for H-type firms' problem are defined by

$$\Omega_H(k,b,\psi,\varepsilon) = \left[(1-\delta)k + \bar{I}, \min\left\{\bar{k}_H(k,b,\psi,\varepsilon), \bar{k}(k,\psi,\varepsilon), K^w(k,\psi,\varepsilon)\right\}\right],$$

where $\bar{k}_H$ is the maximum affordable capital with binding collateral constraints for H-type firms,

$$\bar{k}_H = \frac{(1-\tau^c)\pi(k,\varepsilon) - b + (1-\tau^c\omega)(1-\delta)k + \tau^c\delta^\psi\psi}{1-\tau^c\omega\xi - q\theta}$$

The Bellman equation for L-type firms is defined as

$$\begin{aligned} J^L(k,b,\psi,\varepsilon;\mu) &= \max_{k' \in \Omega_L(k,b,\psi,\varepsilon)} \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^\varepsilon V^0(k', b_L(k'), \psi', \varepsilon_j; \mu'), \\ &\text{subject to} \\ b_L(k') &= \frac{1}{q}\Big(-(1-\tau^c)\pi(k,\varepsilon) + b - \tau^c\delta^\psi\psi + (1-\tau^c\omega)(k' - (1-\delta)k)\Big), \\ \psi' &= (1-\delta^\psi)\psi. \end{aligned} \tag{33}$$

The choice set $\Omega_L(k,b,\psi,\varepsilon)$ is defined as

$$\Omega_L(k,b,\psi,\varepsilon) = \left[0, \max\left\{0, \min\left\{(1-\delta)k + \bar{I}, \bar{k}_L(k,b,\psi,\varepsilon), K^w(k,\psi,\varepsilon)\right\}\right\}\right],$$

while the maximum affordable capital is

$$\bar{k}_L = \frac{(1-\tau^c)\pi(k,\varepsilon) - b + (1-\tau^c\omega)(1-\delta)k + \tau^c\delta^\psi\psi}{1-\tau^c\omega - q\theta}.$$

Lastly, the value function iteration for N-type firms are

$$\begin{aligned} J^N(k,b,\psi,\varepsilon;\mu) &= \max_{k' \in \Omega_N(k,b,\psi,\varepsilon)} \beta \sum_{j=1}^{N_\varepsilon} \pi_{ij}^\varepsilon V^0(k', b_N(k'), \psi', \varepsilon_j; \mu'), \\ &\text{subject to} \\ b_N(k') &= \frac{1}{q}\Big(-\pi(k,\varepsilon) + b + (k' - (1-\delta)k)\Big), \\ \psi' &= (1-\delta^\psi)\psi + (1-\mathcal{J}(k',k))\omega(k' - (1-\delta)k), \end{aligned} \tag{34}$$

The choice set $\Omega_N(k,b,\psi,\varepsilon)$ is defined as

$$\Omega_N(k,b,\psi,\varepsilon) = \left[0, \min\left\{\bar{k}_N, \max\left\{\bar{k}, 0\right\}, K^w(k,\psi,\varepsilon)\right\}\right]$$

while the maximum affordable capital is

$$\bar{k}_N = \frac{\pi(k,\varepsilon) - b + (1-\delta)k}{1-q\theta}.$$

Let the capital stock solving (33), (33), and (34) be $\hat{k}_H(k,b,\psi,\varepsilon)$, $\hat{k}_L(k,b,\psi,\varepsilon)$, and $\hat{k}_N(k,b,\psi,\varepsilon)$. The constrained firms' decision rules on capital and bonds are

$$K^c(k,b,\psi,\varepsilon) = \begin{cases} \hat{k}_H(k,b,\psi,\varepsilon) & \text{if } J(\cdot) = J^H(\cdot) \text{ and } k > \tilde{k} \\ \hat{k}_L(k,b,\psi,\varepsilon) & \text{if } J(\cdot) = J^L(\cdot) \text{ and } k > \hat{k} \\ \hat{k}_N(k,b,\psi,\varepsilon) & \text{if } J(\cdot) = J^N(\cdot) \end{cases} \tag{35}$$

4 Calibration

Table 1 lists the parameter set obtained from calibration and exogenous sources, and Table 2 summarizes the calibrated moments. The total factor productivity z is set to 1 in the steady state. I set the length of the period to one year to match the establishment-level investment data. The functional form of the representative household's utility is assumed to be $u(c,l) = \log c + \varphi l$, following Rogerson (1988). I assume Cobb-Douglas production function, $z\varepsilon F(k,n) = z\varepsilon k^{\alpha} n^{\nu}$. The initial capital k_0 is defined as a fraction of steady-state aggregate capital, as specified in (24). Both initial bond level b_0 and initial tax capital ψ_0 are set to zero. The household's discount rate β is set to imply 4 percent of the annual interest rate. The disutility from working, φ, is determined to reproduce hours of work equal to one-third. The rate of capital depreciation, δ, corresponds to an investment-capital ratio of approximately 6.9 percent. The labor share ν is 60 percent, as shown in US postwar data.

I choose three parameters, ρ_ε, $\sigma_{\eta_\varepsilon}$, and ω to match the investment rate distribution in Cooper and Haltiwanger (2006). I assume the idiosyncratic productivity shock ε follows log AR(1) process with persistence ρ_ε and standard deviation $\sigma_{\eta_\varepsilon}$. The evolution of ε is $\log \varepsilon' = \rho_\varepsilon \log \varepsilon + \eta'_\varepsilon$, with $\eta'_\varepsilon \sim N(0, \sigma^2_{\eta_\varepsilon})$. Given the value specified in table 1, I use Tauchen (1986) method to discretize the firm's log-normal idiosyncratic productivity process with 7 values ($N_\varepsilon = 7$) to obtain $\{\varepsilon_j\}_{j=1}^{N_\varepsilon}$ and $(\pi^\varepsilon_{ij})_{i,j=1}^{N_\varepsilon}$. However, it is impossible to match the persistence of the investment rate distribution without the potential loss created by the tax wedge when a firm is downsizing. In this model, such loss is illustrated by the increment of taxable income when firms disinvest, and the equipment-capital ratio ω governs the relative scales between the cost of purchasing and selling capital.

