Université de Montréal

Essays on the Effects of Corporate Taxation

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À mes parents Joséphine et Séverin Gbohoui

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Résumé

Cette thèse est une collection de trois articles en macroéconomie et finances publiques. Elle développe des modèles d'Equilibre Général Dynamique et Stochastique pour analyser les implications macroéconomiques des politiques d'imposition des entreprises en présence de marchés financiers imparfaits.

Le premier chapitre analyse les mécanismes de transmission à l'économie, des effets d'un ré-échelonnement de l'impôt sur le profit des entreprises. Dans une économie constituée d'un gouvernement, d'une firme représentative et d'un ménage représentatif, j'élabore un théorème de l'équivalence ricardienne avec l'impôt sur le profit des entreprises. Plus particulièrement, j'établis que si les marchés financiers sont parfaits, un ré-échelonnement de l'impôt sur le profit des entreprises qui ne change pas la valeur présente de l'impôt total auquel l'entreprise est assujettie sur toute sa durée de vie n'a aucun effet réel sur l'économie si l'état utilise un impôt forfaitaire. Ensuite, en présence de marchés financiers imparfaits, je montre qu'une une baisse temporaire de l'impôt forfaitaire sur le profit des entreprises stimule l'investissement parce qu'il réduit temporairement le coût marginal de l'investissement. Enfin, mes résultats indiquent que si l'impôt est proportionnel au profit des entreprises, l'anticipation de taxes élevées dans le futur réduit le rendement espéré de l'investissement et atténue la stimulation de l'investissement engendrée par la réduction d'impôt.

Le deuxième chapitre est écrit en collaboration avec Rui Castro. Dans cet article, nous avons quantifié les effets sur les décisions individuelles d'investissement et de production des entreprises ainsi que sur les agrégats macroéconomiques, d'une baisse temporaire de l'impôt sur le profit des entreprises en présence de marchés financiers imparfaits. Dans un modèle où les entreprises sont sujettes à des chocs de productivité idiosyncratiques, nous avons d'abord établi que le rationnement de crédit affecte plus les petites (je-

unes) entreprises que les grandes entreprises. Pour des entreprises de même taille, les entreprises les plus productives sont celles qui souffrent le plus du manque de liquidité résultant des imperfections du marché financier. Ensuite, nous montré que pour une baisse de 1 dollar du revenu de l'impôt, l'investissement et la production augmentent respectivement de 26 et 3,5 centimes. L'effet cumulatif indique une augmentation de l'investissement et de la production agrégés respectivement de 4,6 et 7,2 centimes. Au niveau individuel, nos résultats indiquent que la politique stimule l'investissement des petites entreprises, initialement en manque de liquidité, alors qu'elle réduit l'investissement des grandes entreprises, initialement non contraintes.

Le troisième chapitre est consacré à l'analyse des effets de la réforme de l'imposition des revenus d'entreprise proposée par le Trésor américain en 1992. La proposition de réforme recommande l'élimination des impôts sur les dividendes et les gains en capital et l'imposition d'une seule taxe sur le revenu des entreprises. Pour ce faire, j'ai eu recours à un modèle dynamique stochastique d'équilibre général avec marchés financiers imparfaits dans lequel les entreprises sont sujettes à des chocs idiosyncratiques de productivité. Les résultats indiquent que l'abolition des impôts sur les dividendes et les gains en capital réduisent les distorsions dans les choix d'investissement des entreprises, stimule l'investissement et entraîne une meilleure allocation du capital. Mais pour être financièrement soutenable, la réforme nécessite un relèvement du taux de l'impôt sur le profit des entreprises de 34% à 42%. Cette hausse du taux d'imposition décourage l'accumulation du capital. En somme, la réforme engendre une baisse de l'accumulation du capital et de la production respectivement de 8% et 1%. Néanmoins, elle améliore l'allocation du capital de 20%, engendrant des gains de productivité de 1.41% et une modeste augmentation du bien être des consommateurs.

Mots-clés: Hétérogénéité des entreprises, Marchés financiers imparfaits, Taxation des entreprises, Réforme fiscale, Régime de financement, Modèle d'équilibre général dynamique et stochastique, Investissement, Equivalence ricardienne, Dynamiques de transition, Multiplicateur fiscal.

Abstract

This thesis is a collection of three papers in macroeconomics and public finance. It develops Dynamic Stochastic General Equilibrium Models with a special focus on financial frictions to analyze the effects of changes in corporate tax policy on firm level and macroeconomic aggregates.

Chapter 1 develops a dynamic general equilibrium model with a representative firm to assess the short-run effects of changes in the timing of corporate profit taxes. First, it extends the Ricardian equivalence result to an environment with production and establishes that a temporary corporate profit tax cut financed by future tax-increase has no real effect when the tax is lump sum and capital markets are perfect. Second, I assess how strong the ricardian forces are in the presence of financing frictions. I find that when equity issuance is costly, and when the firm faces a lower bound on dividend payments, a temporary tax cut reduces temporary the marginal cost of investment and implies positive marginal propensity of investment. Third, I analyze how do the intertemporal substitution effects of tax cuts interact with the stimulative effects when tax is not lump-sum. The results show that when tax is proportional to corporate profit, the expectations of high future tax rates reduce the expected marginal return on investment and mitigate the stimulative effects of tax cuts. The net investment response depends on the relative strength of each effect.

Chapter 2 is co-authored with Rui Castro. In this paper, we quantify how effective temporary corporate tax cuts are in stimulating investment and output via relaxation of financing frictions. In fact, policymakers often rely on temporary corporate tax cuts in order to provide incentives for business investment in recession times. A common motivation is that such policies help relax financing frictions, which might bind more during recessions. We assess whether this mechanism is effective. In an industry equilibrium model where some firms are financially constrained, marginal propensities to invest are high. We consider a transitory corporate tax cut, funded by public debt. By increasing current cash flows, corporate tax cuts are effective at stimulating current investment. On impact, aggregate investment increases by 26 cents per dollar of tax stimulus, and aggregate output by 3.5 cents. The stimulative output effects are long-lived, extending past the period the policy is reversed, leading to a cumulative effect multiplier on output of 7.2 cents. A major factor preventing larger effects is that this policy tends to significantly crowd out investment among the larger, unconstrained firms.

Chapter 3 studies the effects of the 1992's U.S. Treasury Department proposal of a Comprehensive Business Income Tax (CBIT) reform. According to the U.S. tax code, dividend and capital gain are taxed at the firm level and further taxed when distributed to shareholders. This double taxation may reduce the overall return on investment and induce inefficient capital allocation. Therefore, tax reforms have been at the center of numerous debates among economists and policymakers. As part of this debate, the U.S. Department of Treasury proposed in 1992 to abolish dividend and capital gain taxes, and to use a Comprehensive Business Income Tax (CBIT) to levy tax on corporate income. In this paper, I use an industry equilibrium model where firms are subject to financing frictions, and idiosyncratic productivity and entry/exit shocks to assess the long run effects of the CBIT. I find that the elimination of the capital gain and dividend taxes is not self financing. More precisely, the corporate profit tax rate should be increased from 34% to 42% to keep the reform revenue-neutral. Overall, the results show that the CBIT reform reduces capital accumulation and output by 8% and 1%, respectively. However, it improves capital allocation by 20%, resulting in an increase in aggregate productivity by 1.41% and in a modest welfare gain.

Keywords : Firm heterogeneity, Financing frictions, Corporate Tax Policy, Corporate tax reform, Finance regime, Dynamic Stochastic General Equilibrium, Investment Dynamics, Ricardian equivalence, Transitional Dynamics, Tax Cut Multipliers.

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Chapter 1

Are Government Bonds Net Wealth? Ricardian Equivalence with Corporate Taxation

1.1 Introduction

Corporate tax policy is a common instrument of government intervention in the economy. Policymakers often rely on temporary corporate tax cuts to stimulate or to stabilize the economy. For example, the Jobs and Growth Tax Relief Reconciliation Act of 2003 temporary reduces the dividend and capital gains taxes through 2008 to promote growth in the U.S.. During the 2008 crisis, policymakers in almost all developed economies provide temporary tax incentives to households and businesses to avert recession.[1] In macroeconomic literature, there are conditions under which these stabilization policies may not have any real effects. More precisely, the Ricardian equivalence theorem, revisited by Barro [1974], predicts an equivalence in terms of prices and allocations between any two time paths of lump-sum taxes used to finance a given pattern of government spending. This theory has been extensively analyzed on the consumer side and related theoretical and empirical studies focus on personal income taxes.

The goal of this paper is to assess how aggregate investment and output respond to temporary corporate profit tax cuts financed by future increases. First, it extends the Ricardian equivalence result to an environment with production. For instance, it establishes that temporary reductions in corporate profit taxes have no real effects if the tax is lump-sum, the present value of tax burden is unchanged, and capital markets are perfect. Second, I find that when external financing is costly, a temporary corporate tax cut temporarily reduces the marginal cost of investment and implies a positive marginal propensity to invest. Third, I show that when the tax is proportional to corporate profit, the expectations of higher future tax rates reduce the expected marginal return on investment and counteract the direct effects of the tax incentives. The sign as well as the size of the net response of investment or output depend on the relative strength of each effect.

I focus on a simple general equilibrium model which integrates a representative household, a government and a representative firm. The firm owns capital and is subject to a minimum dividend distribution policy. Accordingly, its optimal investment may require some external fundings in addition to internal cash flows. But, I assume that equity issuance is costly. In

1. Without being exhaustive, I can cite the US 2010 Job Creation act which provides first year full depreciation for qualified investment made between September and december 2011, and the corporate tax provisions of the 2009 American Recovery and Reinvestment Act.

the absence of the lower bound on dividend payment and the cost of external financing, my setup satisfies a Ricardian proposition if tax is lump-sum. Therefore, the effects of temporary tax cuts on investment and output in this paper heavily depend on the extent of financial frictions and the nature of the tax instrument.

This paper draws on the macroeconomic literature that analyzes the effects of temporary corporate tax cuts. Abel [1982], Auerbach and Kotlikoff [1987], and Auerbach and Hines [1987] study the effects of corporate tax changes, but they do not provide a general equilibrium analysis. In a general equilibrium model, Gourio and Miao [2011] quantify the effects of the 2003 dividend and capital gain tax cuts assuming that they are temporary. However, their model incorporate firm heterogeneity and they do not isolate the incentive effects from the timing effects of tax cuts. In a setting where the government is subject to an intertemporal budget constraint, and capital taxes in any period are stochastic, Dotsey [1994] shows that lowering taxes on capital and financing government spending by higher deficit reduces investment. In contrast, my paper considers deterministic tax rate and is in line with Heathcote [2005] [2] who quantifies the short-run effects of temporary personal income tax cuts on households' optimal consumption. Heathcote [2005] finds that the effects of temporary tax cuts are higher when the tax is proportional to the household income than when it is lump-sum.

This paper begins by extending the Ricardian equivalence result to the firm side. More precisely, it establishes that if capital markets are perfect and all agents live infinitely, the representative firm should not change its investment plan in response to temporary changes in lump-sum corporate profit tax, which maintain the present value of tax burden unchanged. The logic is that when tax decreases, the firm uses the extra cash flows provided by the tax cut to pay more dividends or to repurchase equity. Stockholders save the extra revenue by investing in government debt. When government increases tax later, the firm reduces dividend payments or issue new equity to finance the higher tax, leaving its investment plan unaffected. The representative household keeps its consumption plan unchanged and uses its savings plus interest to buy new equity issued by the firm, or to compensate the reduction in revenue due to lower dividend payments. As a result, all adjustment takes place through changes in the capital structure of the firm and implies no real

2. The literature on Ricardian equivalence is summarized by Seater [1993] and Ricciuti [2003]

effects. This result is consistent with the well-known Modigliani and Miller [1958] theorem, which states that the capital structure of firms has no effect on their investment in a frictionless environment.

Afterwards, I consider a framework in which the firm chooses investment and financing policies subject to dividend constraint and equity issuance costs. In this case, the capital structure of the firm matters and the firm uses external financing only if it is dividend-constrained. I use this framework to assess how financial frictions affect the dynamics of the economy following temporary tax cuts. More precisely, I assume that the economy is initially in a steady-state where the firm is dividend-constrained. Then, the government unexpectedly implements a tax cut, large enough to relax the constraint on the firm's decisions. The results show that the investment response varies both quantitatively and qualitatively, depending on the tax instrument as well as on the marginal cost of external financing. These findings are driven by two opposite forces. One on hand, the tax cut reduces the marginal cost of investment because it allows the firm to use retained-earnings as the source of investment financing, avoiding the additional cost associated with equity issuance. Thus, the size of the tax incentives depends on the marginal cost of external finance. More precisely, the higher the cost of equity issuance, the higher is the reduction in the marginal cost of investment.[3] When the tax is lump-sum, these direct benefits imply an increase in investment. On the other hand, the expectation of high future tax rates reduces the expected marginal return on investment and mitigates the direct benefits of the tax cut when tax is proportional to corporate profit. The dominant effect depends on how costly are the financial frictions in place before the tax cut. For relatively lower marginal costs of equity issuance, the adverse effects of expected high tax rates offset the direct benefits provided by the tax cut and investment decreases. In contrast, the tax cut implies positive propensities to invest if equity issuance is highly costly. As illustration, the sensitivity analysis shows that the propensity of investment goes from negative to positive values as the cost of external financing varies from 1 cent to 6 cents per dollar of new equity issued. This finding is consistent with the results of Dotsey [1994] who showed that a temporary reduction in capital tax, financed by future tax-increase, implies a reduction in investment.

3. The benchmark calibration uses a value of $\kappa = 0.027$ which is in the range of direct estimates in the literature. For example Gomes [2001], Altinkiliç and Hansen [2000] and Hennessy and Whited [2005] estimate cost of external financing equal to 0.028, 0.0515 and 0.0509, respectively. Gourio and Miao [2011] in a framework similar to mine set κ to 0.03.

1.2 Model

Time is discrete and runs from $t = 0$ to ∞. The economy consists of a representative household, a representative firm, and a government.

1.2.1 Firm

A representative firm combines labor N_t and capital K_t to produce a final good using a Cobb-Douglas production technology with a Constant Return to Scale (CRS), $Y_t = K_t^{\alpha}, N_t^{1-\alpha}$. Physical capital depreciates geometrically at rate δ leading to the following law motion of capital:

$$K_{t+1} = I_t + (1-\delta)K_t \tag{1.1}$$

where I_t is the investment at period t and K_t the capital stock at the beginning of period t.
The firm may issue new shares or repurchase old shares. Thus, the price of the firm at date $t+1$ satisfies: $P_{t+1} = P_{t+1}^0 + Z_{t+1}$, where Z_{t+1} denotes the value of new shares issued (repurchased) at period $t+1$ if $Z_{t+1} \geq (<)0$, and P_{t+1}^0 is the period $t+1$ value of equity outstanding in period t. The managers of the firm act on behalf of the stockholders in order to maximize the value of the firm. The net after-tax return to the owners of the firm at time t comprises current dividends and capital gains. Under the assumption of no uncertainty and perfect capital markets, the return on firms' shares must equal the return on government bonds, r_{t+1}, if the owners are to be content holding their shares in equilibrium. Then, if D_{t+1} denotes the dividend payments of the firm at period $t+1$, $r_{t+1} = \dfrac{(P_{t+1}^0 - P_t) + D_{t+1}}{P_t}$ where the term in parentheses represents the capital gain component of the return. The equity value of the firm stems from the non-arbitrage condition governing the valuation of its shares and can be derived as:

$$P_t = \frac{(P_{t+1} - Z_{t+1}) + D_{t+1}}{1 + r_{t+1}} \tag{1.2}$$

I follow Gourio and Miao [2010] and define the cum- dividend equity value, V_{t+1}, at period $t+1$ as:

$$V_{t+1} = P_{t+1} - Z_{t+1} + D_{t+1} \tag{1.3}$$

Using (1.2):

$$V_t = P_t - Z_t + D_t = D_t - Z_t + \frac{V_{t+1}}{1 + r_{t+1}} \tag{1.4}$$

In the absence of any bubbles, solving (1.4) forward and using the transversality condition on stock prices, $\lim_{T\to\infty} \prod_{t=0}^{T} (1 + r_t)^{-1} P_{T+1} = 0$, yields the firm's market value at period 0 given by (1.5).

$$V_0 = \sum_{t=0}^{+\infty} \Lambda_{0,t} (D_t - Z_t) \tag{1.5}$$

Here $\Lambda_{0,t} = \prod_{i=0}^{t-1} \Lambda_{i,i+1} = \prod_{i=0}^{t-1} \frac{1}{1 + r_{i+1}}$ is the firm's discount factor between periods 0 and t. The value of the firm is simply the present discounted value of its future dividend stream. This specification implies that dividends are paid out at the end of the period. The firm takes employment, investment and financing decisions to maximize its market value (1.5) subject to the law motion of capital (1.1), and its resource constraint:

$$D_t = F(K_t, N_t) + Z_t - w_t N_t - I_t - \tau_t \tag{1.6}$$

where τ is a lump-sum tax on corporate profits. Dividends are defined as the the firm's residual profits after expenditures. Cash inflows include current output and undepreciated capital, while cash outflows consist of dividend and factor payments, tax liability and investment expenditures. Under the assumption of perfect capital markets, the capital structure does not matter for the firm's value. In other words, it does not matter for the firm's value and investment policy how much earnings to retain for use as internal financing, rather than distributing dividends and raising new equity in the external equity market. More precisely in the firm's problem, the payout $D_t - Z_t$ can be determined but D_t and Z_t will be undetermined. This is the Modigliani and Miller [1958] dividend policy irrelevance theorem. Thus, for the remainder of this section, I define for simplicity the payouts of the firm as d_t:

$$d_t = D_t - Z_t \tag{1.7}$$

Substituting sequentially (1.7) into (1.6) and (1.5) for d_t, and using (1.1) to eliminate I_t from the problem, the first-order conditions of the firm's maximization problem are:

$$w_t = F_2(K_t, N_t) \quad (1.8a)$$
$$1 = \Lambda_{t,t+1}\left(F_1(K_{t+1}, N_{t+1}) + 1 - \delta\right) \quad (1.8b)$$

Equation (1.8a) implies that wage equals the marginal product of labor. The left-hand side of equation (1.8b) shows the marginal cost of investing one unit of output in physical capital. The right-hand side represents the discounted marginal benefit of investing in capital. The return on investment consists of the marginal product of capital and the undepreciated capital. Along the optimal path, the marginal cost of investment must equal the marginal gain from investment. In addition, equation (1.8b) implies that the return on investment in physical capital equals the discount factor of the firm.

1.2.2 Household

A representative household with unit measure derives utility from consumption alone, according to a standard time-additive utility function $U(C) = \log C$, with future utility discounted at rate $0 < \beta < 1$. A time endowment of 1 is supplied inelastically every period.
The household trades equity shares in the firm, as well as a government bond. Let θ_t denote the shareholding at the start of period t valued at price P_t^0, P_t the equity price at the end of period t (including capital gain in t) and B_{t+1} the government bondholding paying interest rate r_t.
The problem of the representative household can be derived as follows:

$$\max_{C_t, B_{t+1}, \theta_{t+1}} \sum_{t=0}^{+\infty} \beta^t U(C_t) \quad (1.9)$$

subject to

$$B_{t+1} + C_t + \theta_{t+1} P_t = w_t + \theta_t (P_t^0 + D_t) + (1 + r_t) B_t \quad (1.10a)$$
$$\lim_{T\to\infty} \prod_{t=0}^{T} (1 + r_t)^{-1} B_{T+1} \geq 0 \quad (1.10b)$$
$$\lim_{T\to\infty} \prod_{t=0}^{T} (1 + r_t)^{-1} \theta_{T+1} \geq 0 \quad (1.10c)$$

Equation (1.10a) is the household's budget constraint. The household's income consists of labor earnings, plus the income from government bondholding, plus shareholding income. The consumer spends his resources on consumption, government bonds, and equity purchases.
Equations (1.10b) and (1.10c) represent the no-Ponzi game constraints on government bonds and firm's shares holdings, respectively.

First-Order Conditions

$$U'(C_t) = \beta(1+r_t)U'(C_{t+1}) \tag{1.11a}$$
$$P_t U'(C_t) = \beta U'(C_{t+1})(P^0_{t+1} + D_{t+1}) \tag{1.11b}$$

Equation (1.11b) implies that the stock price P_t is given by the discounted present value of dividends. In addition, equations (1.11a-1.11b) imply that the gross return on government bonds equals the inter temporal marginal rate of substitution of consumption, which equals the return on firm's shares.

1.2.3 Government

Government spends a constant amount of resources $G > 0$ at each time t, funded either by lump sum corporate taxation τ_t, or by issuing one period debt B_{t+1} held by the representative consumer. The government's budget constraint is

$$(1+r_t)B_t + G = \tau_t + B_{t+1},$$

together with the no Ponzi game condition:

$$\lim_{T\to\infty} \prod_{t=0}^{T} (1+r_t)^{-1} B_{T+1} \leq 0. \tag{1.12}$$

Requiring that the government wastes no resources and therefore satisfies the no Ponzi game condition with equality, I obtain the present value budget constraint:

$$B_0 + G\sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1} = \sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\tau_t, \tag{1.13}$$

where I assume $B_0 = 0$.
The government's policy will be a sequence $\{\tau_t, B_{t+1}\}_{t=0}^{\infty}$ of tax rates and debt issuance which satisfies (1.13).

1.2.4 Competitive Equilibrium

Given the government policy $\{\tau_t, B_{t+1}\}_{t=0}^{+\infty}$, a competitive equilibrium consists of a set of prices $\{w_t, r_t, P_t\}_{t=0}^{+\infty}$, and allocations $\{C_t, N_t, K_{t+1}, B_{t+1}, d_t, \theta_{t+1}\}_{t=0}^{+\infty}$, such that: the household optimizes given prices, the firm optimizes given prices and the tax rate, the government satisfies its inter-temporal budget constraint and all markets (good, firm's shares, bond and labor) clear.
Now I am in position to derive a Ricardian equivalence result with corporate tax.

1.2.5 Ricardian Equivalence with Corporate Taxation

Proposition 1. *Ricardian Equivalence Statement*
Given initial conditions (B_0, K_0), *and a government spending* G[4], *let the set of allocations* $\{C_t, N_t, K_{t+1}, B_{t+1}, \theta_t, d_t\}_{t=0}^{+\infty}$ *and prices* $\{w_t, r_t, P_t\}_{t=0}^{+\infty}$, *be an initial equilibrium under a government policy* $\{\tau_t, B_{t+1}\}_{t=0}^{+\infty}$.
If $\left\{\hat{C}_t, \hat{N}_t, \hat{K}_{t+1}, \hat{B}_{t+1}, \hat{\theta}_t, \hat{d}_t\right\}_{t=0}^{+\infty}$ *and* $\left\{\hat{w}_t, \hat{r}_t, \hat{P}_t\right\}_{t=0}^{+\infty}$ *constitute another equilibrium with a government policy* $\left\{\hat{\tau}_t, \hat{B}_{t+1}\right\}_{t=0}^{+\infty}$, *such that:*
$\sum_{t=0}^{+\infty}\prod_{i=0}^{t}(1+\hat{r}_i)^{-1}\hat{\tau}_t = \sum_{t=0}^{+\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\tau_t$. *Then:*

$$
\begin{aligned}
\left\{\hat{C}_t, \hat{N}_t, \hat{K}_{t+1}, \hat{\theta}_t\right\}_{t=0}^{+\infty} &= \{C_t, N_t, K_{t+1}, \theta_t\}_{t=0}^{+\infty} \\
\left\{\hat{w}_t, \hat{r}_t, \hat{P}_t\right\}_{t=0}^{+\infty} &= \{w_t, r_t, P_t\}_{t=0}^{+\infty} \\
\hat{d}_t + \hat{\tau}_t &= F(K_t, N_t) + (1-\delta)K_t - w_tN_t - K_{t+1} \\
\hat{B}_{t+1} - R_t\hat{B}_t - \hat{d}_t &= w_tN_t - C_t \\
\hat{B}_{t+1} + \hat{\tau}_t - R_t\hat{B}_t &= G
\end{aligned}
$$

According to the theorem, the temporal pattern of lump-sum tax required to finance a particular public expenditure stream is irrelevant to the determination of real variables of the economy. That is, substituting taxes today for taxes plus interest tomorrow via debt financing affects neither the investment decision of the firm, nor the wealth of the individuals. The reason is that

4. While I have assumed constant government spending in the previous sections, the result does not require such assumption to be valid.

under perfect capital markets, infinitely lived and perfect foresighted private agents can exactly undo any financing policy undertaken by the government [5]. Given the Barro [1974]'s Ricardian equivalence result, the statement established here is not surprising but it has some implications which are absent in the standard Ricardian equivalence analysis. For instance, it helps characterizing the effects of the policy on the optimal decisions of the firm and their transmission channel to other variables in the economy. In addition, it is useful for understanding the dynamics of the economy when I depart from the Ricardian framework.

1.3 Departure from the Ricardian Result

As in the standard Ricardian equivalence theorem, the result established in proposition 1 will fail if one or more of the assumptions behind the result are violated. In this paper, I focus on two important deviations from the basic framework. First, I impose a lower bound on dividend payment and introduce costly external financing. Afterwards, I consider proportional rather than lump-sum corporate taxation. Let me start with the financial market imperfection.

1.3.1 Financing Frictions

The analysis of the effects of temporary tax cuts on firm decisions requires a model that departs from Modigliani-Miller. I consider a simple way to achieve this by imposing two standard constraints on firm financing decisions.

First, I impose a lower bound on dividend payments. A possible interpretation is that the firm has an established dividend practice that leads stockholders to expect a minimum dividend payment, $\hat{D}$, after each operating year. In the U.S., Poterba et al. [1987] presented evidence of remarkable stability of dividend payouts throughout periods of extensive tax changes. Since the stock of capital K_t is given at the beginning of each period, the only variables under the control of the firm are the input of labor, N_t, the dividend payment, D_t, and the equity issuance Z_t. Thus, if the firm is dividend-constrained and it wishes to keep the production plan unchanged, it needs to issue new equity to finance investment. Second, I follow Gomes [2001] and assume that each additional dollar of new equity implies an additional

5. A detailed analytical proof is given in annex A.1.

cost of κ, $0 \leq \kappa \leq 1$. This cost of equity issuance can be interpreted as transaction costs as pointed out by some researchers in the literature. For instance, Greenwald et al. [1984] and Myers and Majluf [1984] find that capital market frictions increase the cost of outside capital relative to internally generated funds. Without this constraint, firms would be able to raise enough equity to finance desired investment and the dividend constraint would be useless. Although share repurchases are allowed in the United States, I impose no share-repurchases constraint similarly to Auerbach [2002], Gomes [2001], Desai and Goolsbee [2004], Hennessy and Whited [2005] and Gourio and Miao [2010], for simplicity. In addition, I abstract from debt [6] and assume that firms are all equity financed. Incorporating debt financing would complicate my analysis since I would need to include debt as an additional state variable in the dynamic programming problem of the firm.
Now, I consider the firm's problem in the presence of financing frictions.

1.3.2 Firm's Problem with Lump-sum Taxation

I start by the model with lump-sum tax and consider the model with proportional tax later on. When tax is lump-sum, the representative firm's problem is as follows.

$$\max_{\{D_t,N_t,I_t,K_{t+1},Z_t\}_{t=0}^{+\infty}} \sum_{t=0}^{+\infty} \Lambda_{0,t}(D_t - Z_t)$$

subject to:

$$D_t = K_t^{\alpha} N_t^{1-\alpha} + Z_t - \kappa Z_t - w_t N_t - I_t - \tau_t \tag{1.14a}$$

$$I_t = K_{t+1} - (1-\delta) K_t \tag{1.14b}$$

$$D_t \geq \hat{D} \tag{1.14c}$$

$$Z_t \geq 0 \tag{1.14d}$$

$$K_0 \quad \textit{given}$$

Let q_t, λ_t^d and λ_t^z be the Lagrange multipliers associated with the constraints (1.14b)-(1.14d), respectively. Using (1.14a) to eliminate D_t, the first-order conditions are:

6. Auerbach and Hassett [2003], Desai and Goolsbee [2004], and Gourio and Miao [2010] among others make this choice.

First Order Conditions

$$
\begin{aligned}
N_t &: \; w_t = (1-\alpha)K_t^{\alpha}N_t^{-\alpha} && (1.15a)\\
I_t &: \; q_t = 1 + \lambda_t^d && (1.15b)\\
K_{t+1} &: \; q_t = \Lambda_{t,t+1}(1+\lambda_{t+1}^d)\left(\alpha K_{t+1}^{\alpha-1}N_{t+1}^{1-\alpha} + 1 - \delta\right) && (1.15c)\\
Z_t &: \; 1 = (1-\kappa)(1+\lambda_t^d) + \lambda_t^z && (1.15d)
\end{aligned}
$$

The usual transversality conditions and the complementary slackness conditions are omitted here for simplicity.

Proposition 2. *Under lump-sum tax, the Ricardian equivalence result holds if* $\hat{D} = -\infty$.

