Capital Taxes with Real and Financial Frictions*

Jason DeBacker †

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Abstract

This paper studies how frictions, both real and financial, interact with capital tax policy in a dynamic, general equilibrium model with heterogeneous firms. Comparative statics show that tax policy can have substantially different effects depending upon the frictions present. Analytical and numerical exercises show that accounting for firm heterogeneity is important when evaluating the responses of economic aggregates to capital tax policy. The effects of tax cuts on allocational efficiency are found to be quantitatively significant, often accounting for the majority of the change in output following a reduction in taxes on capital.

JEL Classifications: D21; E22; G31; H25

Keywords: Corporate Finance; Firm Dynamics; Capital Taxation; Allocational Efficiency

Taxes on capital take many forms. Most common are the taxation of capital gains, corporate profits, and dividend payments. The choice of tax instrument can affect corporate investment policy and thus, if a government finds it optimal to tax capital, it must choose among these tax instruments. Beyond taxes, investment behavior is also shaped by the real and financial frictions firms face. In the following analysis, I study how real and financial frictions interact with tax policy in an economy with heterogeneous firms. I use comparative statics to understand how taxes affect investment decisions when firms face various frictions. In addition, I decompose the changes in output following tax cuts to determine the effects of tax policy on allocational efficiency.

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†U.S. Department of the Treasury, 1111 N. Pitt St., #1C, Alexandria, VA 22314, Tel: 770-289-0340, Email: jason.debacker@gmail.com

This paper relates three well-established literatures. Firm dynamics have an extensive literature in both economics and finance. Economists have largely focused on the role of real frictions in explaining investment behavior (e.g., Cooper and Haltiwanger (2006)) whereas those in finance have tended towards the use of financial frictions to explain the behavior of firms (e.g., Hennessy and Whited (2005)). There has been strikingly little overlap between these two lines of research.[1] The typical finance paper takes financial frictions seriously, but assumes the real frictions are quadratic in nature to support Q-theory based regressions. Economists often ignore financial frictions, but allow for more flexible specifications of the real costs of adjusting the firm's capital stock. I span these two literatures, allowing for non-convexities in real and financial frictions to affect firm dynamics. Distinguishing between real and financial frictions is potentially important in the evaluation of tax policy. For example, with the quadratic costs of adjustment typically assumed in the finance literature, firms' investment is less elastic with respect to current cash flows, and thus tax policy will be found to have relatively small effects on aggregate investment. The economics literature citing the importance of non-convexities in capital accumulation decisions (e.g., Cooper and Haltiwanger (2006)), on the other hand, suggests cash flow can be very important in explaining investment behavior. Empirical tests of Q-theory such as Gilchrist and Himmelberg (1995) support the significance of cash flow in explaining investment rates. Miao (2008) shows that non-convexities in the costs of adjusting capital can lead to a larger response of investment behavior to tax policy. Similarly, financial frictions can increase the significance of cash flow because external financing is more expensive. Financial frictions also drive a wedge between internal and external funding, which dampen the effects of tax policy. Understanding these costs is key to understanding what drives the capital elasticity of output and other determinants of the impact of tax policy (Chirinko (2002)).

The following study also relates to the public finance and macroeconomics literature on the aggregate, general equilibrium effects of capital taxation (Auerbach and Kotlikoff (1987), Barro (1989), Baxter and King (1993)). Important in the public finance literature are the two main views of dividend taxation. The "traditional view" suggests the marginal source

[1]Notable exceptions include Cooley and Quadrini (2001), Cooper and Ejarque (2003) and Bayraktar, Sakellaris and Vermeulen (2005).

of funds for investment is new equity and the return on investment is used to pay dividends. In this view, dividend taxes influence the investment decisions of firms by affecting the value of the investment via the after tax value of dividend income. Alternatively, the "new view" suggests firms use internal funds to finance investment and so do not issue new equity. This means dividend taxes do not affect investment decisions since a dividend tax cut does not affect the user cost of capital. Poterba and Summers (1985) analyze dividend taxation in a dynamic model and find support for the traditional view. However, the empirical results have been mixed, as Desai and Goolsbee (2004) find support for the new view. The model in this paper nests both views. Depending on the firm's capital stock and productivity, its marginal source of funds may be internal or external funds.

I make two main contributions in this paper. First, I provide an analysis of tax policy when firms face both convex and non-convex costs to adjusting capital and costly external financing. Auerbach (1979b), Edwards and Keen (1984), and Poterba and Summers (1985) are examples of papers analyzing capital taxes without frictions. Gourio and Miao (2010), Gourio and Miao (2011), and House and Shapiro (2006) examine tax policy in models with quadratic costs of capital adjustment. Although Gourio and Miao (2010) include a section describing the effects of tax policy with marginal costs to issuing equity, they do not allow for non-convexities in either the real or financial costs facing firms. Miao (2008) studies the effects of fixed costs of capital adjustment on results of tax policy, but does not include financial costs. I allow for non-convexities in both the real and financial costs. Given the evidence of Hennessy and Whited (2007), Whited (2006), Cooper and Haltiwanger (2006), and Gilchrist and Himmelberg (1995), non-convexities play an important role in the investment and financing behavior of firms. The second significant contribution is the decomposition of the effects of tax cuts into their allocational and incentive effects. The large role for allocational efficiencies in the effects of tax policy on economic output underscore the importance of modeling firm heterogeneity. Indeed, I find that changes in allocative efficiency account for more than half of the change in output following a cut in the dividend tax rate or corporate income tax rate.

The paper is organized as follows: Section 1 presents evidence on the investment behavior of firms and their responses to tax policy. Section 2 describes the model. Section 3 discusses the investment decisions of firms and how they are affected by frictions and taxes. I provide numerical comparative statics for models with and without non-convexities in Section 4. Section 5 concludes and discusses ideas for future research.

1 Investment Behavior and Evidence of Real and Financial Frictions

1.1 Investment Facts

Costs of raising external funds and costs associated with changes in a firm's capital stock reflect many different factors which are difficult to measure directly or precisely (Cooper and Haltiwanger (2006)).[2] Because of this, these costs are typically studied indirectly, by looking at investment behavior. Investment behavior at the plant and firm level is characterized by:

1. An investment rate distribution that is non-normal and skewed to the right, with fat tails and a mass around zero.
2. Long periods of inactivity punctuated by bursts of intensive investment.
3. A "low" correlation between investment rates and measures of marginal Q.
4. A "high" correlation between investment rates and measures of cash flow.

The first fact is evident in the Compustat data presented in Figure 1. This figure shows the annual investment rate, $(\frac{i}{k})$, for firms in the Compustat North America files over the 1988-2007 period[3] The density has a long right tail and a mass around zero. Over 25% of the observations have an investment rate higher than 30%. Whited (2006) documents the second fact, showing the investment hazard functions of firms using the same Compustat dataset. She finds a pattern of "lumpy" investment exists for large and small firms. That

[2] Costs associated with changing the capital stock can include, among many sources, costs associated with learning a new production process and disruption costs when installing the new capital. Financial costs include the fixed and marginal floatation costs such as the commissions paid to brokers, legal fees, accounting costs, and the bid-ask spread on the issue.

[3] The data used for this graph and the subsequent estimation is described in Appendix Section A-1.

is, firms undertake investment in bursts, with many periods of low investment in between these spikes in activity.

Facts 3 and 4 are evidenced in Gilchrist and Himmelberg (1995) and Fazzari, Hubbard and Petersen (1988). Contrary to the predictions of Q-theory, both studies find a low correlation between investment rates and measures of marginal Q using firm level data. In addition, these studies find that investment is quite sensitive to measures of cash flow. As in this paper, Gilchrist and Himmelberg (1995) use Compustat, while Fazzari et al. (1988) use Value Line as their source for firm level data.