I calibrate the value of two policy tools, ξ and $\bar{I}$, to the 2015 level of bonus rate and Section 179 threshold. In 2015, the bonus rate is 0.5, i.e., $\xi = 0.5$. In the same year, the Section 179 threshold is \$500,000. To find the model counterpart of the Section 179 threshold, I calculate the average investment in 2015 using data from the Bureau of Economic Analysis and Statistics of U.S. Businesses. The investment in 2015 from BEA Table 3.7 is 2459.8 billion. Meanwhile, there are 5,900,731 firms in the US. This gives me an average investment of \$416,853. As the threshold is \$500,000, I calibrate the value of $\bar{I}$ using the same proportionality between aggregate investment generated by the model and average investment in the data. To be specific, I calculate $\bar{I} = 0.092 = (500,000/416,853)$ times aggregate investment from the model.

Table 1: Parameters for quantitative model

	Parameter	Value	Reason
Calibrated parameters			
Discount rate	β	0.96	4% real interest rate
Capital share	α	0.3	private capital-output ratio
Labor share	ν	0.6	labor share
Labor tax rate	τ^n	0.25	government spending-output ratio
Preference for leisure	φ	2.05	one-third of time endowment
Capital depreciation rate	δ	0.069	average investment-equipment ratio
Collateralizability	θ	0.54	debt-to-capital ratio
Credit crunch	θ_l	0.3942	26% decrease in debt
Persistence of ε	ρ_ε	0.6	investment distribution moments
Standard deviation of ε	$\sigma_{\eta_\varepsilon}$	0.113	investment distribution moments
Equipment-capital ratio	ω	0.6	investment distribution moments
Exogenous parameters			
fraction of entrants capital endowment	χ	0.1	10% of aggregate capital
exogenous exit rate	π_d	0.1	10% entry and exit
Corporate tax rate	τ^c	0.21	US Tax schedule after TCJA
Tax benefit depreciation rate	δ^ψ	0.138	$\delta^\psi = 2\delta$ (Double-declining balance)
Bonus depreciation rate in baseline	ξ	0.5	2015 bonus rate
Section 179 threshold	$\bar{I}$	0.092	2015 threshold model counterpart

5 Results and Policy Experiments

5.1 Steady state

Figure 2 presents the stationary distribution in my model over capital and leverage levels at the maximum productivity. I collapse this distribution by summing over the tax capital state variable. This figure effectively displays two distributions, the constrained firms' distribution in color green, and the unconstrained firms' distribution in color red. The highest spikes in the constrained firms' distribution represent 10 percent of entering firms, with zero debt and initial capital at k_0. The spike of mass gradually decreases as the capital stock increases, indicating how the forward-looking collateral constraints limit firms' capability to accumulate

Table 2: Calibrated moments

Parameter	Target		Model
$\beta = 0.96$	real interest rate	$= 0.04$	0.04
$\alpha = 0.3$	private capital-output ratio	$= 2.3$	2.03
$\nu = 0.6$	labor share	$= 0.6$	0.6
$\tau^n = 0.25$	government spending-output ratio	$= 0.21$	0.201
$\delta = 0.069$	average investment-capital ratio	$= 0.069$	0.069
$\varphi = 2.05$	hours worked	$= 0.33$	0.33
$\theta = 0.54$	debt-to-assets ratio	$= 0.37$	0.371
$\theta_l = 0.3942$	decreases in debt	$= 0.26$	0.257
$\rho_\varepsilon = 0.6$	std. investment rate distribution	$= 0.337$	0.300
$\sigma_\varepsilon = 0.1$	corr. investment rate distribution	$= 0.058$	0.050
$\omega = 0.6$	lumpy investment $> 20\%$	$= 0.186$	0.185

their capital. Once a firm becomes unconstrained, it follows the minimum saving policy implied by the unconstrained level of capital. What's different from the standard model is that there is a small mass of firms that are holding high levels of leverage and capital simultaneously. This qualitatively matches the empirical fact from Compustat that firms' leverage is increasing with its size (Chatterjee and Eyigungor, 2023).

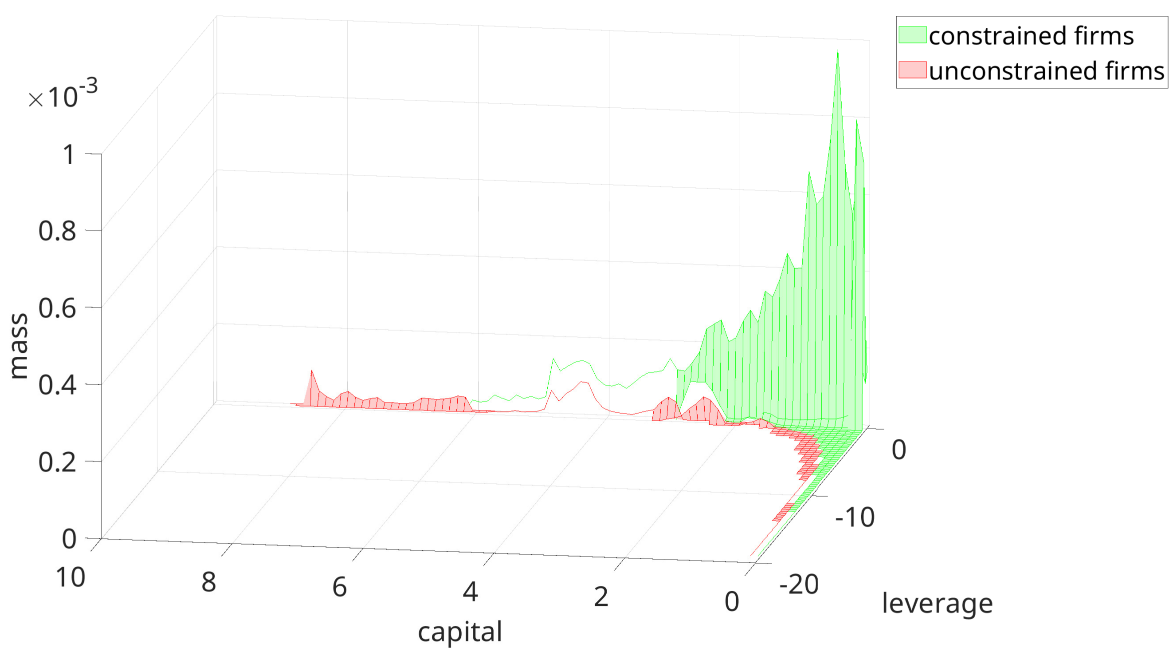
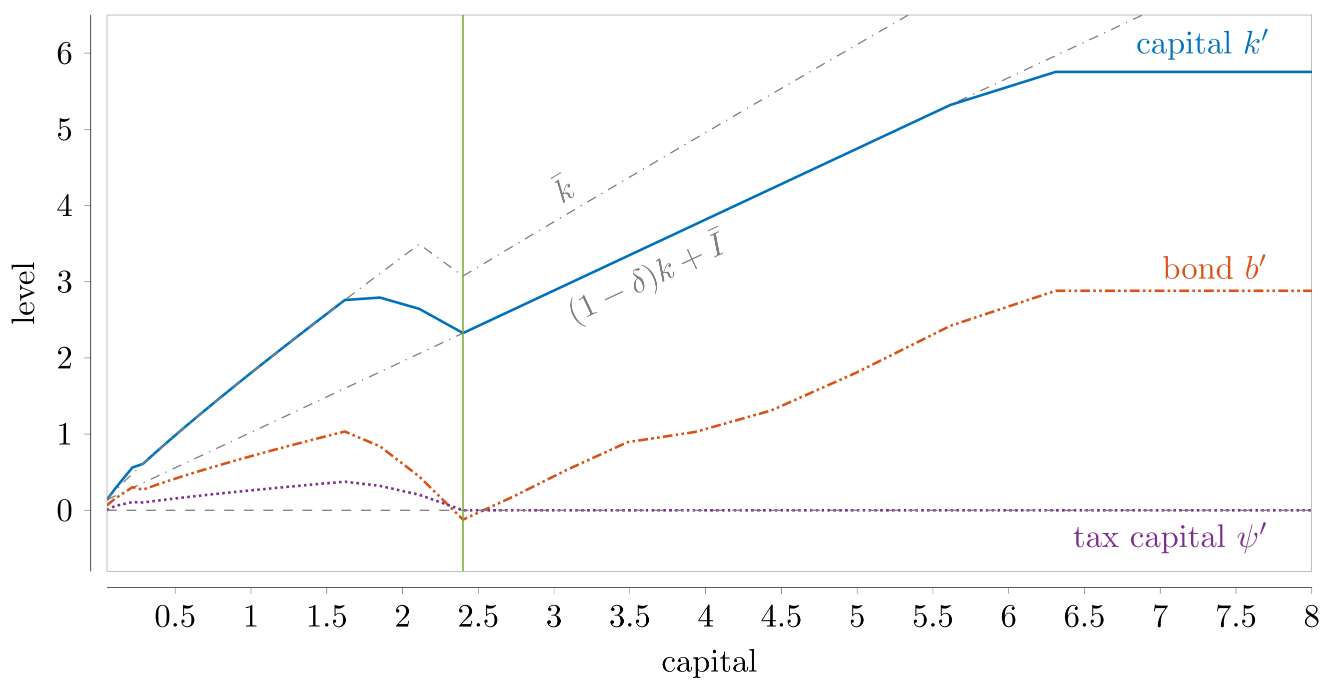


