Capital Taxes with Real and Financial Frictions*

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Abstract

This paper studies how frictions, real and financial, affect the outcomes of capital tax policy in a dynamic, general equilibrium model. Comparative statics show tax policy can have substantially different results depending on the frictions present. Using firm level data on investment and financial policy, I estimate a model that allows for non-convexities in both the real and financial frictions firms face. With estimates of the true frictions in hand, I then conduct policy experiments, including calculating the long run effects on the aggregate capital stock and aggregate welfare from the 2003 tax cuts and from the tax proposals of President Obama. The effects of such tax policy are found to be much larger than those in models which do not allow for non-convexities in the frictions firms face.

JEL Classifications: D21; E22; G11; H25

Keywords: Corporate Finance; Firm Dynamics; Capital Taxation

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 so, even if a government finds it optimal to tax capital, it still must choose among these tax instruments. Beyond taxes, investment policy is also affected by the real and financial frictions firms face when undertaking investment. In the following analysis, I study how real and financial frictions interact with tax policy in an economy with heterogenous firms. My study has three main parts. First, I undertake some comparative statics, to understand how tax policy affects investment decisions when firms face various frictions. Second, I estimate several models of real and financial frictions and find the model

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that best fits the data on firm dynamics. Finally, I use the estimated model to evaluate the long run impact of actual and proposed changes in tax policy.

This paper relates to 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 strands.[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 adjustment. I span these two literatures, allowing for non-convexities in the 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-convexitites 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 a 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),

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

Barro (1989), Baxter and King (1993)). Important in public finance literature are the two main views of dividend taxation. The "traditional view" suggests the marginal source 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 (2008), Gourio and Miao (2007), and House and Shapiro (2006) examine tax policy in models with quadratic costs of capital adjustment. Although Gourio and Miao (2008) include a section on the effects of tax policy with marginal costs to issuing equity they do not allow for non-convex costs 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 will 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 estimation of a model that allows for the presence of non-convexities in both real and financial frictions. Hennessy and Whited (2007), Bayraktar, Sakellaris, and Vermeulen (2005), Cooper and Ejarque (2003), and Cooper and Haltiwanger (2006) (for plant level data), and others have estimated models with real and financial frictions. However, only Bayraktar, Sakellaris, and Vermeulen (2005) allow for non-convexities in the costs of adjusting capital alongside costly external financing. Furthermore, even Bayraktar, Sakellaris, and Vermeulen (2005) lack non-convexities in the financial frictions they specify, which could result in a biased measurement of the real non-convexities. To the best of my knowledge, this is the first study to estimate a model that allows for non-convexites in both real and financial frictions.

In this paper, I first show how adjustment costs interact with tax policy both analytically and numerically. Following this exercise, I estimate the nature and size of the investment frictions firms face- both real and financial. Using the estimated model, I then conduct two policy experiments. The policy experiments include the tax changes brought forth by the Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA), which changed the tax rates on dividend and capital gains income, and the campaign tax proposals of President Obama.

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. Section 4 outlines the econometric procedure used to pin down the nature of the real and financial frictions. Section 5 presents the results of the estimation. Section 6 describes the policy experiments and their results. Section 7 concludes and presents ideas for future research.

1 Investment Behavior and Evidence of Real and Financial Frictions

1.1 Data

The following facts and the model estimation described in Section 4 are based on firm-level data from the Compustat North America annual data files. I drop financial and regulated firms (SIC codes 4900-4999 and 6000-6999) and those with missing values for the important variables (dividends, equity issued, capital, earnings). I also drop 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 in the calculation of all the moments I use in the model estimation

Table 1: Summary Statistics, Compustat 1988-2002

	Mean	Std. Dev
Tobin Q	2.723	8.552
Investment, i	123.002	696.419
Capital Stock, k	794.417	3945.39
Investment Rate, $(\frac{i}{k})$	0.281	0.251
New Equity Issues, s	20.338	157.496
Equity Issue Rate, $\frac{s}{k}$	0.261	0.615

since the period precedes the 2003 tax cuts.

Table 1 summarizes the data. Investment, capital stocks, and new equity issues are all measured in millions of 2007 dollars and delfated using the GDP deflator. The rate of new equity issues is "windsorized", as several outliers have very large rates of equity issuance and skew the results significantly. A good deal of variation is present in all the variables. This represents the difference in the investment and financing behavior of different firms, which is discussed in more detail below. For smaller firms and firms who are more productive, Tobin's Q is high, as is the investment rate and rate of equity issuance. For larger firms or those with lower productivity, these variables are much lower. One can see the variation in firm size shown by the standard deviation of the capital stock variable.

1.2 Investment Facts

Costs of raising external funds and costs associated with changes in a firm's capital stock both 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 the behavior of investment. 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.

[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.

4. A "high" correlation between investment rates and measures of cash flow.

Facts 1 and 2 are 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. 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 investment hazard function of firms using the same Compustat dataset. She finds a pattern of "lumpy" investment exists for large and small firms. That 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, Hubbard, and Petersen (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 spread the fixed costs of adjusting their capital stock over a large investment. Cooper and Haltiwanger (2006) find behavior similar to 1-2 at the plant level and estimate significant non-convexities in the costs of adjustment faced by firms. 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 Fazzari, Hubbard, and Petersen (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, Hubbard, and Petersen (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).[3] Altinkilic and Hansen (2000) and Smith (1977) find the existence of such economies of scale in equity floatation costs.

[3] 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.