Facts 1-4 suggest either non-convexities in the real costs of adjustment or financial frictions. Non-convex adjustment costs result in investment "bursts" as firms try to minimize the fixed costs incurred when adjusting their capital stock by making fewer and larger investments. Cooper and Haltiwanger (2006) find behavior similar to 1 and 2 at the plant level and estimate significant non-convexities in the costs of adjustment faced by plants. Non-convexities in the costs of adjusting capital can also result in the lack of sensitivity of the investment rate to measures of Tobin's marginal Q that Fazzari et al. (1988) and Gilchrist and Himmelberg (1995) report. An alternative explanation of the investment bursts and sensitivity to cash flow is costly external financing (see, for example, Whited (2006) and Fazzari et al. (1988)). For example, if issuing equity involves costs with economies of scale, firms who finance projects with external funds will do so in bursts. Firms' investment will also be sensitive to the cash flows, as they try to finance with internal funds when possible. This story is put forth by Gomes (2001) and Whited (2006).[4] Altinkilic and Hansen (2000) and Smith (1977) find the existence of such economies of scale in equity floatation costs.

1.2 Responses to Tax Changes

The Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA) made two major changes in law to promote capital formation and long run growth. First, the act reduced the tax rate on capital gains for those in the top four income tax brackets (those with federal marginal income tax rates of 25, 28, 33, and 35 percent) from 20% to 15%.

[4] Although Cooper and Ejarque (2003) reject the hypothesis of financial frictions driving firm-level investment dynamics, they do no attempt to match the financing behavior of firms.

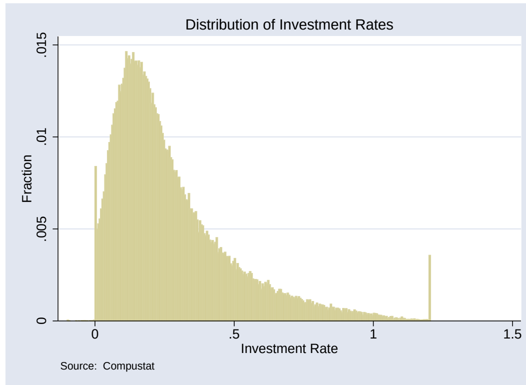
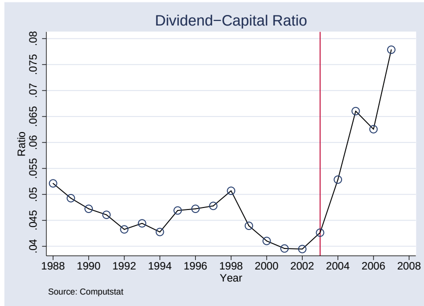


Figure 1: PDF of Investment

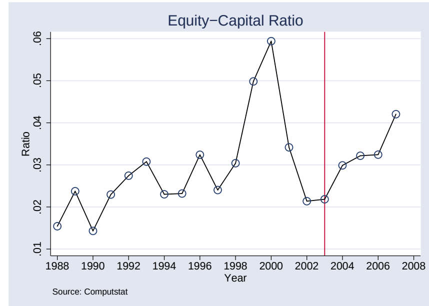
Second, the act brought the tax rate on dividends in-line with the rate on capital gains. Previously, dividend income was taxed as regular income. The JGTRRA reduced the tax rate on dividend income to 15% for those in the top four tax brackets, taxing dividends at the same rate as capital gains. There is an abundance of work on the effects of the 2003 tax cuts. Here, I offer some further evidence on the results of the policy change and its effects on the financial and investment policies of firms. This helps to frame the discussion in the following sections.

Chetty and Saez (2005) represents one of the most cited studies of the 2003 tax cuts. The authors find a 20% increase in the amount of dividends distributed following the tax cuts. More firms issue dividends and the amount of dividends issued increased. In Figure 2(a)-2(d), I present evidence on the effects of the tax cut on aggregate dividends, aggregate new equity issuance, aggregate investment, and aggregate earnings. Figure 2(a) shows the large increase in dividend distribution Chetty and Saez (2005) and others have documented. Figures 2(b)-2(d) show increases in new equity issues, investment, and earnings following the tax cuts of 2003.

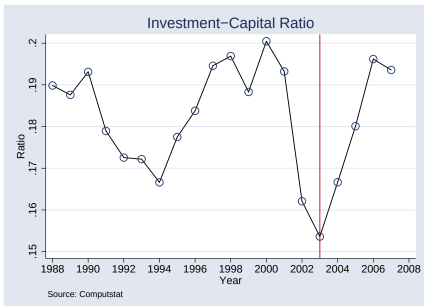
Figures 3(a)-3(c) show the fractions of firms in various financing regimes before and after the 2003 tax cuts. In the dividend distribution regime, the marginal source of funds is retained earnings (this financing behavior corresponds to the new view of dividend taxation). These firms are able to finance investment through retained earnings and are able to issue dividends. In the equity issuance regime, the marginal source of funds is new equity (such financing behavior corresponds to the traditional view of dividend taxation). These firms



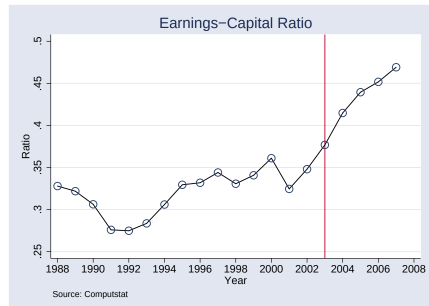
(a) Dividend-Capital Ratio



(b) Equity Issuance - Capital Ratio



(c) Investment - Capital Ratio



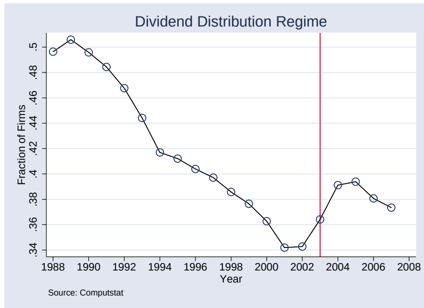
(d) Earnings - Capital Ratio

Figure 2: Aggregate Corporate Investment and Financing Behavior.

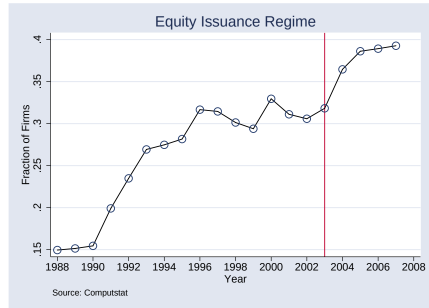
issue new equity to finance investment. I classify firms in Compustat as being in the dividend distribution regime if they are observed distributing dividends. Firms are classified as being in the equity issuance regime if they issue new equity equal to at least 2% of the value of their capital stock.[5] Firms who do not distribute dividends or issue new equity make up the liquidity constrained regime. These firms finance investment through retained earnings. They do not find it optimal to seek external funding to finance investment, but exhaust their retained earnings and do not issue dividends.

As suggested by Figures 2(a) and 2(b), one can see an increase in the fraction of firms who distribute dividends and in the fraction of firms who issue equity in Figures 3(a) and 3(b), respectively. In Figure 3(c), one can see the drop in the fraction of firms who are in the liquidity constrained regime following the tax cuts. The movement of firms from this

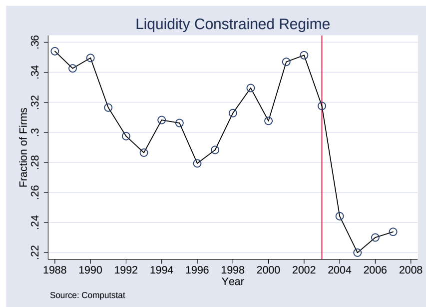
[5]There exist a non-trivial number firms who both issue equity and distribute dividends. This behavior constitutes the “dividend puzzle”. The model presented in this paper can not account for this seemingly suboptimal behavior. See Bernheim (1991) and Chetty and Saez (2007) for examples of papers attempting to explain the puzzling behavior through models with asymmetric information. Auerbach (1979a) offers another explanation using a overlapping generations model with population growth. Because my model cannot account for the dividend puzzle, the firms who both distribute dividends and issue equity are classified as being in the dividend distribution regime.