Proof: $\hat{D} = -\infty$ implies that the dividend constraint will never binds. Thus, $\lambda_t^d = 0$, $\lambda_t^z = \kappa > 0$, and the conditions characterizing the competitive equilibrium are identical to those characterizing the firm's problem in the absence of frictions. The intuition is that if the firm is allowed to issue an infinite amount of new equity, i.e. to pay infinite negative dividend, it will never be dividend-constrained.

1.3.3 Firm's Problem with Proportional Taxation

When tax is proportional to corporate profit, the firm problem is as follows.

$$
\max_{\{D_t, N_t, I_t, K_{t+1}, Z_t\}_{t=0}^{+\infty}} \sum_{t=0}^{+\infty} \Lambda_{0,t}(D_t - Z_t) \qquad (1.16)
$$

subject to:

$$
\begin{aligned}
D_t &= (1-\tau_t)\left[K_t^{\alpha}N_t^{1-\alpha} - w_t N_t\right] + \tau_t \delta K_t + (1-\kappa)Z_t - I_t && (1.17a)\\
I_t &= K_{t+1} - (1-\delta)K_t && (1.17b)\\
D_t &\geq \hat{D} && (1.17c)\\
Z_t &\geq 0 && (1.17d)\\
K_0 & \quad \textit{given}
\end{aligned}
$$

Let q_t, λ_t^d and λ_t^z be the Lagrange multipliers associated with the constraints (1.17b)-(1.17d), respectively. Equation (1.17a) implies that depreciation is tax deductible. Using (1.17a) to eliminate D_t, the first-order conditions are:

First-Order Conditions[7]

$$\begin{aligned}
N_t &: \quad w_t = (1-\alpha) K_t^{\alpha} N_t^{-\alpha} && (1.18a)\\
I_t &: \quad q_t = 1 + \lambda_t^d && (1.18b)\\
K_{t+1} &: \quad q_t = \Lambda_{t,t+1}(1+\lambda_{t+1}^d)\left[(1-\tau_{t+1})\left(\alpha K_{t+1}^{\alpha-1} N_{t+1}^{1-\alpha} - \delta\right) + 1\right] && (1.18c)\\
Z_t &: \quad 1 = (1-\kappa)(1+\lambda_t^d) + \lambda_t^z && (1.18d)
\end{aligned}$$

1.3.4 Firm's Financial Policy

I analyze the financing and investment decisions of the representative firm in the presence of financing frictions under both lump sum and proportional corporate profit taxes. I begin by analyzing the firm's financial policy, holding the investment policy fixed. The financial policy of the firm is determined by equations (1.15d) and (1.18d) under lump-sum and proportional taxation, respectively. These two equations are identical. Accordingly, the type of the tax does not matter for the financial decision of the firm. For the remainder of this section, I consider equation (1.18d), which has the following interpretation: raising one unit of new equity to pay dividends relaxes the dividend constraint and the share repurchase constraint. In addition, when the firm raises one unit of new equity, the shareholder receives $1-\kappa$ because equity issuance involves an additional marginal cost of κ. Thus, the expression on the right-hand side of equation (1.18d) gives the marginal benefit to the shareholder. On the other hand, a one-unit increase in new shares lowers equity value by one unit, and the expression on the left-hand side of equation (1.18d) represents the marginal cost to the shareholder. Equation (1.18d) requires that the marginal benefit and the marginal cost must be equal at equilibrium.

If external financing is costless, meaning $\kappa = 0$, there is no difference between internal financing and external financing. Equation (1.18d) implies that $\lambda_t^d = \lambda_t^z = 0$. In this case, the firm's financial policy is irrelevant. Thus, it does not matter for the firm's value and investment policy how much earnings to retain for use as internal financing, rather than distributing dividends and raising new equity in the external equity market. In this case, the Ricardian equivalence result holds if tax is lump-sum.

7. The usual transversality conditions and the complementary slackness conditions are omitted here for simplicity.

In contrast, if new equity issuance is costly, i.e. $\kappa > 0$, the firm's financial policy matters. In this case, it follows from equation (1.18d) that it can not be true that $\lambda_t^d = \lambda_t^z = 0$. For instance, equation (1.18d) shows first that if $\lambda_t^d = 0$, then $\lambda_t^z = \kappa > 0$. This means that if the dividend constraint is not binding, then the share repurchase constraint is binding. In other words, it is not optimal for the firm to issue new equity if it is not dividend-constrained because equity issuance is costly. I refer to the case where the dividend constraint is not binding as the *internal financing* or *retained-earnings financing* regime. Second, equation (1.18d) shows that if $\lambda_t^z = 0$, then $\lambda_t^d = \dfrac{\kappa}{1-\kappa} > 0$. That is, if the firm is issuing new equity, then the dividend constraint is binding. In this case, the firm is in the *external financing* or *equity issuance* regime.

In summary, equation (1.18d) implies that the firm will use external financing if and only if the dividend constraint is binding. The reason is that it is not optimal for the firm to simultaneously distribute more dividend than $\hat{D}$ and issue new equity. In fact, one unit of new equity reduces the equity value by one unit, whereas shareholders receive only $1-\kappa$. If the firm is not dividend-constrained, using retained earnings to finance investment is costless.

1.3.5 Firm's Investment Policy

The firm's investment policy is governed by equations (1.18c) and (1.18b) under proportional taxation, or (1.15c) and (1.15b) under lump sum taxation. Equations (1.18b) and (1.15b) show that the nature of the tax does not affect the marginal cost of investment, which depends only on the dividend constraint, and the share-repurchase constraint. In other words, the marginal cost of investment depends solely on the marginal source of finance.

If the dividend constraint is binding, the marginal source of finance is new equity. In this case, $Z_t > 0$ and $\lambda_t^z = 0$. Using equation (1.18d), $\lambda_t^d = \dfrac{\kappa}{1-\kappa}$ and I can derive the investment equation:

$$q_t = \frac{1}{1-\kappa} \tag{1.19}$$

Thus a dividend-constrained firm stops investing when the marginal product of investment, q_t, equals the cost of financing one additional unit of investment by new equity, $\dfrac{1}{1-\kappa}$.

On the other hand, if the firm is not dividend-constrained, then the marginal source of finance is retained-earnings. In this case, $D_t > \hat{D}$ and $\lambda_t^d = 0$. I can derive the investment equation:

$$q_t = 1 \tag{1.20}$$

Thus, the shareholder will stop investing when he or she is indifferent between receiving one dollar of additional dividend and investing one dollar in firm's shares. That is, he stops investing when the marginal benefit of investing q_t equals the cost of investment. Comparing equations (1.18b) and (1.15b) reveals that the marginal cost of investment is higher in an equity-issuing regime than in an internal-financing regime.
I now turn to the effect of corporate tax on investment. To this end, I use equations (1.18b) and (1.18c) to obtain the optimality condition for investment (1.22), and equations (1.15b) and (1.15c) to obtain (1.21) when tax is proportional or lump-sum, respectively.

$$1 + \lambda_t^d = \Lambda_{t,t+1}(1 + \lambda_{t+1}^d)\left(\alpha K_{t+1}^{\alpha-1} N_{t+1}^{1-\alpha} + 1 - \delta\right) \tag{1.21}$$

$$1 + \lambda_t^d = \Lambda_{t,t+1}(1 + \lambda_{t+1}^d)\left[(1 - \tau_{t+1})\left(\alpha K_{t+1}^{\alpha-1} N_{t+1}^{1-\alpha} - \delta\right) + 1\right] \tag{1.22}$$

When the tax is lump-sum, equation (1.21) shows that the tax policy does not influence investment policy if it does not change the marginal source of finance between two adjacent periods. In fact, if the current and the next marginal sources of finance are new equity, i.e $\lambda_t^z = \lambda_{t+1}^z = 0$ (implying $\lambda_t^d > 0$ and $\lambda_{t+1}^d > 0$), then $1 + \lambda_t^d = 1 + \lambda_{t+1}^d = \dfrac{1}{1-\kappa}$. Similarly, if the current and the next marginal sources of finance are retained-earnings, i.e $\lambda_t^d = \lambda_{t+1}^d = 0$, then $1 + \lambda_t^d = 1 + \lambda_{t+1}^d = 1$. In both cases, the factors $1 + \lambda_t^d$ and $1 + \lambda_{t+1}^d$ cancel out in equation(1.21).
In contrast, under proportional tax, the corporate tax policy affects investment policy even if the marginal source of finance remains unchanged. More precisely, a tax cut financed by a tax increase one period later will reduce the expected marginal after-tax return on investment while the marginal cost of investment remains unchanged. In response, the firm will reduce investment.
Now, I consider the case where the corporate tax policy changes the marginal source of finance between two adjacent periods. In particular, I focus on tax cuts, which push the marginal source of investment financing from equity to retained earnings. More precisely, I assume that the firm is initially in a

steady state where it is dividend-constrained and switches instantaneously and temporarily to the retained-earnings financing regime at the period of tax cut. One period later, when government increases tax to repay its debt, the firm switches back to the external financing regime. Under lump sum taxation, the tax cuts temporarily reduce the marginal cost of investment from $\frac{1}{1-\kappa}$ to 1. Since the tax policy does not affect the expected marginal return of investment, equation (1.21), current investment should increase. However, when the tax is proportional to corporate profits, two forces are present. A temporary tax cut reduces the current marginal cost of investment from $\frac{1}{1-\kappa}$ to 1 as before, but the higher future tax rate pins down the after-tax return on current investment. Thus, the net effect on investment will depend on the relative intensity of each force. If the increase in future tax rate is more than proportional to the reduction in the marginal cost of investment, investment will decrease. In contrast, if the decrease in the marginal cost of investment fully offsets the reduction in after-tax return on investment, investment will increase. Equations (1.19) and (1.20) show that the reduction in marginal cost of investment, $\frac{\kappa}{1-\kappa}$, is an increasing function of the additional cost, κ, induced by external financing.

1.3.6 Other Agents' Problems

The household's problems under the two types of tax are identical to the household problem in the basic framework. In contrast, the government policy is affected by the type of tax. Under lump-sum tax, its problem in the presence of external costly financing is the same as in the benchmark problem. I focus now on the government problem when tax is proportional. When tax is proportional to corporate profits, the government budget is given by:

$$R_t B_t + G = \tau_t \left[K_t^{\alpha} N_t^{1-\alpha} - w_t N_t - \delta K_t\right] + B_{t+1} \tag{1.23}$$

Again, it may run a deficit in the short to medium term, but is not allowed to play a Ponzi game with other agents. Accordingly, its inter-temporal budget constraint is:

$$B_0 + G \sum_{t=0}^{+\infty} \prod_{i=0}^{t} R_i^{-1} = \sum_{t=0}^{+\infty} \prod_{i=0}^{t} R_i^{-1} \tau_t \left[K_t^{\alpha} N_t^{1-\alpha} - w_t N_t - \delta K_t\right] \tag{1.24}$$

The definition of competitive equilibrium under both types of tax in the presence of costly external financing is similar to the definition in the basic framework.

1.4 Steady State Properties

This section derives some properties [8] of the long-run equilibrium of the economy which ensure the feasibility of the tax experiments undertaken later on. I focus particularly on a steady state with zero government debt.

Proposition 3. *The steady state stock of capital does not depend on the target of dividend under either lump-sum taxation or proportional taxation.*

Proposition 4. *A higher proportional tax rate implies lower capital stock at steady state while lump-sum tax does not affect long-run capital stock.*

The reason is that a proportional tax reduces the after-tax marginal return on investment while lump-sum tax does not.

Proof: With lump-sum tax $K_{ss}^{lump} = \left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{1}{1-\alpha}}$. Under proportional tax $K_{ss}^{prop} = \left[\frac{\alpha\beta(1-\bar{\tau})}{1-\beta+\delta\beta(1-\bar{\tau})}\right]^{\frac{1}{1-\alpha}}$ and $\frac{\partial K_{ss}^{prop}}{\partial \bar{\tau}} < 0$.

Lemma 1. *Under lump-sum tax, a government spending G is feasible at a zero debt steady state if and only if $G < \hat{G}_l$, with:*

$$\hat{G}_l = \left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} \left[(1-\alpha)(1-\kappa) + \frac{\alpha(1-\beta)}{(1-\beta(1-\delta))}\right] - \hat{D}\kappa$$

Lemma 1 shows that under lump-sum tax, it is not feasible to finance more than $\hat{G}_l$ in a sustainable way even when the firm produces optimally and all the production is entirely devoted to finance government spending.

Assumption 1. *Assume that:* $\hat{D} \leq \hat{D}_l^{hi} \equiv \frac{1-\beta}{\beta}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{1}{1-\alpha}}$.

8. Detailed proofs of all results derived here are given in Annex A.1.

Proposition 5. *Under lump-sum tax, if assumption 1 is violated, then the firm will be constrained at steady state regardless of the size of the government.*

This result implies that if the shareholders request more dividend payment than the return on their investment, the firm will be issuing new equities to pay dividend and to finance investment. In fact, $\hat{D}_l^{hi}$ is the interest rate times the value of capital at steady state and it is meaningful to assume that a stockholder may not require a dividend higher than the return on its investment.

Proposition 6. *Let assumption 1 hold. Then, the firm will be in the equity-issuing regime if and only if the government size is larger than* $\bar{G}_l \equiv \hat{D}_l^{hi} - \hat{D}$.

This result derives the maximum receipt that the government can raise by using lump-sum tax without distorting the firm's investment.

Assumption 2. *Assume that* $\hat{D} < \hat{D}_l^{lo} \equiv -(1-\alpha)\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}}$.

Proposition 7. *Assume that assumption 2 holds. Then:* $\bar{G}_l < \hat{G}_l$.

The proposition implies that there exists a range of feasible government size which constrains the firm to using equity as a marginal source of investment financing.

Lemma 2. *At the zero government debt steady state, the tax receipt is a non-linear function of the proportional tax rate. That is:*

$$G(\tau) = \left(\frac{\alpha\beta(1-\tau)}{1-\beta+\delta\beta(1-\tau)}\right)^{\frac{\alpha}{1-\alpha}} \frac{\alpha(1-\beta)\tau}{1-\beta+\delta\beta(1-\tau)}$$

In addition, there exists a critical tax rate $\hat{\tau}_p$, $0 < \hat{\tau}_p < 1$ *so that the tax revenue is increasing (respectively decreasing) in* τ *if and only if* $\tau < \hat{\tau}_p$ *(respectively* $\tau > \hat{\tau}_p$*) where* $\hat{\tau}_p = \frac{(1-\beta+\delta\beta)(1-\alpha)}{1-\beta+\delta\beta(1-\alpha)}$. *The maximum tax revenue that government can collect in a zero debt steady state using proportional tax is:* $\hat{G}_p = \alpha(1-\alpha)\left(\frac{\alpha^2\beta}{1-\beta+\delta\beta}\right)^{\frac{\alpha}{1-\alpha}}$.

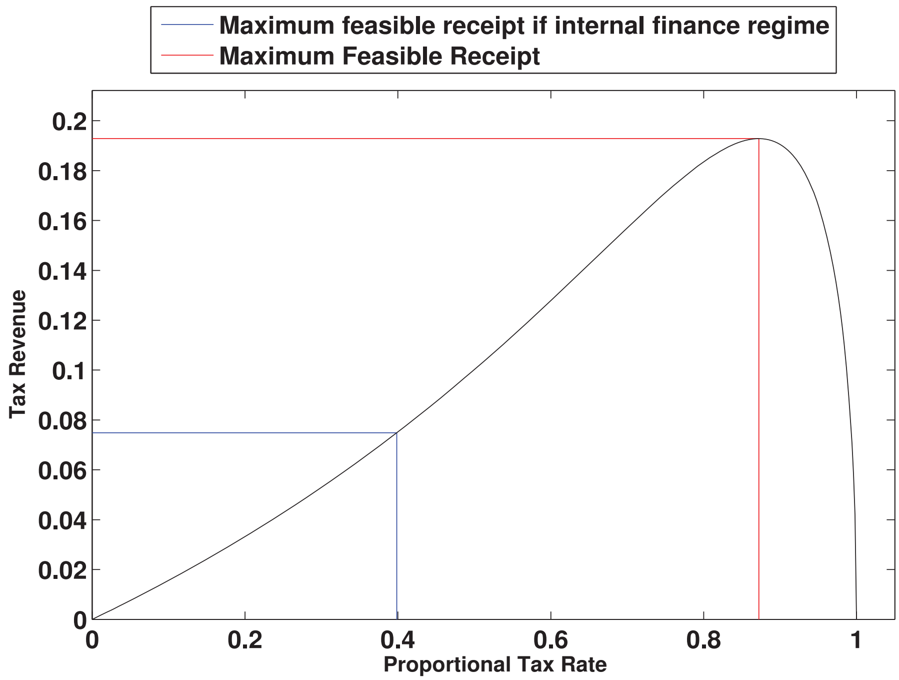


Figure 1.1: Laffer Curve

Lemma 2 shows that the tax receipt is increasing in the tax rate for tax rates lower than $\hat{\tau}_p$. However beyond $\hat{\tau}_p$, an additional increase in the marginal tax rate results in a lower tax revenue. This is the well known Laffer Curve. The reason is that beyond $\hat{\tau}_p$, the elasticity of the corporate profit to the marginal tax rate is higher than that of the tax receipt to the marginal tax rate. As a result, the profit decreases more than proportionally to the increase in tax rate. Thus, it is suboptimal for the government to raise the tax rate beyond $\hat{\tau}_p$. Figure 1.1 plots the evolution of government receipt as a function of tax rate for standard values of technology and preference parameters presented in Table 1.1.

Proposition 8. *Let* $\hat{D}_p^{lo} \equiv \frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta-\delta\beta^2}\right]^{\frac{1}{1-\alpha}}$ *and* $\hat{D}_p^{hi} \equiv \frac{1-\beta}{\beta}\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}}$.
For $\alpha, \beta, \delta, \kappa$ *satisfying* $0 < \alpha, \beta, \delta, \kappa < 1$*:* $\hat{D}_l^{lo} < \hat{D}_p^{lo} < \hat{D}_l^{hi} < \hat{D}_p^{hi}$.

Assumption 3. *Assume that:* $\hat{D} < \hat{D}_l^{hi} = \frac{1-\beta}{\beta}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{1}{1-\alpha}}$.

Proposition 9. *If assumption 3 holds, then there exists a critical tax rate* $\bar{\tau}_p$*,* $0 < \bar{\tau}_p < 1$ *such that the firm will be dividend-constrained if and only if* $\tau > \bar{\tau}_p$*, with* $\bar{\tau}_p = \frac{\alpha\beta^\alpha(1-\beta)^{1-\alpha} - \hat{D}^{1-\alpha}(1-\beta+\delta\beta)}{\alpha\beta^\alpha(1-\beta)^{1-\alpha} - \delta\beta\hat{D}^{1-\alpha}}$ *and the corresponding government spending is:* $\bar{G}_p = \alpha\left(\frac{\beta\hat{D}}{1-\beta}\right)^\alpha - \frac{\delta\beta\hat{D}}{1-\beta} - \hat{D}$.

Assumption 4. *Assume that:* $\hat{D}_p^{lo} < \hat{D} < \hat{D}_p^{hi}$.

Lemma 3. *Let assumption 4 hold. Then,* $0 < \bar{\tau}_p < \hat{\tau}_p < 1$.

When assumption 3 holds, proposition 9 derives the tax rate, $\bar{\tau}_p$, above which the firm will be forced to issue new equity to finance investment under proportional taxation. For standard values of technology and preference parameters, the blue and red lines in Figure 1.1 plot the tax rates $\bar{\tau}_p$, and $\hat{\tau}_p$, respectively. In order to compare the effects of lump sum tax cuts and those of reductions in proportional tax rates, it is meaningful to consider tax cuts which imply the same reduction in government revenue. Proposition 8 ensures that it is feasible to consider such tax cuts experiments starting from initial steady-states where the dividend constraint is binding. Lemma 3 has some important implications for the policy experiments considered in this paper. It provides sufficient conditions on dividend target, which guarantee the existence of a feasible tax rate such that the dividend constraint is binding at initial steady state. For the policy experiments in this paper, I consider dividend targets which satisfy these conditions.

1.5 Effects of Temporary Tax Cuts

I first use the closed-form solution to determine the long run equilibrium of the model. Next, I fix a length for the transition and solve for the transitional dynamics following tax cut by backward induction.The detailed algorithm is presented in annex A.2.

1.5.1 Parameterization

The parameter values are set to illustrate the workings of the model and do not intend to match the real business cycle data. However, I still require these parameters to be within the range of values estimated or calibrated by other studies in the literature. I assume that a time-period in the model corresponds to one year in the data and the capital share is set to 1/3 as in the macroeconomic literature. The marginal cost of external financing, κ, is set to 0.027 closed to the estimated value 0.028 by Gomes [2001]. As the quantitative exercise is done for illustration, the values of the remaining parameters are similar to standard values used in the literature, while ensuring the well functioning of the model. The parameter values are summarized in Table 1.1. These parameters values imply that the tax rate, $\bar{\tau}_p$, above which the

Table 1.1: Baseline Parameterization

Description	Parameter	Value
Capital income share	α	0.33
Discount factor	β	0.959
Depreciation rate	δ	0.101
Marginal cost of external financing	κ	0.027
Lower Bound on Dividend	$\hat{D}$	0.113

firm is dividend-constrained at steady state is equal to the highest US federal statutory corporate rate of 39%. This tax rate is high enough so that large tax cuts which allow temporary switching of financing regime are feasible under both lump sum and proportional taxation. The critical proportional tax rate, $\hat{\tau}_p$, corresponding to the maximum feasible government spending is equal to 87%. These tax rates imply that the set of feasible tax rates, for which the dividend constraint is binding at steady state under both lump-sum and proportional taxes, is non-empty ($]\bar{\tau}_p, \hat{\tau}_p[\neq \{\phi\}$). In addition, $\bar{\tau}_p$ is located on the upward section of the Laffer Curve ($\bar{\tau}_p < \hat{\tau}_p$), ensuring that there is a room to simulate policy experiments in which firms are initially constrained.

1.5.2 Policy Experiments

I assume exogenous and time-invariant government spending, and zero government debt in steady-state to isolate eventual effects associated with changes in government size. Figure 1.2 presents a typical experiment in which the government uses a lump-sum tax to raise revenue.
The blue solid line represents the tax level corresponding to the maximum feasible government spending. The black line is the tax level at steady state and is equal to the exogenous size of the government. The blue dashed line refers to the critical level of tax above which the dividend constraint is binding at steady state. The green line shows the evolution of the government debt. The economy is initially in a steady-state where the dividend constraint is

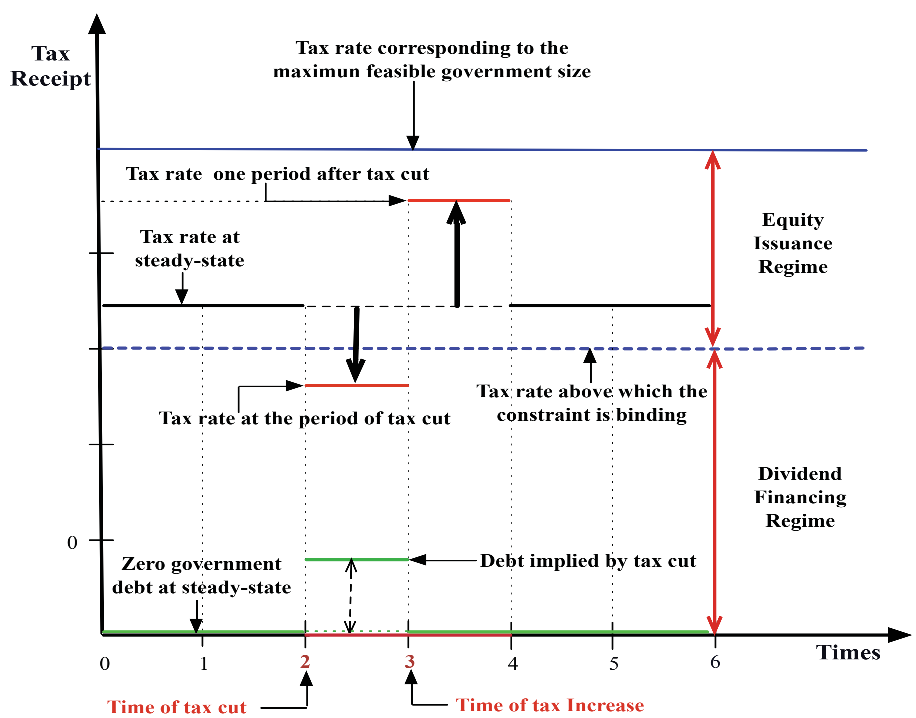


Figure 1.2: Timing of Tax Cut

binding. At period 2, the government unexpectedly cuts tax, large enough to relax the dividend constraint. The firm then temporarily switches to a retained-earnings financing regime. The government issues one-period debt to finance the deficit induced by the tax cut. Once the tax cut occurs, all agents have perfect foresight about the future tax path. At period 3, the government increases tax to repay its debt and related service. From period 3 and onwards, the economy goes through a transition but converges to the initial steady state because the tax rate and the government debt revert to their steady-state values after period 4.

Table 1.2: Description of Experiments

	Lump-sum tax		Proportional tax				
	1	2	3	4	5	6	7
Steady tax rate	0.1635	0.5250	0.15	0.41	0.41	0.41	0.41
Rate after tax cut	0.1058	0.0621	0.10	0.05	0.05	0.05	0.05
Equity issuance cost κ	0.027	0.027	0.027	0.027	0.01	0.04	0.06

I perform several tax experiments to assess the theoretical implications of the model. Table 1.2 presents the description of all experiments. Tax is lump-sum in experiments 1 and 2 and proportional in experiments 3 to 7. To ensure comparability, I set the lump-sum tax rates under experiments 1 and 2 to equal the government revenue under experiments 3 and 4 when tax is proportional, respectively. In experiments 1 and 3, the steady-state tax rate is chosen so that the firm is initially unconstrained. Thus, the tax cuts do not imply a change in the marginal source of finance between two adjacent periods. In this case, any differences between the dynamics of the economy after policy experiments 1 and 3 should be fully explained by the the distortionary effects of the proportional tax. In the other experiments, the firm is initially in equity issuance regime and the tax cuts temporarily relax the constraint on the firm, allowing it to temporarily switch to a retained-earnings financing regime. All differences between the dynamics of the economy under experiments 1 and 2 are due to the presence of financing frictions.

1.5.3 Transitional Dynamics After Tax Cuts

Figures 1.3 and 1.4 present the transitional dynamics of the economy after tax cuts. In all experiments, the economy converges back to steady-steady-state after around 30 periods.

Let start with Figure 1.3 which plots the dynamics of the economy in experiments 1 and 3. In these experiments, the economy is initially in steady state where the firm is in internal finance regime. The proportional tax rate is 15%, and the government decreases it to 10% at period 2. The black and the red lines in Figure 1.3 plot the dynamics of the economy under lump-sum and proportional taxes, respectively. In each panel, the horizontal axis measures the time period. The vertical axes measure the absolute values in the first two columns, and the percentage deviation from the initial steady state before the tax cuts in the last column.

Under both lump-sum and proportional tax, this policy does not change the marginal source of financing. Since external financing is costly and the firm is not dividend-constrained, it stays in the internal financing regime and equity issuance is equal to zero during the whole transition.

When the tax is lump-sum, the black line shows that the firm devotes all the tax cut to dividend payment at the tax cut period. It keeps its investment plan unchanged because the lump-sum tax affects neither the marginal cost, nor the return on investment. As the after interest rate is unchanged, the tax cut does not distort the inter-temporal consumption decisions of the household. Accordingly, the consumer maintains its consumption plan unchanged and invests all the extra dividend in government bonds. When tax increases one period later, the firm reduces dividend payments by the additional tax liability and keeps its investment plan unchanged. The household uses its savings plus interest to maintain their consumption path unchanged. As a result, all the adjustment takes place through the dividend policy of the firm. The red line shows that under proportional tax, the firm reduces investment and increase dividend by more than the total amount of the tax cut. This behavior is explained by the effect of the tax cut on the future tax policy. In fact, the expectation of higher tax in the future reduces the after-tax return on current investment. This expectation of low after-tax returns on investment provides disincentives for firm's investment in capital. As after-tax interest rate falls, households are induced to save less and to consume more. As a result, a temporary cut in proportional corporate profit tax boosts consumption at the expense of lower investment. These investment dynamics are consistent with the findings of previous researches. For instance, Dotsey [1994] find that a temporary cut on capital tax, followed by a tax increase, reduces investment.