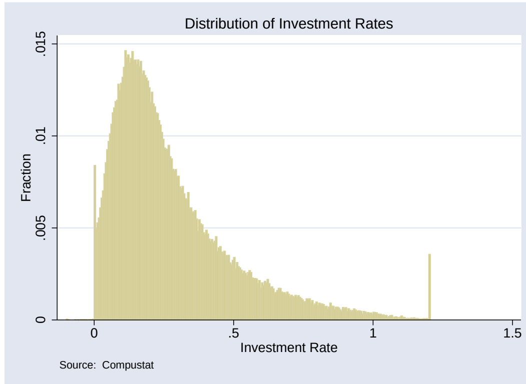


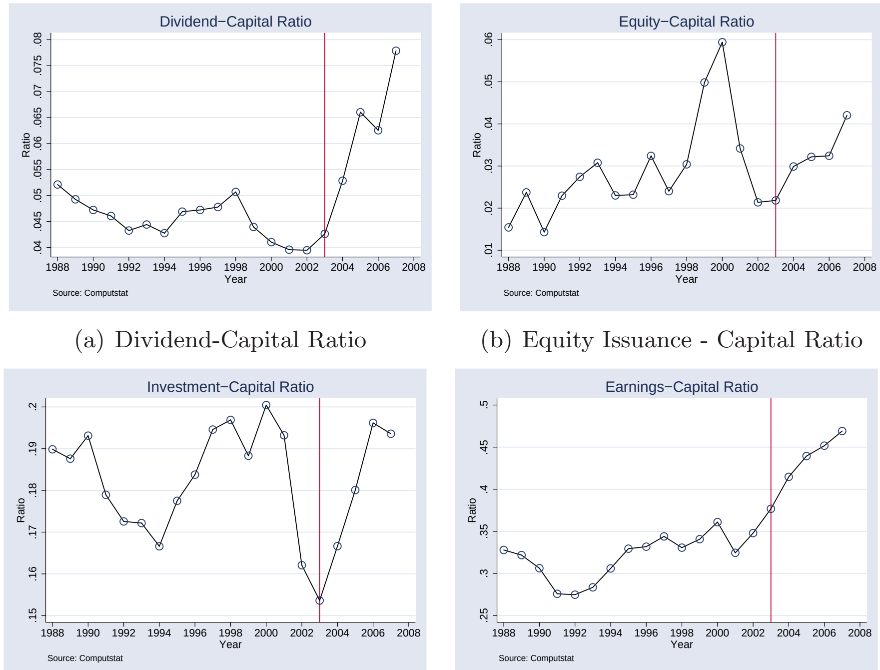
Figure 1: PDF of Investment

1.3 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 tax rates of 25, 28, 33, and 35 percent) from 20% to 15%. 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 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 observed. 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 the various financing regimes before



(a) Dividend-Capital Ratio

(b) Equity Issuance - Capital Ratio

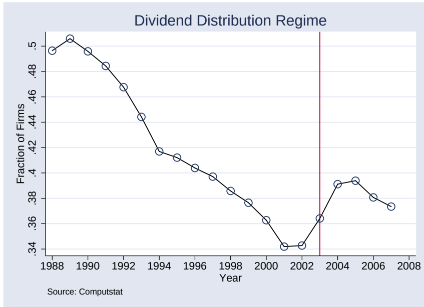
(c) Investment - Capital Ratio

(d) Earnings - Capital Ratio

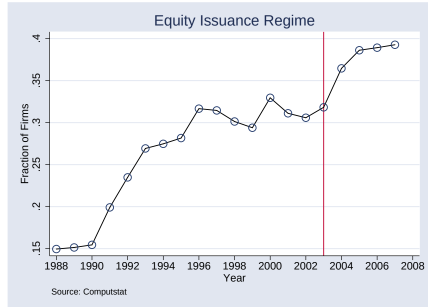
Figure 2: Aggregate Corporate Investment and Financing Behavior.

and after the 2003 tax cuts. In the dividend distribution regime, the marginal source of funds is retained earnings (corresponding to the new view). 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 (corresponding to the traditional view). These firms issue new equity to finance investment. I classify firms 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.[4] 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 or to issue dividends.

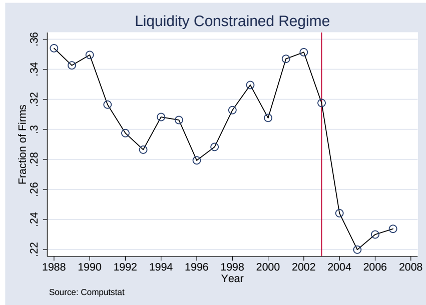
[4]There exist a non-trivial number firms who both issue equity and distribute dividends. This behavior constitutes the "dividend puzzle". The model presented in this paper can not account for this seemingly suboptimal behavior. See Bernheim (1991) and Chetty and Saez (2007) for examples of papers attempting 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.

As suggested by Figures 2(a) and 2(b), one can see an increase in the fraction of firms who distributed 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 regime accounts for much of the efficiency gains from the tax cuts of 2003.

2 Model

The quantitative model of capital taxation incorporates the various forms of capital taxation (capital gains, dividend income, corporate income) and accounts for important general equilibrium effects of taxation. In additon, 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.[5] No aggregate uncertainty is present in the model. Below, I outline each part of the economy. I start 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, recieves transfers, and consumes. Labor is supplied inelastically and the risk free bonds are in zero net supply. The household chooses 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 Γ_t characterizes the distribution of firms in period t and d_t are dividends issued in period t. r_t is the return on the 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 is returned to the household and is represented by $\tilde{\Phi}_t$.

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

[5]For an analysis of temporary changes in tax policy in a partial equilibrium model, see Gourio and Miao (2007). For a study of temporary and and predicted changes in tax policy, see House and Shapiro (2006).

equilibrium the pricing kernal 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 so at any point in time, firms are heterogenous 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:

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

V^O_{t+1} is the t+1 value of shares outstanding in period t and $V^O_{t+1} = V_{t+1} - s_t$. Because the only uncertainty are the idiosyncratic shocks to the firms, there is no aggregate uncertainty. Without aggregate uncertainty, asset pricing equlibrium implies: $E_t(R_t) = (1-\tau_i)r$, 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. Thus, asset pricing equilibrium says the expected after-tax returns on the bond and on equity must 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:

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

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, it is clear the firm's problem is represented by the following Bellman Equation:

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

In Equation 2.5, z denotes the firm's productivity, k its capital stock, s its equity issuance, and the other variables are the same as described in previous equations. 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 distribution, 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 $\underline{s} = 0$.[6]

[6]Admittedly, when $\underline{s} = 0$, as it does for the analysis this paper, one can not answer questions regarding

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 omits the firm's policy function 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 and thus the choice of labor is omitted from Equation 2.5.

It is clear 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 effect of taxation on investment decisions, which is 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 unnecessary to understand the mechanisms of interest.