Figure 2: Distribution: maximum productivity

To illustrate this property on firm distribution more clearly, figure 3 presents policy functions on capital k', tax capital ψ', and bond b' across capital stock for high level of idiosyncratic productivity ε. Three investment options, L, H and N, are characterized by two boundaries: Section 179 threshold $\bar{I}$ and upper bound for taxable income $\bar{k}$. The green vertical line denotes the boundary between constrained (left) and unconstrained (right). When productive firms are constrained and do not pay corporate tax, they borrow debt to accumulate both their capital and tax capital stock. As return on investment comes in both ways, N-type firms quickly reach $k^*_N(k, \psi, \varepsilon)$ and gradually repay their debt ($b > 0$), eventually holding financial savings ($b < 0$). Once they become imperious to financial frictions, the existence of Section 179 threshold induces them to raise debt to invest up to $\bar{I}$, since their flow return on investment, i.e., EBITDA $z\varepsilon f(k, n) - wn$, has to be taxed, while the current cost of investment has dropped from 1 to $1 - \tau^c\omega$ unit of final goods. The distortion in flow return and current cost incentivizes firms to utilize their financial saving to undertake investments to compensate for the loss from EBITDA. Eventually, the largest firms voluntarily hold high levels of capital stock and debt, as seen in Compustat data.

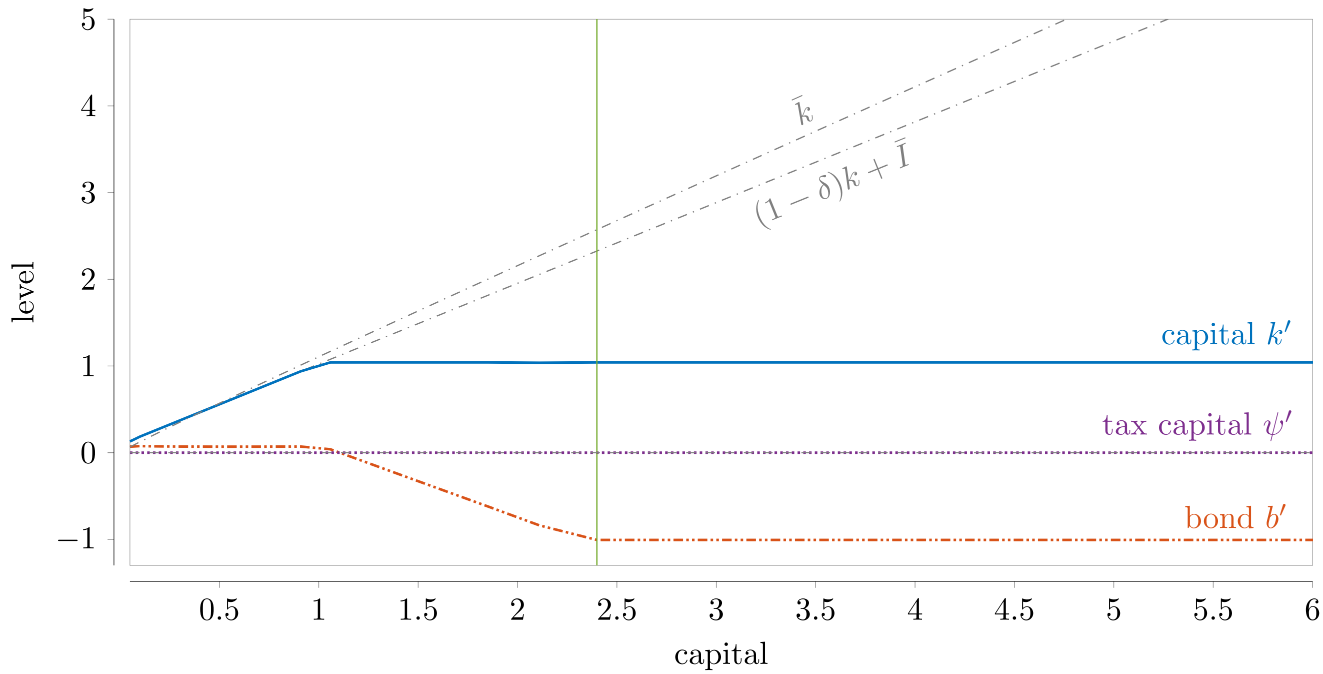
Figure 3: Firm decision rules with high productivity ($\varepsilon = 1.1289$)



Note: Decision rules are plotted given zero current bond and zero current tax capital stock.