In summary, the firm behaves in a Ricardian fashion when the tax is lump-sum and financial markets are perfect. However, the expectation of future

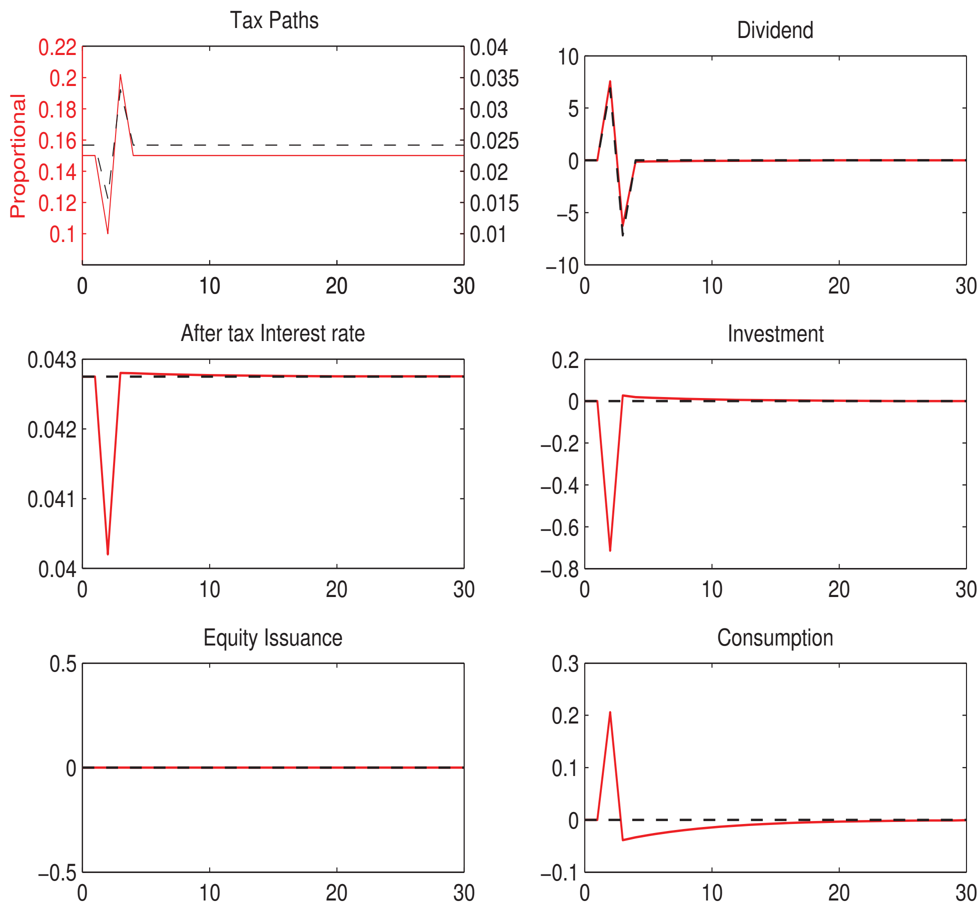


Figure 1.3: Transitional Dynamics without Financing Frictions

high tax rate reduces investment when the tax is proportional to corporate profits.

Now, I consider an economy with financial frictions. As described in Table 1.2, the economy is initially in a steady state where the tax rate equals 41% and the firm is dividend-constrained. Then, the government cuts tax to 5%. This tax relief is large enough to temporarily release the dividend constraint under both lump-sum and proportional taxes. The black and the red lines in Figure 1.4 plot the dynamics of the economy under lump-sum and proportional tax, respectively. They show that in the initial steady state, dividend payments are equal to the lower bound and the firm finances investment by

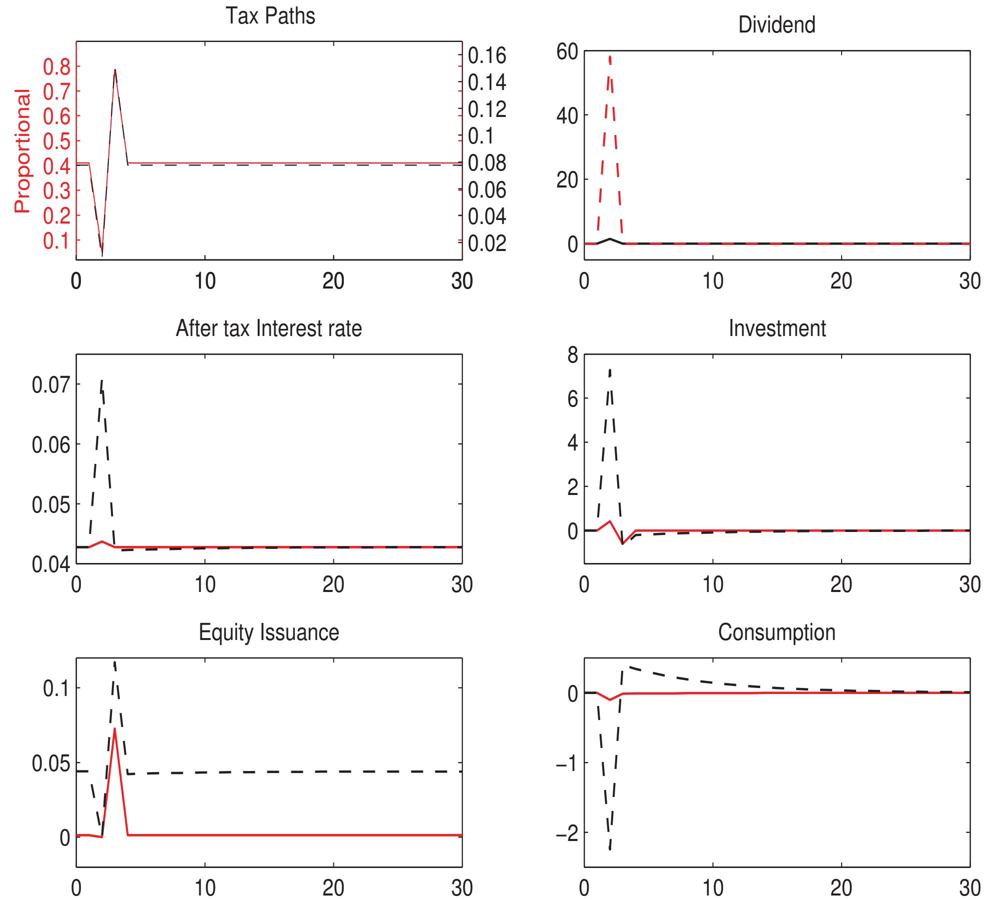


Figure 1.4: Transitional Dynamics with Financing Frictions

issuing new equity. At period 2 when tax decreases, the additional cash flows provided by the tax cuts allow the firm to increase dividend payments above the lower bound. Thus, the firm switches from equity-issuance regime to internal financing regime and temporarily experiences lower marginal cost of investment. Equity issuance falls to zero under both taxes at this period. Moreover, the decrease in investment cost increases the net return on investment and provides incentives to the firm to investment more in capital. In response, the firm devotes almost all the tax cut to investment. Figure 1.4 shows that investment rises initially by about 8%, then declines below its steady-state level when tax increases and gradually rises to the steady-state level. However, investment increases by less than 1% when the tax is proportional to corporate profit. The reason for this is that when tax is proportional, the future high tax rate reduces the expected after-tax return. This expectation of low net after-tax return on investment counteracts the positive effects of low marginal cost of investment. In response, the firm increases dividends relatively more than in an economy with lump-sum taxation. In the benchmark simulation, the increase in the net return on investment induced by the decrease in the marginal investment cost dominates the investment disincentives generated by the expectation of future high tax rate. As a result, the net investment effect is positive. Under both lump sum and proportional taxes, higher demand of capital puts upward pressure on interest rate. This higher return on investment induces the household to consume less and to save more in government bonds. From period 3 to the steady state, the firm switches back to the equity-issuance regime. The marginal cost of investment increases and firm reduces investment. In response, interest rate falls at period 3 and converges monotonically to the steady-state. Consumption jumps above the steady state when tax rises before declining monotonically to the steady state.

In a nutshell, temporary cuts in lump-sum tax stimulate investment because they reduce the marginal investment cost by allowing firms to avoid the additional cost associated with external financing. When the tax is proportional, this effect is mitigated by the expectation of high tax in future, which reduces the after-tax return on investment. In the benchmark calibration, the positive effects of the tax cuts offset the adverse effects of future tax rate and investment increases.

1.5.4 Sensitivity analysis

From the analysis above, the response of investment to temporary reduction in proportional corporate profit tax is driven by two forces. First, the tax cut temporarily reduces the marginal cost of investment because the additional cash flow provided by the tax relief allows the firm to switch to the internal financing regime. The size of this effect highly depends on the extent of investment distortion in the economy before the tax cut, which is proportional to the marginal cost of external financing. Second, the expectation of future high tax rate reduces the expected net return on current investment. Thus, the first effect provides incentives to invest while the last one discourages investment. Accordingly, the net effect of temporary tax cut on investment depends on the relative strength of each force. In this section, I discuss the sensitivity of the investment response to the amount of frictions in the economy.

More precisely, I consider proportional corporate profit taxes and simulate the dynamics of the economy following a reduction of the tax rate from 41% to 5% for three different values of the marginal cost of external financing. I consider values of equity issuance cost in the range of those used [9] by the macroeconomic literature, $\kappa \in \{0.01, 0.04, 0.06\}$. To isolate the effect of the future tax policy, I start in both experiments from the same steady-state and implement the same tax cut. Thus, the expectations of future tax increase are identical in both experiments because the tax cuts generate the same size of current government deficit. [10] Therefore, any difference in the investment dynamics between the three experiments fully results from the difference in the cost of equity-issuance.

The black, the red and the blue lines in Figure 1.5 plot the dynamics of the economy when the cost of equity issuance is 1, 4 and 6 cents, respectively, per dollar of external funding. In each panel, the horizontal axis measures the time period. The vertical axes measure the absolute value in the left panel, and the percentage deviation from the steady state in the right panel. Figure 1.5 shows that at period 2 when government cuts tax, the firm increases dividend payment above the lower bound in all experiments. Consequently, it temporarily switches from the external financing regime to the internal financing regime. One period later when tax increases, equity issuance increases beyond the steady-state level and falls monotonically to steady state. The main goal in this section is to explain the difference in the firm's responses between the three simulations in period 2. For instance, Figure 1.5 shows that the size of the increase in dividend payments varies with the marginal cost of equity issuance. Dividend payments increase by about 70%, 50% and 35% when κ is $0.01, 0.04$ and 0.06, respectively. Furthermore, investment increases by around 10% and 5% if raising one dollar of new equity costs 6 and 4 cents for the firm. However, it decreases by more than 3% when

9. Gomes [2001], Altinkiliç and Hansen [2000] and Hennessy and Whited [2005] estimate the cost of external financing equal to 0.028, 0.0515 and 0.0509, respectively. Gourio and Miao [2011] set κ equals to 0.03.

10. In fact, the tax liability of the firm at any period in steady-state is given by $liability = \tau\left[K_t^{\alpha} N_t^{1-\alpha} - w_t N_t - \delta K_t\right] = \tau\left[\alpha\left(\frac{1-\alpha}{w_t}\right)^{\frac{1-\alpha}{\alpha}} - \delta\right] K_t.$

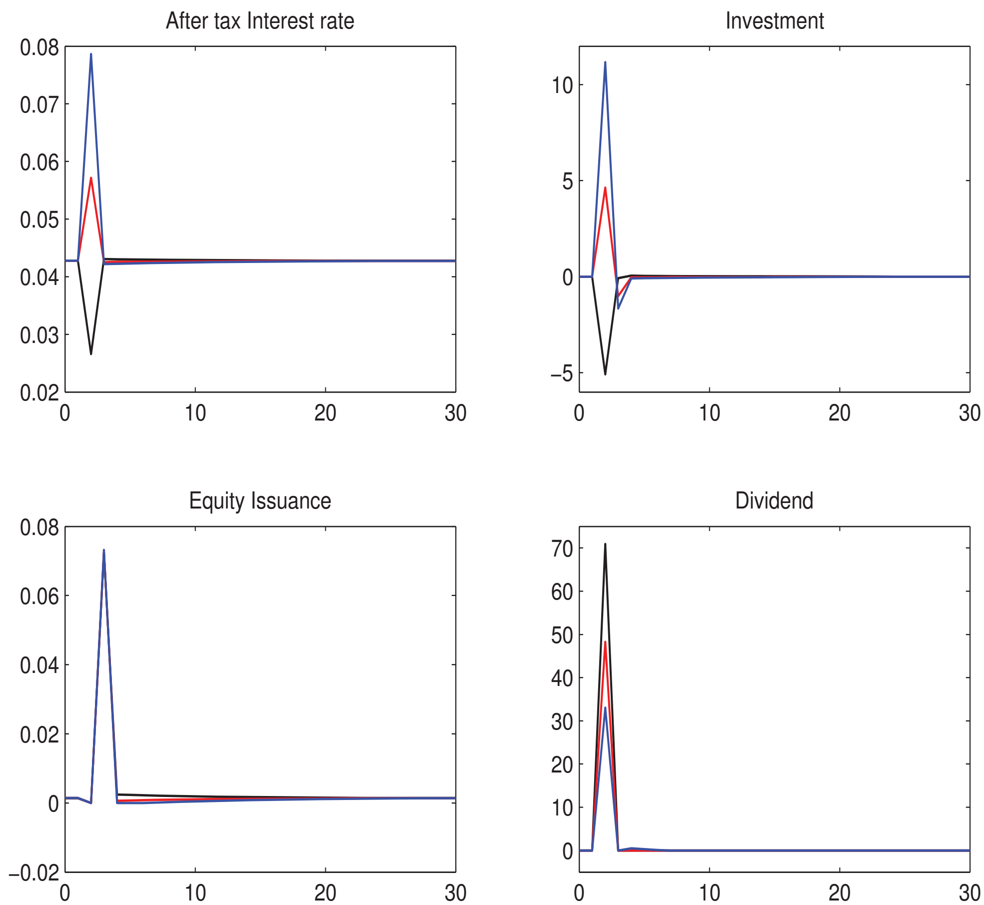


Figure 1.5: Sensitivity analysis

the cost of external financing equals 1 cent per dollar of new equity issued. The logic behind this result is s follows. The investment incentives provided by the tax cut are proportional to the extent of investment distortion in the economy before the tax cut because I have shut down the effects of high future rate. How distorted the investment is before the tax cuts in turn depends on the marginal cost of equity issuance, κ. More precisely, the higher the marginal cost of equity issuance, the higher is the reduction in the marginal cost of investment, and hence the incentives from the temporary tax relief. Consequently, for lower values of κ, the negative effects of lower after-tax return dominate the direct incentives of the tax relief. In response, the firm decreases investment. As the marginal cost of equity issuance increases, the direct benefits tax cuts increase and offset the disincentives from expectations of higher future taxes. Accordingly, investment increases. Consistent with this reasoning, Figure 1.5 shows that the firm decreases investment for $\kappa = 0.01$, while it increases investment when $\kappa = 0,06$ than if $\kappa = 0.04$.

1.6 Conclusion

This paper studies the short run effects of changes in the timing of corporate taxation in the presence of financial market imperfections. I analyze the full transition of the economy following temporary tax cuts financed by future tax increase using a dynamic general equilibrium model in which a representative firm takes investment and financing decisions subject to equity issuance costs and dividend constraint. I first establish that firms behave in a Ricardian fashion when capital markets are perfect and taxes are lump-sum. Second, I show that changes in the timing of lump-sum tax affect investment if they imply a change in the marginal source of finance between two adjacent periods. In this case, temporary tax cuts followed by subsequent tax increase provide a boost to investment at the cost of a contraction in consumption. The result is primarily generated by the reduction in the marginal cost of investment induced by the switching from costly external financing to internal financing regime. Third, when the government uses proportional tax on corporate profits to finance its expenditure, temporary tax cuts may have real effects even if they don't imply a change in the marginal source of financing. The reason is that current tax cuts imply high future tax, inducing expectation of low after-tax return on current investment. As a result, tax cuts provide incentives to current consumption, crowding out investment if capital markets are perfect. When the firm is initially dividend-constrained and the tax cut is large enough to relax the constraint, the qualitative as well as the quantitative effects of tax cuts depend on the extent of distortion on investment before the tax cuts. More precisely, the net effect is driven by two opposite forces. On one hand, switching from an equity-issuance regime to an internal financing regime reduces the marginal cost of investment, providing incentives to investment. On the other hand, current tax cuts imply future tax-increase, lowering expected after-tax marginal benefit of investment. The size as well as the sign of the net effect on investment depends on the relative strength of each effect. The sensitivity analysis shows that the higher the

marginal cost of equity issuance, the higher is the positive effect of the tax relief on investment. These findings suggest that the effects of corporate tax incentives on investment depend on how constrained the firm is before the tax relief. In addition, both the size of the tax cuts and the tax instrument matter for the efficiency of tax incentives in stimulating investment.
The analysis in this paper could be extended along a few directions. Particularly, firms are heterogenous in several dimensions. Thus, at any point in time, different firms may be in different financing regimes and hence respond to the temporary corporate tax cut in different ways. Therefore, one would ideally study the policy experiment in an environment with firm heterogeneity. Incorporating firm heterogeneity also allows to quantify the effects of temporary tax relief.

Chapter 2

Stimulative Effects of Temporary Corporate Tax Cuts

2.1 Introduction

Policymakers often rely on temporary corporate tax cuts in order to provide incentives for business investment in recession times. For example, the Jobs and Growth Tax Relief Reconciliation Act of 2003 temporary reduces the dividend and capital gains taxes through 2008 to promote growth in the U.S.. During the 2008 crisis, the 2009 American Recovery and Reinvestment Act also provides generous tax provisions to businesses. A common motivation for such policies is the presence of financial frictions. That is, recessions are viewed as periods when firms' access to credit is particularly tight. A reduction in corporate taxation during downturns may help alleviate financial market imperfections by effectively making more internal funds available. Aggregate investment and output are expected to increase as a result, mitigating the economic slowdown.

Our goal is to quantify how effective temporary corporate tax cuts are when firms are subject to financing frictions. We consider temporary tax cuts funded by public debt, so that only the timing of corporate taxation changes. We find that, on impact, a temporary reduction in corporate taxation increases aggregate investment by 26 cents per dollar of tax stimulus, and aggregate output by 3.5 cents. As the policy reverses and corporate taxation eventually increases, the stimulative effect on investment is also partially reversed. Over the long-run, the cumulative investment multiplier is just 4.6 cents per dollar of tax stimulus. The stimulative effect on output is instead very persistent, as the initial buildup of capital increases future cash-flows and allows firms to relax financial constraints, even long after the period of the tax cut reversal. We find a cumulative output multiplier of 7.2 cents per dollar of tax stimulus. These are reasonably large multiplier effects. The main reason why they are not larger is that although we find a significant expansion of investment and output among the smallest, constrained firms, this is to a large extent achieved by crowding out the investment of the largest, unconstrained firms.

Among constrained firms, we do find investment multipliers either very close or equal to one, especially among new entrants. For these firms, the the tax cut is entirely channelled to investment, and the policy achieves full effectiveness. However, the increased aggregate demand for capital puts upward pressure on the interest rate, which discourages investment among the large, unconstrained firms. To quantify the crowding out effect, we prevent the wage and the interest rate from adjusting, and find that the multipliers could be two and four times larger for investment and output, respectively. Our approach is to concentrate on a simple general equilibrium model which integrates a representative household, a government, and a production sector featuring heterogeneous firms potentially subject to financing frictions. Firms are subject to idiosyncratic productivity and entry/exit shocks, and we abstract from aggregate uncertainty. The firm's optimal investment decisions in response to shocks may require funds from the household sector, in addition to retained earnings. We assume that there is an upper bound on the amount of external funds a firm has access to. The industry equilibrium features some firms which are financially constrained. The number of constrained firms, as well as the extent of investment distortions, are key for estimating the expansionary effect of the corporate tax cut policy. We infer these features by requiring the model to match certain properties of the cross-sectional distribution of cash flow and investment rates across U.S. establishments.

The literature has mostly considered a different justification for temporary corporate tax cuts, which relies on intertemporal substitution. That is, when the reduction in taxes is temporary, firms may have an incentive to concentrate investment and production activities in the periods of lower taxation. Related policy interventions may also rely, for instance, on temporary investment tax credits [Abel, 1982]. These policies have in common their distortionary nature, and therefore their impact on intertemporal marginal costs and benefits from investing. The literature has provided a number of analysis of this channel. One example is Dotsey [1994], who considers an environment where the government is subject to an intertemporal budget constraint and capital taxes in any given period are stochastic. In this setting, lowering capital taxes today entails higher expected taxes in the future. This may actually lower investment today when taxation is distortionary and if the effect of higher future distortions dominates the firms' investment decisions. Another recent example is Gourio and Miao [2011]. These authors study the 2003 dividend and capital gain tax cuts in the U.S., under the assumption that they were unexpected and temporary. They conclude that the capital gain tax cut alone would temporarily increase investment by nearly 10 percent, in accordance with the intertemporal substitution effect. However, when combined with the dividend tax cut, investment actually declines by slightly more than 10 percent. The reason is that firms choose to cut investment expenditures in order to pay more dividends when the dividend tax is temporarily low, an effect large enough to overturn the capital gain tax one.

Gourio and Miao [2011] use a setting which is related to ours, in the sense that they also rely on a general equilibrium model with firm heterogeneity. However, they concentrate on the firm's choice of how to fund investment expenditures (retained earnings, debt, or equity), whereas our focus is on the presence of an overall external financing constraint.
Missing from the literature is precisely an assessment of the role of temporary tax relief policies in alleviating financial frictions. In order to separate this channel from the intertemporal substitution channel, we assume corporate taxes are non-distortionary. Our setup satisfies a Ricardian proposition, in the sense that absent financial frictions temporary corporate tax cuts produce no aggregate effects. We start the economy from the stationary equilibrium, and consider a surprise temporary reduction in corporate tax rates when firms are subject to financial frictions. Our calibration ensures that the extent of financial frictions allows the model to replicate salient features of the firm-level data at steady-state. We solve for the model's transition back to the initial steady-state, and compute the investment and output effects of the policy on impact. Our results show that the expansionary effect of these policies is reasonably large. These results are consistent with Heathcote [2005], who shows that temporary income tax cuts when consumers (instead of firms) face borrowing constraints generate increases in aggregate consumption of 11.4 cents per dollar of lost tax revenue with lump-sum taxes (like here), and of 29 cents with proportional taxes. Financing constraints therefore generate significant departures from Ricardian equivalence, both among firms and among consumers.

2.2 Model

The model consists of a representative household, a continuum of firms with a unit mass, and a government. Time is discrete and indexed by t.

2.2.1 Firms

Firms face both idiosyncratic productivity shocks, and idiosyncratic entry and exit shocks. The current productivity shock, denoted by ε_t, follows a Markov chain with transition probabilities $\pi(\varepsilon_t, \varepsilon_{t-1})$ and takes values on the finite set E.
The entry and exit shock follows a Bernoulli process. Each incumbent firm

faces a per period exit probability of $\eta \in (0, 1)$, following production. In every period, the total mass η of exiters is replaced by an equal mass of entrants, each drawn from an homogenous pool of potential entrants. The total mass of active firms in every period is normalized to 1.
Our modelling of entry and exit is similar to the existing literature, see for example Khan and Thomas [2013]. Entry and exit allows for a nontrivial equilibrium firm distribution and ensures some firms will always be financially constrained. We assume a law of large numbers holds so that aggregate quantities and prices are deterministic for given government policy.

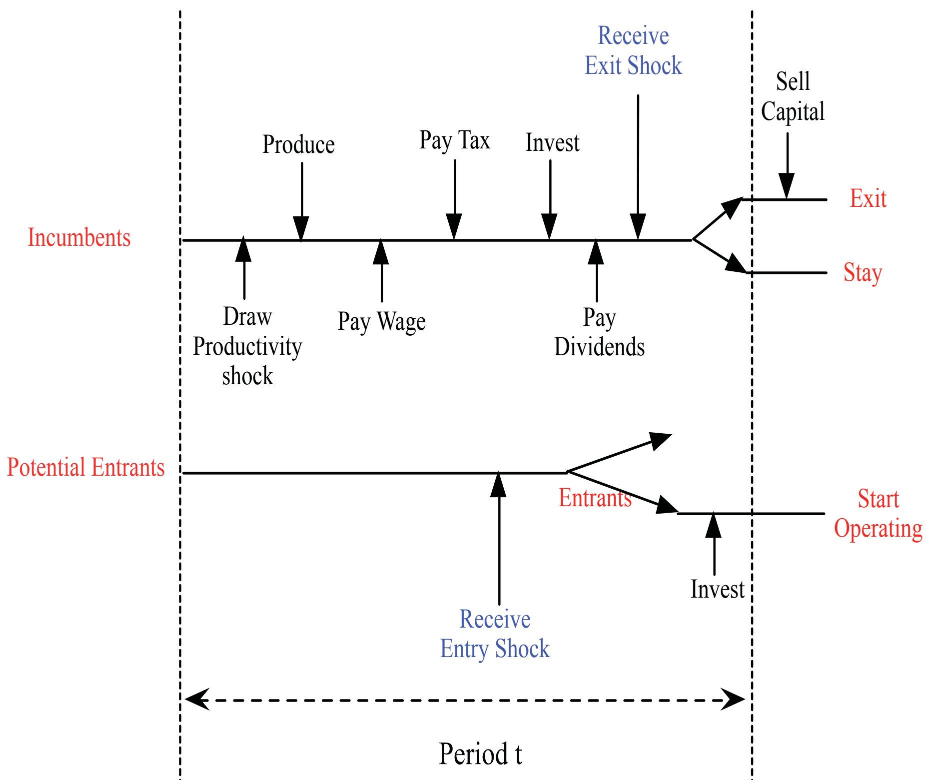


Figure 2.1: Timing of the model

Figure 3.1 illustrates the timing of the model according to the type of firm, incumbent or prospective entrant. At the beginning of period t, incumbents draw a productivity shock, and then hire labor, produce, pay corporate taxes, invest in physical capital, and pay dividends to their shareholders. An exit shock is drawn at the end of the period. If an incumbent is to exit, we assume it sells its capital stock at the beginning of next period, and permanently leaves the industry.

Potential entrants are ex-ante identical, and they all start with no initial capital. Upon entering the industry at time t, a new entrant needs to raise funds and invest in order to begin producing next period. These new entrants become incumbent firms at time $t+1$, and they all begin production activity with the same initial level of capital.

Firms are owned by the representative consumer, who holds an equity stake on each of them. In every period firms pay dividends to the representative consumer. Firms are neither allowed to issue new equity nor make equity repurchases. We also assume, without loss of generality, that firms do not have access to the bond market, or any other source of external funding. In our model, firms may therefore access external funds by paying negative dividends, while new entrants also raise funds by selling equity. We say without loss of generality because our main focus is to model the effect of constraints on the overall extent of external financing a firm may obtain, irrespective of the source.

2.2.1.1 Incumbent Firm

We formalize the problem of the firm when government policy follows a deterministic path, likewise for aggregate prices. Denote by $V_t(k_t, \varepsilon_t)$ the value of a firm at time t, with capital stock k_t and productivity shock ε_t. The Bellman equation is:

$$V_t(k_t, \varepsilon_t) = \max_{n_t, k_{t+1}, d_t} \left\{ d_t + \frac{1}{1+r_{t+1}} \left[\begin{array}{r} \eta k_{t+1} + (1-\eta) * \\ \sum_{\varepsilon_{t+1}} \pi(\varepsilon_{t+1}, \varepsilon_t) V_{t+1}(k_{t+1}, \varepsilon_{t+1}) \end{array} \right] \right\} \tag{2.1}$$

subject to

$$y_t = d_t + w_t n_t + \tau_t + k_{t+1} - (1-\delta)k_t \tag{2.2a}$$

$$d_t \geq -\bar{d} + \zeta k_t, \tag{2.2b}$$

where output is $y_t = \varepsilon_t f(k_t, n_t) = \varepsilon_t \left({k_t}^{\alpha} n_t^{1-\alpha} \right)^{\nu}$, with $0 < \alpha, \nu < 1$, and

$\delta \in (0,1)$ is the depreciation rate. A decreasing returns to scale technology ensures that firm size is always well-defined.
Equation (2.2a) describes the flow of funds condition for the firm. Output is the only cash inflow, while cash outflows include gross investment expenditures, plus tax liabilities, plus wage and dividend payments. Incumbents cannot issue new equity nor make equity repurchases.
Without any constraint on dividend payments the Modigliani-Miller theorem holds, and temporary (lump-sum) tax cuts do not affect firm decisions. Our departure from the Modigliani-Miller theorem stems from the presence of (2.2b). This constraint simultaneously captures two types of restrictions on dividends. First, we impose an upper bound on the access to external funds $-\bar{d} < 0$, which is unconditional on firm size as measured by the stock of capital. Second, we also impose a minimum dividend payout requirement, which is increasing in firm size for $\zeta > 0$. [1]
The first restriction is our key friction governing firms' access to external funds. Our second restriction can be justified by appealing to the notion that minimum dividend payments may help mitigate agency problems between shareholders and managers and work as signaling device [see Allen and Michaely, 2003, for a review]. The fact that they're increasing with firm size is also consistent with evidence that large corporations tend to pay out a larger fraction of their earnings [Allen and Michaely, 2003]. Bianchi [2013] adopts a similar dividend payout policy, although we allow it to vary with firm size.
Our main motivation for adopting this flexible specification is for calibration purposes. Having $\zeta > 0$ effectively tightens the financial constraints faced by larger firms. [2] This parameter affords us better control in matching the average size of entrants relative to the average size of incumbents.
Let λ_t be the Lagrange multiplier associated with (2.2b). The optimality

1. Let $-d_t^b \geq 0$ denote the total amount of borrowing from the household sector. As explained previously, we assume this borrowing takes the form of negative dividends. Let $d_t^p \geq 0$ be the total amount of dividend payouts. We impose $d_t^b \geq -\bar{d}$ and $d_t^p \geq \zeta k_t$. Since we model net dividend payouts $d_t \equiv d_t^b + d_t^p$, the overall constraint on this variable is therefore as in (2.2b). Whenever (2.2b) binds in our model, then $d_t^b = -\bar{d}$ and $d_t^p = \zeta k_t$. Otherwise, d_t is split arbitrarily between d_t^b and d_t^p, subject to $d_t^b \geq -\bar{d}$ and $d_t^p \geq \zeta k_t$.