The Government Budget Constraint in any period (where I drop the time subscripts for

the observed "dividend puzzle".

simplicity) is:

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

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, Lucas, and Prescott (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, Lucas, and Prescott (1989) show Γ^* exists, is unique and the sequence of measures generated by the transition fuction, $\{H^n(\Gamma_0)\}_{n=0}^{\infty}$ converges weakly to Γ^* from any Γ^0. The measure of firms is normalized to one.

With the denition of the stationary distribution in hand it is straightforward 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: $\bar{L} = \int l(k,z;w^*)\Gamma^*(dk,dz)$

- The goods market clears: $Y(\Gamma^*;w^*) = C(\Gamma^*;w^*) + I(\Gamma^*;w^*) + \Upsilon(\Gamma^*;w^*)$[7]

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 effect 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 the marginal product of capital and results in less investment.

3 The Firm's Decision Problem

Substitution of the first constraint in the firm's problem (given by Equation 2.6) into 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:

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

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

[7]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.

where λ^d and λ^s are the Lagrange 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 some costs were incurred when issuing the 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 famous Modigliani-Miller Theorem (Miller and Modigliani (1958)). In this environment, by Equation 3.1 $\lambda^d = \lambda^s = 0$. 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 there are no financial frictions ($\frac{\partial \Phi}{\partial s} = 0$). Also 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 (2008), 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. Figure 4 plots the equity issuance policy function as a function of k for firms with different levels of productivity. One can see smaller firms and firms with high levels of productivity are in the equity issuance regime. For firms in this regime, $\lambda^d > 0$ and $\lambda^s = 0$.

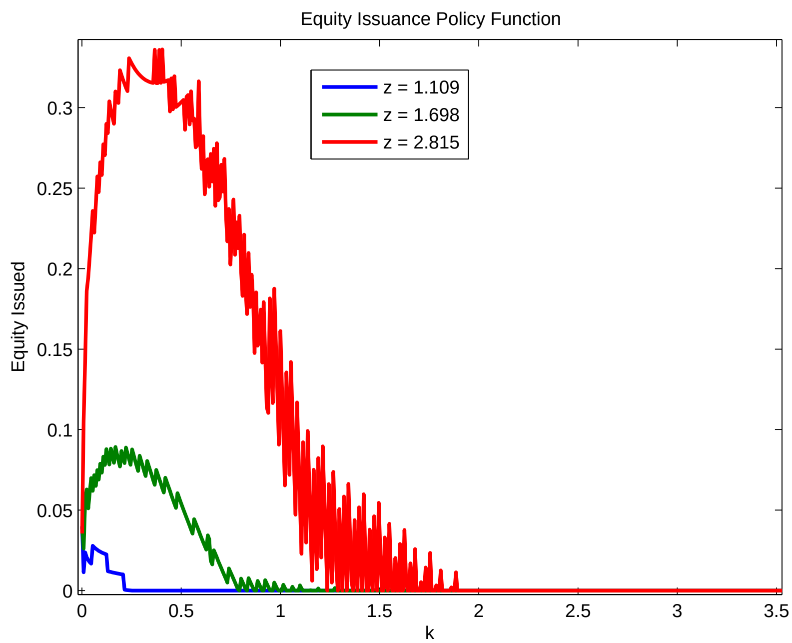


Figure 4: Equity Issuance Policy Function

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. Figure 5 presents the dividend distribution policy function for firms with different levels of productivity. 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*. These firms fund investment using internal funds, but do not distribute dividends. For these firms, the marginal product

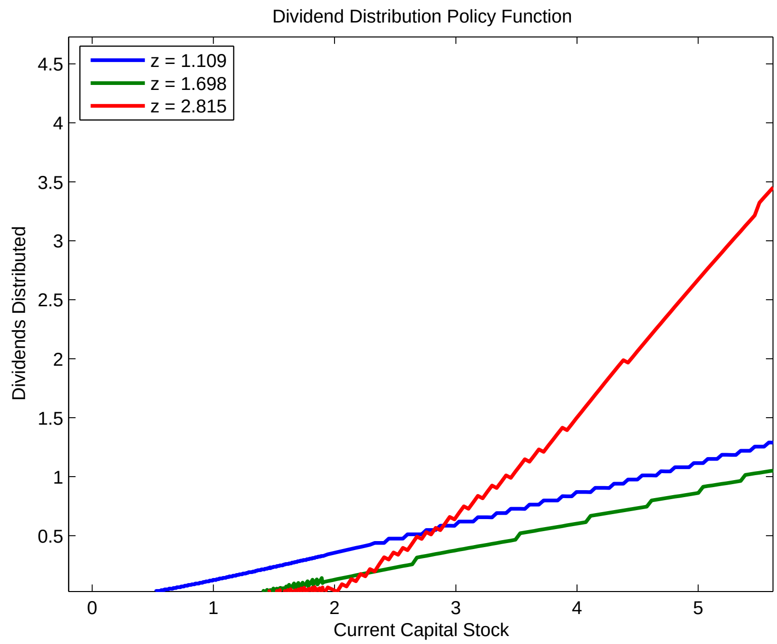


Figure 5: Dividend Distribution Policy Function

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 Figure 6 one can see a firm with a constant level of productivity transition from the equity issuance regime to the dividend distribution regime as its capital stock increases. Between these regimes, the firm is in the liquidity constrained regime, where both dividends and equity issuance are zero. In this regime, $\lambda^d = 0$ and $\lambda^s = 0$.

3.2 Q-Theory with Taxes and Frictions

In order to better see the effects of taxes and frictions on investment behavior, assume for now the costs to adjusting capital are quadratic in nature and there is linear cost to issuing new equity. Formally, let $\upsilon(k, k') = \frac{\psi(k'-(1-\delta)k)^2}{2k}$ and $\Phi(s) = \phi_1 * s$, as in Cooley and Quadrini (2001). Under these assumptions, the first order condition for k' implies:

$$\left(\frac{1-\tau_d}{1-\tau_g} + \lambda^d\right)\left(1 + \frac{\psi i}{k}\right) = \tilde{q}, \tag{3.3}$$