(a) Dividend Distribution Regime



(b) Equity Issuance Regime



(c) Liquidity Constrained Regime

Figure 3: Financing Regimes.

regime accounts for much of the efficiency gains from the tax cuts of 2003.

2 Model

The model I use to analyze the effects of capital taxation incorporates the various forms of capital taxes (capital gains, dividend income, corporate income) and accounts for important general equilibrium effects of taxation. In addition, the model includes the real and financial frictions firms face, which are necessary to explain the investment behavior of firms. Finally, the model accounts for the observed financing decisions of firms where one sees both internal and external sourcing of funding used for investment. That is, firms behave according to both the new and traditional views of dividend taxation. My interest is in the long-run effects of tax policy, thus I focus my analysis and model on the steady state effects of an unanticipated change in tax policy.[6] No aggregate uncertainty is present in the model, but firms realize idiosyncratic productivity shocks. Below, I outline each part

[6] For an analysis of temporary changes in tax policy in a partial equilibrium model, see Gourio and Miao (2011). For a study of temporary and and predicted changes in tax policy, see House and Shapiro (2006).

of the economy. I begin with households.

2.1 Households

There is a representative household who supplies labor, trades shares in all firms and a risk free bond, pays taxes, receives transfers, and consumes. Labor is supplied inelastically and risk free bonds are in zero net supply. The household chooses consumption, equity holdings, and bond holdings to solve:

$$\max_{\{C_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(C_t), \tag{2.1}$$

where C_t is consumption in period t , β is the rate of time preference, and the utility function has the standard properties ($U' > 0$, $U'' < 0$) and satisfies the Inada condition. The household's choice of C must satisfy:

$$\begin{aligned} C_t + b_{t+1} + \int V_t \theta_{t+1} d\Gamma_t = & \int [(1-\tau_d)d_t + V_t^O - \tau_g(V_t^O - V_{t-1})]\theta_t d\Gamma_t \\ & + (1+(1-\tau_i)r_t)b_t + (1-\tau_i)w_t\bar{L} + T_t + \tilde{\Phi}_t, \end{aligned} \tag{2.2}$$

where b_{t+1} represents the holding of bonds expiring in period $t+1$, V_t is the value of the firm in period t, V_t^O is the period t value of the shares outstanding in period $t-1$, and θ_{t+1} are the shares of firms held in period $t+1$. The function $\Gamma_t(k_t, z_t; w_t)$ characterizes the distribution of firms in period t and d_t are dividends issued in period t. r_t is the return on a risk free bond and w_t is the wage rate. The government transfers T_t to the household, and τ_d, τ_g, and τ_i are the tax rates paid on dividend income, capital gains income, and labor income, respectively. $\bar{L}$ is the amount of labor the household inelastically supplies to the firms. The total financing costs paid by firms when raising external funding are returned to the household and are represented by $\tilde{\Phi}_t$.[7]

Equilibrium requires $b_t = 0$ and $\theta_t = 1$ for all t. Gomes (2001) shows that in a stationary

[7]Unlike the real costs of adjusting capital, the financial frictions are transaction costs paid by firms to financial intermediaries. To close the model, it is assumed that households own these financial institutions and thus receive these costs. The affect of this assumption is to increase household income and thus consumption and investment by the household.

equilibrium the pricing kernel is given by β. That is, in a stationary equilibrium, r solves, $\beta(r(1-\tau_i)+1) = 1$.

2.2 Firms

There are a continuum of ex-ante identical firms. Each firm chooses its capital stock, hires labor, issues equity and distributes dividends to maximize firm value. Firms face idiosyncratic shocks to productivity and thus, at any point in time, firms are heterogeneous in both productivity and their capital stock.

If V_t is the value of a firm at time t, then the expected, after tax return to a shareholder is given by:

$$E_t(R_t) = \frac{(1-\tau_d)d_t + (1-\tau_g)(E_t V_{t+1}^O - V_t)}{V_t} \tag{2.3}$$

V_{t+1}^O is the $t+1$ value of shares outstanding in period t and $V_{t+1}^O = V_{t+1} - s_t$. Because the only uncertainty derives from the idiosyncratic productivity shocks to the firms, there is no aggregate uncertainty. Without aggregate uncertainty, asset pricing equilibrium implies: $E_t(R_t) = 1 + (1-\tau_i)r$, where r is the risk free interest rate. The right hand side of this equation is the after-tax return on holding the risk free bond. That is, asset pricing equilibrium requires the expected after-tax return on bonds and equity to be the same for the household to trade both assets in equilibrium.

Using Equation 2.3 together with the asset pricing equilibrium condition, iterating forward, and applying the transversality condition one can obtain the value of a firm at time t:

$$V_t = E_t \sum_{j=0}^{\infty} \left(\frac{1}{1 + r(1-\tau_i)/(1-\tau_g)}\right)^j \left(\frac{1-\tau_d}{1-\tau_g} d_{t+j} - s_{t+j}\right) \tag{2.4}$$

Equation 2.4 is a standard representation of the value of a firm in the presence of taxes (Auerbach (2002)). The equation says the value of the firm is the expected present value of the after-tax dividends less the present value of new shares issued, which the current share holders would have to purchase to maintain their claim on the same fraction of the firm's total dividends and profits.

From Equation 2.4, one can see the firm's problem of maximizing shareholder value can be represented by the following Bellman Equation:

$$V(k, z; w) = \max_{k', d, s} \left(\frac{1 - \tau_d}{1 - \tau_g} \right) d - s + \frac{1}{1 + r(1 - \tau_i)/(1 - \tau_g)} E_{z'|z} V(k', z'; w') \tag{2.5}$$

In Equation 2.5, z denotes the firm's productivity, k its capital stock, s its equity issuance. Primed variable denote one period ahead values. Let $\upsilon(k, k')$ characterize the costs a firm faces when changing its capital stock and $\Phi(s)$ characterize the financial frictions the firm faces when issuing equity. Additionally, let $\pi(k, z; w)$ represent the firm's profit function given capital and productivity, δ be the rate of physical depreciation and τ_c be the taxes paid on corporate income. The firm's capital stock evolves according to the standard law of motion for capital; $k' = (1 - \delta)k + i$, where i is the investment undertaken by the firm. The firm faces the following constraints:

$$k' - (1 - \delta)k + \upsilon(k, k') + d = (1 - \tau_c)\pi(k, z; w) + \tau_c \delta k + s - \Phi(s) \tag{2.6}$$

$$d \geq 0 \tag{2.7}$$

$$s \geq \underline{s} \tag{2.8}$$

That is, it must be able to finance current investment and dividend distributions, dividends must be non-negative, and equity issues must be above some lower bound. The first two constraints are straight forward. The reasons for the bound on equity issues are *de facto* or *de jour* restrictions on shares repurchases. There may be large costs associated with share repurchases due to asymmetric information (Brennan and Thakor (1990), Barclay and Jr. (1988)) or there may be legal restrictions on share repurchases. For example, in the United States, while share repurchases are allowed, regular repurchases may lead the IRS to treat repurchases as dividends. Throughout, I assume $\underline{s} = 0$.[8]

Firm's combine capital and labor to produce output. The firm's intratemporal profit function is given by:

$$\pi(k, z; w) = \max_{l \geq 0}\{F(k, l, z) - wl\} \tag{2.9}$$

$F(k, l, z)$ is the firm's production function, which may be a decreasing returns to scale function. The solution to this intratemporal problem yields the firm's policy functions for labor, $l(k, z; w)$, and output, $y(k, z; w)$. That is, the intratemporal labor demand decision is determined by the capital stock and productivity of the firm and the market wage. Thus I omit the choice of labor is from Equation 2.5.

The future value of the firm is discounted by a rate less than one if the household's rate of time preference parameter β is less than one. One can show the function $V(k, z; w)$ is concave, bounded, and continuous, so long as the firm's production function $F(k, l, z)$ does not exhibit increasing returns to scale. Given this, one can apply the arguments of Stokey, Lucas and Prescott (1989) to show the solution to Equation 2.5 exists and consists of unique functions $V(k, z; w)$, $k'(k, z; w)$, $d(k, z; w)$, and $s(k, z; w)$.