On the other hand, unproductive firms' behavior is similar to the standard model, as shown in figure 4. As their target capital is low, they maintain the same level of debt instead of raising it. Once they reach the target capital, they start to deleverage, eventually becoming unconstrained firms. The comparison elucidates how productivity dictates firms' exposure to distortion generated by corporate taxation.

Figure 4: Firm decision rules with low productivity ($\varepsilon = 0.7847$)



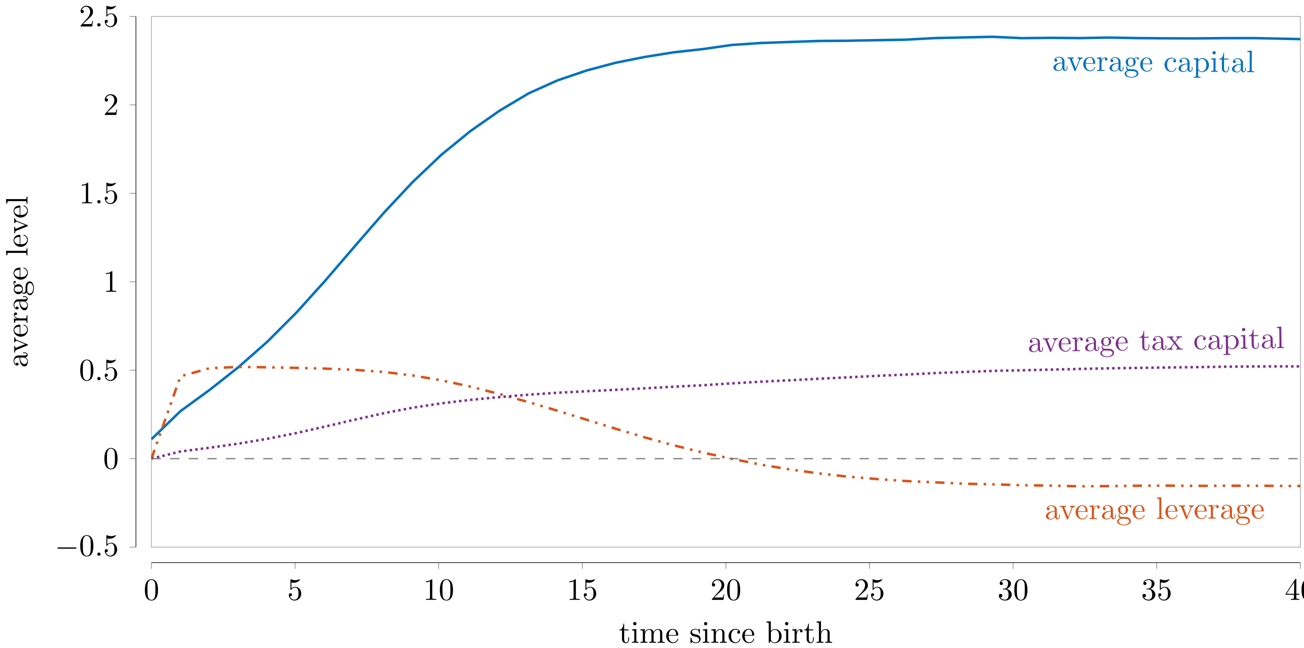
Note: Decision rules are plotted given zero current bond and zero current tax capital stock.

The difference in decision rules for firms with different productivity leads to a long-term impact in terms of firms' life cycle. Figure 5 displays the average capital and leverage choices for a cohort of 50,000 firms over 100 periods without the exogenous entry and exit. On average, firms raise capital, tax capital, and debt for the first 3 periods of their life. Thereafter, firms reduce their debt to finance the accumulation of capital and tax capital with their retained earnings from period 7. However, the average firm cannot completely deleverage until period 20, as some high-productivity firms start to borrow once they become unconstrained.

I conduct three policy experiments to evaluate the effectiveness of both policy tools. I set the value of both policy tools such that the implied cost of policy $\tilde{T}$ to fund either policy is 0.3 percent of baseline output. This gives me $\bar{I} = 0.292$ and $\xi = 0.69$. Table 3 summarized the result across four steady states: baseline, raising Section 179 threshold $\bar{I}$, raising bonus rate ξ, and implementing both policies.

By comparing three policy experiments with the baseline model, I reach two conclusions. First, all experiments show a positive impact on aggregate output, consumption, capital, and investment, yet raising the Section 179 threshold is the effective The output and consumption are increased by 1.61 and 1.55 percent to the increment of the threshold. Meanwhile, raising the

Figure 5: Cohort in steady state



bonus rate only delivers 1.06 and 0.92 percent boost in output and consumption, respectively. When both policies are implemented, the boost in output and consumption is 2.00 and 1.91 percent, smaller than the effect of individual policies combined. Given that the combined implementation of both policies equaled 0.41 percent of baseline output, I assessed their efficiency by dividing the resulting increase in output by the total policy cost. For every dollar of taxpayer money spent, raising the Section 179 threshold increases GDP by $5.40, while implementing both policies yields a smaller increase of $4.74. This replicates the empirical findings in Ohrn (2019) that raising one policy erodes the effectiveness of the other.

Second, government spending that does not contribute to aggregate outcomes eventually goes to dividend payment and stock market performance. Table 3 shows that both aggregate dividend and average firm value increase in all three experiments, but the increment is the highest when raising the bonus rate. Raising the bonus rate leads to 8.98 percent more dividend payment than the baseline model, while that number is merely 0.74 percent when the government increases the Section 179 threshold. Moreover, implementing both policies results in 12 percent more dividend payment than the baseline model. This comes from the untargeted nature of raising the bonus rate. As existing unconstrained firms enjoy the lower user cost of capital, it is easier for them to achieve corresponding target capital and utilize the remaining cash in dividend payments. As a result, such endogenous interaction between firms' financial position and investment decisions works against the policy goal of boosting the economy.