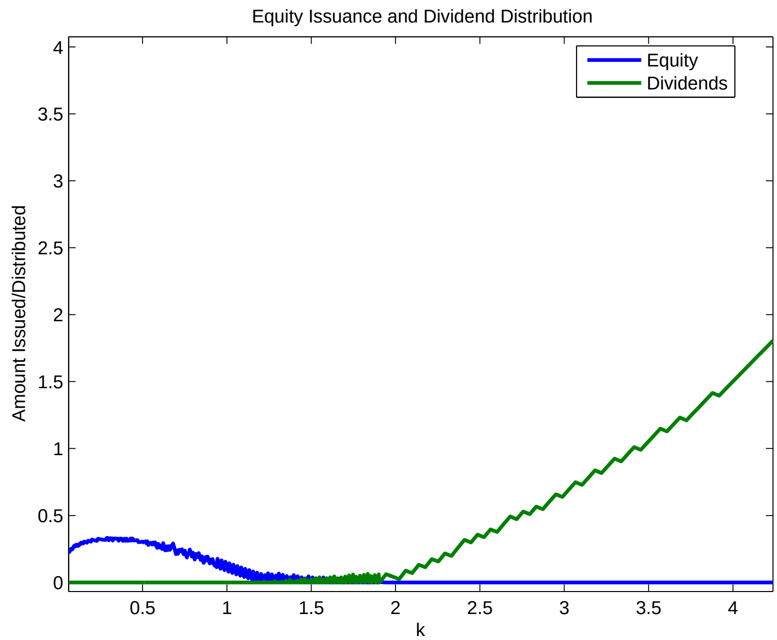


Figure 6: Three Regimes

where $\tilde{q} = \frac{1}{1+r(1-\tau_i)/(1-\tau_g)} E_{z'|z} \frac{\partial V(k',z')}{\partial k'}$ denotes expected, discounted, marginal Q. Again, this represents the return on a dollar invested in the firm.

If the firm is in the equity issuance regime (this is, the marginal source of funds is external), 3.3 can be rewritten as:

$$\frac{i}{k} = \frac{1}{\psi}[\tilde{q}(1-\phi_1) - 1] \tag{3.4}$$

The empirical work on Q-theory is built around estimating equations like Equation 3.4 (Q-regressions). With $\phi_1 = 0$, if Q-theory is correct and $\tilde{q}$ is measured properly, then Q-regressions should allow one to measure the size of adjustment costs, ψ.[8] Additionally, if Q-theory is correct and if $\tilde{q}$ is measured properly, Q-regressions should find a significant coefficient on measures of $\tilde{q}$ and insignificant coefficients on other variable entered into the equation such as cash flow.[9]

From the above equation characterizing optimal investment, one can see that the firm

[8] See Hayashi (1982) for a discussion of when average Q and marginal Q are the same.

[9] In short, Q-regressions have not given strong support to Q-theory. Reasons for the failure of Q-theory include measurement error (Gomes (2001), Erickson and Whited (2000)), the misspecification of the empirical model because of market power (Cooper and Ejarque (2003)), and financial frictions (Whited (2006)).

invests until the increase in firm value from another dollar of investment equals the costs of raising the dollar. That is, the firm invests until $\tilde{q} = \frac{1}{(1-\phi_1)} \geq 1$.

On the other hand, suppose the marginal source of funds is retained earnings. Now the firm is in the dividend distribution regime, or the new view of dividend taxation. The firm weighs the benefits of another dollar invested in the firm against the benefits of a dollar distributed as dividends. The optimality condition for investment is given by the following equation:

$$\frac{i}{k} = \frac{1}{\psi}[\tilde{q}\left(\frac{1-\tau_g}{1-\tau_d}\right) - 1] \tag{3.5}$$

The firm whose marginal source of funds is retained earnings invests up to the point $\tilde{q} = (\frac{1-\tau_d}{1-\tau_g}) \leq 1$.

In an environment where firms have different levels of productivity and may, at any point in time, be in different financing regimes, there is a clear wedge between these regimes since $(\frac{1-\tau_d}{1-\tau_g}) \leq 1 \leq \frac{1}{(1-\phi_1)}$. Firms with a $\tilde{q}$ falling within this wedge find issuing equity or distributing dividends suboptimal. That is, these firms are in the liquidity constrained regime. As financing frictions increase, or as the difference between capital gains and income taxes increases, this size of this wedge, and thus the number of firms in the liquidity constrained regime, increases. Such a wedge leads to a misallocation of resources. For example, there may be a firm who would, if dividend taxes were lower, issue dividends who does not issue them currently. Thus this firm invests its retained earnings in itself instead of allowing shareholders to invest those funds in more productive firms. Similarly, financing frictions discourage high productivity firms from accessing external sources of funding.

What is puzzling about Equations 3.4 and 3.5 is the presence of dividend taxes in 3.5, but not in 3.4. Though this seems counterintuitive, the reason is that dividend taxes are capitalized into the value of the firm. Thus, in the traditional view, dividend taxes affect investment through their affect on $\tilde{q}$. However, the effects of dividend taxes cancel out in 3.5.

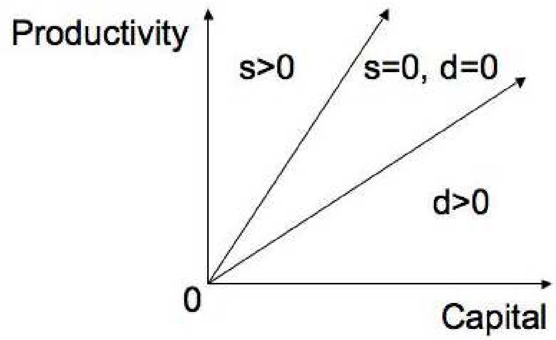


Figure 7: Three Regimes

3.3 Optimal Investment with Taxes and Frictions

To see more precisely how all taxes affect investment, I rewrite Equation 3.2 in a different way. Applying the Envelope Theorem to 3.2 yields (where I include time subscripts to make more clear the intertemporal effects):

$$\begin{aligned}&\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d\right)\left(1+\frac{\psi i_t}{k_t}\right)=\\&\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_{t+1}^d\right)\left(\frac{1}{1+r(1-\tau_i)/(1-\tau_g)}\right)\times\\&E_{z_{t+1}|z_t}\left[(1-\tau_c)\pi_k+\tau_c\delta+(1-\delta)+\frac{2\psi(1-\delta)i_{t+1}}{k_{t+1}}+\frac{\psi i_{t+1}^2}{k_{t+1}^2}\right],\end{aligned}\tag{3.6}$$

where the left hand side represents the marginal costs of investment and the right hand side represents the marginal benefit of investment.