2. Financial constraints are still overall tighter for smaller firms in the model, since these tend to be farther away from their unconstrained optimal size. See the discussion surrounding Figure 3.3

conditions for labor and capital are:

$$w_t = \varepsilon_t f_2(k_t, n_t)$$

$$1 + \lambda_t = \frac{\eta}{1 + r_{t+1}} + \frac{1 - \eta}{1 + r_{t+1}} \mathbf{E}_t \left\{ \begin{array}{r} (1 + \lambda_{t+1})(1 - \delta + \varepsilon_{t+1} f_1(k_{t+1}, n_{t+1})) \\ -\zeta \lambda_{t+1} \end{array} \right\} \quad (2.3)$$

The discounted marginal gains from investing are on the right-hand-side of (2.3). When (2.2b) doesn't bind tomorrow ($\lambda_{t+1} = 0$) we obtain the familiar terms. That is, either the value of undepreciated capital plus the marginal product if the firm survives, or the value of investment if the firm exits. When $\lambda_{t+1} > 0$, and conditional on survival, the discounted value of future cash flows increases, since they help fund future investment. However, a larger firm size tomorrow also tightens the dividend constraint tomorrow through the dividend payout requirement, which lowers the marginal gain from investing.

One important point stemming from (2.3) is that corporate taxation, even if lump-sum, affects the firm's investment behavior when the dividend constraint (2.2b) binds. This effect is summarized in the value of the multiplier $\lambda_{t+1} > 0$, and obtains by applying the Envelope theorem. If the dividend constraint is instead slack, then lump-sum corporate taxes do not impact investment decisions. This sets our paper apart from the related literature emphasizing the intertemporal substitution effects of tax cuts [Abel, 1982, Dotsey, 1994, Gourio and Miao, 2011].

2.2.1.2 New Entrant

A new entrant is like an incumbent with a zero capital stock, and no corporate tax liability. Its main decision is to invest in order to start operating next period. The investment is fully funded by the sales of equity to the household sector at price p_t^e, whose amount is normalized to one, net of any dividend payout d_t^e, which we assume can take place within the period of new equity issuance. This assumption simplifies our formulation of the new entrant's financing constraint. Denote by V_t^e the value of a new entrant. Then

$$V_t^e = \max_{k_{t+1}^e, d_t^e} \left\{ d_t^e + \frac{1}{1 + r_{t+1}} \sum_{\varepsilon_{t+1}} \bar{\pi}(\varepsilon_{t+1}) V_{t+1}(k_{t+1}^e, \varepsilon_{t+1}) \right\}$$

subject to

$$p_t^e = k_{t+1}^e + d_t^e \tag{2.4}$$

$$p_t^e - d_t^e \leq \bar{d}, \tag{2.5}$$

where $\bar{\pi}(\varepsilon_{t+1})$ is the long-run probability of state ε_{t+1}, and V_{t+1} is the incumbent's value function defined previously. The initial productivity of new entrants is therefore drawn from the stationary distribution of the Markov chain.

Equation (2.4) is the cash-flow constraint of the firm. We impose a constraint on the dividend payout of new entrants, equation (2.5), leading to the same maximal net amount of funds $\bar{d}$ they can obtain from the household sector as when they become incumbents. Since new entrants are homogeneous, they all choose the same initial level of capital. In addition, our parameterization is such that $\bar{d}$ is sufficiently low compared to the unconditional mean of the productivity shocks, so that new entrants will always find themselves constrained. The solution to their problem is:

$$d_t^e = -\bar{d} + p_t^e$$
$$k_{t+1}^e = k^e = \bar{d}.$$

As pointed out previously, we assume the amount of shares outstanding by each firm stays constant throughout their life-cycle at the level issued upon entry.

2.2.2 Aggregation

Denote the incumbent's decision rule for investment by $k_{t+1}(s_t)$, where $s_t \equiv (k_t, \varepsilon_t)$ is the individual state. Let $S \equiv K \times E$ denote the set of individual states, where K is the set of capital stock levels. Let Ω_S denote the product $\sigma - algebra$ on S with typical subset $\mathcal{A}$.

We can summarize the aggregate distribution of firms with a measure defined over the state space S, $\mu_t(\mathcal{A})$, which is the mass of firms engaged in production at time t, with state $s_t \in \mathcal{A} \subseteq S$. This includes incumbents as of $t-1$ which survive into t, and the new entrants replacing the exiters as of $t-1$.

Now define the transition function Q_t of incumbents across states:

$$\begin{aligned} Q_t \quad : \quad S \times \Omega_S \quad &\rightarrow \quad [0,1] \\ (s_t, K \times E) \quad &\mapsto \quad Q_t(s_t, K \times E) = \sum_{\varepsilon_{t+1} \in E} \pi(\varepsilon_{t+1}, \varepsilon_t) \mathbb{1}_{k_{t+1}(s_t) \in K}, \end{aligned}$$

where $\mathbb{1}_K$ is the indicator function on the set K.
For any Borel set $\mathcal{A} \in \Omega_S$, the law motion of the aggregate state of the economy is:

$$\mu_{t+1}(\mathcal{A}) = (1-\eta) \int_S Q_t(s, \mathcal{A}) \mu_t(s) ds + \eta \psi(\mathcal{A}), \tag{2.6}$$

where ψ is the distribution of new entrants,

$$\psi(K \times E) = \sum_{\varepsilon_{t+1} \in E} \bar{\pi}\left(\varepsilon_{t+1}\right) \mathbb{1}_{k^e \in K}. \tag{2.7}$$

It is useful to define aggregate investment at this point:

$$i_t = \int_S k_{t+1}(s) d\mu_t(s) - (1-\delta) \left[(1-\eta) \int_S k_t(s) d\mu_{t-1}(s) + \eta k^e\right] + \eta \left[k^e - \int_S k_t(s) d\mu_{t-1}(s)\right], \tag{2.8}$$

where the first two terms correspond to the total gross investment of incumbent firms as of time t (which includes the fraction $1-\eta$ of those that were already operating at $t-1$, plus the fraction η of new entrants at $t-1$), and the last term corresponds to the investment of new entrants as of time t, net of the disinvestment of exiters.

2.2.3 Household

A representative household with unit measure derives utility from consumption alone, according to a standard time-additive utility function $u(c) = \log c$, with future utility discounted at rate $0 < \beta < 1$. A time endowment of 1 is supplied inelastically every period.
The household trades equity shares in the firms, as well as a government bond. Let $\theta_t(s)$ denote the shareholding of type $s \in S$ firms at the start of period t (θ_t^e for new entrants), valued at price $p_t(s)$ (p_t^e for new entrants), and b_t the government bondholding, paying interest rate r_t.
Let W_t denote the household's value function, which solves the Bellman equation:

$$W_t(\omega_t) \quad = \max_{c_t, b_{t+1}, \theta^e_{t+1}, \{\theta_{t+1}(s)\}_{s \in S}} \left\{\log c_t + \beta W_{t+1}(\omega_{t+1})\right\} \tag{2.9}$$

subject to

$$c_t + b_{t+1} + \eta\left(p_t^e - d_t^e\right)\theta_{t+1}^e + \int_S p_t(s)\theta_{t+1}(s)d\mu_t(s) = \omega_t \tag{2.10a}$$

$$\begin{aligned}\omega_{t+1} \equiv w_{t+1} + (1+r_{t+1})b_{t+1} + \eta\int_S k_{t+1}(s)\theta_{t+1}(s)d\mu_t(s) + \\ \int_S \left[p_{t+1}(s) + d_{t+1}(s)\right]\left[(1-\eta)\theta_{t+1}(s) + \eta\theta_{t+1}^e\right]d\mu_{t+1}(s).\end{aligned} \tag{2.10b}$$

Equation (2.10a) is the household's budget constraint. The consumer spends his resources ω_t on consumption, government bonds, and equity purchases of new entrants, net of current dividend payouts, plus equity purchases of incumbents at time t. Income from (2.10b) equals labor earnings, plus the income from government bondholdings, plus the income from physical capital sales of exiting firms, plus shareholding income. The latter equals the dividend plus share value of new entrants at time t and surviving incumbents from t to $t+1$.

The sole outcome from the household's problem which is relevant for our analysis is the real interest rate determination. From the first-order condition for government bonds

$$\frac{c_{t+1}}{c_t} = \beta(1 + r_{t+1}),$$

and in steady-state we obtain $1 = \beta(1 + r)$.

2.2.4 Government

Government spends a constant amount of resources $g > 0$ at each time t, funded either by lump sum corporate taxation, providing total revenue equal to τ_t, or by issuing one period debt b_{t+1}, held by the representative consumer.[3] The government's budget constraint is

$$(1 + r_t)b_t + g = \tau_t + b_{t+1},$$

together with the no Ponzi game condition:

$$\lim_{T\to\infty}\prod_{t=0}^{T}(1 + r_t)^{-1}b_{T+1} \leq 0.$$

3. We also assume g is small enough relative to average productivity, so that government spending does not necessarily exhaust aggregate production.

Requiring that the government wastes no resources and therefore satisfies the no Ponzi game condition with equality, we obtain the present value budget constraint:

$$b_0 + g\sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1} = \sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\tau_t, \tag{2.11}$$

where we assume $b_0 = 0$.
The government's policy will be a sequence $\{\tau_t, b_{t+1}\}_{t=0}^{\infty}$ of tax rates and debt issuance which satisfies (2.11).

2.2.5 Stationary Equilibrium

We now provide a formal definition of the equilibrium, focusing on the steady-state. Given a stationary government policy $(\tau_t, b_{t+1}) = (\tau, b)$, a stationary recursive competitive equilibrium is a value function $V(s_t)$, with $s_t \equiv (k_t, \varepsilon_t)$, and a set of decision rules for incumbents, $n(s_t)$, $k(s_t)$, $y(s_t)$ and $d(s_t)$, a value function V^e and a decision rule for new entrants k_e, a value function W and a set of decisions for the representative household c, b, θ^e and $\{\theta(s_t)\}_{s_t \in S}$, time-invariant cross-sectional distributions of new entrants and incumbents, respectively μ and ψ, and prices r, w, $\{p(s_t)\}_{s_t \in S}$ and p^e such that:

1. Given prices, each agent's value function and decision rules solve their corresponding problem.
2. Given prices, the government's policy satisfies the present value budget constraint (2.11).
3. Markets clear:
   — Labor market: $\int_S n(s)d\mu(s) = 1$.
   — Equity market:
   new entrants: $\theta^e = 1$.
   incumbents: $\theta(s) = 1$, for all $s \in S$.
   — Final good: $\int_S y(s)d\mu(s) = i + c + g$, where i is defined in (2.8).
4. μ is the fixed point of (3.9), and ψ is defined in (2.7).

2.3 Model Solution

We solve our model by numerical methods. The algorithm consists of two parts. First, we compute the steady-state, which characterizes the economy

both before and in the long-run following the tax cut. This requires first solving for the industry equilibrium given wages (the real interest rate is pinned-down by β), and then computing wages to clear the labor market. As part of the solution, we obtain aggregate consumption from the economy's resource constraint, with aggregate production and investment being the outcome of the industry equilibrium.
Second, for the transition of the economy following the transitory tax cut, we use a backward induction algorithm. We guess a transition length and a sequence of wages and real interest rates along the transition, and solve for the industry equilibrium and household consumption at each point in time. We then ensure that prices clear the labor and the final good markets at each point along the transition. The details of the numerical algorithm are in the Appendix.

2.4 Calibration

The steady-state of the model is calibrated to U.S. data for establishment-level investment dynamics.[4] This data is reported annually, thus one model period corresponds to one calendar year. Our parameters can be classified into two groups. The first group includes parameters we set a priori and are reported in Table 3.1. The return to scale parameter $\nu = 0.85$ has a standard

Table 2.1: Parameters selected a priori

Parameter		Value	Source
Return to scale	υ	0.85	Atkeson and Kehoe [2005] and others
Capital elasticity	α	1/3	income share data
Discount factor	β	0.96	interest rate of 4%
Exit probability	η	0.05	Evans [1987], Lee and Mukoyama [2012]

value in the literature employing the same production function specification as ours [Restuccia and Rogerson, 2008, Atkeson and Kehoe, 2005, Pavcnik, 2002, Veracierto, 2001, Atkenson et al., 1996, Gomes, 2001, Clementi and

4. Although we calibrate our model to establishment-level data, we still refer to production units in our model as firms.

Palazzo, 2013], as is the capital share parameter $\alpha = 1/3$.[5] An annual exit rate of 5% is in the middle range of the estimates provided by Evans [1987] and Lee and Mukoyama [2012].

The parameters calibrated internally, by requiring the model to match a set of moments, are presented in Table 3.2. The corporate tax in the model delivers a value for the share of corporate tax revenue of GDP as in the data. From IRS (Internal Revenue Service) data, capital gains and dividend taxes represent roughly 1% of GDP on average for the 2000-2005 period. Taxes on S corporations (whose income is taxed at the shareholder rather than at the corporation level) account for around 1% of GDP over the 2004-2007 period. Corporate profits taxes represent about 2% of GDP on average over the 2000-2007 period. We therefore target a value of 4%.

Table 2.2: Internal calibration

Parameter		Value	Target	Data	Model
Tax rate, gov spending	τ, g	0.057	Corp tax revenue to GDP	0.040	0.041
Depreciation rate	δ	0.069	$avg(i)/avg(k)$	0.069	0.069
Productivity	γ	0.531	$sd\,(i/k)$	0.337	0.300
	σ	0.253	$avg\,(i/k)$	0.122	0.151
	ρ	0.618	$sd\,(cf/k)$	0.161	0.152
Borrowing limit	$\bar{d}$	1.574	$avg(cf)/avg(k)$	0.102	0.127
	ζ	0.382	Rel size entrants	0.600	0.585

The depreciation rate δ is calibrated to deliver an aggregate investment-to-capital ratio of 0.069. This is the same value targetted by Khan and Thomas [2013], and is based on private capital stock estimates from the Fixed Asset Tables, controlling for growth, for the 1954-2002 period.

Firm level productivity follows an $AR(1)$ process:

$$\ln \varepsilon_t = (1-\rho)\gamma + \rho \ln \varepsilon_{t-1} + \sigma \varsigma_t, \tag{2.12}$$

5. In order to arrive at a 1/3 capital share in our model, we assume that the profits firms generate after incurring investment expenditures and making payments to labor are attributed to capital and labor according to the shares α and $1-\alpha$.

where ς_t follows an i.i.d. standard normal distribution. For solving the model, this process is discretized into a 5-state Markov chain using Tauchen's (1986) procedure. The three parameters of the AR(1) process are selected to match three cross-sectional moments: (i) a standard deviation of investment rates as a fraction of capital of 0.337, and (ii) an average investment rate of 0.122, both as reported by Cooper and Haltiwanger [2006], (iii) a standard deviation of the cash to assets ratio of 0.161, as reported by Khan and Thomas [2013] using Compustat data for the 1954-2011 period.

The parameters governing the extent of financial frictions are key. We infer them by requiring that the model matches two additional moments relating to the plant-level dynamics: (i) an average employment size of new entrants (firms in their first production year) of 60% of the average size of incumbents, as reported by Lee and Mukoyama [2012] using data from the U.S. Census Bureau's Annual Survey of Manufactures (ASM) for the 1972-1997 period; (ii) an aggregate cash-to-asset ratio of 0.102, as reported Khan and Thomas [2013] for Compustat data.

Our calibration implies $\bar{d} > 0$ and $\zeta > 0$. As pointed out previously, this implies binding borrowing constraints, which are overall tighter for smaller firms. To illustrate this point, Figure 3.3 plots the ratio of actual to unconstrained investment levels in the model as a function of current capital (firm size).[6] Two lines are plotted, one for a high and the other for a low value of current (hence expected future) productivity. A value of one means the firm is operating at the unconstrained level, and the lower the ratio the tighter the borrowing constraint is. The parameter ζ allows us to control how fast this ratio increases with firm size. As the figure illustrates, the magnitude we obtain for ζ is still consistent with smaller firms, which generate less cash flows, being the most constrained. See Beck et al. [2005] and Angelini and Generale [2008] for some evidence consistent with this model prediction.

The figure also shows that high productivity firms are more constrained, given their higher unconstrained optimal level of investment. Our calibration, namely the degree of persistence of the productivity shocks, is such that this effect always dominates the effect of higher current cash-flows due to higher current productivity.

6. The unconstrained investment level k^*_{t+1} is the solution to either the new entrant or the incumbent's problem when ignoring the dividend constraint.

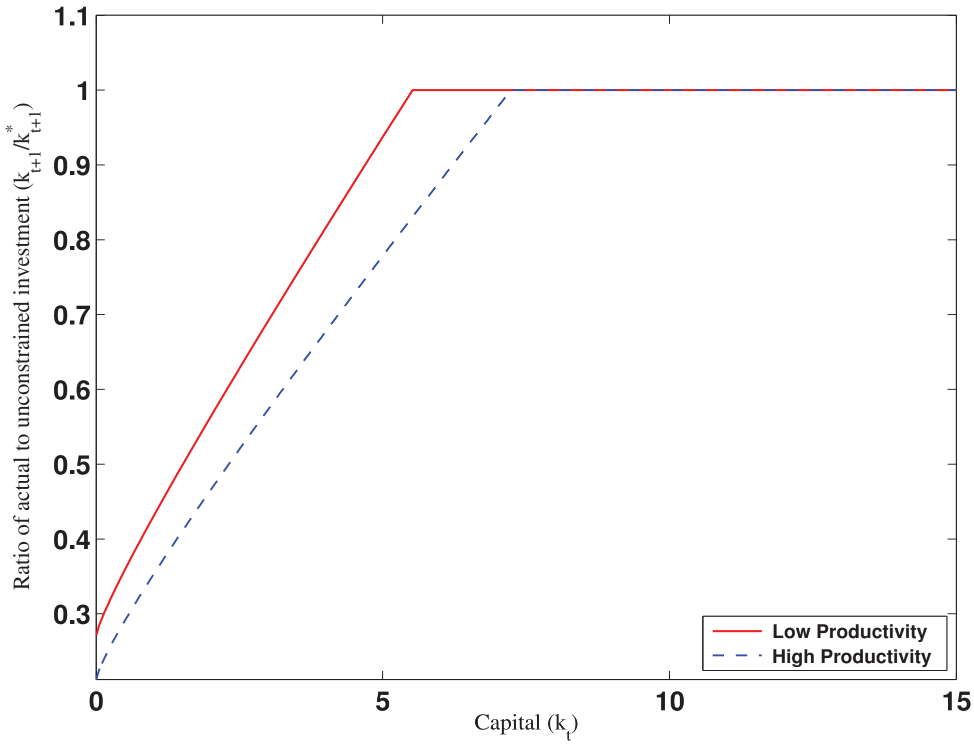


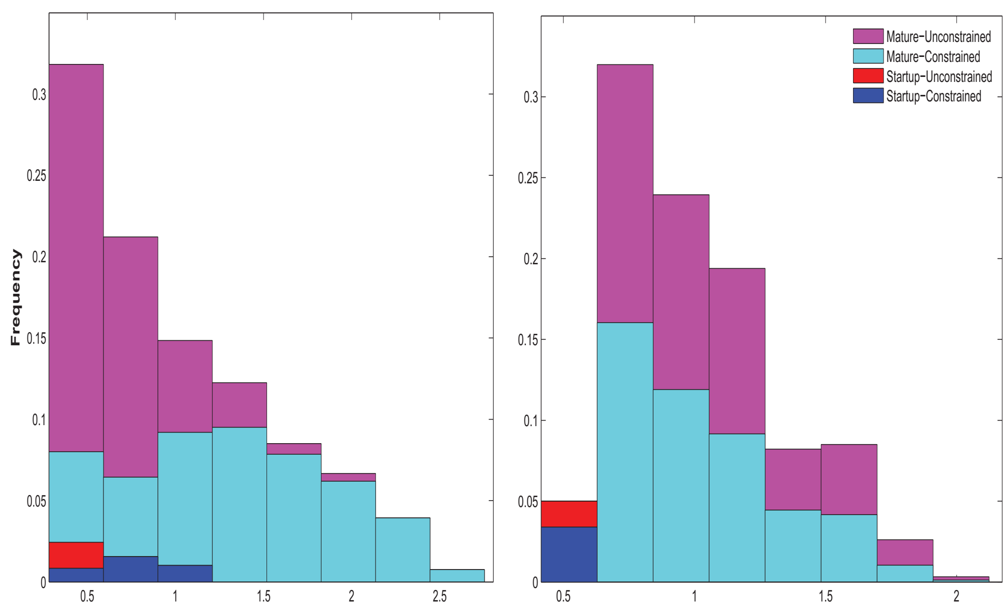
Figure 2.2: Tightness of the Dividend Constraint

2.5 Steady-State Properties

2.5.1 Firm Size Distribution

Figure 2.3 plots the firm size distribution that obtains in the stationary equilibrium, when size is measured by either employment or capital. Figure 2.3a displays a right-skewed employment distribution which resembles its empirical counterpart in the U.S. [Hsieh and Klenow, 2014, Henly and Sanchez, 2009].

Since capital is predetermined whereas employment is not, some of the model's properties are more transparent when looking at the capital distribution in Figure 2.3b. We identify several firm types. Startups, defined as firms in their first year of productive activity, are among the smallest firms in the economy, and are mostly borrowing-constrained. The remaining firms, widely distributed across different sizes, are what we label mature incumbents. The fraction of constrained mature incumbents does not decline with firm size, and the reason is that larger firms also tend to have higher expected productivity, hence they are also more likely to be constrained (recall also Figure 3.3).



(a) Employment (relative to unconditional mean)

(b) Capital (relative to unconditional mean)

Figure 2.3: Stationary Firm Size Distribution

Table 2.3 provides further information about the steady-state distribution of firms. Startups are only 5 percent of the total number of firms, given by the exogenous entry probability, and since they tend to be constrained and small, they contribute to an even lower percentage of about 3 percent of aggregate output. Most of aggregate output is therefore produced by mature incumbents. An important feature is that although constrained firms are only about half of all mature incumbents, they contribute to almost 2/3 of total output. This is again explained by the fact that these firms tend to be very productive in the model.

Table 2.3: Relative Importance of Startups and Mature Incumbents

	Share of total (in %)		
	firms	capital	output
Startups	5	2.3	3
constrained	3.4	1.6	2.5
unconstrained	1.6	0.7	0.5
Mature	95	97.7	97
constrained	46.9	47.8	63.7
unconstrained	48.1	49.9	33.3

2.5.2 Firm Dynamics

Table 3.3 reports the job creation and job destruction rates in the stationary equilibrium and in the data [Lee and Mukoyama, 2012]. The job creation rate is defined in the usual way, as the total employment change among expanding firms, relative to the initial employment size across all firms.[7] The job destruction rate is defined in an analogous way for shrinking firms.

Table 2.4: Job Creation and Job Destruction Rates

	Job Creation		Job Destruction	
	Model	Data	Model	Data
	20.7	9	20.7	10
Relative Contribution				
startups	14	17	0	0
mature	86	83	76	76
exiters	0	0	24	24

The table shows that, in the aggregate, the job creation and destruction rates in the model are twice as high compared to the data. This is in part due to the way we model entry (initial productivity drawn from the unconditional distribution, rather than from a distribution with lower mean) and

7. In the empirical counterpart, initial employment size is defined as $(n_t + n_{t-1})/2$, where n_t is aggregate employment at time t. In our model, $n_t = 1$ for all t.

exit (random across all incumbents, rather higher among smaller firms).
The relative contribution of the different firm types, however, is totally in line with the data, in spite of this not being a calibration target. Mature incumbents are responsible for most job creation and destruction in the economy.
Figure 3.4b plots average employment growth conditional on firm employment. Our model's implications are consistent with the empirical evidence that firm growth is unconditionally negatively correlated with size as reported by Dunne et al. [1988]. Models along the lines of Hopenhayn's (1992), such as ours, deliver this implication due in large measure to the mean-reverting nature of the stochastic process for productivity.

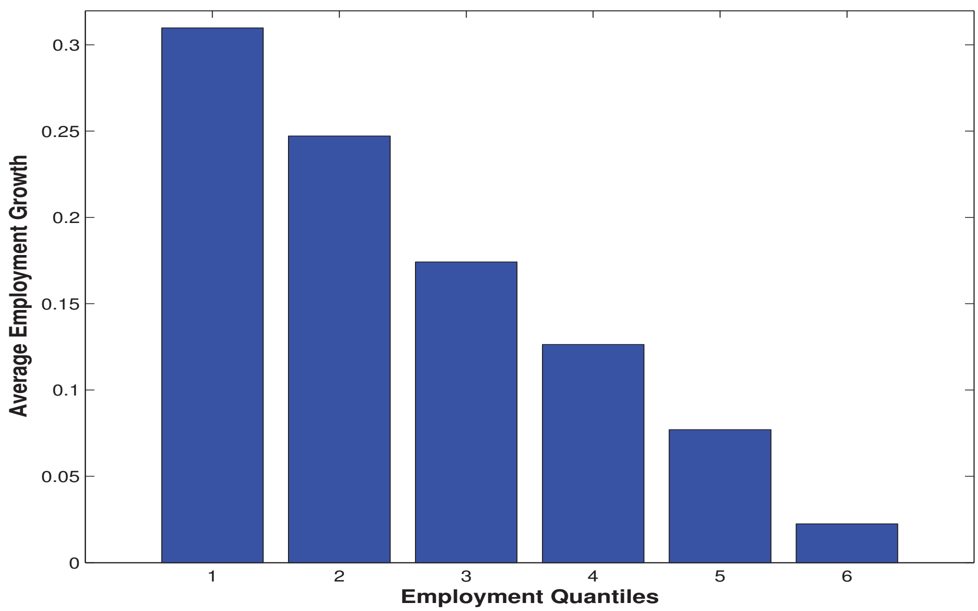


Figure 2.4: Average Employment Growth Conditional on Size

In our specific case, the presence of capital as a production input subject to financial constraints provides additional mechanisms both contributing and going against the overall pattern in Figure 3.4b. Smaller firms in our model not only have higher expected future productivity, some of them are also financially constrained and hence have a relatively low current level of capital. These firms tend to grow fast as they catch up to their unconstrained-optimal level of capital. On the other hand, larger firms subject to low productivity shocks are unable to adjust their current level of capital instantly, hence they tend to reduce their employment level by less than what their productivity alone would imply. These features are shared by other models with predetermined capital and either financial frictions or adjustment costs to capital [e.g Khan and Thomas, 2013, Clementi and Palazzo, 2013].

2.6 Temporary Corporate Tax Cut

To quantitatively assess the effects of temporary cuts in corporate taxes, we undertake the following experiment. We assume that, in period 0, the economy is in steady-state with $\tau_0 = g$ and $b_0 = 0$. In period 1, the government unexpectedly announces the following policy change. In period 1, corporate taxes are cut down to zero, $\tau_1 = 0$. Since the amount of government spending is held constant and no other forms of taxation are available, the tax cut is absorbed by an increase in public debt in period 1, $b_1 = g$. In period 2, the government increases corporate taxes, by an amount sufficient to cover not only the period 2 spending, but also the full servicing of the outstanding debt, $\tau_2 = (2 + r_2)g$ and $b_2 = 0$. This allows the government to revert back to its initial policy of funding government spending totally out of corporate taxes, with zero public debt issuance. The top panel in Figure 2.5 displays the dynamics of corporate taxes associated with this policy.
We assume that, in period 1, agents in our model have full information about the new government policy, and perfect foresight about its future effect on prices. Although the policy itself reverts back to its initial state after period 2, the price effects are long-lived, as the economy slowly transitions back to its initial steady-state. Appendix B.2 provides some details on the computation of the economy's transition.

2.6.1 Transitional Dynamics

Figure 2.5 plots the tax policy, as well as the transitional dynamics of investment and output. In period 0, the economy is in the steady-state. After 10 periods following the tax cut, the economy approximately converges back to the initial steady-state. In period 1, since capital is predetermined, there are no aggregate output effects. Aggregate investment, however, increases on impact, namely due to the response of financially constrained firms. In period 2, as the tax rate increases significantly, overshooting its steady-state level, aggregate investment decreases. This decreasing in aggregate investment is relatively small, however it persists while the economy gradually converges back to its initial steady-state. These dynamics of aggregate investment imply that output increases significantly in period 2. This stimulative effect is long-lasting, with the initial investment build-up being the dominant force keeping the aggregate capital stock above its steady-state level all along the transition.