Table 3: Aggregate results from policy experiments

	Description	baseline	S179	bonus	both
Aggregates					
$\tilde{T}/Y$	cost of policy / baseline output	-	0.30	0.31	0.42
Y	aggregate output	100 (0.54)	101.61	101.06	102.00
C	aggregate consumption	100 (0.36)	101.55	100.92	101.91
K	aggregate capital	100 (1.10)	104.22	103.21	105.30
I	aggregate investment	100 (0.08)	104.22	103.21	105.30
N	aggregate labor	100 (0.33)	100.06	100.13	100.09
$B > 0$	aggregate debt	100 (0.41)	106.35	113.01	112.48
R	corporate tax revenue	100 (0.03)	94.25	94.08	91.89
$\hat{z}$	measured TFP	100 (1.02)	100.32	100.02	100.38
$dY/\tilde{T}$		-	5.40	3.44	4.74
$dC/\tilde{T}$		-	3.42	1.98	2.98
$dI/\tilde{T}$		-	1.98	1.46	1.76
Prices					
p	marginal utility of consumption	100 (2.80)	98.47	99.08	98.13
w	wage	100 (0.97)	101.55	100.92	101.91
Distribution					
μ_{unc}	unconstrained firm mass	0.080	0.093	0.099	0.129
μ_{con}	constrained firm mass	0.920	0.907	0.901	0.871
$\mu_{\text{unc}}K$	capital: unconstrained	100 (2.70)	94.31	99.78	92.51
$\mu_{\text{con}}K$	capital: constrained	100 (0.96)	104.36	100.39	100.03
$\mu_{\text{unc}}I$	investment: unconstrained	100 (0.01)	170.53	7.04	102.47
$\mu_{\text{con}}I$	investment: constrained	100 (0.18)	102.29	106.01	105.38
Financial Variables					
D	dividend	100 (0.03)	102.08	110.14	115.64
$\mu V(\cdot)$	average firm value	100 (3.41)	98.02	94.13	95.35
μc	user cost of capital	100 (0.14)	86.26	97.44	85.45
τ^*	effective corporate tax rate	100 (0.10)	92.43	94.08	91.68

Notes: values in parenthesis are expressed as a percentage of the baseline value. Baseline model: $(\bar{I}, \xi) = (0.092, 0.5)$. S179 model: $(\bar{I}, \xi) = (0.292, 0.5)$. Bonus model: $(\bar{I}, \xi) = (0.092, 0.69)$. Both model: $(\bar{I}, \xi) = (0.292, 0.69)$.

5.2 Perfect Foresight Transition

I next consider the business cycles in my model. I solve the perfect foresight transition of this model up to period $\bar{T}$ against the TFP and credit shocks. During the experiments, I fix the government spending $\{G_t\}_{t=1}^{\bar{T}}$ as the baseline model, and derive the cost of policies $\{\tilde{T}_t\}_{t=1}^{\bar{T}}$ for certain experiment as the sum of labor tax revenue changes and lump-sum tax. Figure 6 plots dynamics of aggregate variables following a 2.18 percent drop in TFP with persistence 0.909. I chose the size of the shock to match the observed decline in measured TFP in the US from 2007 to 2009. The response from the baseline model is similar to the canonical business cycle model[3]. I implement all policy experiments at period 1 with the same value in Section 5.1. In empirical literature[4], firms' investments respond to the immediate realization of tax benefits rather than potential future tax deductions. In my model, a temporary boost in either Section 179 deduction or bonus depreciation only generates a spike in investment response at the year of policy implementation. However, as capital is a slow-moving object, such a temporary incentive mitigates the initial drop in capital, leading to a different trajectory compared with the baseline model.

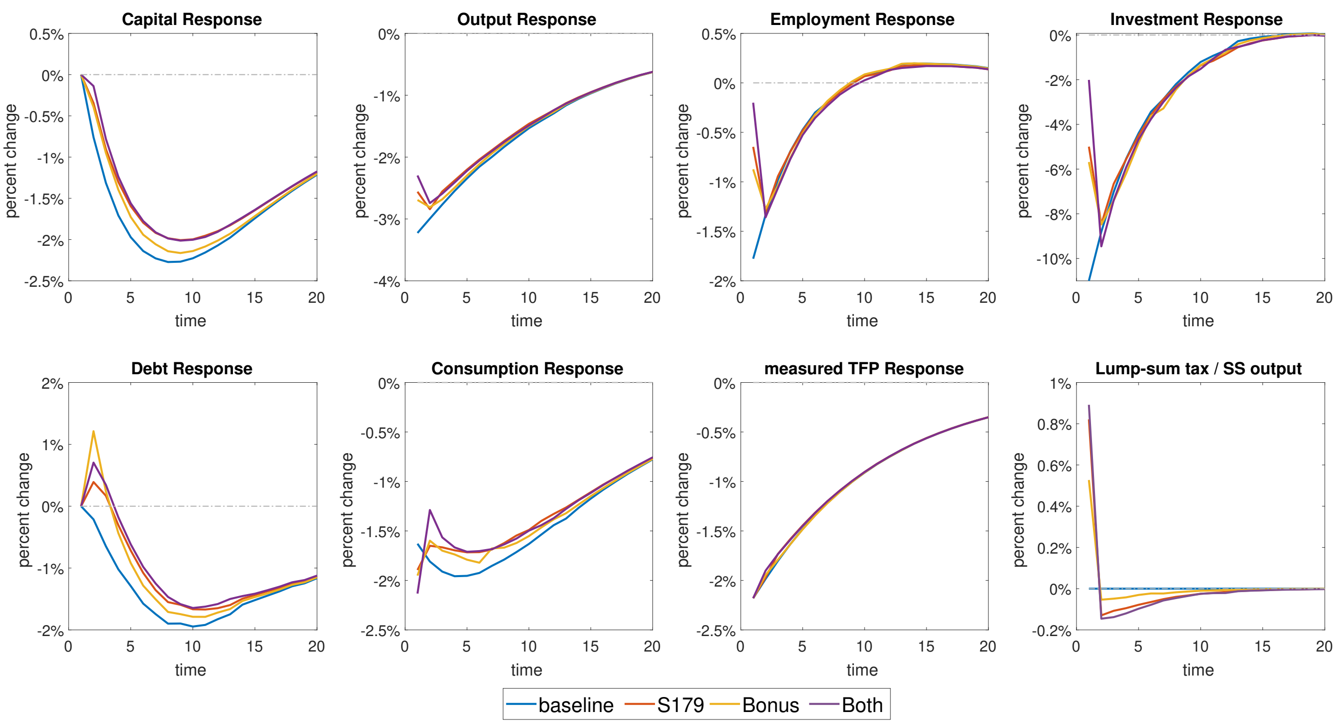
This figure shows that the Section 179 threshold dominates bonus depreciation in its effectiveness of mitigating troughs during the recession. Such subsidy also encourages firms to raise their debt at the first few periods to undertake investment, rather than pay out as dividends. As a result, the trajectory of capital is much higher in the S179 model (*orange line*) than in the Bonus model (*yellow line*), leading to a boost in output, employment, and consumption. This boost in output also allows the government to repay the lump-sum tax. Implementation of both policies (*purple line*) resulted in an initial surge exceeding the S179 model, but this effect rapidly diminished, converging with the S179 trajectory in capital, output, and consumption.