2.3 Government

The government levies linear taxes on labor income, capital gains income, dividend income, and corporate profits. The government does not issue debt. The revenues from the taxes are assumed to be distributed in a lump sum manner to the household so the government budget balances each period. The assumption of a lump sum transfer is made for simplicity. Government spending on goods and services would introduce additional distortions to the model unrelated to the effects of taxation on investment decisions, which are the focus of the analysis. Additionally, government spending on goods and services would mean tax cuts would necessarily have to be accompanied by spending reductions in the stationary equilibrium, which would further complicate the analysis in a way that is unnecessary to understand the mechanisms of interest.

[8]Admittedly, when $\underline{s} = 0$, as it does for the analysis this paper, one can not answer questions regarding the observed "dividend puzzle".

The government budget constraint in any period (where I drop the time subscripts for simplicity) is:

$$T = \tau_c \int (\pi(k,z;w) - \delta k)\Gamma(dk,dz;w) + \tau_d \int d(k,z;w)\Gamma(dk,dz;w) + \tau_i w\bar{L} - \tau_g \int s(k,z;w)\Gamma(dk,dz;w) \tag{2.10}$$

2.4 Stationary Distribution and Aggregates

Idiosyncratic shocks to the productivity of firms represent the only source of uncertainty in the model. At each point in time the economy is characterized by a measure of firms, $\Gamma_t(k,z;w)$ for each level of capital stock $k \in \mathbf{K} = [\underline{k}, \bar{k}]$ and productivity, $z \in \mathbf{Z} = [\underline{z}, \bar{z}]$. For there to be a stationary measure of firms, it must be the case that firms never accumulate capital beyond some endogenously determined level $\bar{k}$. If the optimal decision rule for capital accumulation is increasing in z, it is clear the value of $\bar{k}$ is determined by the point at which the decision rule $k'(k,\bar{z};w)$ crosses the 45° line.

The law of motion of $\Gamma_t(k,z;w)$ is given by:

$$\Gamma_{t+1} = H_t(\Gamma_t) \tag{2.11}$$

Let A and B be Borel sets of $\mathbf{K}$ and $\mathbf{Z}$ respectively and let $P(z,z')$ be the probability the firm transitions from a productivity of z to productivity z'. The function H_t can then be written as follows:

$$\Gamma_{t+1}(A \times B) = \int \mathbf{1}_{\{k'(k,z;w)\in A\}} P(z,B)\Gamma_t(dk,dz;w), \tag{2.12}$$

where $\mathbf{1}$ is the indicator function.

I study the long run effects of tax policy and therefore focus the analysis on the invariant distribution of firms denoted Γ^*. The invariant distribution is found by solving for the fixed point in the mapping given by H. That is, Γ^* solves $\Gamma^* = H(\Gamma^*)$. Stokey et al. (1989) state the conditions necessary to prove the existence of an invariant distribution. The decision rules of the firms and the stochastic process give rise to the mapping from the current distribution of firms to the distribution of firms next period. Stokey et al. (1989) show Γ^* exists, is unique and the sequence of measures generated by the transition function, $\{H^n(\Gamma_0)\}_{n=0}^{\infty}$, converges weakly to Γ^* from any Γ^0. The measure of firms is normalized to one.

With the definition of the stationary distribution in hand, it is straight forward to calculate the aggregate quantities in this economy:

- aggregate output

$$Y(\Gamma^*; w) = \int y(k, z; w)\Gamma^*(dk, dz; w) \tag{2.13}$$

- aggregate labor demand

$$L^d(\Gamma^*; w) = \int l(k, z; w)\Gamma^*(dk, dz; w) \tag{2.14}$$

- aggregate investment

$$I(\Gamma^*; w) = \int (k'(k, z; w) - (1 - \delta)k)\Gamma^*(dk, dz; w) \tag{2.15}$$

- aggregate adjustment costs

$$\Upsilon(\Gamma^*; w) = \int \upsilon(k, k'(k, z; w))\Gamma^*(dk, dz; w) \tag{2.16}$$

- aggregate financing costs

$$\tilde{\Phi}(\Gamma^*; w) = \int \Phi(s(k, z; w))\Gamma^*(dk, dz; w) \tag{2.17}$$

2.5 Stationary Equilibrium

Definition 1. (SRCE) A Stationary Recursive Competitive Equilibrium (SRCE) consists of a wage rate w^*, a distribution of firms $\Gamma^*(k, z; w^*)$, and functions $V(k, z; w^*)$, $l(k, z; w^*)$, $k'(k, z; w^*)$, $d(k, z; w^*)$, and $s(k, z; w^*)$ such that:

- Given w^*, $V(k,z;w^*)$, $l(k,z;w^*)$, $k'(k,z;w^*)$, $d(k,z;w^*)$, and $s(k,z;w^*)$ solve the firm's problem.

- The stationary distribution is such that $\Gamma^*(k,z;w^*) = H^*(\Gamma^*(k,z;w^*)$

- Given w^*, the household maximizes utility subject to its budget constraint.

- The labor market clears: $\bar{L} = \int l(k,z;w^*)\Gamma^*(dk,dz;w^*)$

- The goods market clears: $Y(\Gamma^*;w^*) = C(\Gamma^*;w^*) + I(\Gamma^*;w^*) + \Upsilon(\Gamma^*;w^*)$[9]

The above are standard conditions for a stationary equilibrium. The value function and policy functions are such that they solve the firm's problem given prices. The evolution of the distribution reproduces itself each period and is consistent with the equilibrium decision rules of the firms and the distribution of idiosyncratic shocks to firms. Finally, the representative household maximizes utility and markets clear.

Using a general equilibrium framework is important because the feedback of wages dampens the effects of tax policy. For example, lowering dividend taxes increases the capital stock and so increases the marginal product of labor and thus the wage. The higher wage lowers employment and thus the marginal product of capital. Allowing wages to adjust reduces the effect of tax policy on investment relative to a partial equilibrium model.

3 The Firm's Decision Problem

Substitution of the budget constraint (Equation 2.6)) into the firm's objective function (Equation 2.5) leaves the firm with two decisions; the choice of capital stock and the choice of equity issuance. When there are no non-convexities present, the first order conditions for the choice of equity and the choice of capital, respectively, are:

$$s: \left(\frac{1-\tau_d}{1-\tau_g} + \lambda^d\right)\left(1 - \frac{\partial \Phi}{\partial s}\right) + \lambda^s = 1, \tag{3.1}$$

[9]Note the absence of financial frictions in this condition. Financial frictions are not real costs. These transactions costs are assumed to go to the households.

$$k' : \left(\frac{1-\tau_d}{1-\tau_g} + \lambda^d\right)\left(1 + \frac{\partial \upsilon(k,k')}{\partial k'}\right) = \frac{1}{1+r(1-\tau_i)/(1-\tau_g)} E_{z'|z} \frac{\partial V(k',z')}{\partial k'}, \qquad (3.2)$$

where λ^d and λ^s are the Lagrangian multipliers on constraints 2.7 and 2.8.

The left hand side of Equation 3.1 represents the marginal benefits of issuing equity. This is equal to the increase in dividends the firm can issue and the relaxation of the constraints 2.7 and 2.8. The marginal cost of issuing new equity is the right hand side of 3.1. Issuing one dollar of new equity lowers the value of the firm by one dollar and relaxes the constraint 2.8 by one dollar. However, with financial frictions, one dollar of new equity does not translate into a one dollar increase in dividends, as costs are incurred when issuing equity.

Equation 3.2 characterizes the marginal costs and benefits of increasing the capital stock. On the left hand side are the marginal costs. Increasing investment leaves less money for dividends and increases the adjustment costs incurred. The right hand side is the marginal benefit, which is the expected, discounted marginal Tobin's Q. That is, the marginal benefit is the expected present value of the increase in firm value for an additional dollar invested within the firm.