The asymmetric response of aggregate investment to initial tax cut and subsequent tax increase is a key point of our analysis, leading to persistent expansionary effects out of a purely transitory policy change. The initial tax cut allows financially constrained firms to expand their productive capacity, resulting in a large aggregate investment effect. This initial capital build-up allows firms to generate larger cash-flows in the subsequent periods. Some of these firms are therefore able to either escape, or at least mitigate, the effect of financial constraints, resulting in higher investment levels. This effect is long-lasting because it takes time to erode the effect of the higher initial capital, requiring a sufficient number of negative productivity and exit shocks for cash-flows to return to their initial levels, and financial constraints to be as binding.

Figure 2.6 shows the response of the interest rate, wages, and aggregate consumption and the net firm payout to the household sector. The latter is defined as the sum of net dividend payouts by incumbents ($\int d_t(s)d\mu_t(s)$), plus the dividend payouts net of the spending on new equity issuance by new entrants ($d_t^e - \eta p_t^e$). Its negative corresponds to the net amount that firms borrow from the household sector.

As firms increase labor demand from period 2 onwards, and given our inelastic aggregate labor supply, wages are higher along the transition. Wages decline monotonically toward the steady-state, alongside labor demand. The real interest rate parallels the dynamics of aggregate investment, increasing initially and then decreasing, and finally converging back to its initial steady-state from below.

The net firm payout increases initially, as only some incumbent firms rely on the additional cash-flows generated by the corporate tax cut in order to increase investment, whereas others simply transfer it back to consumers in the form of higher dividends. In period 2, the net firm payout collapses significantly, given the sharp increase in corporate taxes and the need to keep funding investment and make payments to labor.

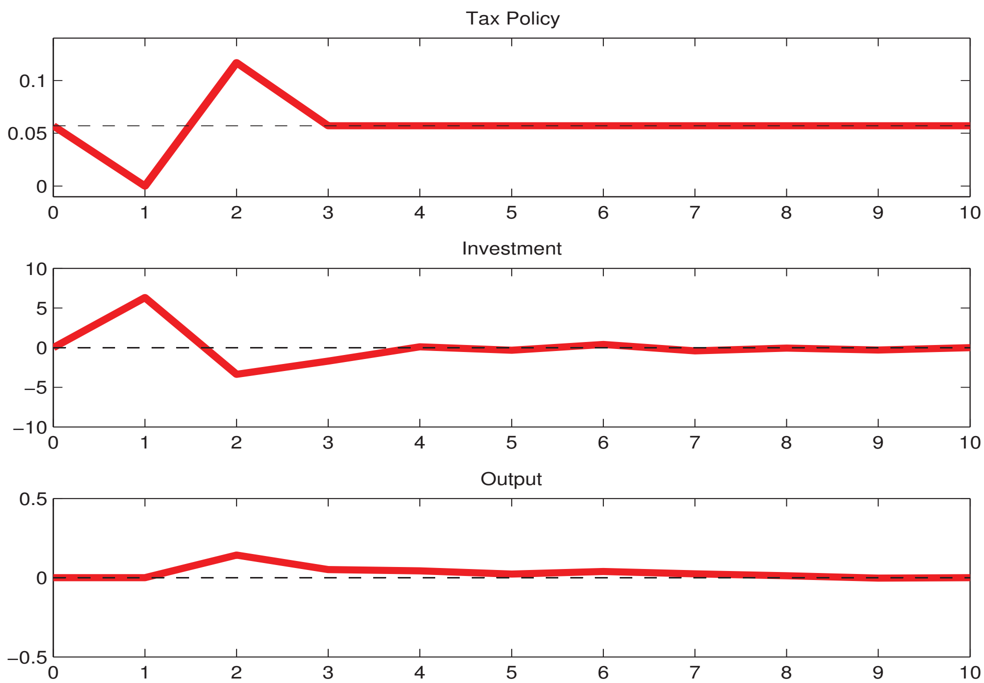


Figure 2.5: Transitional Dynamics of Aggregate Investment and Output

Aggregate consumption is the mirror image of the net firm payout. It declines in period 1, in spite of an increase in net firm payout. The latter, however, is less than the full amount of the corporate tax decline, as some firms invest out of this windfall, and there is no change in production. The household must therefore be enticed to save more, via a higher interest rate, to purchase the government debt necessary to finance the level of government expenditure. Consumption increases in period 2, since again the net firm payout varies by less than the amount of period 2's tax increase, as firms rely partially on the higher retained earnings afforded by the increased production. The supply of government bonds, however goes back to zero, and a lower interest rate is needed to encourage the household to actually increase consumption.

It is useful to consider the situation in which financial frictions are absent. In this case, the full amount of the corporate tax decline is transferred to the household in the form of higher dividends, and there is no impact on produc-

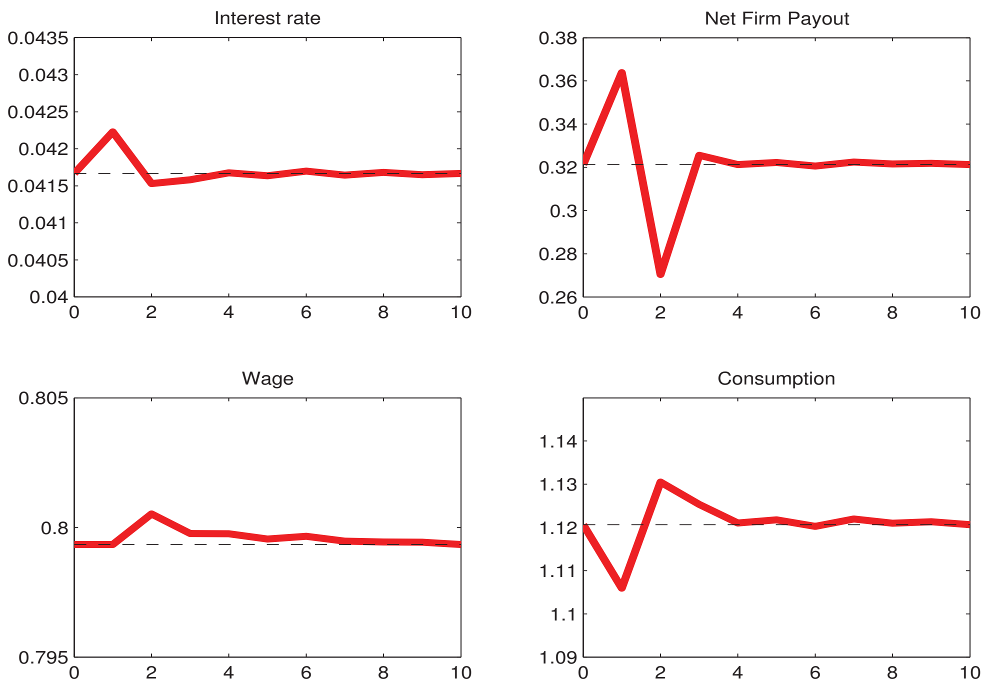
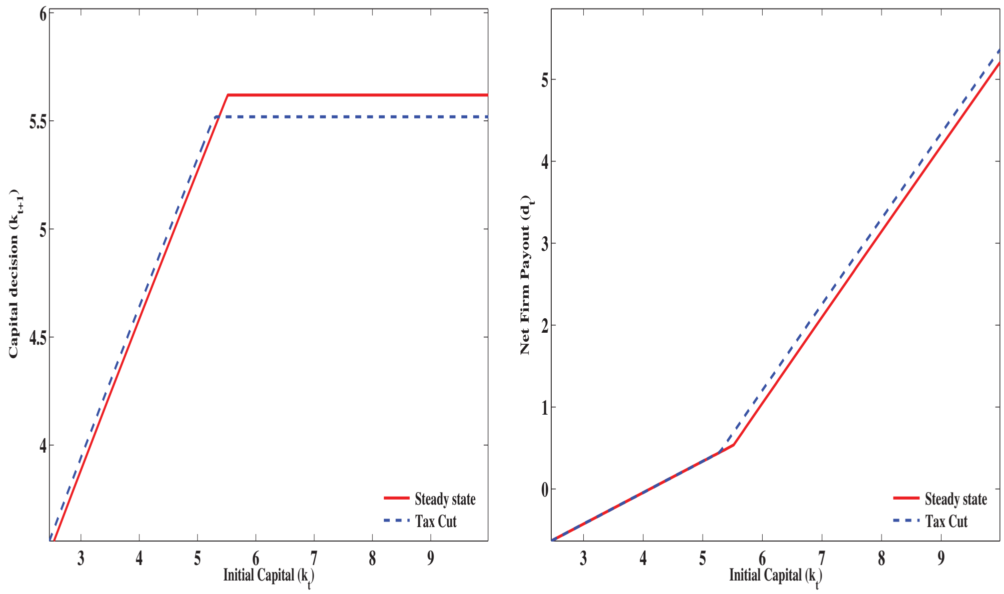


Figure 2.6: Prices, Net Firm Payout, and Consumption

tion. The household behaves just like in the standard Ricardian Equivalence result. Rather than changing (in this case increasing) consumption, the consumer opts to save all the extra income. The real interest rate remains unchanged. This saving serves to pay for the future anticipated decline in dividends, which will occur as firms seek resources to cover the corporate tax increase.

Figure 2.7 shows how the incumbent's decision rules for investment and the net firm payout (just dividends in this case) change as a result of the cut in corporate taxes. The figure plots the decision rules in period 1 under two scenarios, the benchmark steady-state and the tax cut policy. All decision rules are conditional on the same level of productivity. Notice that the tax cut produces a direct effect on the decision rules, by increasing cash flows, and an indirect general equilibrium effect by increasing the wage rate and the interest rate.

In both panels, the kink occurs at the level of capital beyond which the firm



(a) Investment **(b)** Net Firm Payout

Figure 2.7: Decision Rules in Period 1

ceases to be constrained. Figure 2.7a shows that the impact of the tax cut is to relax the financial constraint, in the sense that the kink moves to the left, and also in the sense that investment is higher in the constrained region. The same figure also reveals that the tax cut produces the opposite effect for unconstrained incumbents. For them the investment is lower, due to both a higher wage rate (higher production costs) and a higher interest rate (heavier discounting of future dividends). The tax cut therefore crowds-out the investment among the larger, unconstrained firms.

Figure 2.7b provides a consistent message. Dividend payouts remain unchanged for firms that remain constrained, as the full amount of the tax windfall is used to fund investment. For unconstrained incumbents, however, dividend payouts increase, as firms pass the corporate tax cut to consumers, given that their investments needs are met with their level of retained earnings.

2.6.2 Corporate Tax Cut Multipliers

To quantify the stimulative effects of the transitory corporate tax cut, we compute the associated aggregate output and investment tax cut multipliers. We are interested in comparing aggregate output and investment along the transition relative to the steady-state. We also look at the behavior of the net firm payout, in order to better understand the behavior of external funding from the household sector.

More specifically, let $\{x_t\}_{t=1}^{\infty}$ denote the transition path for either aggregate output, aggregate investment, or the net firm payout, following period 1's tax cut. Let $\bar{x}$ be the steady-state value, and define the change relative to steady state as $\Delta x_t \equiv x_t - \bar{x}$. Similarly, the extent of the tax cut is $\Delta\tau_1 \equiv -(\tau_1 - g) = g$. We compute two types of multiplier:

1. Impact Multiplier: $mi_t(x) \equiv \dfrac{\Delta x_t}{\Delta \tau_1}$, for $t = 1, 2$.
2. Cumulative Multiplier: $mc(x) \equiv \dfrac{1 + r_1}{\triangle \tau_1} \displaystyle\sum_{t=1}^{\infty} \dfrac{\Delta x_t}{\prod_{i=1}^{t} (1 + r_i)}$.

Given the different timing of the impact responses of aggregate output and investment seen in Figure 2.6, we compute the impact multipliers $mi_1(i)$ and $mi_1(np)$ for aggregate investment and net firm payout, respectively, and the impact multiplier $mi_2(y)$ for aggregate output. For the cumulative multipliers, we compute $mc(i)$, $mc(np)$ and $mc(y)$ for aggregate investment, net firm payout, and output, respectively. The model's equilibrium interest rate sequence along the transition is used to discount future changes back to period 1. Based upon our results, the cumulative multiplier computed over a ten-year long transition provides a good approximation to the one computed over the whole transition.

Table 2.5 reports the responses of aggregate and firm-level investment, output, and net firm payout. The top panel reveals that per dollar of tax stimulus, these variables increase on impact by 25.7, 74.3, and 3.5 cents, respectively.

Compared with the impact multipliers, the cumulative multipliers are substantially lower for investment and the net firm payout. In particular, the cumulative investment effect is only about one quarter of the impact effect. The net firm payout increases only by 1 cent over the long run, while it increases by more 70 cents instantaneously with the tax cut. For output, instead, the cumulative multiplier is about twice as high as the impact multiplier since, as explained previously, the temporary tax cut generates a long-lasting stimulative production effect.

Table 2.5: Corporate Tax Cut Multipliers (cents per dollar of tax stimulus)

	Investment	Output	Net Firm Payout
Aggregate			
impact	25.7	3.5	74.3
cumulative	4.6	7.2	1
Firm-level, impact			
Startups	68.1	15.9	31.9
constrained	100	24.8	0
unconstrained	-0.02	-3.0	100.02
Mature	23.4	2.2	76.6
constrained	82.4	16.5	17.6
unconstrained	-34.1	-11.8	134.1

The bottom panel of Table 2.5 reports the impact multipliers conditional on specific firm-types. For startups, the investment multiplier is of 68 cents per dollar of tax revenue, whereas the remaining 32 cents are paid out as dividends. The stimulative effect on output is of 16 cents. These multipliers are naturally higher for constrained startups. For these, the full amount of the tax reduction is channeled to investment, with no additional dividend payouts. As a result, the output effect is also maximized with an impact multiplier of about 25 cents. The opposite happens for the relatively fewer number of unconstrained startups, who channel the entirety of the additional cash-flows to dividend payouts. Their investment and output end up declining in the end, given that prices increase on impact.

The response of mature incumbents is qualitatively similar, although the multipliers are of lower magnitude overall. In particular, the stimulative effect on investment is only about 23 cents, whereas on output is only 2 cents per dollar of tax revenue. For constrained mature incumbents the multipliers are higher, without reaching the same level as the startups. The decline in corporate taxes is sufficient to allow some of these firms to become unconstrained, and hence transfer some of this tax decline back to consumers in the form of higher dividends. The unconstrained mature incumbents, instead, face negative growth, as they face higher prices without any productive use for the higher cash flows.

2.6.3 Quantifying the Crowding-Out Effect

We have shown how the tax cut crowds out investment among larger, unconstrained firms due to higher prices. To quantify the dampening effect of general equilibrium price movements, we now perform a partial equilibrium analysis, by implementing the temporary tax cut while fixing the wage rate and the interest rate at their steady-state levels.

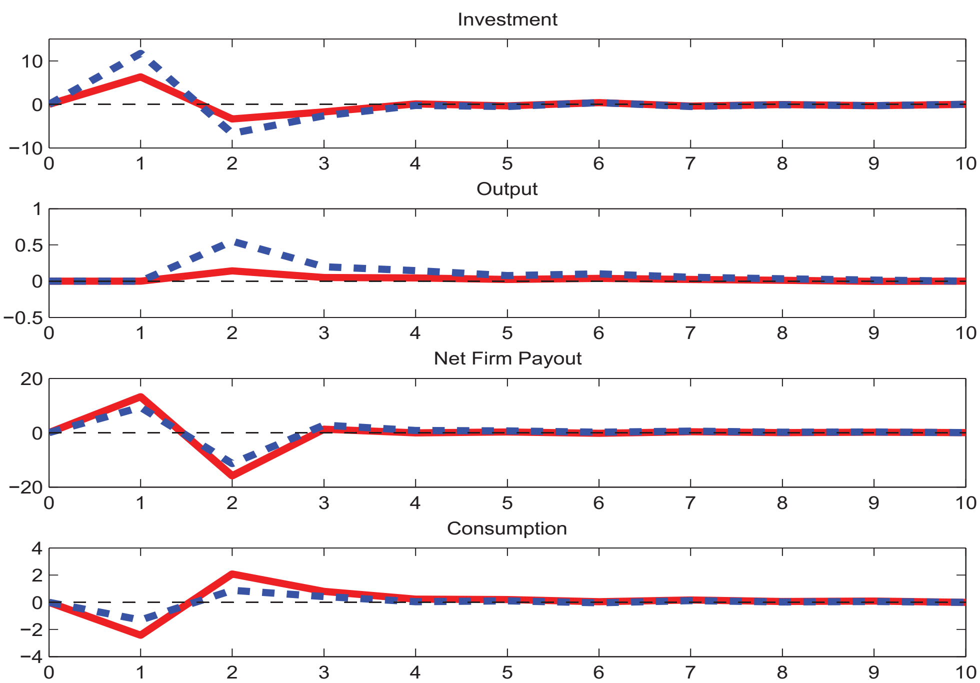


Figure 2.8: Transitional Dynamics, benchmark (solid) vs partial equilibrium (dashed)

Figure 2.6 compares the transition dynamics with and without the price adjustment. To facilitate the comparison, all variables are reported in percentage deviation from their steady-state values. As anticipated, the investment, output, and consumption effects are stronger in partial equilibrium, whereas the net firm payout is weaker.

Table 2.6: Partial Equilibrium Multipliers (cents per dollar of tax stimulus)

	Investment	Output	Net Firm Payout
Aggregate			
impact multiplier	47.6	13.6	52.4
cumulative multiplier	9.4	25.2	5.9
Firm-level impact multiplier			
Startups	68.1	20.0	31.9
constrained	100	29.3	0
unconstrained	0	0	100
Mature	46.5	12.6	53.6
constrained	94.1	25.4	5.9
unconstrained	0	0	100

Table 2.6 gives a sense of the magnitudes, by computing the same multipliers as in Table 2.5. Comparing the two tables shows that both the impact and the cumulative multipliers are significantly larger in partial equilibrium, not only in the aggregate, but also conditional on firm types. The impact effect is around two times larger for investment and four times larger for output. The reason is once again that the partial equilibrium exercise eliminates the crowding-out effect among unconstrained firms. Further, there is also an additional positive effect among constrained firms, as they are able to channel some of the lower wage level into further investment.

2.7 Conclusion

We have assessed the effectiveness of temporary reductions in corporate taxes in raising aggregate investment and output. The mechanism we have focused upon relies on the presence of financing constraints. Temporary tax relief for firms raises investment because credit constrains induce high marginal propensities to invest. Our analysis has traced out the full transition following the tax cut, using a model with heterogeneous firms. Our main finding is that this policy is reasonably effective at raising investment. The effect on impact is an increase in investment by 26 cents per dollar of tax stimulus, and an increase in aggregate output by 3.5 cents. The cumulative effects are increases in investment and output of 4.6 and 7.2 cents, respectively.

There are several ways in which our analysis could be improved. One would ideally study the policy experiment in an environment with aggregate uncertainty, and cyclical variation in the severity of financing frictions. It would also be interesting to endogeneize entry and exit decisions, given that temporary changes in corporate taxation could have potentially important effects along these margins. Finally, the model could be very easily amended to feature distortionary taxation, which would allow us to incorporate the intertemporal substitution effects typically considered in the literature into our analysis.

Chapter 3

Reforming Corporate Taxation: Effects of A Comprehensive Business Income Tax

3.1 Introduction

The US tax code stipulates taxation of capital income at the firm level and at the household level. In fact, dividends are paid out of corporate profit net of corporate income tax and are further taxed when distributed to shareholders. Similarly, retained earnings are taxed twice to the extent that they are capitalized in higher share values and are subject to capital gain tax when realized. In public economics, this double taxation of corporate income is recognized [1] to reduce the overall return on investment and the efficiency of capital allocation. For instance, by taxing corporate equity income twice, the classical corporate tax system distorts the allocation of resources by discouraging the use of the corporate form. This double taxation also encourages debt financing, as interest on corporate bonds are not subject to corporate taxes. In addition, the current tax system relies on the *realization principle* to measure capital gains, while corporate-level tax occurs when income is earned and the investor-level tax is postponed until the corporation distributes dividends. Accordingly, the U.S. tax code distorts the timing of financial decisions because it encourages investors to engage in tax-motivated stock trading strategies. For example, Ivkovic et al. [2005] present evidence of trading behavior that is consistent with year-end tax-loss selling. Furthermore, corporate earnings distribution through dividend is much taxed than through capital gain generated by reinvested earnings. These tax asymmetries may lead to *lock-in* effects for asset with capital gains and impair the efficiency of capital markets. Tax reforms have therefore been at the center of numerous debates, intended to find ways to reduce or remove these distortions, among economists and policymakers. As part of this debate, the U.S. Treasury Department studied in 1992 four alternative approaches to integrate the individual and corporate tax systems. [2] According to the *imputation credit* prototype, corporations determine their income for tax purposes as in the existing tax system and pay a corporate-level tax. Shareholders include in their income the amount of dividend they receive and the associated tax paid at the corporate level. They apply toward individual tax payments a credit equal to the amount of corporate tax that would be associated with gross dividends, (Hubbard [1993]). But the Treasury recommended against

1. For example Fullerton et al. [1981] measures the efficiency cost of double corporate income taxation.

2. McNulty [1994] present further details on almost all the proposals of tax integration in U.S..

this form of integration. Under the *shareholder allocation* model, corporate earnings would be allocated to shareholders, and the allocated earnings would be taxable to shareholders even though not distributed to them. The Treasury Department recommended against this allocation approach as well. Under the third model, *dividend-exclusion* prototype, corporates should continue to pay the usual corporate income tax as in the existing tax system but dividends would be excluded from the taxable income of shareholders. The Treasury Department suggested that this reform could serve as a transition to a most comprehensive reform, the *Comprehensive Business Income Tax* (CBIT). Under the CBIT reform, a schedular or flat tax rate would be collected at the entity level on the earnings of all businesses, non-corporate and corporate. Most importantly, the CBIT proposal denies deductions for payments to debt-holders and to equity-holders. In addition, both interest and equity distributions generally would be excludable from income by investors.[3] The treasury Department considered the CBIT reform as a long-run tax reform and suggested that it may be brought into effect by a series of phases. Accordingly, the CBIT reform is the appropriate prototype to focus on because my interest is in the long run effects of corporate tax reform. In addition, the CBIT would eliminate tax distortions in organizational form, capital structure, and dividend policy more completely than any of the other prototypes. More precisely, the CBIT reform is intended to eliminate three distortions from the current tax system. First, it removes the distinction between corporate and non-corporate businesses, and place all business organizations under the same tax regime. Second, it removes the tax differentials between dividends and capital gains by abolishing the second level of tax. Third, it equalizes debt and equity as sources of financing. Hence, corporate earnings would be taxable once, to the entity, at a single rate, whether distributed or not, and whether distributed as dividends or interests.

This paper assesses the effects of a prototype CBIT reform on capital formation, output, welfare and allocational efficiency when firms are subject to financing frictions. I find that the elimination of dividend and capital gain taxes is not self-financing. More precisely, the results show that the corporate profit tax rate should be adjusted from 34% to 42% to keep the reform revenue-neutral. Overall, the CBIT reform results in a decrease in long run aggregate capital stock and output by 8% and 1%, respectively. However, it has a positive reallocation effect that raises aggregate productivity by 1.41%

3. See Gentry and Hubbard [1998] for further details on the CBIT proposal.

and welfare by 0.05%. In addition, capital allocation efficiency measured by the correlation between capital and productivity increases by 20%. Two forces may explain these findings. First, the elimination of taxes on both capital gain and dividend raises the after-tax return on firms' shares and provides a boost to aggregate capital, output, firm value and wage. Second, the increase in corporate profit tax reduces after-tax return on investment. This second force counterbalances the positive effects of zero capital gain and dividend tax rates on investment. Another mechanism explains the efficiency and welfare gains. In fact, the elimination of the tax wedge makes external equity and retained earnings perfect substitutes as sources of funds. Thus, relatively small and highly productivity firms tap into the equity market to finance investment. In addition, the reform removes the deferral advantage given to retained earnings and eliminates incentives for larger firms to reinvest in projects with below-market yield. Together, the two effects improve the efficiency of capital accumulation. This positive reallocation effect is strengthened by the increase in the rate of corporate profit tax. In fact, by reducing the return on investment, higher corporate profit tax rate discourages investment among larger and cash-rich firms. Lower aggregate capital demand causes labor demand to decrease and put downward pression on wage. But, the decline in wage increases the current disposable income of equity-constrained firms. These firms increase investment because they have higher marginal productivity of capital and unused investment opportunities. This reallocation improves the efficiency of capital allocation. As a result, aggregate output decreases less than proportional to the decline in aggregate investment, leading to a modest welfare gains.

My approach considers an industry equilibrium model which integrates a representative household, a government, and a production sector featuring heterogeneous firms potentially subject to financing frictions, and to idiosyncratic productivity and entry/exit shocks. However, there is no aggregate uncertainty. Firms' optimal investment decisions in response to shocks may require external financing, in addition to retained earnings. But, I assume there is an upper bound on the amount of external funds a firm has access to. In addition, there is an equity constraint that imposes a minimum dividend payment to shareholders at each period. The firm heterogeneity along with the financial frictions play a key role in my analysis. At any period of time, a firm may find itself in four different financing regimes depending on its productivity shock and its capital stock. In the *equity-constrained* regime, the firm's investment is limited by its current cash flows plus the maximum amounts of equity it can issue minus the minimum dividend payments. In the *cash-constrained* regime, dividend payments are reduced to the minimum value admissible. External equity remains the marginal financing source, but the firm is able to fund all profitable investments. In the *internal-growth* regime, the dividend constraint remains binding but the marginal source of investment finance is retained earnings. Finally, in the *cash-rich* regime, the firm is large enough that it generates sufficient cash-flows to fund investment. In addition, it distributes larger dividends than the minimum payout requirement. The firm's response to corporate tax reform depends on which financing regime the firm is in before the reform and the extent to which its investment is distorted.

Fullerton et al. [1981] estimate efficiency gains from different integration plans of personal and corporate taxes. However they do not incorporate an explicit theory of individual firm behavior. Nadeau and Strauss [1993] also study the effects of a decrease in shareholder dividend tax rates compensated by an increase in corporate income tax rates in U.S.. They find that the policy increases dividend payments and investment in a partial equilibrium analysis. In a general equilibrium analysis, Guner et al. [2012] evaluate revenue-neutral reforms to the U.S. tax system in a life-cycle setup but they focus on household heterogeneity and the effects on labor supply. Gourio and Miao [2010] and Atesagaoglu et al. [2014] analyze the implications of a revenue neutral tax reform that reduces and equalizes dividend and capital gain taxes at the expense of higher labor income tax. Atesagaoglu et al. [2014] incorporate both firm and household heterogeneity and find that the reform leads to a decrease in the capital stock, but an increase in output because capital is more efficiently allocated across firms. Gourio and Miao [2010] use a setting which is more related to mine, in the sense that they also rely on a general equilibrium model with only firm heterogeneity, but they do not consider an overall external financing constraint as in this paper. They find that aggregate capital, output and consumption increase. In contrast to Gourio and Miao [2010] and Atesagaoglu et al. [2014], I use the corporate profit tax, instead of labor income tax, to compensate the reduction in tax revenue.

Missing from the literature is precisely the assessment of the long run effects of a tax reform that completely eliminates the capital gain and dividend taxes, and compensates the government revenue lost by an increase in the corporate profit tax rate. This is the prototype of the 1992's proposal of the U.S. Treasury Department. The results show that the reform leads to a reduction in aggregate capital stock and output 8% and 1%, respectively in the long run. However, the policy improves capital allocation by 20%, resulting in an increase in aggregate productivity by 1.41% and in a modest welfare gain.

3.2 Model

The model consists of a representative household, a continuum of firms with a unit mass, and a government. There is no aggregate uncertainty. Time is discrete and is indexed by t.