This pattern persists in policy response persist in credit shock. I define the credit shock as the drop of the credit parameter θ in the collateral constraint. The scale is set to 27 percent to replicate a 26 percent decrease in debt. The timing of the policy is set at period 4 to mimic the timing of both raising bonus depreciation and Section 179 threshold in 2010 while is recession started in late 2007. Figure 7 demonstrates the capability of Section 179 policy in terms of mitigating capital misallocation through the endogenous TFP channel. To avoid the anticipation effect, firms in figure 7 are not aware that the policies will be implemented at period 4 when they are in the first three periods. Among all three experiments, the S179 model has the lowest cost of the policy and the highest mitigating effect against recession. We can see a hump in measured TFP around period 6, indicating the disparity between exogenous TFP and endogenous TFP has been alleviated by the S179 policy.

[3]See Hansen (1985), Khan and Thomas (2013)

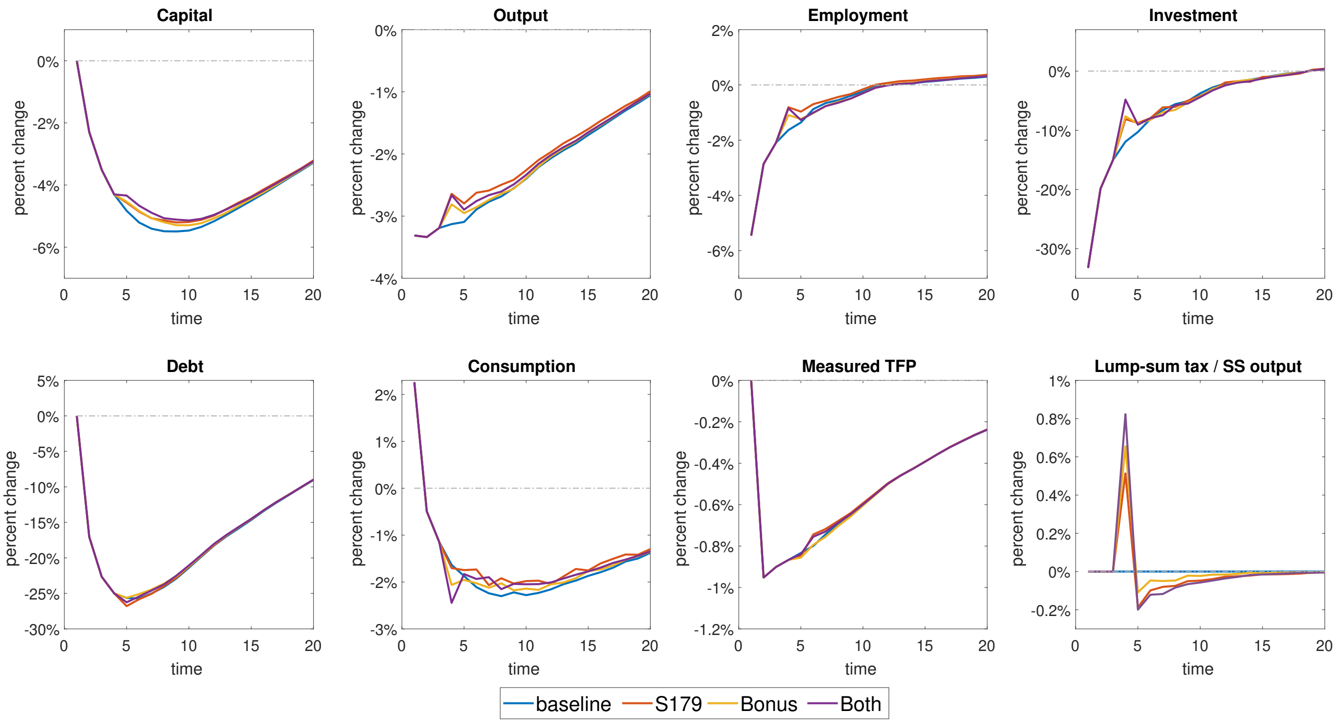
[4]House and Shapiro (2008) and Zwick and Mahon (2017)

Figure 6: Impulse Response to 2.18 percent drop in total factor productivity with persistent 0.909



Notes: Three policy experiments are implemented at period 1. Starting from period 2, the policy tools fall back to baseline value. Baseline model: $(\bar{I}, \xi) = (0.092, 0.5)$. S179 model: $(\bar{I}, \xi) = (0.292, 0.5)$ Bonus model: $(\bar{I}, \xi) = (0.092, 0.69)$. Both model: $(\bar{I}, \xi) = (0.292, 0.69)$.

Figure 7: Impulse Response to 27 percent drop in credit parameter with persistent 0.909



Notes: Three policy experiments are implemented at period 4. Starting from period 5, the policy tools fall back to the baseline value. Baseline model: $(\bar{I}, \xi) = (0.092, 0.5)$. S179 model: $(\bar{I}, \xi) = (0.292, 0.5)$ Bonus model: $(\bar{I}, \xi) = (0.092, 0.69)$. Both model: $(\bar{I}, \xi) = (0.292, 0.69)$.

6 Concluding Remarks

I have developed a general equilibrium model with heterogeneous firms and collateral constraints to evaluate the efficacy of investment subsidy policies. I have calibrated the model to match the aggregate moments and micro-level data on investment and finance. My model economy generates a positive size-leverage relationship and investment rate distribution documented in the empirical literature.

Different from ordinary policies, both investment subsidy policies, the Section 179 deduction, and bonus depreciation, are implemented in the form of corporate taxable income deductions in the United States. Bonus depreciation ensures all firms can enjoy a lower user cost of capital, while the effect from tax capital lowers the investment incentive of unconstrained firms and motivates them to increase dividend payment, leading to inefficient usage of taxpayers' money. On the other hand, Section 179 deduction facilitates firms on the margin to outgrow their financial constraints without any countering forces. In equilibrium, the bonus depreciation leads to high dividend payments, and thus the Section 179 deduction is a more effective policy per unit of government spending forgone.