Suppose a firm plans to issue equity this period and next or plans to distribute dividends this period and next. In these cases $\lambda_t^d = \lambda_{t+1}^d$ and 3.6 reduces to:

$$\begin{aligned}&\left(1+\frac{\psi i_t}{k_t}\right)=\\&\frac{1}{1+r(1-\tau_i)/(1-\tau_g)}\times\\&E_{z_{t+1}|z_t}\left[(1-\tau_c)\pi_k+\tau_c\delta+(1-\delta)+\frac{2\psi(1-\delta)i_{t+1}}{k_{t+1}}+\frac{\psi i_{t+1}^2}{k_{t+1}^2}\right]\end{aligned}\tag{3.7}$$

Here, as in the new view of dividend taxation, dividend taxes have no effect on investment. Because the marginal source of funds is not changing between periods, the firm is either issuing another dollar of equity this period to reduce equity issued next or the firm is withholding an additional dollar this period in order to distribute more dividends next period. An increase in capital gains taxes results in an decreases in investment because it increases the discount rate of firms. An increase in the corporate income tax rate decreases investment because it lowers the after-tax value of a dollar invested in the firm. Financial frictions are not to be found in 3.7. The reason is the same as the reason dividends do not enter this equation. Financial frictions do not matter for investment decisions because the firm does not change its marginal source of funds from one period to the next. Issuing equity this period incurs financing costs today, but helps to reduce equity issuance (and thus financing costs) next period.

Suppose a firm goes from distributing dividends this period ($\lambda_t^d = 0, \lambda_t^s > 0$) to issuing equity next ($\lambda_{t+1}^d > 0, \lambda_{t+1}^s = 0$). In this case, the condition for optimal investment can be written as:

$$\begin{aligned}
&\left(\frac{1-\tau_d}{1-\tau_g}\right)\left(1+\frac{\psi i_t}{k_t}\right) = \\
&\frac{1}{1+r(1-\tau_i)/(1-\tau_g)} \times \\
&\left(\frac{1}{1-\phi_1}\right) E_{z_{t+1}|z_t}\left[(1-\tau_c)\pi_k + \tau_c\delta + (1-\delta) + \frac{2\psi(1-\delta)i_{t+1}}{k_{t+1}} + \frac{\psi i_{t+1}^2}{k_{t+1}^2}\right]
\end{aligned} \tag{3.8}$$

Dividend taxes are present here. An increase in the dividend tax rate *increases* investment because it lowers the marginal cost of investment. When facing a lower tax on dividends, firms at the margin would rather remit earnings to share holders. Thus when the tax on dividends is higher (and the after-tax benefits of dividends lower), the firm is more likely to invest those funds internally than to distribute them to shareholders. Increasing τ_g lowers investment both by increasing the discount rate of firms and by increasing the marginal cost of investment. Increasing τ_c decreases investment for the reasons cited in the previous case. Higher financing costs increase the marginal benefits of investment. The benefit of investing more today (by distributing less dividends) is the ability to issue less equity in next period. With costs to external financing, it is even more beneficial for the firm to increase investment today to save on equity issues next periods.

Finally, consider the case where a firm issues equity this period ($\lambda_t^d > 0, \lambda_t^s = 0$) and plans to distribute dividends next ($\lambda^d_{t+1} = 0, \lambda^s_{t+1} > 0$):

$$\begin{aligned}
&\left(\frac{1}{1-\phi_1}\right)\left(1+\frac{\psi i_t}{k_t}\right) = \\
&(\frac{1}{1+r(1-\tau_i)/(1-\tau_g)})\times \\
&\left(\frac{1-\tau_d}{1-\tau_g}\right) E_{z_{t+1}|z_t}\left[(1-\tau_c)\pi_k + \tau_c\delta + (1-\delta) + \frac{2\psi(1-\delta)i_{t+1}}{k_{t+1}} + \frac{\psi i^2_{t+1}}{k^2_{t+1}}\right]
\end{aligned} \tag{3.9}$$

In this case an increase in dividend taxes decreases investment because it lowers the after tax value of the future dividends the investment is intended to produce. An increase in the capital gains tax rate has the perverse effect of *increasing* investment. While a higher capital gains tax rate increases the firm's discount rate, it also lowers the after-tax costs of issuing new equity. The tax on corporate profits acts in the same way as in the other scenarios- an increase in the tax rate decreases the amount of investment undertaken. Financing costs increase the marginal costs of investment, which is financed by equity issuance.

In summary, changes to capital gains taxes and dividend taxes may act to increase, decrease, or may have no effect on investment, depending on the firm's financing regimes and its transition between regimes. Taxes on corporate profits always affect investment decisions and higher taxes on corporate income always result in lower investment. Financial frictions have no effect on investment decisions if firms do not change their financing regime, but may either increase or lower investment depending upon the transition between regimes. Costs of adjusting the capital stock always affect investment decisions by increasing the cost of investment.

3.4 Investment with Taxes and Non-convexities

In the previous subsection, I examined the investment decisions of firms when the costs of adjusting the capital stock and the financing frictions were convex in nature. In this section, I consider non-convexities in the costs of adjustment and the financial frictions. Since the non-convexities result in the decisions rules of the firms necessarily being discontinuous, one cannot study the first order conditions of the firm. Here, I take a different approach and numerically evaluate the effects of tax policy when non-convexities are present.

3.4.1 Model Specification

I assume the firms' production function is Cobb-Douglas; $F(k, l, z) = zk^{\alpha_k} l^{\alpha_l}$. Following the macro literature, I set $\alpha_l = 0.65$ and estimate α_k. 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 estimate the parameters ρ and σ. For the details of this estimation, see Section 4.

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:

$$\upsilon(k_t, k_{t+1}) = \frac{\psi i_t^2}{k_t} \tag{3.10}$$

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:

$$\upsilon(k_t, k_{t+1}) = \begin{cases} (F * k) + \frac{\psi i_t^2}{k_t}, & \text{if } i_t \neq 0; \\ 0, & \text{if } i_t = 0; \end{cases} \tag{3.11}$$

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:

$$\Phi(s) = \phi_0 \mathbf{1}_{\{s>0\}} + \phi_1 s, \tag{3.12}$$

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

3.4.2 Parameterization

The following parameters need values in order to solve the model:

$$\Theta = \{\beta, \delta, \alpha_l, \alpha_k, \rho, \sigma, \psi, F, \phi_0, \phi_1\}, \tag{3.13}$$

where 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 calibrate β to generate an after-tax risk free interest rate of 4%. This implies that $\beta = 0.971$ in the 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.