3.2.1 Firms

Firms face idiosyncratic productivity shocks. In addition to idiosyncratic productivity shocks, I also assume that firms receive exogenous entry and exit shocks. In particular, each firm faces a per period exit probability of $\eta \in (0,1)$, following production. In every period, this mass of exiters is replaced by an equal mass of entrants. This assumption is entertained by several papers, more recently by Khan and Thomas [2013]. Entry and exit allows for a nontrivial equilibrium firm distribution and ensures some firms will always be financially constrained. I assume a law of large numbers holds so that aggregate quantities and prices are deterministic for given government policy, although each firm still faces idiosyncratic uncertainty. Figure 3.1 displays the timing of firm's decisions.
There are two types of firms in the economy at each point in time: incumbents and prospective entrants. At the beginning of each period t, incumbents draw their current productivity shock, hire labor, produce, pay corporate taxes, invest in physical capital, and pay dividends to their shareholders. At the end of the period, they draw the exit shock. This shock can take on two values: exit or stay. If the firm receives exit, I assume it sells its capital stock at the beginning of the following period and forever ceases production.
There is a new entrant drawn from the entrant pool for each firm that exits the industry. Potential entrants are ex-ante identical. Upon entering the industry at time t, each new entrant invests in order to begin producing next period. New entrants at time t become incumbent firms at period $t+1$.
To model the U.S. tax structure in the simplest way, I follow Gourio and Miao [2010]. First, I consider flat tax rates and assume that firms face corporate income tax at the constant rate τ^c, while households face constant rates τ^d on

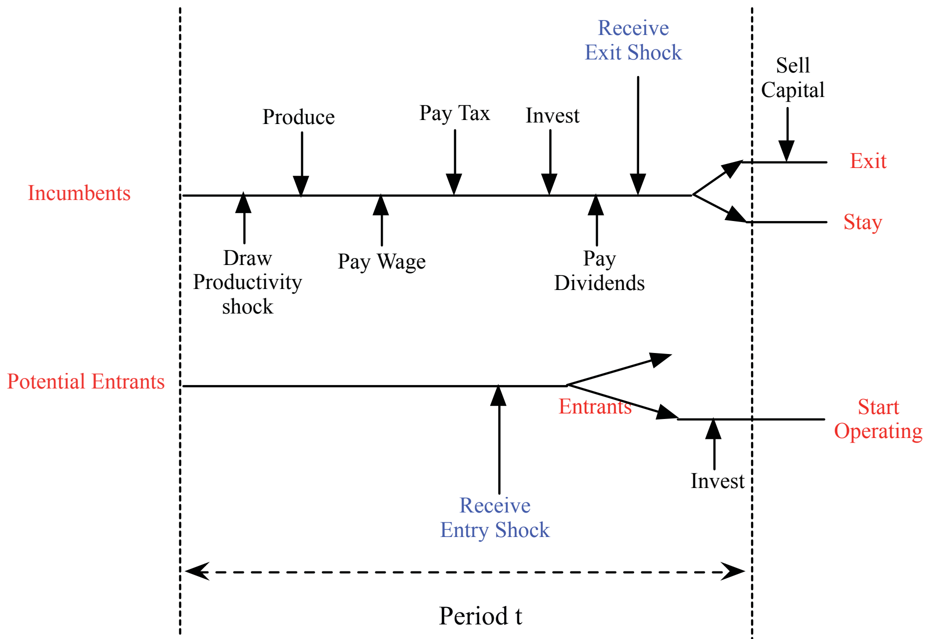


Figure 3.1: Timing of the model

dividend, τ^i on labor and interest incomes, and τ^g on accrued capital gains.[4] Second, I abstract from debt and assume that all firms are equity financed as in the literature.[5] Accordingly, my model can not assess the effects of removing the tax benefits of debt financing. In a similar set-up, Gourio and Miao [2010] studied how the introduction of debt financing affects the effects of changes in dividend taxation. They find smaller equity issuance, and fewer share of firms issuing equity.

3.2.1.1 Equity Valuation

In order to formulate the problem of an incumbent, I first derive the equity valuation equation. As the firm may issue new shares or repurchase old

4. In U.S., capital gains are taxed on realization rather than on accrual. Incorporating a realization-based capital gain tax would complicate the analysis and is not important for the key goal of the paper.

5. A lot of papers make this assumption. Some examples are Auerbach and Hassett [2003], Desai and Goolsbee [2004], and Poterba and Summers [1985].

shares, equity value at date $t+1$ satisfies $p_{t+1} = p^0_{t+1} + z_{t+1}$, where z_{t+1} denotes the value of new shares issued (repurchased) at period $t+1$ if $z_{t+1} \geq (<) 0$, and p^0_{t+1} is the period $t+1$ value of equity outstanding in period t. The no-arbitrage condition (3.1) must hold in equilibrium.

$$r_{t+1} = \frac{1}{p_t}\mathbf{E}_t\left[(1-\tau^d_{t+1})d_{t+1} + (1-\tau^g_{t+1})(p^0_{t+1} - p_t)\right] \tag{3.1}$$

where $\mathbf{E}_t[\cdot]$ is the expectation operator conditional on the productivity shocks, r_{t+1} is the after-tax required return rate on equity, d_{t+1} is the firm's dividend payment, and $(p^0_{t+1} - p_t)$ represents the capital gains component. As the firm is owned by the household, the after-tax return on equity equals the after-tax return on government debt. That is:

$$r_{t+1} = (1-\tau^i_t)\bar{r}_{t+1} \tag{3.2}$$

where $\bar{r}_{t+1}$ is the pre-tax interest rate. Using equations (3.1)-(3.2), I can derive:

$$p_t = \frac{1-\tau^g_{t+1}}{(1-\tau^i_{t+1})\bar{r}_{t+1} + (1-\tau^g_{t+1})}\mathbf{E}_t\left[\frac{1-\tau^d_{t+1}}{1-\tau^g_{t+1}}d_{t+1} + p_{t+1} - z_{t+1}\right] \tag{3.3}$$

Following Gourio and Miao [2010] in defining the cum-dividend equity value, V_{t+1}, at period $t+1$ as:

$$V_{t+1} = \frac{1-\tau^d_{t+1}}{1-\tau^g_{t+1}}d_{t+1} + p_{t+1} - z_{t+1} \tag{3.4}$$

One can show that:

$$p_t = V_t - \frac{1-\tau^d_{t+1}}{1-\tau^g_{t+1}}d_t + z_t$$

Then, using (3.3) I can derive:

$$V_t = \frac{1-\tau^d_t}{1-\tau^g_t}d_t - z_t + \frac{\mathbf{E}_t[V_{t+1}]}{1 + \frac{1-\tau^i_{t+1}}{1-\tau^g_{t+1}}\bar{r}_{t+1}} \tag{3.5}$$

3.2.1.2 Incumbent

I consider the problem of the firm at the steady-state, when government policy is stationary. Denote by $V(k_t, \varepsilon_t)$ the value of an incumbent firm with capital stock k_t and productivity shock ε_t. $V(k_t, \varepsilon_t)$ satisfies the following Bellman equation:

$$V(k_t, \varepsilon_t) = \max_{n_t, x_t, k_{t+1}, z_t, d_t} \left[\frac{1-\tau^d}{1-\tau^g} d_t - z_t + \frac{\eta k_{t+1} + (1-\eta)\mathbf{E}_t V(k_{t+1}, \varepsilon_{t+1})}{1 + \frac{1-\tau^i}{1-\tau^g} \bar{r}_{t+1}} \right] \tag{3.6}$$

subject to

$$x_t + d_t = (1-\tau^c)\left[y_t - wn_t\right] + z_t + \tau^c \delta k_t \tag{3.7a}$$

$$x_t = k_{t+1} - (1-\delta)k_t \tag{3.7b}$$

$$z_t \geq 0 \tag{3.7c}$$

$$z_t \leq \bar{z} \tag{3.7d}$$

$$d_t \geq \zeta k_t \tag{3.7e}$$

where output is $y_t = \varepsilon_t f(k_t, n_t) = \varepsilon_t \left(k_t^{\alpha} n_t^{1-\alpha} \right)^{\nu}$, with $0 < \alpha, \nu < 1$, and $\delta \in (0,1)$ is the depreciation rate. A decreasing returns to scale technology ensures that firm size is always well-defined.$\bar{r}_{t+1}$ is the pre-tax interest rate between the period t and the period $t+1$.

Equation (3.7a) describes the flow of funds condition for the firm. Cash inflows consist of output, undepreciated capital and equity issuance, while cash outflows include investment expenditures, tax liabilities, wage and dividend payments.

Equation (3.7b) is the law motion of capital at the firm level where δ is the depreciation rate. Each firm can invest x to increase its capital stock.

While share repurchases are allowed in the United States, I follow most papers in the literature to impose the constraint (3.7c) for simplicity. Auerbach [1979], Auerbach [2002] and Gourio and Miao [2010] among others make this assumption. [6]

The main financial frictions in this paper are described by equations (3.7d) and (3.7e). First, I impose an upper bound, $\bar{z}$, on the amount of external funds a firm has access to, equation (3.7d). Several papers in the literature highlight the role of informational imperfections in limiting the ability of firms to issue new equity. For example, Greenwald et al. [1984] argue that

6. Gourio and Miao [2010], following Poterba and Summers [1985], impose a non-zero upper bound on share repurchases. They find that when firms can avoid the costly dividend distribution by using the return on investment to repurchase shares, they make larger investment and issue more equity to finance the investment if possible.

equity funds may reduce the value of a firm by intensifying incentive problems because it allows more profits to be diverted to the private uses of the firm's managers. According to Ross [1977], signalling effects may also restrict a firm's access to equity markets because managers of strong firms, rely more on debt than equity. Thus, attempting to sell equity may convey a strong negative signal about a firm's quality and reduce its market value. In this paper, the firms will issue equity only if they are dividend constrained because dividends are heavily taxed than capital gains as in the U.S. tax code.
Second, I impose a minimum dividend payout requirement, equation (3.7e). While Bianchi [2013] imposes a constant lower limit on dividend payments, I assume that firms are subject to a collateral constraint that limits the minimum amount of dividend payments to an increasing function ($\zeta > 0$) of their capital holdings. A special case of this dividend constraint, common in the literature, is the restriction that dividends need to be non-negative when $\zeta = 0$. My main motivation for adopting this flexible specification is for calibration purposes. Having $\zeta > 0$ effectively tightens the financial constraints faced by larger firms. [7] This parameter affords me better control in matching the average size of entrants relative to the average size of incumbents. A possible justification of the constraint (3.7e) is that minimum dividend payments may help mitigate agency problems between shareholders and managers and work as signaling device [see Allen and Michaely, 2003, for a review]. The fact that they're increasing with firm size is also consistent with evidence that large corporations tend to pay out a larger fraction of their earnings [Allen and Michaely, 2003].

3.2.1.3 New Entrant

In the period of entry, new entrants are identical, do not produce, pay no dividends and are not subject to corporate tax liability. Their investment is fully funded by the sales of equity to household sector. I assume that new entrants are endowed with an amount $\bar{z}$ of equity, equal to the maximal amount of external funds incumbents have access to. Therefore, each new entrant at period t invests $k^e = \bar{z}$ in order to start operating at period $t + 1$. Accordingly, all the decisions of new entrants can be summarized as follows.

7. Financial constraints are still overall tighter for smaller firms in the model, since these tend to be farther away from their unconstrained optimal size.

$$
\begin{aligned}
z_t^e &= z^e = \bar{z} \\
k_{t+1}^e &= k^e = \bar{z} \\
d_t^e &= d^e = 0.
\end{aligned}
$$

Given the continuation value of incumbents V, the value of a new entrant is:

$$
V^e = -\bar{z} + \frac{1}{1 + \frac{1-\tau^i}{1-\tau^g}\bar{r}} \sum_{\varepsilon_{t+1}} \bar{\pi}(\varepsilon_{t+1}) V(\bar{z}, \varepsilon_{t+1}) \tag{3.8}
$$

where $\bar{\pi}(\varepsilon_{t+1})$ is the long-run probability of state ε_{t+1}. At period $t+1$, new entrants at period t are in the same position as an incumbent which has a stock of capital $\bar{z}$. The initial productivity of new entrants is drawn from the stationary distribution of the Markov chain.

3.2.2 Aggregation

Denote the incumbent's decision rule for investment by $k(s_t)$, where $s_t \equiv (k_t, \varepsilon_t)$ is the individual state. Let $S \equiv K \times E$ denote the set of individual states, where K is the set of capital stock levels. Let Ω_S denote the product $\sigma - algebra$ on S with typical subset $\mathcal{S}$. We can summarize the aggregate distribution of firms with a measure defined over the state space S. Formally we define the measure μ_t as follows:

$$
\begin{array}{cccc}
\mu_t & : & \Omega_S & \rightarrow & \mathbb{R}_+ \\
 & & \mathcal{A} & \mapsto & \mu_t(\mathcal{A}),
\end{array}
$$

where $\mu_t(\mathcal{A})$ is the mass of firms engaged in production at time t, with state $s_t \in \mathcal{A} \subseteq S$. This includes incumbents as of $t-1$ which survive into t, and the new entrants replacing the exiters as of $t-1$.
First define the transition function Q of incumbents across states:

$$
\begin{array}{cccl}
Q & : & S \times \Omega_S & \rightarrow & [0,1] \\
 & & (s_t, K \times E) & \mapsto & Q(s_t, K \times E) = \sum_{\varepsilon_{t+1} \in E} \pi(\varepsilon_{t+1}, \varepsilon_t) \mathbb{1}_{k(s_t) \in K}
\end{array}
$$

where $\mathbb{1}_K$ is the indicator function on the set K.

For any Borel set $\mathcal{A} \in \Omega_S$, the law motion of the aggregate state of the economy is:

$$\mu_{t+1}(\mathcal{A}) = (1-\eta)\int_S Q(s,\mathcal{A})\mu_t(s)ds + \eta\psi(\mathcal{A}), \tag{3.9}$$

where ψ is the distribution of new entrants,

$$\psi(K \times E) = \sum_{\varepsilon_{t+1}\in E} \bar{\pi}\left(\varepsilon_{t+1}\right) \mathbb{1}_{k^e \in K}. \tag{3.10}$$

The stationary distribution μ is defined as the fixed point of this mapping. It is useful to define aggregate investment.

$$i_t = \int_S k_{t+1}(s)d\mu_t(s) - (1-\delta)\left[(1-\eta)\int_S k_t(s)d\mu_{t-1}(s) + \eta k^e\right] + \eta\left[k^e - \int_S k_t(s)d\mu_{t-1}(s)\right], \tag{3.11}$$

where the first two terms correspond to the total gross investment of incumbent firms as of time t (which includes the fraction $1-\eta$ of those that were already operating at $t-1$, plus the fraction η of new entrants at $t-1$), and the last term corresponds to the investment of new entrants as of time t net of the disinvestment of exiters.

3.2.3 Household

A representative household with unit measure derives utility from consumption alone, according to a standard time-additive utility function $u(c) = \log c$, with future utility discounted at rate $0 < \beta < 1$. A time endowment of 1 is supplied inelastically every period. The household is subject to dividend taxes τ^d, personal income taxes τ^i, and capital gain taxes τ^g.
The household holds wealth as shares in firms. It also trades government bond in zero net supply. Let $\theta_t(s)$ denote the shareholding of firm type $s \in S$ at the start of period t (θ_t^e for new entrants), valued at price $p_t(s)$ at the end of period t (p_t^e for new entrants), and b_t the government bondholding, paying interest rate r_t. At the start of period t, the share of incumbent type s is valued at price $p_t^0(s)$, which is the period t value of equity outstanding in period $t-1$. The difference, $p_t(s) - p_t^0(s)$, is the capital gains in period t. These prices are time-invariant in a stationary equilibrium.

Let W denote the indirect utility of the household, its maximization program is as follows:

$$W_t(\omega_t) = \max_{c_t, b_{t+1}, \theta^e_{t+1}, \{\theta_{t+1}(s)\}_{s\in S}} \{\log c_t + \beta W_{t+1}(\omega_{t+1})\} \tag{3.12}$$

subject to

$$c_t + b_{t+1} + \eta p^e_t \theta^e_{t+1} + \int_S p_t(s)\theta_{t+1}(s) d\mu_t(s) = \omega_t$$

$$\omega_{t+1} \equiv (1-\tau^i_{t+1})w_{t+1} + (1+(1-\tau^i_{t+1})\bar{r}_{t+1})b_{t+1} + \eta \int k_{t+1}(s)\theta_{t+1}(s)d\mu_t(s) + \eta \int \left[p^0_{t+1}(s) + (1-\tau^d_{t+1})d_{t+1}(s) - \tau^g_{t+1}\left(p^0_{t+1}(s) - p_t(s)\right)\right]\theta^e_{t+1} d\mu_{t+1}(s) + T_{t+1} + (1-\eta)\int \left[p^0_{t+1}(s) + (1-\tau^d_{t+1})d_{t+1}(s) - \tau^g_{t+1}\left(p^0_{t+1}(s) - p_t(s)\right)\right]\theta_{t+1}(s) d\mu_{t+1}(s) \tag{3.13}$$

Equation (**??**) is the household's budget constraint. The consumer spends his resources ω_t on consumption, government bonds, and equity purchases of incumbents plus new entrants at time t. Income from (3.13) equals transfers from the government, plus labor earnings, plus the income from government bondholdings, plus the income from physical capital sales of exiting firms, plus the income from shareholding in firms engaged in production. The latter equals the dividend plus share value of new entrants at time t and surviving incumbents from t to $t+1$.

The sole outcome from the household's problem which is relevant for my analysis is the real interest determination. From the first-order condition for government bonds

$$\frac{c_{t+1}}{c_t} = \beta(1+(1-\tau^i_{t+1})\bar{r}_{t+1}) \tag{3.14}$$

and in steady-state I obtain $1 = \beta(1+(1-\tau^i)\bar{r}) = \beta(1+r)$.

3.2.4 Government

In each period, the government collects corporate profit taxes, dividend taxes, capital gain taxes and personal incomes taxes at rates τ^c, τ^d, τ^g, and τ^i, respectively. To isolate eventual effects associated with using distortionary taxation to finance government spending, I assume that there is no government spending and the tax revenue collected is rebated to the household in a lump sum manner. Thus, in a stationary equilibrium with zero government, the government's budget constraint is:

$$T = \tau^c \int_S [y(s) - wn(s) - \delta k] d\mu(s) + \tau^d \int d(s) d\mu(s) - \tau^g \int z(s) d\mu(s) + \tau^i w, \quad (3.15)$$

3.2.5 Stationary Recursive Competitive Equilibrium

Now, I provide a definition of the equilibrium, focusing on the steady-state. Given a stationary government policy $(\tau^c, \tau^d, \tau^i, \tau^g, T)$ and initial equity issuance $\bar{\theta}^e$ for new entrants, a stationary recursive competitive equilibrium consists of a value function $V(s_t)$, with $s_t \equiv (k_t, \varepsilon_t)$, and a set of decision rules for incumbents, $n(s_t)$, $k(s_t)$, $y(s_t)$ and $d(s_t)$, a value function V^e for new entrants, a value function W and a set of decisions for the representative household c, b, θ^e and $\{\theta(s_t)\}_{s_t \in S}$, time-invariant cross-sectional distributions of new entrants and incumbents, respectively μ and ψ, and prices r, w, $\{p(s_t)\}_{s_t \in S}$ and p^e such that:

1. Given prices, the government budget constraint in (3.15) holds.
2. Given prices and the government policy, all types of firms and the representative household optimize.
3. All markets clear:
   — Labor: $\int_S n(s) d\mu(s) = 1$.
   — Equity:
   new entrants: $\theta^e = 1$.
   incumbents: $\theta(s) = 1$, for all $s \in S$.
   — Final good: $\int_S y(s) d\mu(s) = i + c$, where i is defined in (3.11).
4. μ is the fixed point in (3.9), and ψ is defined in (3.10).

3.3 Investment and Financing Policies

In order to assess the firm-level effects of corporate tax reforms, it proves useful to analyze the financial and investment policies of a single incumbent in partial equilibrium. Let $q_t, \lambda_t^d, \lambda_t^z, \lambda_t^{\bar{z}}$ be the Lagrange multipliers associated to the constraints (3.7b - 3.7e), respectively. The Lagrangian of the problem can be written as follows:

$$\mathcal{L}(q_t, \lambda_t^d, \lambda_t^z, \lambda_t^{\bar{z}}, k_{t+1}, d_t) = \left\{ \begin{array}{r} \frac{1-\tau^d}{1-\tau^g} d_t - z_t + q_t(x_t - k_{t+1} + (1-\delta)k_t) \\ +\lambda_t^d(d_t - \zeta k_t) + \lambda_t^z z_t - \lambda_t^{\bar{z}}(z_t - \bar{z}) \\ + \frac{[\eta k_{t+1} + (1-\eta)\mathbf{E}_t(V_{t+1})]}{1 + \frac{1-\tau^i}{1-\tau^g}\bar{r}_{t+1}} \end{array} \right\} \tag{3.16}$$

Using equation (3.7a) to eliminate d_t, we obtain the first-order conditions.

Optimality Conditions

$$n_t \quad : \quad w_t = \varepsilon_t F_2(k_t, n_t) \tag{3.17a}$$

$$z_t \quad : \quad \frac{1-\tau^d}{1-\tau^g} + \lambda_t^d + \lambda_t^z - \lambda_t^{\bar{z}} = 1 \tag{3.17b}$$

$$x_t \quad : \quad q_t = \frac{1-\tau^d}{1-\tau^g} + \lambda_t^d \tag{3.17c}$$

$$k_{t+1} \quad : \quad q_t = \frac{\left[\eta + (1-\eta)\mathbf{E}_t\left(\frac{\partial V_{t+1}}{\partial k_{t+1}}\right)\right]}{1 + \frac{1-\tau^i}{1-\tau^g}\bar{r}_{t+1}} \tag{3.17d}$$

$$\lambda_t^d \quad : \quad \lambda_t^d(d_t - \zeta k_t) = 0; \lambda_t^d \geq 0$$

$$\lambda_t^z \quad : \quad \lambda_t^z z_t = 0; \lambda_t^z \geq 0$$

$$\lambda_t^{\bar{z}} \quad : \quad \lambda_t^{\bar{z}}(z_t - \bar{z}_t) = 0; \lambda_t^{\bar{z}} \geq 0$$

Envelop Condition

$$\frac{\partial V_t}{\partial k_t} = q_t(1-\delta) - \zeta\lambda_t^d + \left(\frac{1-\tau^d}{1-\tau^g} + \lambda_t^d\right)[\delta\tau^c + (1-\tau^c)\varepsilon_t F_1(k_t, n_t)]$$

Euler Equation

$$\frac{1-\tau^d}{1-\tau^g} + \lambda_t^d = \frac{\eta}{1+\frac{1-\tau^i}{1-\tau^g}\bar{r}_{t+1}} + \frac{1-\eta}{1+\frac{1-\tau^i}{1-\tau^g}\bar{r}_{t+1}} \mathbf{E}_t \left\{ \begin{array}{r} ((1-\tau^c)\varepsilon_t F_1(k_{t+1}, n_{t+1}) + \delta\tau^c + (1-\delta)) * \\ \left(\frac{1-\tau^d}{1-\tau^g} + \lambda_{t+1}^d\right) - \zeta\lambda_{t+1}^d \end{array} \right\} \quad (3.18)$$

Equation (3.17a) shows that the financial constraints don't affect the employment decision of the firm. It hires up to the point where the marginal productivity of labor equals the wage established in the labor market.

The financial policy of the firm is determined by equation (3.17b). To interpret this equation, let focus first on a firm for which the maximum equity-issuance constraint is not binding, i.e. $\lambda_t^{\bar{z}} = 0$. The left side of (3.17b) represents the marginal benefit to the shareholder of raising one unit of new equity. It says that, issuing one unit of new equity to pay dividends relaxes the dividend constraint and the shareholder receives $\frac{1-\tau^d}{1-\tau^g}$ as dividend after tax. When the equity-issuance constraint is binding, $\lambda_t^{\bar{z}}$ measures the value of one additional dollar of new equity for the firm.

q_t in (3.17c) is the shadow price of investment and can be referred to as the marginal q. The investment policy of the firm is described by (3.18). The left side of (3.18) represents the marginal cost of investment, while the right side represents the marginal benefit of investment. This marginal gain from investment consists of the un-depreciated capital and the after-tax marginal product of capital.

In an economy where there is no tax differential between dividend payments and retained earnings, i.e. $\tau^d = \tau^g$, the firm's financial policy is irrelevant if the maximum equity-issuance constraint is not binding. In order words, if $\tau^d = \tau^g$, $\lambda_t^{\bar{z}} = 0 \Rightarrow \lambda_t^z = \lambda_t^d = 0$. In this case, the capital structure of the firm does not matter for its value. This is the well-known Miller and Modigliani [1961]'s theorem. However, the financial policy of the firm affects its value if $\tau^d \neq \tau^g$. If one assumes $\tau^d > \tau^g$ as in the United States before the 2003's dividend tax cut, it is impossible to have $\lambda_t^z = \lambda_t^d = 0$. Otherwise, equation (3.17b) implies that $\frac{1-\tau^d}{1-\tau^g} - \lambda_t^{\bar{z}} = 1$ which is unfeasible because $\frac{1-\tau^d}{1-\tau^g} < 1$. In fact, it is not optimal for the firm to simultaneously raise new equity and distribute higher dividends than the minimum requirement. The intuition is that to maximize equity value, the firm should reduce dividends and use retained earnings to finance investment because dividends are heavily taxed than capital gains. Thus, one of the constraints (3.7c) and (3.7d) must be binding. In addition, both (3.7d) and (3.7e) can not be simultaneously binding. In fact, $z_t = 0$ implies $z_t < \bar{z}$ because $\bar{z} > 0$. In addition, $z_t = \bar{z}$ implies $z_t > 0$ because $\bar{z} > 0$. Given these observations, a firm can be in four different *finance regimes* characterized as follows:

1. *Equity-constrained regime*: $z_t = \bar{z}$; $d_t = \zeta k_t$,

$$k_{t+1} = (1-\tau^c)(1-\nu(1-\alpha))\left[\varepsilon_t k_t^{\alpha\nu}\left(\frac{\nu(1-\alpha)}{w_t}\right)^{\nu(1-\alpha)}\right]^{\frac{1}{1-\nu(1-\alpha)}} + (1-\delta+\zeta+\delta\tau^c)k_t + \bar{z}.$$

2. *Cash-constrained regime*: $0 < z_t < \bar{z}$; $d_t = \zeta k_t$; $\lambda_t^z = \lambda_t^{\bar{z}} = 0$; $\lambda_t^d = \dfrac{\tau_d - \tau^g}{1-\tau^g}$; and k_{t+1} solves the equation:

$$1 + \frac{1-\tau^i}{1-\tau^g}\bar{r}_{t+1} = \eta + (1-\eta)\mathbf{E}_t\left\{\begin{array}{r}((1-\tau^c)\varepsilon_t F_1(k_{t+1}, n_{t+1}) + \delta\tau^c + (1-\delta)) * \\ \left(\dfrac{1-\tau^d}{1-\tau^g} + \lambda_{t+1}^d\right) - \zeta\lambda_{t+1}^d\end{array}\right\}$$

3. *Internal-growth regime*: $z_t = 0$; $d_t = \zeta k_t$; and $\lambda_t^{\bar{z}} = 0$.
4. *Cash-rich regime*: $z_t = 0$; $d_t > \zeta k_t$; $\lambda_t^{\bar{z}} = \lambda_t^d = 0$, and $\lambda_t^z = \dfrac{\tau_d - \tau^g}{1-\tau^g}$.

The number of financing regimes as well as their characterization, constitute a key distinction between this paper and the existing literature. In contrast to Gourio and Miao [2010] and Gomes [2001], my model features four finance regimes instead of three. The regimes in Gomes [2001] are generated by the transaction costs of external financing. In Gourio and Miao [2010], they stem from the differential tax treatments between capital gain and dividend. While my model shares some resemblance with Gourio and Miao [2010] in this aspect, it integrates an overall borrowing constraint which is absent in Gourio and Miao [2010]. More precisely, the upper bound on equity issuance in my model may prevent the firm from financing investment with positive net return while in Gourio and Miao [2010], the firm may issue an infinite amount of new equity. Next, I present the typical trajectory of a firm through the financing regimes post-entry.

3.4 Firm Transition Across finance Regimes

To illustrate the transition of firms across finance regimes, the red, the blue and the magenta curves in figure 3.2 plot for a given productivity shock, the investment, the dividend and the equity issuance policies as functions of initial capital. The dashed vertical lines delimit the different finance regimes. Moving from the left to the right in figure 3.2, the first regime is the *equity-constrained regime* in which firms are the smallest ones. They reduce dividend to the minimum requirement, raise equity to the maximum admissible value in addition to their internal cash flows to fund investment. Moreover, they still have unused investment opportunities, which can not be financed because they are liquidity-constrained. Therefore, they adjust their size gradually, not being able to instantaneously jump to their optimal size. [8]

The second regime is the *cash-constrained regime*. Firms in this regime are relatively larger than in the *equity-constrained regime*. Neither the upper-bound on equity issuance, nor the share repurchase constraint are binding. However, firms do not generate enough cash flows to internally finance investment. They reduce dividend to the minimum requirement and tap into the equity market to finance investment. In this regime, the left-hand side of equation 3.18 shows that the marginal cost of investment equals 1. Accordingly, all firms in this regime increase their capital stock until their expected marginal product of capital equals 1. Thus, all of them choose the same capital level implying an horizontal investment decision rule. To reach this size, relatively smaller firms issue more equity than larger ones to finance investment.