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A Additional figures

Figure 8: Section 179 Deduction Limits and Bonus Depreciation Rates (2000-2024)

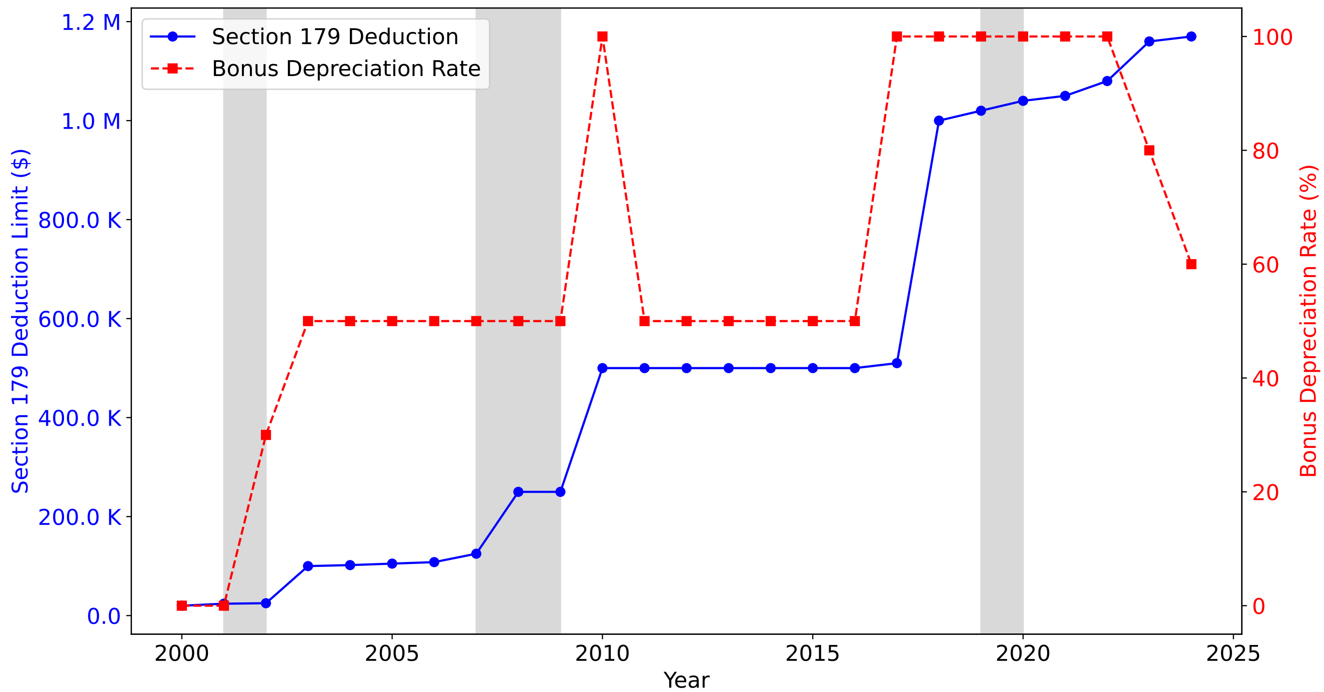
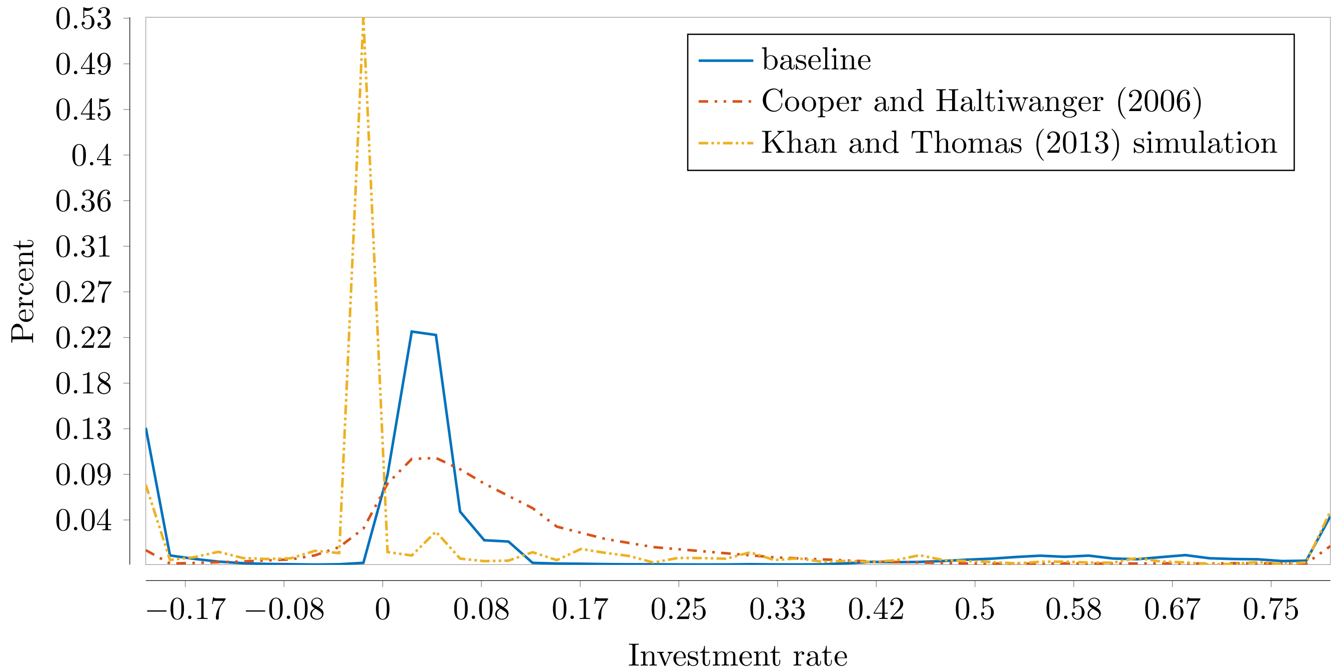
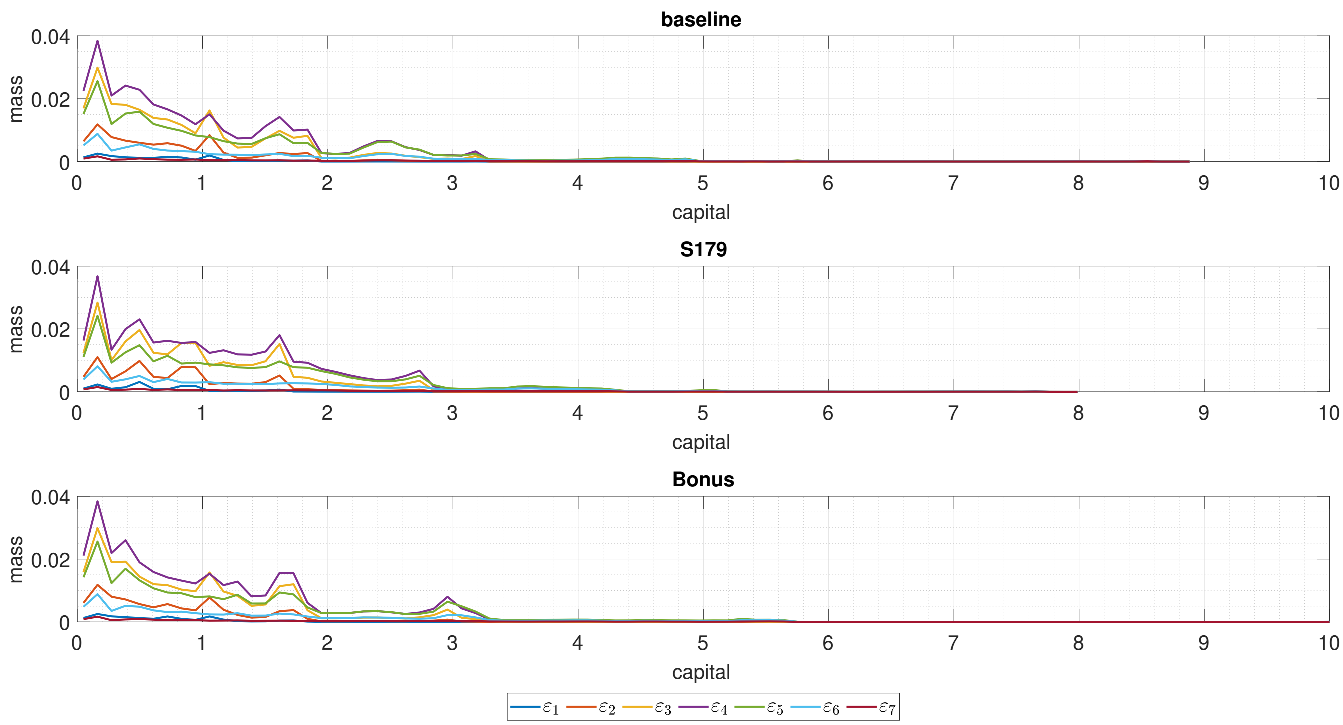