I follow Gourio and Miao (2008) by setting $\alpha_l = 0.65$ since the labor share is approximately 65% in the U.S. Given the parameter values given thus far, I estimate α_k, ρ, and σ as described in Section 4.

In the following sections, I estimate the real and financial frictions. At this point, I set the parameters determining the sizes of these frictions to values given by others in the literature with somewhat similar models. I set $\psi = 1.08$ as done in Gourio and Miao (2008). This value is similar to the parameter's value in Cummins, Hassett, and Hubbard (1994) and elsewhere. To my knowledge, Bayraktar, Sakellaris, and Vermeulen (2005) provide the only estimate of non-convex real costs of adjustment for firms in a model with financial frictions. While firms in their model finance investment externally by issuing debt, I nonetheless set the fixed costs of adjustment parameter to the parameter estimate Bayraktar, Sakellaris, and Vermeulen (2005) report; $F = 0.031$.

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

The model parameterization is summarized in Table 2.

Table 2: Parameter Values Used in Numerical Comparative Statics

Parameter	Value	Source
β	0.971	4% after tax risk free rate
δ	0.154	I/K
α_l	0.650	Gourio and Miao (2008)
α_k	0.311	Gourio and Miao (2008)
ρ	0.767	Gourio and Miao (2008)
σ	0.211	Gourio and Miao (2008)
ψ	1.080	Gourio and Miao (2008)
F	0.031	BSV (2005)
ϕ_0	0.040	Whited (2002)
ϕ_1	0.020	Whited (2002)

3.4.3 Numerical Comparative Statics

For each model, I calculate the equilibrium values of the following aggregates: capital stock, output, consumption, average Q, and the wage. 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 unanticipated changes to tax policy. First, I lower the dividend tax rate 4% to 0.21. Next, I lower the capital gains tax rate 4% to 0.16. The last policy change is to lower the capital gains tax rate 4% to 0.30. For each model, I calculate the percent changes in the aggregates following the respective tax change. The results are reported below.

Table 3: Four Percent Cut in the Dividend Tax Rate

Aggregate	No Cost	$\psi = 1.08$	$\psi = 1.08,\ F = 0.031$	$\psi = 1.08,$ $\phi_0 = 0.04,\ \phi_1 = 0.02$
%Δ Capital	23.00	0.57	1.87	-0.25
%Δ Output	6.79	0.72	0.89	0.38
%Δ Cons.	3.77	0.40	0.34	0.25
%Δ Dividends	36.84	7.22	6.73	3.66
%Δ Equity	54.14	35.41	25.62	42.53
%Δ Wage	5.47	0.70	0.91	0.42
%Δ Avg Q	10.23	6.26	2.70	3.67

Different forms of capital taxation have differential effects on firms' investment decisions and on the macroeconomic aggregates. This is clear and has been shown by others. The noteworthy results shown here are the differential effects of tax policy across the models of real and financial frictions. Magnitudes and directions of the changes in aggregates vary, depending upon the frictions present. This highlights the importance of understanding the real and financial frictions firms face when evaluating fiscal policy. Measuring the true

Table 4: **Four Percent Cut in the Capital Gains Tax Rate**

Aggregate	No Cost	$\psi = 1.08$	$\psi = 1.08$, $F = 0.031$	$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$
%Δ Capital	-2.39	1.76	0.23	1.98
%Δ Output	-1.42	-0.05	-0.28	0.04
%Δ Cons.	-1.23	-0.16	-0.15	-0.12
%Δ Dividends	-22.19	-5.84	-5.89	-4.19
%Δ Equity	-30.82	-23.07	-17.84	-35.75
%Δ Wage	-2.07	-0.02	-0.28	0.00
%Δ Average Q	-19.40	-3.98	-0.15	-1.10

Table 5: **Four Percent Cut in the Corporate Income Tax Rate**

Aggregate	No Cost	$\psi = 1.08$	$\psi = 1.08$, $F = 0.031$	$\psi = 1.08$, $\phi_0 = 0.04$, $\phi_1 = 0.02$
%Δ Capital	2.42	3.05	3.73	2.28
%Δ Output	0.36	1.17	1.28	1.05
%Δ Cons.	-0.03	0.52	0.47	0.52
%Δ Dividends	3.98	5.63	5.43	6.86
%Δ Equity	3.70	6.68	4.29	17.08
%Δ Wage	0.82	1.13	1.28	1.09
%Δ Average Q	5.49	4.49	3.57	4.77

frictions is the topic of the next section.

4 Estimation

Given an understanding of the effects of taxes and frictions on investment decisions and knowing the results from the previous section on the differential effects of taxes under different specifications of the frictions, an obvious next step is to try to uncover the nature and size of the actual frictions firms face. This allows one to more accurately evaluate how actual changes in tax policy impact the investment decisions of firms, which is the subject of the Section 6.

Estimation of the model is done in two stages. In the first, I estimate the parameters of the model directly using observations on the profitability of firms and aggregate investment rates. In the second stage, I take an indirect approach to estimate the costs of capital adjustment and the financial frictions, which are difficult to observe directly. The approach taken in this stage is to estimate the unknown parameters via a simulated method of moments (SMM) procedure. That is, I identify the model parameters by matching moments characterizing the investment and financing behavior of actual firms to the same moments from a panel of firms which are simulated using the solution to the model presented in Section 2. Before discussing the estimation procedure, I explain the tax rates and assumptions on the behavior of households I use in the model estimation.