The third regime is the *internal-growth regime*. In this regime, firms are relatively larger than the ones in previous two regimes. In addition, they

8. Accordingly, they are expanding and their investment decision rule has a positive slope. $\dfrac{\partial k_{t+1}}{\partial k_t}(w_t) = (1-\tau^c)(1-\nu(1-\alpha))\left[\varepsilon_t k_t^{-(1-\nu)}\left(\dfrac{\nu(1-\alpha)}{w_t}\right)^{\nu(1-\alpha)}\right]^{\frac{1}{1-\nu(1-\alpha)}} + (1-\delta+\zeta+\delta\tau^c) > 0$

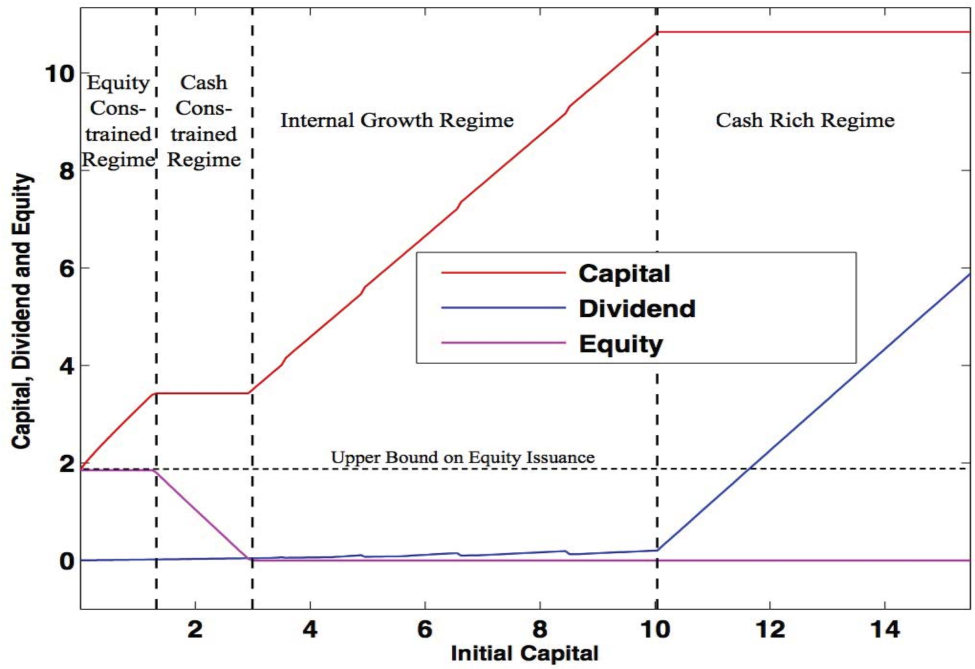


Figure 3.2: Firm Transition Across finance Regimes

generate enough internal funds to finance investment. The marginal product of capital does not warrant raising funds externally, but it is high enough so that the value of one dollar invested in the firm is higher than the value of a dollar invested outside of the firms. Firms reduce dividend to the minimum possible and do not issue new equity because of the tax-differential. As firm are still dividend-constrained, they adjust their size gradually. In contrast to the previous two regimes, the marginal source of investment finance is retained earnings.

The last regime is the *cash-rich regime*. Here, only the share repurchase constraint is binding. Cash-rich firms are large enough not to be dividend constrained and jump instantaneously to their optimal size. They generate enough cash flows to internally finance investment and to distribute larger dividends than the minimum payout policy. Moreover, they do not raise equity and the marginal source of investment finance is retained earnings.

In summary, a firm in the *equity-constrained* or the *cash-constrained* regimes raises equity to finance investment while in other regimes, the marginal source of investment finance is retained earnings. Figure 3.2 shows that equity-constrained or cash-constrained firms tap into the equity market and reduce dividend to the minimum possible. Largest firms use internal funds to finance investment and distribute much dividend than the minimum requirement. Finally, medium-size firms in the internal growth regime do not issue equity and reduce dividend to the minimum possible. The transition of a firm across regimes depends on the history of productivity shocks it experiences along its lifetime. Consequently, a firm starting from the equity-constrained regime does not have to transit successively across the *cash-constrained regime* and the *internal-growth regime* before reaching the *cash-rich regime*.

3.5 Model Solution and Calibration

Because this model does not permit closed form solution, I resort to numerical methods. I provide a detail description of the numerical algorithm in the Appendix. The model is calibrated on U.S. data for establishment-level investment dynamics. [9] This data is reported annually, thus one model period corresponds to one calendar year. My parameters can be classified into two groups. The first group includes parameters I set a priori and are reported in Table 3.1.

Table 3.1: Parameters selected a priori

Parameter		Value	Source
Return to scale	υ	0.85	Atkeson and Kehoe [2005] and others
Capital elasticity	α	1/3	income share data
Discount factor	β	0.96	interest rate of 4%
Exit probability	η	0.05	Evans [1987], Lee and Mukoyama [2012]
Tax rates			Gourio and Miao [2010]
Corporate income	τ^c	0.34	
Individual income	τ^i	0.25	
Dividend	τ^d	0.25	
Capital Gains	τ^g	0.20	

9. Although I calibrate the model to establishment-level data, I still refer to production units in my model as firms.

Tax system. The tax rates follow closely the ones in Gourio and Miao [2010] and set the corporate income tax rate $\tau^c = 0.34$. In addition, I assume that the representative household has an average income which falls into the lowest of the top four tax brackets at the income tax rate $\tau^i = 0.25$. As dividends are taxed at the personal income tax rate, I set the dividend tax rate $\tau^d = 0.25$. This household faces the capital gains tax rate $\tau^g = 0.20$.
The return to scale parameter $\nu = 0.85$ has a standard value in the literature employing the same production function specification as mine [Restuccia and Rogerson, 2008, Atkeson and Kehoe, 2005, Pavcnik, 2002, Veracierto, 2001, Atkenson et al., 1996, Gomes, 2001, Clementi and Palazzo, 2013], as is the capital share parameter $\alpha = 1/3$. [10] An annual exit rate of 5% is in the middle range of the estimates provided by Evans [1987] and Lee and Mukoyama [2012].
The parameters calibrated internally, by requiring the model to match a set of moments, are presented in Table 3.2. The depreciation rate δ is calibrated to deliver an aggregate investment-to-capital ratio of 0.069. This is the same value used by Khan and Thomas [2013], and is based on private capital stock estimates from the Fixed Asset Tables, controlling for growth, for the 1954-2002 period.
The process for firm level productivity shocks is estimated by fitting an $AR(1)$ process:

$$\ln \varepsilon_t = \rho \ln \varepsilon_{t-1} + \varsigma_t \tag{3.19}$$

where ς_t follows an i.i.d. standard normal distribution with mean γ and variance σ^2. For solving the model, this process is discretized into a 5-state Markov chain using the quadrature method of Tauchen and Hussey [1991]. The three parameters of the AR(1) process are selected to match three cross-sectional moments: (i) a standard deviation of investment rates as a fraction of capital of 0.337, and (ii) an average investment rate of 0.122, both as reported by Cooper and Haltiwanger [2006], (iii) a standard deviation of the cash to assets ratio of 0.161, as reported by Khan and Thomas [2013] using Compustat data for the 1954-2011 period.
The parameters governing the extent of financial frictions are key. I infer them by requiring that the model matches two additional moments relating to the plant-level dynamics: (i) an average employment size of new entrants

10. In order to arrive at a $1/3$ capital share in this model, I assume that the profits firms generate after incurring investment expenditures and making payments to labor are attributed to capital and labor according to the shares α and $1-\alpha$.

Table 3.2: Internal calibration

Parameter		Value	Target	Data	Model
Depreciation rate	δ	0.069	$avg(i)/avg(k)$	0.069	0.069
Productivity	γ	0	$sd\,(i/k)$	0.337	0.317
shock process	σ	0.231	$avg\,(i/k)$	0.122	0.139
	ρ	0.577	$sd\,(cf/k)$	0.161	0.149
Borrowing	$\bar{z}$	1.853	$avg(cf)/avg(k)$	0.102	0.107
limit	ζ	0.015	Rel size entrants	0.600	0.627

(firms in their first production year) of 60% of the average size of incumbents, as reported by Lee and Mukoyama [2012] using data from the U.S. Census Bureau's Annual Survey of Manufactures (ASM) for the 1972-1997 period; (ii) an aggregate cash-to-asset ratio of 0.102, as reported Khan and Thomas [2013] for Compustat data.

My calibration implies $\bar{d} > 0$ and $\zeta > 0$. As pointed out previously, this implies binding borrowing constraints, which are overall tighter for smaller firms. To illustrate this point, Figure 3.3 plots the ratio of actual to unconstrained investment levels in the model as a function of current capital (firm size). Two lines are plotted, one for a high and the other for a low value of current (hence expected future) productivity. A value of one means the firm is operating at the unconstrained level, and the lower the ratio the tighter the borrowing constraint is. The parameter ζ allows me to control how fast this ratio increases with firm size. As the figure illustrates, the magnitude I obtain for ζ is still consistent with smaller firms, which generate less cash flows, being the most constrained. See Beck et al. [2005] and Angelini and Generale [2008] for some evidence consistent with this model prediction.

The figure also shows that high productivity firms are more constrained, given their higher unconstrained optimal level of investment. My calibration, namely the degree of persistence of the productivity shocks, is such that this effect always dominates the effect of higher current cash-flows due to higher current productivity.

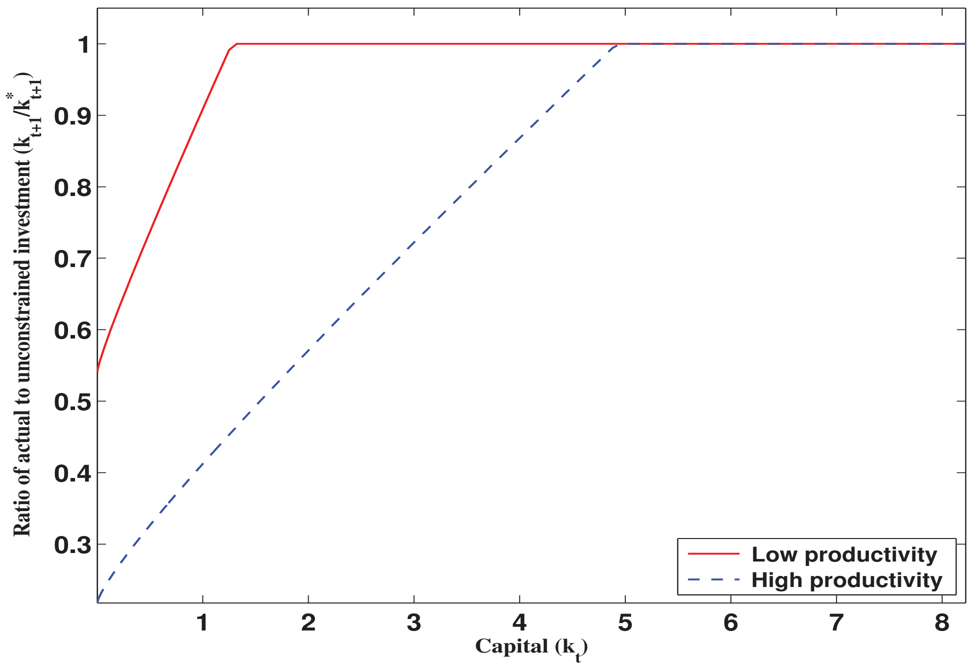


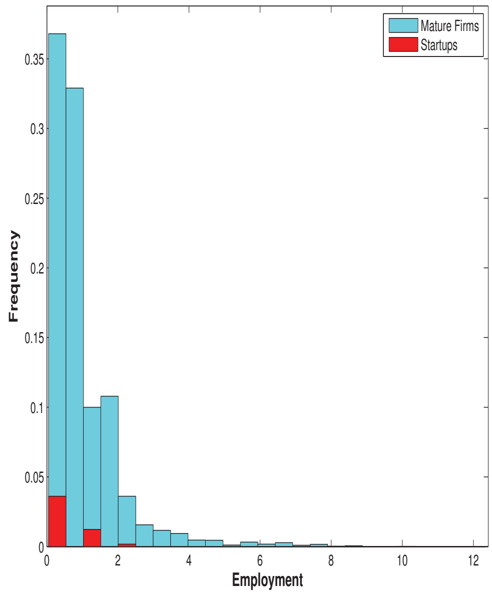
Figure 3.3: Tightness of the Dividend Constraint

3.6 Steady-State Implications

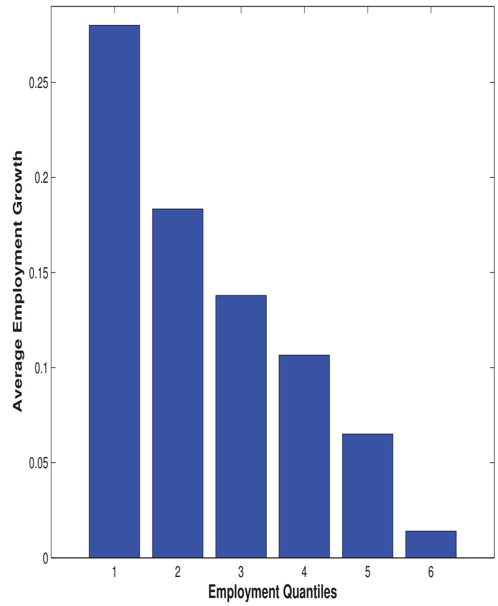
Now, I discuss the model's implications to ensure that the extent of financial frictions allows it to replicate salient features of firm-level data at the steady-state.

3.6.1 Firm Size Distribution and Firm Growth

In this section, I describe and compare the model's implications for firm size distribution and firm growth with the empirical evidence. Figure 3.4a displays a right-skewed employment distribution which resembles its empirical counterpart in the U.S. [Hsieh and Klenow, 2014, Henly and Sanchez, 2009]. This result implies that in stationary equilibrium, there is a big mass of small firms and a small mass of large firms. The result holds true even when I use capital as a measure of size.
Figure 3.4b plots average employment growth conditional on firm employ-



(a) Stationary Firm Distribution



(b) Firm Growth

Figure 3.4: Firm Dynamics

ment. The model's implications are consistent with the empirical evidence that firm growth is unconditionally negatively correlated with size as reported by Dunne et al. [1988]. Models along the lines of Hopenhayn's (1992), such as mine, deliver this implication due in large measure to the mean-reverting nature of the stochastic process for productivity.

In my specific case, an additional mechanism contributes to generating the right unconditional correlation between growth and size. In fact, there are two state variables: productivity and capital. If I consider all the firms with the same employment, Hopenhayn [1992] predicts that they will behave identically. Here, they may behave differently depending on their current capital stock and productivity shock. In fact, some of these firms are characterized by a relatively low capital and high shock, and others by a relatively high capital and low shock because financial constraints prevent the instantaneous adjustment of capital to the first-best implied by productivity. The former will grow faster because investment and capital are catching up the optimal size induced by productivity. The latter will shrink as the scale of production is adjusted to the new lower level of productivity. These features are shared by other models with pre-determined capital and either financial frictions or adjustment costs to capital [e.g Khan and Thomas, 2013, Clementi and Palazzo, 2013].

3.6.2 Job Turnover

While I do not target employment dynamics in the calibration, the model delivers some quantitative implications consistent with the data. Table 3.3 reports the job creation and job destruction in stationary equilibrium and in the data (Lee and Mukoyama [2012]).

Table 3.3: Job Creation and Job Destruction

	Job creation		Job destruction	
	Model	Data	Model	Data
Total	25	9	25	10
Relative Contribution				
Startups	13	17	0	0
Mature	87	83	80	76
Exiters	0	0	20	24

The job creation is defined in the usual way, as the total employment change among growing firms and new entrants relative to the initial employment size across all firms. The job destruction rate is defined in an analogous way among shrinking firms and exiters. The table shows that, in the aggregate, the model is unable to deliver the job creation and job destruction rate in the data. This is in part due to the way I model entry (initial productivity drawn from the unconditional distribution) and exit (random across all incumbents). The relative contribution of the different firm types, however, is totally in line with the data, in spite of this not being a calibration target. Mature incumbents are responsible for most job creation and destruction in the economy.

3.6.3 Distribution of firms across finance regimes

I suppose that the economy under the parameter values in Tables 3.1, and 3.2 has reached the steady-state. As firms in different finance regimes may respond to the tax cuts in different ways, it proves useful to discuss first the finance regime for the firms in the cross section. Table 3.4 presents the distribution of firms across finance regimes at the stationary equilibrium. The share of firms for a regime is equal to the total number of firms in that regime divided by the total number of firms in all regimes. The average capital (respectively output, equity issuance) for a regime is equal to the total capital stock (respectively output and equity issuance) of all firms in that regime divided by the number of firms in the regime.

Table 3.4: Firms' Distribution across Finance Regimes

$\tau^g = 0.20$ $\tau^d = 0.25$ $\tau^c = 0.34$	Equity Constrained Regime	Cash Constrained Regime	Internal Growth Regime	Cash Rich Regime
Share of firms	2	10	45	43
Average Capital	3.19	2.08	2.86	4.04
Average Output	5.16	1.92	1.45	1.49
Average Equity issuance	1.85	0.88	0	0

Table 3.4 reveals that the cash-rich firms represent 43% of the firm distribution. In average, firms in the cash-rich regime are the largest in the economy and do not issue equity. In addition, they produce less output in average than firms in other regimes, implying that they are less productive in average. In fact, the ratio of average output to average capital is a proxy of average productivity. This ratio equals 1.62, 0.92, 0.51, 0.37 for firms in equity-constrained, cash-constrained, internal growth and cash-rich regimes, respectively. Firms in the internal-growth regime represent 45% of the overall distribution at steady state. As cash-rich firms, they do not raise new equity. Firms in the internal-growth and cash-constrained regime are the smallest ones. In average, a cash-constrained firm is smaller than a firm in the internal-growth regime but produces more output. This result suggests that Cash-constrained firms are relatively more productive than those which are growing internally. Their marginal productivity of capital is high enough that they tap into the equity market to finance investment and to pay dividends. In average, equity-constrained firms are the most productive at steady-state. Consequently, they also issue new equity to finance investment

and are of medium-size. Equity-constrained and cash-constrained firms constitute, respectively, 10% and 2% of the total number of firms. These results reflect the fact that most firms do not tap the equity market because the tax differential between capital gain and dividend makes equity issuance costly.

3.7 Tax Reform Experiments

To analyze the effects of the CBIT, I concentrate on a revenue-neutral tax reform which uses only the corporate profit tax to raise revenue on businesses as proposed by U.S. Treasury Department in 1992. I proceed in three steps and consider two experiments. I start by an experiment in which capital gain and dividend taxes are eliminated with no changes to the other taxes. I find that the tax cuts are not self-financing and the corporate profit tax rate needs to be adjusted upward from 34% to 42% to keep the reform revenue-neutral. Thereafter, I assess the effects of a tax reform which abolishes the dividend and capital gain taxes and increases the corporate profit tax rate to 42%. I assume that the tax changes are permanent in order to study the long run steady-state effects.

After each tax experiment, I compute the percentage change in aggregate variables from the initial steady-state. Table 3.5 reports the aggregate effects of the two experiments, while Table 3.6 reports the effects on the firm-distribution across finance regimes. All aggregate variables are measured in percentage deviation from the initial steady-state.

3.7.1 Elimination of Dividend and Capital Gain Taxes

I begin by the experiment in which both the capital gain and the dividend taxes are eliminated permanently with no changes to the corporate profit tax rate. As both taxes disappear, the tax differential between capital gain and equity vanishes and the firm's financial policy becomes irrelevant. It does not matter for the firm's value the amount of earnings to retain as internal finance, rather than distributing dividends and raising equity in the external equity market. Thus, the values of dividend and new equity are indeterminate, and it becomes impossible to differentiate the firms in cash-constrained regime from those in internal growth regime. Both are marked as "N/A" in Columns 3 and 4 of Table 3.6.

Table 3.5: Aggregate Effects of Tax Reforms

Aggregate Changes (%)	$\tau^g = 0$, $\tau^d = 0$, $\tau^c = 0.34$	$\tau^g = 0$, $\tau^d = 0$, $\tau^c = 0.42$
Quantities		
Capital	8.06	-8.79
Output	3.72	-1.22
Consumption	2.99	0.05
Prices		
Wage	3.27	-1.19
Share Value	17.69	-1.55

Table 3.6: Effects on the Distribution of Firms

	Equity Constrained Regime	Cash Constrained Regime	Internal Growth Regime	Cash Rich Regime
Initial steady-state				
$\tau^g = 0.20$, $\tau^d = 0.25$, $\tau^c = 0.34$				
Share of firms	2	10	45	43
Average Size	3.19	2.08	2.86	4.04
Zero div. and cap. gain taxes				
$\tau^g = \tau^d = 0$, $\tau^c = 0.34$				
Share of firms	31	N/A	N/A	56
Average Size	3.07	N/A	N/A	3.94
CBIT reform				
$\tau^g = \tau^d = 0$, $\tau^c = 0.42$				
Share of firms	22	N/A	N/A	61
Average Size	3.41	N/A	N/A	3.24

Column 2 of Table 3.5 reveals that the elimination of capital gain and dividend taxes, results in an increase in long-run aggregate capital stock, output, consumption, wage and stock price.
Investment may increase after the tax cuts for two reasons. First, the tax cuts remove the tax differential between equity and dividend. Thus, profitable firms in the cash-constrained or the internal-growth regime tap into the equity market to invest more after the tax cuts. Second, the firm's problem (equation 3.6) shows that the discount factor of the firm is given by $\bar{r}(1-\tau^i)/(1-\tau^g)$, which equals the after-tax return required by equity owners. Therefore, a decrease in τ^g reduces the cost of investment for all firms. Both effects boost investment and imply an increase in aggregate capital, output and labor demand. In response, wage increases to clear labor market because labor supply is inelastic. Consistent with this intuition, Column 2 of Table 3.5 shows that the wage rate increases by 3.27%.
Consumption increases because the elimination of dividend and capital gain taxes raises equity values. In fact, it comes from equation (3.5) that starting from a situation in which the capital gain tax rate is lower than the dividend tax rate, the elimination of both taxes increases the factor $\dfrac{1-\tau^d}{1-\tau^g}$ from a value lower than 1 to 1, increasing the value of all firms. Higher wage and share values make shareholders wealthier and induce them to consume more.
Table 3.6 reveals that the tax cuts also affects the distribution of firms across finance regimes. This effect works through two direct channels. By increasing cash-flows, the tax cuts firstly release the constraint on initially constrained firms. As a result, some medium-size and initially constrained firms increase investment and join the cash-rich regime. Secondly, external equity and retained earnings become perfect substitutes as sources of investment financing. Thus, some small and relatively highly productive firms, which are initially in cash-constrained or internal growth regimes, issue equity up to the maximum amounts admissible. Consistent with these intuitions, Columns 2 and 5 in Table 3.6 show that the proportions of equity-constrained and cash-rich firms increase after the tax cuts in comparison to the initial steady-state. Moreover, larger firms may initially have incentives to re-invest retained earnings in projects with below-market yield due to the tax advantage of capital gains. As the policy abolishes this tax asymmetry, it reduces these incentives, generating disincentives for over-accumulation of capital by larger firms. The reduction in the average size of equity-constrained and cash-rich firms in comparison to the initial steady-state, as reported in columns 2 and 5 of

Table 3.6 highlights this effect.

3.7.2 Effects of the CBIT Reform

I now focus on the experiment in which both dividend and capital gain taxes are eliminated permanently, and corporate profit tax is adjusted upward to keep the reform revenue-neutral. This experiment is the prototype of the Comprehensive Business Income Tax (CBIT) reform proposed by the U.S. Department of Treasury. From 34%, my numerical simulation implies that the corporate profit tax rate should be increased to 42% for the reform to be revenue-neutral. Column 3 of Table 3.5 reports the aggregate effects of the reform.

Starting from the steady-state with zero capital gain and dividend taxes, Table 3.6 reveals that the increase in corporate profit taxes is accompanied by a reduction of the number of equity-constrained firms while the proportion of cash-rich firms increases. This effect on the firm distribution is explained by the lower net return on investment, induced by the higher corporate profit tax. In fact, lower after tax marginal productivity of capital implies lower after-tax net return if the marginal cost of investment is unchanged. Consequently, some equity-constrained firms reduce equity issuance and move to another regime, reducing the number of equity-constrained firms. In addition, lower after-tax marginal productivity of capital reduces the optimal size of firms. Therefore, some medium size firms (initially in the internal growth regime) become less willing to invest. The reduction in investment allows them to pay more dividends, releasing the dividend constraint. As a result, they join the cash-rich regime, increasing the number of cash-rich firms increases.

It also appears from Table 3.6 that the average cash-rich firm shrinks, while equity-constrained firms expand in average. Cash-rich firms shrink because their after-tax marginal productivity of capital declines and their marginal cost of investment is unchanged. Initially, equity-constrained firms are firms which have unused investment opportunities because they are borrowing constrained. For those firms, an increase in the corporate profit tax has two opposite effects.[11] The higher tax rate reduces the after-tax return on investment, but the reduction in wage increases their disposable current rev-

11. $k_{t+1} = (1-\tau^c)(1-\nu(1-\alpha)) \left[\varepsilon_t k_t^{\alpha\nu} \left(\frac{\nu(1-\alpha)}{w_t}\right)^{\nu(1-\alpha)}\right]^{\frac{1}{1-\nu(1-\alpha)}} + (1-\delta+\zeta+\delta\tau^c)k_t + \bar{z}.$

enue and relaxes the constraint on investment. The net effects depend on how constrained the firm is in the steady-state with no dividend and capital gain taxes, and the magnitude of the corporate profit tax increase. In my numerical experiment, the former effect dominates the latter. This explains the expansion of equity-constrained firms. The fact that firms in the equity constrained regime are more productive than larger firms in the cash-rich regime suggests that there is a positive capital reallocation from large and low productivity firms to small and highly productive firms because.

Compared with the initial steady-state before the tax reform, the increase in the corporate profit tax rate plays in opposite direction to the effects of eliminating capital gain and dividend taxes. This implies lower after-tax return, discouraging investment. In my numerical experiment, this negative effect dominates the positive effects on investment obtained under the previous experiment. As a result, Column 3 of Table 3.5 reveals that, following the CBIT reform, the long-run aggregate capital stock and output decrease, while consumption increases. Lower capital demand reduces the aggregate demand for labor. In the new equilibrium, wage goes down to clear the labor market because labor supply is inelastic, as reported in Column 3 of Table 3.5. Firms' value also decreases as the higher corporate profit tax rate reduces the after-tax return on equity. Aggregate consumption increases because the reduction in output is less than proportional to the decline in investment. This positive effect on consumption is mainly explained by the positive capital reallocation across firms. As in the previous experiment, the elimination of the tax wedge reduces the distortion on the investment of firms, which are not cash-rich. But, an additional force contributes to the better capital allocation in the current experiment. In fact, higher corporate profit tax discourages investment from unconstrained firms. However, the induced lower wage allows initially borrowing-constrained (especially equity-constrained) firms to expand because it increases their disposable current cash flows. This improves the efficiency of capital allocation because equity-constrained firms are the most productive. I analyze the efficiency and welfare effects of the tax reform in the next section.

3.7.3 Productivity and Welfare Effects

I have shown that the CBIT reform has two opposite effects on long run capital accumulation. The elimination of capital gain and dividend taxes stimulates long run capital formation, while the increase in corporate profit

tax rate discourages investment. Overall, the reform reduces aggregate capital accumulation. Although lower capital accumulation implies lower output, the tax reform leads to an increase in consumption because the reduction in output is less than proportional to the decline in aggregate investment. This fact suggests that there is an improvement in capital allocation across firms in different finance regimes, which may generate some productivity gains.
In this paper, I use the total factor productivity $\left(TFP = Y/K^{\alpha\nu}N^{\nu(1-\alpha)}\right)$ to quantify the productivity gain as in Gourio and Miao [2010]. The higher the TFP, the more efficient the allocation of inputs across firms. In addition, I use the correlation between capital and productivity level to assess how efficiently capital is allocated. According to Gourio and Miao [2010], the higher the correlation between capital and productivity, the more efficient the allocation of capital across firms. The efficiency of labor allocation is measured by the labor productivity (Y/L).[12] A higher labor productivity also implies a better allocation of labor across firms.
The general equilibrium framework also allows to conduct welfare analysis. To evaluate the welfare effect, it is important to make the distinction between the utility gain in steady state and the utility gain during transition. Since my interest is in the long run effects of the CBIT reform, I focus on the utility gain in stationary equilibrium. More precisely, I measure the welfare gain or loss as the consumption compensation required for the household to be indifferent between the equilibrium before and after the tax change. With inelastic labor supply, the change in welfare is equal to the percentage change in steady-state consumption.[13]
Table 3.7 reports the productivity and welfare changes following each tax experiment. All aggregate variables are measured in percentage deviation from the initial steady-state before the tax cuts.
Let start by the first column of Table 3.7 which reports the effects of eliminating both capital gains and dividend taxes with no changes to other tax rates. Column 2 shows that the elimination of both taxes implies a better allocation of capital and labor. More precisely, the increase in the correlation between capital and productivity implies that there is a reallocation of capital from low productivity to high productivity firms. The increase in labor productivity is due to the increase in wage. This increase in wage is in turn due to the increase in capital because the latter raises marginal

12. Further details on the computation are provided in Appendix C.2.
13. Details are provided in Appendix C.2

Table 3.7: Efficiency and Welfare Gains from Tax Cuts

Percentage Change (%)	$\tau^g = 0$ $\tau^d = 0$ $\tau^c = 0.34$	$\tau^d = 0$ $\tau^g = 0$ $\tau^c = 0.42$
TFP	1.22	1.41
Y/L	3.27	-1.19
Correlation between $\ln k$ and $\ln z$	18.78	20.39
Welfare	2.99	0.05

product of labor. As both inputs are more efficiently allocated, one should expect an increase in aggregate productivity. Row 1 of Column 2 confirms this intuition. Two mechanisms explain these results. First, initially high productivity firms with low capital issue new equity to finance investment as the tax wedge disappears. Second, as dividend and capital gain become perfect substitutes as sources of investment financing, large and cash-rich firms have less incentives to over-reinvest earnings. This latter effect reduces the lock-in effect.