3.1 Financial Policy

If the capital gains tax is equal to the dividend tax and there are no financial frictions, then we are in the environment of the Modigliani-Miller Theorem (Miller and Modigliani (1958)). In this environment, one can use Equation 3.1 to show $\lambda^d = \lambda^s = 0$. That is, neither the constraint on dividends nor the constraint on equity bind. In this case, financial policy is irrelevant to the value of the firm and to investment decisions. One dollar raised through equity and one dollar of internal funds have the same cost to the firm and so the firm is indifferent between financing investment with internal or external funds. This is the Modigliani-Miller Theorem of the irrelevance of corporate finance.

However, if $\tau_d \neq \tau_g$ and/or $\frac{\partial \Phi}{\partial s} \neq 0$, then financing decisions do matter. In this environment, a firm never finds it optimal to both distribute dividends and issue new equity.

Suppose $\tau_d > \tau_g$, as it was in the U.S. before the tax cuts of 2003. In this case, a firm will be in one of three finance regimes.

Following Gourio and Miao (2010), call the the first regime type the *equity issuance regime*. The marginal source of funds for firms in this regime is external equity. This reflects the "traditional view" of dividend taxation. These firms do not issue dividends and raise funds for investment by issuing equity. Firms in the equity issuance regime can be thought of as "growth" firms. They have a high marginal product of capital, do not distribute dividends and issue equity to finance their investments. Smaller firms, and those with higher level of productivity, issue more equity. For firms in the equity issuance regime, $\lambda^d > 0$ and $\lambda^s = 0$.

The second type of financing regime is the *dividend distribution regime*. Firms in this regime finance investment internally, buy back shares to the extent possible, and issue dividends with their remaining earnings. Those in the dividend distribution regime correspond to the "new view" of dividend taxation. One can think of these firms as "value" firms. Larger firms and those with lower productivity make up the firms in this regime. For firms in the dividend distribution regime, $\lambda^d = 0$ and $\lambda^s > 0$.

The final regime type is the *liquidity constrained regime*. Constrained firms fund investment using internal funds, but do not distribute dividends. For these firms, the marginal product of capital does not warrant raising funds externally, but is high enough that the value of a dollar invested within the firm is higher than the value of a dollar invested outside the firm. Hence no dividends are distributed and no equity is issued. In this regime, $\lambda^d = 0$ and $\lambda^s = 0$.

Figure 4 presents the regions (in the capital stock-productivity space) that constitute the three financing regimes. In the top right are those firms with high levels of productivity and/or a small capital stock. These firms have a high marginal product of capital and issue equity. Firms in the bottom right of the area are those with a large capital stock and/or low levels of productivity. These firms distribute dividends. As the tax wedge or financial frictions increase, the center region, representing firms who are liquidity constrained, expands.

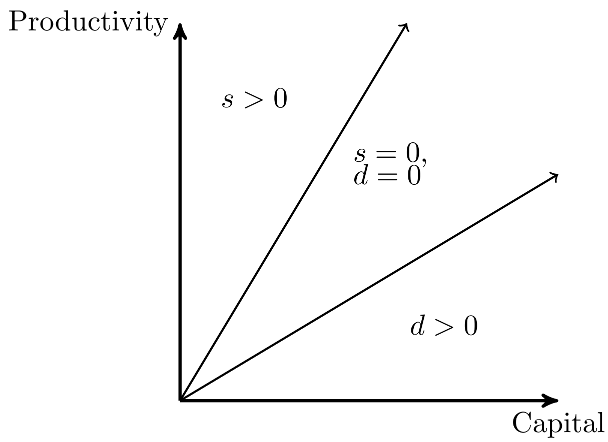


Figure 4: Three Regimes

4 Numerical Comparative Statics

Here, I numerically evaluate the effects of tax policy when non-convexities are present. I consider the responses to changes to the dividend tax, capital gains tax, and corporate income tax, separately for four common specifications of investment frictions.

4.1 Model Specification

I assume the firms' production functions are Cobb-Douglas; $F(k, l, z) = zk^{\alpha_k} l^{\alpha_l}$. Firms may have decreasing or constant returns to scale. I also assume the productivity shocks follow an AR(1) process; $z_{i,t} = \rho z_{i,t-1} + u_{i,t}$, where $u_{i,t} \sim N(0, \sigma)$.

I consider four models. In the first, there are no frictions. The second has convex costs of adjusting capital and no financial frictions. The costs are assumed to be quadratic in nature. Formally:

$$\upsilon(k_t, k_{t+1}) = \frac{\psi i_t^2}{2k_t} \tag{4.1}$$

This represents the most common specification in the literature on the effects of taxes on investment (see, for example, House and Shapiro (2006)). The third model I consider has non-convexities in the costs of adjustment represented by a fixed cost that is proportional to the capital stock. Here, the cost of adjustment function has the following form:

$$\upsilon(k_t, k_{t+1}) = \begin{cases} (F * k) + \frac{\psi i_t^2}{2k_t}, & \text{if } i_t \neq 0; \\ 0, & \text{if } i_t = 0; \end{cases} \tag{4.2}$$

The final model I consider has quadratic costs of adjusting capital and financial frictions. Following Gomes (2001), Cooper and Ejarque (2003), and Hennessy and Whited (2007), I allow for fixed and marginal costs of equity issuance. Financial frictions take the form:

$$\Phi(s) = \phi_0 \mathbf{1}_{\{s>0\}} + \phi_1 s, \tag{4.3}$$

where **1** is the indicator function. The presence of fixed costs to equity issuance has been documented by Altinkilic and Hansen (2000), who study spreads paid in common stock offerings.

4.2 Parameterization

To solve the model, I must find values for the following parameters:

$$\Theta = \{\beta, \delta, \alpha_l, \alpha_k, \rho, \sigma, \psi, F, \phi_0, \phi_1\} \tag{4.4}$$

The parameter β is the household's rate of time preference, δ is the rate of physical depreciation, α_l is the labor share in the firm's production function, α_k is the capital share in the firm's production function, and ρ and σ parameterize the productivity process. ψ and F characterize the convex and non-convex adjustment costs. ϕ_0 and ϕ_1 characterize the financial frictions.

I assume that labor is supplied inelastically and set $\bar{L} = 0.3$ to match the fact that households spend approximately 30% of their time at work. Given the inelastic labor supply, the choice of $U(\cdot)$ is unimportant, so long as it satisfies the conditions given in Section 2.1.

I set β to generate an after-tax risk free interest rate of 4%. This implies that $\beta = 0.971$ if the representative household has a marginal income tax rate of 25%. The rate of depreciation is set to generate the aggregate investment-capital ratio of 15.4% found in the Compustat data.

Following the macro literature, I set $\alpha_l = 0.65$ because labor's share of output is approximately 65% in the U.S. Given α_l, I estimate α_k, ρ, and σ as described in Appendix Section A-2.

I set the parameters determining the sizes of these frictions to values found by others in the literature who use similar models. I set $\psi = 1.08$ as done in Gourio and Miao (2010). This value is similar to the parameter's value in Cummins, Hassett and Hubbard (1994) and elsewhere. To my knowledge, Bayraktar et al. (2005) provide the only estimate of non-convex real costs of adjustment for firms in a model with financial frictions. While their model allows for firms to also use debt and equity financing, I nonetheless set the fixed cost of adjustment parameter to their estimate of $F = 0.031$.

External financing costs are set to $\phi_0 = 0.04$ and $\phi_1 = 0.02$. These values come from Whited (2006) and Altinkilic and Hansen (2000).

The model parameterization is summarized in Table 1.