4.1 Calibration of Tax Rates and the Household

The tax schedule for households in the United States is non-linear, with several different statutory tax rates. In addition, there can be a large difference between effective and statutory tax rates. I follow Gourio and Miao (2008) and assume the representative household falls in the 25% federal income tax bracket in 2003. This implies that the household faces a 25% tax rate on dividends and a 20% tax rate on capital gains. Although, it has been found that dividend income is skewed towards upper income households, a large share of equity is held by low-tax institutional investors such as pension funds, so a tax rate of 25% on dividends may not be too low (Poterba (2004)). In reality, capital gains are not taxed until the gain is realized. This may result in a the 20% statutory rate being well above the effective rate on capital gains. In the model presented here, capital gains are realized each period. This is a drawback of the model.[10]

Like the tax schedule for households, firms also face a graduated schedule. To simplify the analysis, I assume that firms fall into the bracket facing a tax rate of 34%. This is the statutory rate for firms earning $75,000 to $10MM in income in 2003. While there exist firms in the highest tax bracket in the Compustat data and in the model, the effective tax rate is likely to be lower than the effective tax rate for corporations.[11]

State taxes on firms and households are ignored. Including the varying tax rates and schedules of the states and accounting for the location of the marginal investor is beyond the scope of the paper.

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.

[10] A possible extension is to estimate the effective tax rates as part of the model estimation.

[11] Again, estimation of the effective tax rate, in this case on corporations, would be an interesting extension.

To summarize, the following are the marginal tax rates faced by households and firms in the model I estimate: $\tau_i = 0.25$, $\tau_d = 0.25$, $\tau_g = 0.20$, and $\tau_c = 0.34$.

4.2 Estimation of the Profit Function and Productivity Process

Assuming $F(k, l, z) = zk^{\alpha_k} l^{\alpha_l}$ then 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:

$$ln(\pi_{i,t}) = \alpha_0 + \alpha_1 ln(k_{i,t}) + \eta_{i,t}, \tag{4.1}$$

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:

$$ln(\pi_{i,t}) = \alpha_0 + \alpha_1 ln(k_{i,t}) + b_t + e_{i,t} \tag{4.2}$$

Running the regression specified by Equation 4.2 identifies the parameter $\alpha_1 = \frac{\alpha_k}{(1-\alpha_l)}$. I set α_l equal to 0.65, following Gourio and Miao (2008). Thus I find $\alpha_k = 0.297$ using Compustat data from 1988-2002.

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

$$z_{i,t} = \rho z_{i,t-1} + u_{i,t}, \tag{4.3}$$

where $u_{i,t} \sim N(0, \sigma)$. I find $\hat{\rho}$=0.761 and $\hat{\sigma}$=0.213.

The rate of time preference is set to a value such that the after tax interest rate is 4%, thus $\beta = 0.971$. The rate of physical depreciation, δ is set to match the aggregate investment to capital ratio; 0.154.

Table 6: **Parameter Values: Parameters found outside SMM**

Moment	Value	Std. Error
β	0.971	-
δ	0.154	-
α_l	0.650	-
α_k	0.297	(0.001)
ρ	0.761	(0.003)
σ_z	0.213	(0.001)

4.3 Estimation of Real and Financial Frictions

4.3.1 Specification of Real and Financial Frictions

An important contribution of this paper is the estimation of the real and financial frictions while allowing for non-convexities in both. As I discuss in Section 1, these costs are important for explaining investment behavior and, given the facts, non-convexities are likely to play an important role. Cooper and Ejarque (2003) and Whited (2006) allow for non-convexities in the financial frictions firms face. While Whited (2006) finds evidence of such frictions, Cooper and Ejarque (2003) find no financial frictions, but the presence of market power. However, neither paper allows for non-convexities on the real side. Such non-convexties play an important role in investment behavior at the plant level (see, for example, Cooper and Haltiwanger (2006)), and likely have a role at the firm level as well.

I specify the costs of adjusting capital in two ways. In the convex case, I use the ubiquitous quadratic cost of adjustment function:

$$\upsilon(k_t, k_{t+1}) = \frac{\psi i_t^2}{k_t} \tag{4.4}$$

In the non-convex case, real costs are given by:

$$\upsilon(k_t, k_{t+1}) = \begin{cases} (F * k) + \frac{\psi i_t^2}{k_t}, & \text{if } i_t \neq 0; \\ 0, & \text{if } i_t = 0; \end{cases} \tag{4.5}$$

Following Gomes (2001), Cooper and Ejarque (2003), and Whited (2006) I allow for fixed and marginal costs of equity issuance. Financial frictions take the form:

$$\Phi(s) = \phi_0 \mathbf{1}_{\{s>0\}} + \phi_1 s, \tag{4.6}$$

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

4.3.2 SMM Algorithm

After estimating the profit function and the process for the idiosyncratic productivity shocks, I use a simulated method of moments procedure (SMM) to identify the parameters of the cost functions given in 4.4-4.6.

The parameters $\Theta = (\psi, F, \phi_0, \phi_1)$ are estimated using an SMM approach as described in McFadden (1989). The choice of SMM is clear since estimation based off of the Euler equations cannot be done with non-convex costs and because firms transition between financing regimes, resulting in another non-continuity in the decision rules.

The SMM estimation has the following algorithm: Given the parameters of the profit function and productivity process, a wage rate, w, and a vector Θ, the dynamic programming problem (DPP) of the firms is solved. The solution to the DPP is a set of policy functions determining the firm's optimal choice of investment, dividend distribution and equity issuance given their productivity and capital stock and the market wage. The policy functions are used to solve for the stationary distribution of firms over capital and productivity. From the stationary distribution, I check to see if markets clear. If not, then the wage is updated using a bisection method. The DPP is solved again and a new stationary distribution is found. Once markets clear, I calculate a set of moments. If the data moments and the model moments do not match the vector or parameters is updated using a simulated annealing algorithm (Ferrier, Goffe, and Rogers (1994)). This algorithm is well suited to finding global maxima in highly non-linear problems such as this. Call the vector of simulated moments $\Psi^s(\Theta)$.

The estimate, $\hat{\Theta}$, is the vector of parameters minimizing the weighted distance between

$\Psi^s(\Theta)$ and the vector of moments from the data, Ψ^d. Formally, $\hat{\Theta}$ solves:

$$\pounds(\Theta) = min_{\Theta}[\Psi^d - \Psi^s(\Theta)]' W [\Psi^d - \Psi^s(\Theta)] \tag{4.7}$$

In Equation 4.7, W is the optimal weighting matrix, calculated as the inverse of the variance-covariance matrix of the moments, following Gourieroux, Monfort, and Renault (1993). The variance-covariance matrix is found by bootstrapping the moments from the data. Using the SMM procedure with the optimal weighting matrix ensures consistent and efficient estimates of Θ. Table 7 summarizes the parameters to be estimated in Stage 2.