Column 3 of Table 3.7 reveals that the CBIT reform is followed by a decrease in labor productivity. This is due to the decline in wage. Wage decreases because the aggregate capital decreases. As discussed in section 3.7.1, aggregate capital decreases because the negative effects of higher corporate profit tax on aggregate investment counterbalances the positive effects of eliminating capital gain and dividend taxes. However, Row 3 shows a better allocation of capital. Two reasons may explain the improvement in capital allocation. First, the elimination of the tax wedge between capital gain and dividend improves capital allocation. Second, the effect of higher corporate profit tax on firm-level investment depends on the finance regime of the firm. In fact, by reducing the return on investment, higher corporate profit tax discourages investment from larger and cash-rich firms. These firms reduce investment and labor demand, causing wage to decrease. The decline in wage increases the current disposable cash flows of equity-constrained firms. As these firms have higher marginal productivity of capital and unused investment opportunities, they increase investment. Overall, the direct effects of increased corporate profit tax reduce investment from larger and less productive firm. However, lower wage indirectly increases investment of small and highly productive firms because it increases disposable cash flows. This reallocation of capital improves capital allocation. The CBIT tax reform implies higher productivity gains, as reported in Column 2 and Column 3, because this second effect is absent in the previous experiment. Welfare increases less than in the previous experiment because the aggregate output decreases. One should expect welfare loss if the increase in corporate profit tax does not improve capital allocation.

3.8 Conclusion

This paper studies the long run effects of a Comprehensive Business Income Tax (CBIT) reform proposed in 1992 by the U.S. Treasury's Department. More precisely, I assess the effects of a corporate tax reform which eliminates capital gain and dividend taxes and adjusts corporate profit tax upward to keep the reform revenue-neutral. Firm heterogeneity in productivity and general equilibrium play a key role in the analysis. The firm heterogeneity implies that firms may lie in different finance regimes over time and respond to tax changes in different ways. First, I find that the elimination of capital gain and dividend taxes reduces the distortion on firms' investment and financial policy, and provides a boost to capital accumulation. Second, the increase in the corporate profit tax rate discourages capital accumulation because it reduces the after tax return on investment. The results show that the latter effect counterbalances the former, implying lower capital accumulation, output and wage. However, the general equilibrium effect reinforces the positive reallocation effects and the reform results in productivity and welfare gains.

There are few ways in which the analysis could be improved. One would ideally study the reform in an environment with corporate bonds to assess the effects of eliminating the tax differential between debt and equity financing. It would also be interesting to study the reform while considering the U.S. as an opened-economy. Although the U.S. is the world's largest economy, it accounts for only about one quarter of the world's capital stock. Hence, there is potentially major scope for capital movement in response to fundamental tax reforms.

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Appendices

A Appendix to Chapter 1

A.1 Proofs

Ricardian equivalence result with Corporate Taxation

Let $\mathcal{Z} = \{\tau_t, B_{t+1}\}_{t=0}^{+\infty}$ and $\hat{\mathcal{Z}} = \left\{\hat{\tau}_t, \hat{B}_{t+1}\right\}_{t=0}^{+\infty}$ where:
$\sum_{t=0}^{+\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\hat{\tau}_t = \sum_{t=0}^{+\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\tau_t$, X denote the equilibrium value of the variable X under $\mathcal{Z}$, and $\hat{X}$ the value under $\hat{\mathcal{Z}}$. If $\Xi \equiv \{C_t, N_t, K_{t+1}, \theta_{t+1}\}$, then the equilibrium allocations under the policy $\mathcal{Z}$ is $\left\{\Xi_t, B_{t+1}^h, d_t\right\}_{t=0}^{+\infty}$ where B_{t+1}^h represents the household's investment in government bonds. Given the initial conditions, the proof proceeds in two steps. First, it shows that the changes in the timing of the tax policy do not affect the value of the firm, i.e. $V_0 = \hat{V}_0$. Second, it proves that $\left\{\Xi_t, \hat{B}_{t+1}^h, \hat{d}_t\right\}_{t=0}^{+\infty}$ is the competitive equilibrium allocations under the policy $\hat{\mathcal{Z}}$ under the initial price system.

$$V_0 = \max_{\{K_{t+1},N_t\}_{t=0}^{+\infty}} \sum_{t=0}^{+\infty}\Lambda_{0,t}\left[F(K_t, N_t) + (1-\delta)K_t - w_tN_t - K_{t+1} - \tau_t\right]$$

$$V_0 = -\sum_{t=0}^{+\infty}\Lambda_{0,t}\tau_t + \max_{\{K_{t+1},N_t\}_{t=0}^{+\infty}} \mathrm{H}(K_{t+1}, N_t)$$

$$\hat{V}_0 = -\sum_{t=0}^{+\infty}\Lambda_{0,t}\hat{\tau}_t + \max_{\{K_{t+1},N_t\}_{t=0}^{+\infty}} \mathrm{H}(K_{t+1}, N_t) = -\sum_{t=0}^{+\infty}\Lambda_{0,t}\tau_t + \max_{\{K_{t+1},N_t\}_{t=0}^{+\infty}} \mathrm{H}(K_{t+1}, N_t).$$

In addition, $\{K_{t+1}, N_t\}_{t=0}^{+\infty} = argmax\, \mathrm{H}(K_{t+1}, N_t) = argmax\, V_0 = argmax\, \hat{V}_0$. Thus, $\{K_{t+1}, N_t\}_{t=0}^{+\infty}$ is the equilibrium investment and employment allocations under $\hat{\mathcal{Z}}$, i.e. $\{K_{t+1}, N_t\}_{t=0}^{+\infty} = \left\{\hat{K}_{t+1}, \hat{N}_t\right\}_{t=0}^{+\infty}$. Since the change in the tax path does not affect the household's optimality conditions, proving that $\left\{C_t, \theta_{t+1}, B_{t+1}^h\right\}_{t=0}^{+\infty}$ remains the equilibrium allocations under $\hat{\mathcal{Z}}$ amounts to showing that these allocations are feasible under the household's budget constraint and consistent with market clearing conditions.
From the good's market clearing conditions: $\forall t, C_t = F(K_t, N_t) + (1-\delta)K_t - K_{t+1} - G_t = F(\hat{K}_t, \hat{N}_t) + (1-\delta)\hat{K}_t - \hat{K}_{t+1} - G_t$. $\{C_t\}_{t=0}^{+\infty}$ is feasible. Next, I choose $\forall t, \theta_t = 1$ consistent with firm's shares market clearing, and shows that the implied household's investment in government bonds is consistent with the bond's market clearing condition. The household budget constraint

implies: $\hat{B}^h_{t+1} - R_t\hat{B}^h_t = \hat{d}_t + w_tN_t - C_t$. Thus, these allocations are feasible under $\hat{\mathcal{Z}}$ by construction. Next, I show that they are consistent with the bond's market clearing condition. Using the resource constraint of the firm: $\hat{d}_t = F(K_t, N_t) + (1-\delta)K_t - w_tN_t - K_{t+1} - \hat{\tau}_t$, implying $\hat{B}^h_{t+1} - R_t\hat{B}^h_t = F(K_t, N_t) + (1-\delta)K_t - K_{t+1} - \hat{\tau}_t - C_t$. From the good's market clearing condition: $F(K_t, N_t) + (1-\delta)K_t - K_{t+1} - C_t = G$. Thus, $\hat{B}^h_{t+1} - R_t\hat{B}^h_t = G - \hat{\tau}_t = \hat{B}_{t+1} - R_t\hat{B}_t$. Starting from the initial condition $\hat{B}^h_0 = \hat{B}_0$ and solving forward implies $\hat{B}^h_{t+1} = \hat{B}_{t+1}, \forall t$. Next, I prove that this new debt path satisfies the transversality condition.

$$\hat{B}_{T+1} = R_T\hat{B}_T + G - \hat{\tau}_T \Rightarrow \lim_{T\to\infty}\prod_{t=0}^{T} R_t^{-1}\hat{B}_{t+1} = \lim_{T\to\infty} -\sum_{t=0}^{T}\prod_{i=0}^{t} R_i^{-1}(\hat{\tau}_t - G_t) + B_0 = \lim_{T\to\infty} -\sum_{t=0}^{T}\prod_{i=0}^{t} R_i^{-1}(\tau_t - G_t) - B_0 \equiv 0.$$

Proof of lemma 1

Under lump sum tax, the consumption at steady-state is given by:

$$C_{ss} = \left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}}\left[1-\alpha+\frac{\alpha(1-\beta)}{(1-\beta(1-\delta))(1-\kappa\mathbf{1}_{D_{ss}<\hat{D}})}\right] - \frac{(\bar{\tau}+\hat{D})\kappa\mathbf{1}_{D_{ss}<\hat{D}}}{1-\kappa\mathbf{1}_{D_{ss}<\hat{D}}} - Gl$$

$$C_{ss} = 0 \Rightarrow G = \left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}}\left[(1-\alpha)(1-\kappa)+\frac{\alpha(1-\beta)}{(1-\beta(1-\delta))}\right] - \hat{D}\kappa \equiv \hat{G}_l.$$

Proof of proposition 5

Under lump-sum tax:

$$D_{ss} - \hat{D} = \frac{1}{1-\kappa\mathbf{1}_{D_{ss}<\hat{D}}}\left[\frac{(1-\beta)}{\beta}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{1}{1-\alpha}} - G_l - \hat{D}\kappa\mathbf{1}_{D_{ss}<\hat{D}}\right]$$

$$D_{ss} - \hat{D} = \frac{1}{1-\kappa\mathbf{1}_{D_{ss}<\hat{D}}}\left(\hat{D}^l_{hi} - \hat{D} - G_l\right).$$

$\hat{D} < \hat{D}^l_{hi} \Rightarrow (D_{ss} - \hat{D} < -G_l < 0)$.

Proof of Proposition 6

Under lump-sum tax:

$$D_{ss} = \frac{1}{1-\kappa\mathbf{1}_{D_{ss}<\hat{D}}}\left[\frac{\alpha(1-\beta)}{1-\beta(1-\delta)}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} - G_l - \hat{D}\kappa\mathbf{1}_{D_{ss}<\hat{D}}\right]$$

$$D_{ss} < \hat{D} \Leftrightarrow G_l > \frac{1-\beta}{\beta}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{1}{1-\alpha}} - \hat{D} \equiv \bar{G}_l.$$

Proof of Proposition 7

$$\hat{G}_l - \bar{G}_l = \left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}}\left[(1-\alpha)(1-\kappa) + \frac{\alpha(1-\beta)}{(1-\beta(1-\delta))}\right] - \hat{D}\kappa - \frac{\alpha(1-\beta)}{1-\beta(1-\delta)}\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} + \hat{D}$$

$$\hat{G}_l - \bar{G}_l > 0 \Longleftrightarrow \hat{D} > -(1-\alpha)\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} \equiv \hat{D}^l_{lo}.$$

Proof of Lemma 2

Under proportional tax, the steady state government debt is:

$$B_{ss} = \frac{\beta}{1-\beta}\left[\left(\frac{\alpha\beta(1-\bar{\tau})}{1-\beta+\delta\beta(1-\bar{\tau})}\right)^{\frac{\alpha}{1-\alpha}}\frac{\alpha(1-\beta)\bar{\tau}}{1-\beta+\delta\beta(1-\bar{\tau})} - G\right]$$

$$B_{ss} = 0 \Leftrightarrow G(\tau) = \left(\frac{\alpha\beta(1-\tau)}{1-\beta+\delta\beta(1-\tau)}\right)^{\frac{\alpha}{1-\alpha}}\frac{\alpha(1-\beta)\tau}{1-\beta+\delta\beta(1-\tau)}$$

$$[G(\tau) = \exp[\ln G(\tau)]] \Longleftrightarrow \left[\frac{\partial G(\tau)}{\partial\tau} = \frac{\partial \ln G(\tau)}{\partial\tau}\exp[\ln G(\tau)]\right] \Longleftrightarrow \left[\frac{\partial G(\tau)}{\partial\tau} > 0 \Longleftrightarrow \frac{\partial \ln G(\tau)}{\partial\tau} > 0\right]$$

$$\left[\frac{\partial \ln G}{\partial \tau} = \frac{(1-\tau)(1-\beta+\delta\beta-\alpha\delta\beta)-\alpha(1-\beta)}{\tau(1-\alpha)(1-\tau)[1-\beta+\delta\beta(1-\tau)]}\right] \Longleftrightarrow$$
$$\left[\frac{\partial \ln G(\tau)}{\partial \tau} > 0 \Leftrightarrow \tau < \frac{(1-\beta+\delta\beta)(1-\alpha)}{1-\beta+\delta\beta(1-\alpha)} \equiv \hat{\tau}_p\right]$$

$$G(\hat{\tau}_p) = \hat{G}_p = \left[\frac{\alpha\beta\frac{(1-\beta)\alpha}{1-\beta+\delta\beta(1-\alpha)}}{1-\beta+\delta\beta\left(\frac{(1-\beta)\alpha}{1-\beta+\delta\beta(1-\alpha)}\right)}\right]^{\frac{\alpha}{1-\alpha}}\left[\frac{\alpha(1-\beta)\frac{(1-\beta+\delta\beta)(1-\alpha)}{1-\beta+\delta\beta(1-\alpha)}}{1-\beta+\delta\beta\left(\frac{(1-\beta)\alpha}{1-\beta+\delta\beta(1-\alpha)}\right)}\right]$$
$$\Longleftrightarrow \hat{G}_p = \alpha(1-\alpha)\left(\frac{\alpha^2\beta}{1-\beta+\delta\beta}\right)^{\frac{\alpha}{1-\alpha}}$$
$$\left\{\left[\hat{\tau}_p = \frac{(1-\beta+\delta\beta)(1-\alpha)}{1-\beta+\delta\beta(1-\alpha)} > 0\right] \text{and} \left[1-\hat{\tau}_p = \frac{(1-\beta)\alpha}{1-\beta+\delta\beta(1-\alpha)} > 0\right]\right\}.$$

Proof of Proposition 8

The proof is established as follow:

1.

$$\hat{D}_l^{lo} = (1-\alpha)\left(\frac{\alpha\beta}{1-\beta(1-\delta)}\right)^{\frac{\alpha}{1-\alpha}} < \hat{D}_p^{lo} =$$
$$\frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta(1-\beta)}\right]^{\frac{1}{1-\alpha}}$$

2. $\hat{D}_p^{lo} = \frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta(1-\beta)}\right]^{\frac{1}{1-\alpha}} < \hat{D}_p^{hi} = \frac{1-\beta}{\beta}\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}}$

3.

$$\hat{D}_p^{lo} = \frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta-\delta\beta^2}\right]^{\frac{1}{1-\alpha}} < \hat{D}_l^{hi} =$$
$$\frac{1-\beta}{\beta}\left[\frac{\alpha\beta}{1-\beta(1-\delta)}\right]^{\frac{1}{1-\alpha}}$$

4. $\hat{D}_l^{hi} = \frac{1-\beta}{\beta}\left[\frac{\alpha\beta}{1-\beta(1-\delta)}\right]^{\frac{1}{1-\alpha}} < \hat{D}_p^{hi} = \frac{1-\beta}{\beta}\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}}.$

Proof of Proposition 9

Assume that $\hat{D} < \hat{D}_l^{hi}$. Proposition 8 implies that $\hat{D} < \hat{D}_p^{hi}$. Given this result, I first prove that:

$$D_{ss} < \hat{D} \Longleftrightarrow \tau > \frac{\alpha\beta^\alpha(1-\beta)^{1-\alpha} - \hat{D}^{1-\alpha}(1-\beta+\delta\beta)}{\alpha\beta^\alpha(1-\beta)^{1-\alpha} - \delta\beta\hat{D}^{1-\alpha}} \equiv \bar{\tau}_p$$

Thereafter, I derive the expression of the corresponding government spending:

$$G(\bar{\tau}_p) = \alpha\left(\frac{\beta\hat{D}}{1-\beta}\right)^\alpha + \delta\frac{\beta\hat{D}}{1-\beta} - \hat{D} \equiv \bar{G}_p.$$

Finally, I show that: $\hat{D} < \hat{D}_l^{hi} \Longrightarrow \bar{\tau}_p > 0$

Proof of lemma 3

Lemma 2 and proposition 9 have shown $\hat{\tau}_p < 1$ and $\bar{\tau}_p > 0$, respectively. Then, the proof consists in:

$$\hat{D}_p^{lo} = \frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta-\delta\beta^2}\right]^{\frac{1}{1-\alpha}} < \hat{D} < \hat{D}_p^{hi} = \frac{1-\beta}{\beta}\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}}$$
$$\Longleftrightarrow \bar{\tau}_p < \hat{\tau}_p$$

First, I define $\bar{\bar{\tau}}_p = \dfrac{(1-\alpha)(1+\delta\beta)}{1+\delta\beta(1-\alpha)}$. Afterwards, I show that:

$$\bar{\tau}_p < \bar{\bar{\tau}}_p \Longleftrightarrow \frac{1-\beta}{\beta}\left(\frac{\alpha}{\delta}\right)^{\frac{1}{1-\alpha}} > \hat{D} > \frac{1-\beta}{\beta}\left[\frac{\alpha^2\beta}{1-\beta+\alpha\delta\beta^2+\delta\beta(1-\beta)}\right]^{\frac{1}{1-\alpha}}.$$

Then, I prove $\bar{\bar{\tau}}_p < \hat{\tau}_p$.

A.2 Numerical Algorithm

The algorithm used to compute the transition dynamics of the economy when tax is lump sum is as follows.

1. Solve for the steady state and fix a length for the transition.
2. Make a guess on the status of the constraint for each period of the transition.

3. Given the initial stock of capital and the tax rate after tax cut, make a guess for initial consumption.
4. Given the guess for consumption, use the household's resource constraint to derive the dividend.
5. Given conjecture on the status of the constraint, use the firm's resource constraint to derive the investment.
6. Given the capital choice of next period and the status of the constraint, use in the firm' Euler equation to determine the interest rate.
7. Given the interest rate, use the household's Euler equation to have a guess of the future consumption and tax rate.
8. Given the interest rate, the tax cuts and the zero debt government condition for next period, use the government budget constraint to update the conjecture of the future tax rate. This step is necessarily only for the period after the tax cut. For the other periods, the tax rate is the same as in steady state.
9. Repeat steps 3 to 8 until convergence of the investment decision to its steady state value. If the investment decision does not converge before the end of the transition, go back to step 3 and update the guess on consumption.
10. After convergence, use the path of dividend and investment to check the conjecture of the status of the constraint. If the conjecture is correct then stop. Otherwise, go back to step 3 and update the conjecture on the status of the constraint.

B Appendix to Chapter 2

B.1 Stationary Equilibrium

The algorithm used to solve for the stationary equilibrium consists of the following steps.

1. Guess wages and solve for the decision rules incumbents and new entrants.
2. Compute the stationary distribution by simulation.
3. Verify that the labor market clears.

Firm Optimization

1. Construct a grid for capital $\mathcal{K} \equiv \{k_1, k_2, \cdots, k_{N_k}\}$, with k_1 sufficiently low and k_{N_k} sufficiently large that changing them further has a negligible effect on the solution. In practice $N_k = 300$. We use $N_\varepsilon = 5$ states for the Markov chain.
2. For given wages, solve the dynamic program of the incumbent by value iteration. We linearly interpolate the value function for investment levels outside $\mathcal{K}$. For each state (k_p, ε_q) in the grid and for iteration j:

$$V^{j+1}(k_p, \varepsilon_q) = \max_{k' \in \mathcal{K}} \left\{ d(k_p, \varepsilon_q, k') + \beta \begin{bmatrix} \eta k' + (1-\eta)* \\ \sum_{\varepsilon'} \pi(\varepsilon' | \varepsilon_q) V^j(k', \varepsilon') \end{bmatrix} \right\}$$

   where $d(k_p, \varepsilon_q, k')$ is the dividend conditional on an optimal labor choice, and it also incorporates the dividend constraint.
3. Iterate on the Bellman equation until the following convergence criterion is satisfied:

$$\max_{k_p, \varepsilon_q} \left| \frac{V^{j+1}(k_p, \varepsilon_q) - V^j(k_p, \varepsilon_q)}{10^{-3} + |V^j(k_p, \varepsilon_q)|} \right| < 10^{-6}.$$

4. The solution to the new entrant's problem is simply $k^e = \bar{d}$. We verify that the dividend constraint is in fact binding.

Market Equilibrium

1. Conjecture wages w.

2. Select a simulation length $S = 3$ million $+ 1000$. Choosing a larger number produces no significant changes to the stationary distribution of capital. Initialize an incumbent firm with some arbitrary state (k_0, ε_0).
3. Simulate a sequence of exit shocks of length S by drawing random numbers from a Bernoulli distribution with success probability η.
4. If the firm is to continue producing next period, compute investment using the incumbent's decision rule $k'(k_p, \varepsilon_q)$, and draw next period's productivity shock from the conditional distribution π.
5. If firm is to exit next period, compute investment using the new entrant's decision rule $k' = \bar{d}$, and draw next period's productivity shock from the long-run distribution $\bar{\pi}$.
6. Discard the first 1000 observations, and use the empirical distribution of capital over the remaining simulation periods as an approximation to the steady-state cross-sectional distribution of capital.
7. Check whether aggregate labor demand $n^d \equiv \sum_{s=1001}^{S} n_s/(S-1000) \approx 1$, where n_s is the firm's optimal labor choice at time s.

B.2 Transitional Dynamics

Given the steady-state solution and the policy described in Section 2.6, we solve for the transitional dynamics as follows.

1. Compute the steady-state described in the previous section, and obtain the stationary values for consumption c, wages w, as well as the incumbent's value function V. Guess the approximative length of the transition T. In practice $T = 10$ works well, and increasing it further does significantly change the transition path.
2. Guess paths for consumption $\{c_t\}_{t=1}^{T}$ and wages $\{w_t\}_{t=1}^{T}$, with $c_T = c$ and $w_T = w$.
3. Given the consumption path, derive the path for interest rate, $\{r_{t+1}\}_{t=1}^{T}$ where $r_{t+1} = c_{t+1}/(\beta c_t) - 1$.
4. Given the path for wages and interest rates, solve the dynamic problem of incumbents and new entrants by backward induction, with $V_{T+1} = V$.

5. Starting from each initial condition drawn from the steady-state distribution, simulate the problem of a firm for T periods, following the procedure described in the "market equilibrium" step on the preceding section.
6. From the implied sequence of cross-sectional distributions, compute aggregate investment i_t, output y_t and labor demand n_t^d at each period along the transition. Derive the implied value of consumption $\hat{c}_t$ that would clear the final good market, $\hat{c}_t = y_t - i_t - g$.
7. Check whether $\hat{c}_t \approx c_t$ and $n_t^d \approx 1$ for each $t \in \{1, T-1\}$

C Appendix to Chapter 3

C.1 Numerical Algorithm

I first solve the initial steady-state with the tax parameters in Table 3.1 and store the government revenue. Second, I solve for the steady-state with zero capital gain and dividend taxes while maintaining the corporate profit tax rate unchanged. Third, to compute the effect of the tax reform, I set the dividend and capital gain tax rates to zero. Then, I consider a function which takes as input the corporate profit tax rate and gives as output the difference between the implied total government revenue and the initial government revenue. Thereafter, I solve for the corporate tax rate which equalize this function to zero. The function incorporates a subroutine which solves a stationary equilibrium for each value of corporate profit tax rate considered. Once I obtain the required corporate profit tax rate, I solve the final steady-state. The algorithm used to solve the stationary equilibrium consists of the following steps.

1. Guess wages and solve for the decision rules incumbents and new entrants.
2. Compute the stationary distribution by simulation.
3. Verify that the labor market clears.

Further details on each step are provided in B.1

C.2 Computation of Efficiency and Welfare Gains

To quantify the productivity gains, I use the Total Factor Productivity as in Gourio and Miao [2010].

$$
\begin{aligned}
TFP &= \frac{Y}{K^{\alpha\nu} N^{\nu(1-\alpha)}} \\
&= \frac{\int \varepsilon \left(k^{\alpha} n^{1-\alpha}\right)^{\nu} d\mu(k,\varepsilon)}{\left[\int k d\mu(k,\varepsilon)\right]\left[\int n d\mu(k,\varepsilon)\right]} \\
&= \frac{\left(\frac{\nu(1-\alpha)}{w}\right)^{\frac{\nu(1-\alpha)}{1-\nu(1-\alpha)}} \int \left(\varepsilon k^{\alpha\nu}\right)^{\frac{1}{1-\nu(1-\alpha)}} d\mu(k,\varepsilon)}{\left(\frac{\nu(1-\alpha)}{w}\right)^{\frac{\nu(1-\alpha)}{1-\nu(1-\alpha)}} \left[\int \left(\varepsilon k^{\alpha\nu}\right)^{\frac{1}{1-\nu(1-\alpha)}} d\mu(k,\varepsilon)\right]^{\nu(1-\alpha)} \left(\mathrm{E}_{\mu}[k]\right)^{\nu\alpha}} \\
&= \frac{\mathrm{E}_{\mu}\left[\varepsilon^{\frac{1}{1-\nu(1-\alpha)}}\right] \mathrm{E}_{\mu}\left[k^{\frac{\nu\alpha}{1-\nu(1-\alpha)}}\right] + \mathrm{Cov}_{\mu}\left[\varepsilon^{\frac{1}{1-\nu(1-\alpha)}}, k^{\frac{\nu\alpha}{1-\nu(1-\alpha)}}\right]}{\left(\mathrm{E}_{\mu}[k]\right)^{\nu\alpha}}
\end{aligned}
$$

where E_μ and Cov_μ denote the expectation and covariance operators for the stationary distribution μ, respectively. The covariance term captures the fact that capital may move among firms with different productivity shocks. In this perspective, Gourio and Miao [2010] considers that it represents the reallocation effect. A higher value of this term means that high productivity firms own more capital implying a better capital allocation.
To measure the efficiency of labor allocation, I refer to the labor productivity.

$$\begin{aligned}
\frac{Y}{L} &= \frac{\int \varepsilon\left(k^{\alpha}n^{1-\alpha}\right)^{\nu} d\mu(k,\varepsilon)}{\int n d\mu(k,\varepsilon)} \\
&= \frac{\left(\frac{\nu(1-\alpha)}{w}\right)^{\frac{\nu(1-\alpha)}{1-\nu(1-\alpha)}} \int \left(\varepsilon k^{\alpha\nu}\right)^{\frac{1}{1-\nu(1-\alpha)}} d\mu(k,\varepsilon)}{\left(\frac{\nu(1-\alpha)}{w}\right)^{\frac{1}{1-\nu(1-\alpha)}} \int \left(\varepsilon k^{\alpha\nu}\right)^{\frac{1}{1-\nu(1-\alpha)}} d\mu(k,\varepsilon)} \\
&= \frac{w}{\nu(1-\alpha)}
\end{aligned}$$

This equation shows that any change in the labor productivity is fully explained by a change. The change in wage in turn stems from a change in capital because a change in the latter changes the marginal product of labor.
I measure the welfare gains or losses by the consumption compensation needed to leave the household indifferent between two paths of consumption. In this paper, I focus on the welfare change in steady-state because I am interested in the long run effects of the tax reform. Let $\bar{U}$ and $\hat{U}$ denote the indirect stationary equilibrium life-time utility before and after tax cuts, respectively.

$$\bar{U} = \sum_{t=0}^{+\infty} \beta^t \left[\log(\bar{c})\right] = \frac{\log \bar{c}}{1-\beta}$$

where $\bar{c}$ is the consumption in the stationary equilibrium before the tax cut. If $\hat{U}$ denotes the indirect steady-state life-time utility after the tax cut, the welfare gains or losses $\triangle$ is such that:

$$\hat{U} = \sum_{t=0}^{+\infty} \beta^t \left[\log\left((1+\triangle)\bar{c}\right)\right] = \frac{\log\left((1+\triangle)\bar{c}\right)}{1-\beta} = \frac{\log \hat{c}}{1-\beta}$$

Then:

$$\log\left((1+\triangle)\bar{c}\right) = \log \bar{c} \Rightarrow \triangle = \frac{\hat{c}}{\bar{c}} - 1$$