Table 1: Parameter Values Used in Numerical Comparative Statics

Parameter	Value	Source
β	0.971	$r(1-\tau_i) = 0.04$
δ	0.154	I/K
α_l	0.650	GM (2010)
α_k	0.297	Estimation
ρ	0.761	Estimation
σ	0.213	Estimation
ψ	1.080	GM (2010)
F	0.031	BSV (2005)
ϕ_0	0.040	Whited (2006)
ϕ_1	0.020	Whited (2006)

4.3 Responses of Aggregates to Tax Changes

For each model, I calculate the equilibrium values of the following aggregates: the capital stock, output, the fraction of firms in each financing regime, wages, average Q, and the tax multiplier. The baseline case is where taxes are at their pre-2003 levels for the representative household who falls in the tax bracket with $\tau_i = 0.25 = \tau_d$ and $\tau_g = 0.20$. I set $\tau_c = 0.34$. From this baseline case, I make three changes to tax policy. First, I lower the dividend tax rate four percentage points to 0.21. Next, I lower the capital gains tax rate four percentage points to 0.16. The last policy change is to lower the corporate income tax rate four percentage points to 0.30. For each model, I calculate the percent changes in the aggregates and the tax multiplier of the respective tax change. I use four percentage point changes for a two main reasons. First, they are close in size to the change in the long-term capital gains tax rates resulting from JGTRRA of 2003, which cut the capital gains tax rate from 20% to 15%. Furthermore, the Obama Administration has proposed increasing both the capital gains and dividend tax rates five percentage points. Second, four percentage points keeps a tax wedge even in the case of a reduction in the dividend tax rate for the median household from it's pre-2003 level of 25%. This means that the changes represent a reduction in the tax wedge and not it's elimination. If the tax wedge were eliminated, one could not identify a firm's financial policy in the cases without financial frictions since, as the Modigliani-Miller Theorem (Miller and Modigliani (1958)) predicts, financial policy is irrelevant in the absence of a tax wedge and financial frictions.

Table 2: Four Percent Cut in the Dividend Tax Rate

Aggregate (% Changes)	No Cost	$\psi = 1.08$	$\psi = 1.08$, $F = 0.031$	$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$
Quantities				
Capital	22.96	0.57	1.87	-0.24
Output	6.69	0.72	0.93	0.39
Financial Policies				
Equity Issuance Regime	0.00	19.25	5.18	9.20
Dividend Distribution Regime	5.37	13.32	4.75	7.23
Liquidity Constrained Regime	-40.60	-34.18	-53.99	-2.21
Prices				
Wage	5.51	0.70	0.89	0.41
Average Q	23.39	6.25	2.70	3.41
Tax Multiplier $\left(-\frac{\Delta G}{\Delta T}\right)$	6.00	2.36	3.13	1.40

The model without frictions is the most responsive to changes in the dividend tax rate. The no cost model is followed by the model with non-convexities, the convex model without financial frictions, and, lastly, the model with financial frictions. A decrease in the dividend tax rate can have both positive and negative effects on investment. On the one hand, a dividend tax cut (when the tax rate on dividends exceeds the tax rate on capital gains) results in a smaller tax wedge and a more efficient allocation of resources. As seen in three of the four models, the capital stock is at least as large under the the dividend tax cut because this effect dominates. On the other hand, a lower dividend tax rate will increase the opportunity cost of investment for firms transitioning between the equity issuance and dividend distribution regimes. This will have the effect of reducing those firms' investment in capital. This second effect is more apparent in models with financial frictions, where it is more likely that relatively productive firms will distribute dividends because they face large costs to accessing external financing. In the model with convex real costs and financial frictions, the second effect swamps the first effect when dividend taxes are cut by 4% and overall investment falls. However, even in this, case output does not fall because the tax cut results in a better allocation of capital across firms. One can see this from the decrease in the fraction of firms in the liquidity constrained regime. Among the models exhibiting investment frictions, the model with non-convex costs to adjusting capital shows the largest response to the dividend tax cut. The intuition for the result is that, due to the fixed costs of investment, tax policy operates on both the extensive and intensive margins. More firms invest, and those investing invest more. The large drop in the fraction of firms who are liquidity constrained is evidence of these effects.

Table 3: Four Percent Cut in the Capital Gains Tax Rate

Aggregate (% Changes)	No Cost	$\psi = 1.08$	$\psi = 1.08$, $F = 0.031$	$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$
Quantities				
Capital	-1.81	3.27	2.05	2.96
Output	-1.79	0.57	0.33	0.47
Financial Policies				
Equity Issuance Regime	-27.52	-15.07	-5.32	-15.67
Dividend Distribution Regime	-8.37	-13.69	-5.12	-15.13
Liquidity Constrained Regime	92.67	30.97	57.08	4.45
Prices				
Wage	-1.60	0.54	0.36	0.55
Average Q	-3.42	-1.69	1.75	1.24
Tax Multiplier $\left(-\frac{\Delta G}{\Delta T}\right)$	-5.50	2.14	1.41	5.31

When the capital gains tax is lowered, there are two opposing effects on investment, and thus the aggregate capital stock, in the stationary equilibrium. Investment may increase because the tax change results in a higher after-tax value of the firm. However, a decrease in the capital gains tax rate (from a rate less than the tax rate on dividends) increases the wedge between internal and external funding and leads to a lower capital stock because of a misallocation of resources to lower productivity firms. More firms are in the liquidity constrained regime, ceteris paribus, after lowering the capital gains tax rate. These dual effects are very evident in the first row of Table 3. In the model without frictions, the second effect dominates, the fraction of firms in the liquidity constrained regime increases by over 92% and the aggregate capital stock falls. In models where the real costs of adjusting capital are quadratic in nature, the first effect dominates and investment increases more than in the other specifications. In general, the aggregates are most responsive in a model with no frictions where firms' investments are very elastic. Notably, the change in the fraction of firms in the liquidity constrained regime is least responsive (measured by the percentage change) in the presence of financial frictions. There is smaller percentage increase of firms in the liquidity constrained regime in the presence of financial frictions because these frictions increase the wedge between internal and external funding. Thus there are more constrained firms in the baseline tax regime under this specification. The relative effect of a change in taxes is thus smaller.

Table 4: Four Percent Cut in the Corporate Income Tax Rate

Aggregate (% Changes)	No Cost	$\psi = 1.08$	$\psi = 1.08$, $F = 0.031$	$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$
Quantities				
Capital	2.42	3.05	3.73	2.29
Output	0.28	1.17	1.27	1.06
Financial Policies				
Equity Issuance Regime	0.00	1.77	-0.39	6.56
Dividend Distribution Regime	0.00	-4.48	0.71	-4.72
Liquidity Constrained Regime	-0.03	4.23	-3.14	0.81
Prices				
Wage	0.86	1.13	1.28	1.08
Average Q	6.34	4.49	3.57	4.51
Tax Multiplier $\left(-\frac{\Delta G}{\Delta T}\right)$	0.47	2.50	2.41	2.46

As noted in the previous section, a cut in the the corporate income tax rate always results in an increase in investment. The numerical comparative statics for each model bear this out. The capital stock increases most after the tax cut in the model without frictions. As was the case with the dividend tax cut, the model with quadratic and fixed costs of adjustment has the next largest response to the tax cut. Lower corporate income taxes increase the firm's after-tax cash flow. The presence of fixed costs to adjusting capital results in firm investment decisions being particularly sensitive to cash flow and hence to reductions in the corporate income tax. This is especially true when a tax wedge exists and firms are more likely to fund investment with retained earnings.

Tax policy has differential effects depending upon the real and financial frictions present. Magnitudes and directions of the changes in aggregates vary across models and tax instruments. For example, the long run tax multiplier (the increase in output per dollar of tax revenue foregone) for a corporate income tax cut vary between 0.47 and 2.50. Such differences highlight the importance of understanding the real and financial frictions firms face when evaluating fiscal policy. Non-convexities generally result in investment being more responsive to tax policy. The result is similar to those of Caballero, Engel and Haltiwanger (1995), Cooper, Haltiwanger and Power (1999), and Caballero and Engel (1996) who find that models with non-convexities in capital adjustment costs generate relatively large responses to aggregate shocks.