Figure 9: Investment rate distribution



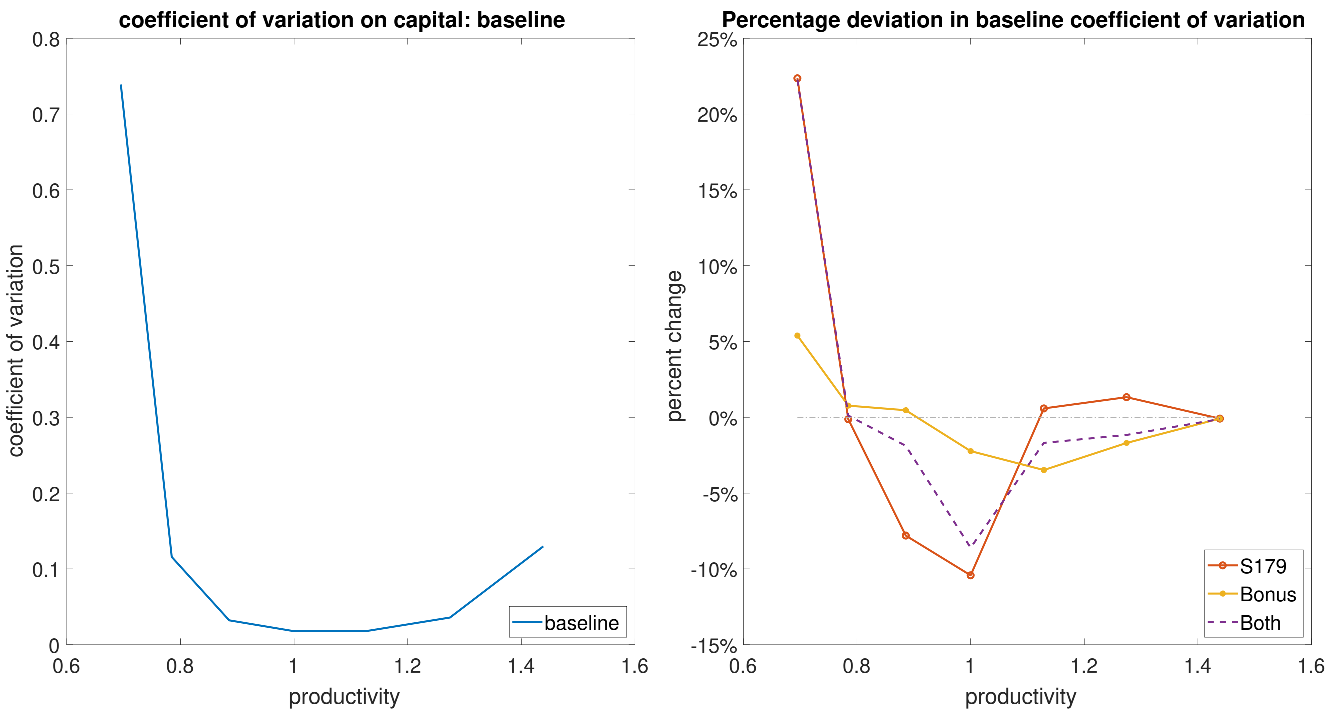
Note: This figure shows the investment rate distribution of baseline model, author's replication of Khan and Thomas (2013), and the empirical dataset from Cooper and Haltiwanger (2006). Both models are generated by simulating 50, 000 unconstrained firms over 100 periods to create a comparable dataset to that in Cooper and Haltiwanger (2006).

Figure 10: Effect of policies on distribution



Note: This figure shows how policies affects the shape of distribution. Compared with baseline model, the S179 model shows a concentration of distribution around median level of capital, while Bonus model represents the opposite. This can also be seen at the tail of the distribution, where S179 model has the shortest right tail, yet Bonus model has the longest.

Figure 11: Coefficient of variation across productivity



Note: The left panel shows the coefficient of variation in baseline model. The right panel shows the percentage deviation of the coefficient of variation in S179, Bonus, and Both model.

Figure 12: Distribution: median productivity