4.4 Allocational Efficiency

Changes in capital taxation affect investment in two ways. First, lower tax rates have the effect of increasing the after-tax value of a firm. A higher marginal Q implies that a given firm will invest more after the tax cut, all else equal. Call this the incentive effect of taxation. Second, lower tax rates affect distribution of firms investing. For example, lowering the dividend tax rate (when it is higher than the tax rate on capital gains) has the effect of reducing the number of firms in the liquidity constrained regime by reducing the tax wedge between internal and external financing. The result is that more high productivity firms access external funding to finance investment. Call the effect of taxation on the distribution of the capital stock across firms the reallocation effect.

Two indicators of allocational efficiency are total factor productivity (TFP) and the correlation between capital and productivity across firms. Let TFP be defined as TFP = $\frac{Y}{K^{\alpha_k}L^{\alpha_l}}$. Table 5 presents the percentage change in TFP and the correlation between capital and productivity by model and tax regime. The baseline case is that in which taxes are at there pre-2003 levels (i.e., $\tau_i = 0.25, \tau_d = 0.25, \tau_g = 0.20$, and $\tau_c = 0.34$). The other three columns represent a reduction in each of the taxes from the baseline. Looking across models, we see that models with frictions have a much lower correlation between capital and productivity than a model without frictions. Costs to adjusting capital or to accessing external financing discourage firms from adjusting their capital stock to the extent they would in a frictionless environment. In all models with frictions, a dividend tax cut increases the measures of allocational efficiency and a capital gains tax cut reduces allocation efficiency. This is expected given the effects these policies have on the tax wedge and the number of firms in the liquidity constrained regime (see Tables 2 and 3). The effect of the dividend tax cut on TFP is counter intuitive in the frictionless model. TFP falls after a dividend tax cut (and reduction in the tax wedge) in this specification. What drives the result is the disproportionate increase in the capital stock among firms with lower productivity. As seen in Table 2, the dividend tax cut results in an almost 23% increase in the capital stock, but only a 6.7% increase in output. Because of the absence of investment frictions, fewer firms are liquidity constrained. The reduction in the tax wedge has the largest percentage impact on those who were constrained prior to the tax cut, but not constrained following the tax cut. These are more likely to be firms with lower productivity. The model with fixed costs to adjusting capital show smaller changes in allocative efficiency than the model with only quadratic costs of adjustment. Although Tables 2-4 show that the model with fixed costs to generally be more responsive to tax changes, the effects on allocative efficiency aren't are large (as compared to the other specifications). This has to do with the distribution of capital across firms of varying productivity prior to the tax change. In the model with fixed costs, investment is done by the most productive firms. Thus, as the dividend tax cut reduces the tax wedge, the effect on the distribution of capital across firms is smaller relative to other models where capital effectively distributed prior to the tax cut.

Table 5: Changes in Productivity and the Allocation of Capital After Tax Cuts

	Baseline		4% Div Cut		4% Cap Gain Cut		4% Corp Inc Cut	
Model	TFP	$corr(k, z)$	TFP	$corr(k, z)$	TFP	$corr(k, z)$	TFP	$corr(k, z)$
No Cost	-	0.582	-1.056	0.578	-1.038	0.565	0.113	0.585
$\psi = 1.08$	-	0.398	0.523	0.411	-0.463	0.391	0.190	0.404
$\psi = 1.08$, $F = 0.031$	-	0.378	0.307	0.389	-0.273	0.373	0.130	0.384
$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$	-	0.338	0.491	0.346	-0.358	0.333	0.374	0.345

To further understand the reallocation effects of tax cuts, I decompose the change in output into the fraction of the change due to incentive effects and the fraction due to allocation effects. Output in the model economy can be written as:

$$
\begin{aligned}
Y &= \int z k^{\alpha_k} l^{\alpha_l} \Gamma(dk, dz; w) \\
&= \int z k^{\alpha_k} l(k, z; w)^{\alpha_l} \Gamma(dk, dz; w) \\
&= \left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}} \left[E_\Gamma z^{\frac{1}{1-\alpha_l}} + E_\Gamma k^{\frac{\alpha_k}{1-\alpha_l}} + \underbrace{cov_\Gamma \left(z^{\frac{1}{1-\alpha_l}}, k^{\frac{\alpha_k}{1-\alpha_l}} \right)}_{\text{Allocation Component}} \right],
\end{aligned}
\tag{4.5}
$$

where E_Γ denotes the expected value given the distribution of firms defined by $\Gamma(k, z; w)$ and $cov_\Gamma(\cdot, \cdot)$ is the covariance across this distribution. The fraction of Y accounted for by the allocational component is represented by the covariance term. Letting Y_{base} be output under the baseline tax system and Y_{cut} represent output under a decrease in one of the tax rates, the percentage change in Y due to the reallocation of capital from lower to higher productivity firms is:

$$
\%\Delta Y \text{ due to reallocation} = \frac{\left(\frac{\alpha_l}{w_{cut}}\right)^{\frac{\alpha_l}{1-\alpha_l}} cov_{\Gamma_{cut}} \left(z^{\frac{1}{1-\alpha_l}}, k^{\frac{\alpha_k}{1-\alpha_l}} \right) - \left(\frac{\alpha_l}{w_{base}}\right)^{\frac{\alpha_l}{1-\alpha_l}} cov_{\Gamma_{base}} \left(z^{\frac{1}{1-\alpha_l}}, k^{\frac{\alpha_k}{1-\alpha_l}} \right)}{Y_{cut} - Y_{base}}
\tag{4.6}
$$

Figure 5 describes the reallocation effect for the four models and three tax cuts considered. The reallocation effect is largest for dividend tax cuts, which have the effect of reducing the tax wedge. Note that the large reallocation effect for a capital gains tax cut in the no cost model is negative. Table 3 shows that the 4% cut to the capital gains tax rate reduces output by 1.79% in this model. The misallocation of capital accounts for approximately 97% of the reduction in output. Thus all models find the allocation effect accounting for a positive fraction of the increase in output following a cut in the corporate income tax and the reduction in the tax on dividends, but a misallocation resulting from the capital gains tax. The allocation effects are large, accounting for the majority of the increases in output. In fact, the allocation effect is over 100% following a dividend tax cut in the model with financial frictions. As seen in Table 2, the capital stock actually decreases in this case.

However, the positive allocation effect overwhelms the reduction in investment; the more efficient distribution of capital results in an increase in output.

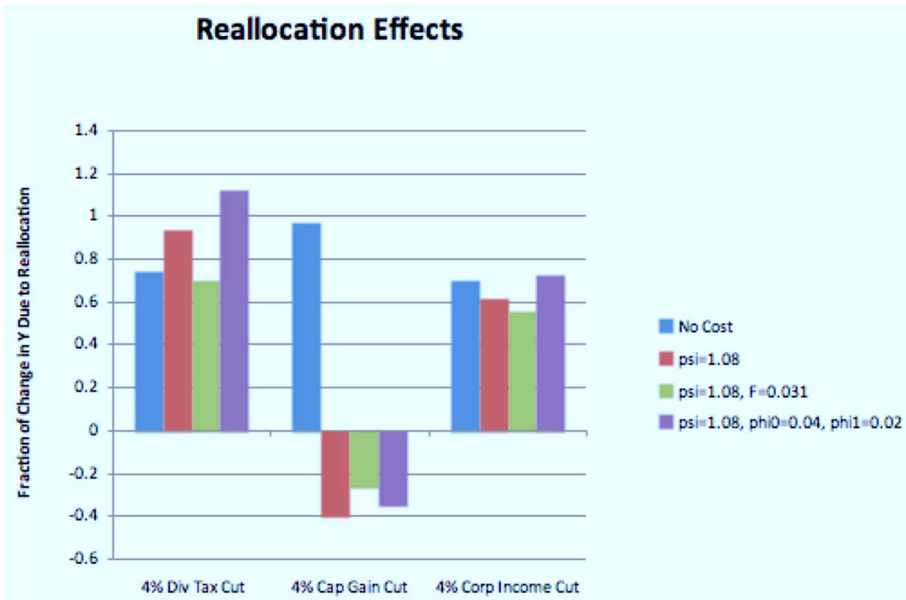


Figure 5: Reallocation Effects of Tax Cuts

Reallocation effects are largest when financial frictions are present. In such an environment, the fraction of firms in the liquidity constrained regime is greatest. A change in tax rates may move many such firms to other financing regimes, aiding allocations efficiency. This is especially true in the case of the dividend tax cut, which directly affects the size of the tax wedge between internal and external financing. But it is also true of tax cuts that affect the cash flows of these constrained firms, such as the cut to the corporate income tax.

Non-convex costs to adjusting capital make firms' investment decisions relatively sensitive to cash flows and thus models with fixed costs to adjusting capital show relatively large responses of investment to tax cuts. However, these fixes costs are barriers to the reallocation of capital across firms. Thus the model with quadratic and fixed costs to adjusting physical capital, in which firms face the largest costs to adjusting capital, is the model where the reallocation effects are smallest. The reallocation effects are still significant in spite of these adjustment costs, accounting for over 60% of the increase in output following a dividend tax cut and over 50% following a cut in the corporate income tax.

5 Conclusion

The analysis in the preceding sections investigates the extent to which the aggregate effects of tax policy depend on real and financial frictions in a general equilibrium model with heterogeneous firms. Understanding how tax policy affects the investment decisions of firms is important. The government, should it decide to tax capital, has several policy tools from which to choose. The choice of tax instrument needs to be considered in light of the economic impact it will have. I determine how frictions interact with three of these instruments: taxes on dividend income, taxes on capital gains, and taxes on corporate income.

In short, this paper shows frictions, both real and financial, matter when evaluating tax policy. Relative to models with only convex costs of adjusting capital, models with non-convexities in the costs of adjustment are often more responsive to tax policy. The presence of financial frictions, on the other hand, dampens the response of aggregate investment to changes in capital taxation. To put in perspective the importance of accounting for investment frictions when evaluating tax policy, consider the predicted effects on output and investment following from a permanent extension of JGTRRA. The model with quadratic and fixed adjustment costs (as parameterized in Section 4.2) predicts a percentage change in output 16.6% larger (1.8% vs. 1.5%) than that from a model with only quadratic costs of adjusting capital. The model with non-convexities predicts a percentage increase in the capital stock that is 46.6% larger (4.7% vs. 3.2%) than the model with only quadratic costs of adjustment. The quadratic specification prevails among models with which tax policy is evaluated (e.g., *A Dynamic Analysis of Permanent Extension of the President's Tax Relief* (2006), Gourio and Miao (2010)), but such models do not account for the sensitivity of investment to capital taxation. Understanding this relationship is importance as policy-makers wrestle with the question of whether or not to further extend the Bush tax cuts.

In addition, this paper highlights the importance of firm heterogeneity in the analysis of the effects of tax policy. When changing marginal capital tax rates, allocational efficiencies account for much of the resulting impact on output. In the case of a cut in the dividend tax rate, these allocational effects are responsible for over 60% of the increases in output across models with a wide range of investment frictions. These allocational effects can be negative when the tax wedge between internal and external financing is widened. For example, lowering the capital gains tax rate further below the tax rate on dividends may not be efficiency enhancing because such a policy increases the tax wedge and results in a (further) misallocation of capital.

Within the context of long run effects of unanticipated changes in tax policy, a number of meaningful extensions to the model and analysis present themselves. Elastic labor supply and heterogeneous households would strengthen any welfare analysis done with the current model. Another extension is to allow firms to borrow and lend. Debt financing is important for many firms, and with the tax advantages of debt, a source of interesting public finance questions.

The work in this paper suggests several other questions for future research. Contrary to the model presented here, changes in tax policy are often predictable and temporary. Frictions are particularly salient in determining the outcome of anticipated changes in tax policy. Convex and non-convex frictions are likely to result in large differences in the effects of changes in tax policy when firms see the change approaching. Second, although the presence of taxes may be one of the few certainties in life, almost as certain is change in tax policy. That is, taxes may be permanent, but the specifics of taxation are not. The expected duration of tax policy interacts with frictions as firms postpone or expedite their investment decisions to engage in tax arbitrage. The effects of temporary tax policies greatly depend on real and financial frictions.

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Appendix

A-1 Data

The following facts and the model estimation described in Section A-2 are based on firm-level data from the Compustat North America annual data files. I omit financial and regulated firms (SIC codes 4900-4999 and 6000-6999) and those missing values for important variables (dividends, equity issued, capital, earnings) from my sample. I also exclude firms with less than one million dollars of capital and those with less than two million dollars in assets to avoid rounding errors. This leaves me 76,372 firm-year observations for the 1988-2002 period. I use this period to calculate of all the moments I use in the model estimation since the period precedes the 2003 tax cuts.

A-2 Estimation of the Profit Function and Productivity Process

Assuming $F(k,l,z) = zk^{\alpha_k}l^{\alpha_l}$, corporate profits are given by $\pi(k,z;w) = (1-\alpha_l)(zk^{\alpha_k})^{\frac{1}{1-\alpha l}}(\frac{\alpha_l}{w})^{\frac{\alpha_l}{1-\alpha_l}}$. Taking the natural log of the profit function one can derive the following equation:

$$ln(\pi_{i,t}) = \alpha_0 + \alpha_1 ln(k_{i,t}) + \eta_{i,t}, \tag{A.2.1}$$

where α_0 is a constant equal to $ln(1-\alpha_l) + \left(\frac{\alpha_l}{1-\alpha_l}\right) ln\left(\frac{\alpha_l}{w}\right)$, α_1 is equal to $\frac{\alpha_k}{1-\alpha_l}$, and $\eta_{i,t} = \frac{z_{i,t}}{1-\alpha_l}$.

The error term, $\eta_{i,t}$ has a common component, b_t and a firm-specific component, $e_{i,t}$. Thus $\eta_{i,t} = b_t + e_{i,t}$. The log profits function can thus be written as:

$$ln(\pi_{i,t}) = \alpha_0 + \alpha_1 ln(k_{i,t}) + b_t + e_{i,t} \tag{A.2.2}$$

Running the regression specified by Equation A.2.2 identifies the parameter $\alpha_1 = \frac{\alpha_k}{(1-\alpha_l)}$. I set α_l equal to 0.65, following Gourio and Miao (2010). Using Compustat data from 1988-2002, I find $\alpha_k = \frac{\alpha_1}{(1-\alpha_l)} = 0.297$.

To find the AR(1) process for technology, I fit an AR(1) to $z_{it} = (1-\alpha_l)\tilde{e}_{i,t}$:

$$z_{i,t} = \rho z_{i,t-1} + u_{i,t}, \tag{A.2.3}$$

where $u_{i,t} \sim N(0,\sigma)$. I find $\hat{\rho}$=0.761 and $\hat{\sigma}$=0.213. These parameter estimates are in-line with those of Gourio and Miao (2011).‘

A-3 Details of Model Solution

I approximate the AR(1) process for productivity using the method of Tauchen and Hussey (1991). The model is solved using value function iteration (VFI). From the decision rules of the firms, I solve for the fixed point in the stationary distribution by iterating on Equation 2.12. Using the stationary distribution, I calculate the aggregate labor demand to see if the labor market (and by Walras' Law the goods market) clears.

There are 10 points in the grid for productivity, which has support:

$$\left[\frac{-4\sigma}{\sqrt{1-\rho^2}}, \frac{4\sigma}{\sqrt{1-\rho^2}}\right] \tag{A.3.1}$$

The capital grid has 217 points. This grid is finer for lower levels of capital stock. The grid of for capital has support:

$$\left[\underline{\mathrm{k}}..., (1-\delta)\bar{k}, (1-\delta)^{1/2}\bar{k}, (1-\delta)^{1/3}\bar{k}, (1-\delta)^{1/4}\bar{k}, \bar{k}\right], \tag{A.3.2}$$

where $\underline{\mathrm{k}} = 0.001$ and $\bar{k} = 8.64$.