Table 7: Parameters to be Estimated

Parameter	Definition
ψ	Coefficient on quadratic costs of investment
F	Fixed cost of investment
ϕ_0	Fixed cost to issuing equity
ϕ_1	Marginal cost to issuing equity

4.3.3 Moments and Identification

Identification of the real frictions, (ψ, F), and the financial frictions, (ϕ_0, ϕ_1), is achieved by use of the following moments: the correlation between the investment rate and profits shocks, the mean investment rate, the serial correlation of the investment rate, the standard deviation of the investment rate, the serial correlation of new equity issues, and the correlation of equity issues and investment. The values of these moments measured from the Compustat annual files from 1988-2002 are presented in Table 8.

Each moment is affected by each parameter to some extent. Still, one can understand which moments are most important in identifying certain parameters of the model. If the

Table 8: Data Moments

Variable	Compustat Value	Std. Error
Corr Investment and Profit Shocks	0.244	(0.001)
Mean Investment Rate	0.281	(0.001)
Serial Corr Investment Rate	0.555	(0.003)
Std Dev Investment Rate	0.251	(0.002)
Serial Corr New Equity Issues	0.155	(0.003)
Corr Equity Issues and Investment	0.192	(0.004)

correlation between investment and productivity is high, this implies either low quadratic costs of adjustment or the existence of non-convexities in the costs of adjusting capital. The mean investment rate is affected by the overall size of the costs to adjusting capital. Large fixed costs induce firms to make large changes to their capital stock at once, but to have many periods where they do not undertake any investment. Large quadratic costs of adjustment lead firms to make small investments over many periods. Clearly, these different adjustment costs lead to differences in the standard deviation of investment rates. The serial correlation of the investment rates help to pin down both the size and nature of the real costs of adjustment. If the costs of adjustment are quadratic, firms try to spread investment out over several periods, leading to a higher serial correlation of the investment rate. On the other hand, if non-convexities are present, firms make large investments in a single period, leading to a low serial correlation. The correlation of equity issues and investment helps to capture the size of financial frictions. Larger marginal or fixed costs to external finance lead one to decrease equity issuance and fund investment internally. The serial correlation of equity issuance is important in identifying the fixed costs involved in issuing equity in the same way the serial correlation of investment rates was important in identifying the nature of the real costs of adjustment faced by firms.

5 Results of SMM Estimation

Looking at Table 9, one can see the estimates of the cost of adjustment parameters are reasonable. My estimates of ψ range from 0.565 to 1.471. Bayraktar, Sakellaris, and Vermeulen (2005) report a ψ of 0.532 when estimating a model with quadratic and real costs of adjustment and costly external financing. Gourio and Miao (2008) find a value of $\psi = 1.08$. My estimate of the fixed cost of adjustment ranges from 0.001 to 0.031. Bayraktar, Sakellaris, and Vermeulen (2005) estimate F to be 0.031. Cooper and Haltiwanger (2006) use plant level data and find an F between 0.039 and 0.069.

The estimates of the fixed cost to issuing equity are larger than seen elsewhere in the literature. Gomes (2001) sets the fixed costs equal to 0.08 and Whited (2006) sets it equal to 0.04. I estimate values between 0.185 and 0.241. The marginal costs of issuing equity

Table 9: Parameter Estimates from SMM

Model	ψ	F	ϕ_0	ϕ_1
No Cost	0	0	0	0
ψ	0.955	0	0	0
ψ, ϕ_0	0.643	0	0.241	0
ψ, ϕ_0, ϕ_1	0.602	0	0.194	0.063
ψ, F	1.471	0.003	0	0
ψ, F, ϕ_0	0.565	0.031	0.212	0
ψ, F, ϕ_0, ϕ_1	0.611	0.001	0.185	0.015

ranges from 0.015 to 0.067 in my estimation. These values are not out of line with the literature. Gomes (2001) and Whited (2006) set the marginal cost of issuing equity equal to 0.028 and 0.0264, respectively.

Table 10 presents actual values of the moments in the data along with the moments from the models I consider. The last column reports the J-statistic (Hansen and Singleton (1982)) for each model. Clearly, a model without frictions is dominated by any model that includes real or financial costs. Most models match the correlation between investment rates and productivity shocks and the size of the mean investment rate reasonably well. Models with financial frictions are better at capturing moments characterizing the financial behavior of firms. While no model closely matches the correlation between investment and new equity issues, several models do generate a standard deviation of new equity issue rates near the value found in the data. The model with quadratic costs of adjustment is the only model where the serial correlation of investment rates and the standard deviation of investment rates are close to the data values. However, this model performs the worst at matching the correlation of investment rates and profits shocks. A large ψ helps to generate the high serial correlation, but means that there will be a high correlation between investment and productivity. Using the J-statistic as the criterion, the best fitting model is the model with quadratic and fixed real costs and a fixed cost to equity issuance. However, several models produce J-statistics close to the statistic for this model and this model severely misses matching the serial correlation of investment rates and the correlation of investment and new equity issues.

The fit of the models is poorer than the fit of the models in Hennessy and Whited (2007) and Cooper and Ejarque (2003), who both use SMM to estimate the costs of equity

Table 10: Data Versus Model Moments

Model	Corr ($\frac{i}{k}, z$)	Mean $\frac{i}{k}$	Corr ($\frac{i_t}{k_t}, \frac{i_{t-1}}{k_{t-1}}$)	Std Dev $\frac{i}{k}$	Corr ($\frac{s_t}{k_t}, \frac{s_{t-1}}{k_{t-1}}$)	Corr (i, s)	$J(\Theta)$
Data	0.244	0.281	0.555	0.251	0.155	0.192	-
No Cost	0.140	8.121	-0.006	90.720	-0.006	0.734	3.46E+08
ψ	0.801	0.176	0.603	0.216	0.474	0.306	14,973.788
ψ, ϕ_0	0.237	0.252	-0.093	0.463	0.049	0.712	5,843.254
ψ, ϕ_0, ϕ_1	0.256	0.245	-0.043	0.454	0.116	0.617	5,866.797
ψ, F	0.258	0.156	0.067	0.094	0.031	0.825	6,186.813
ψ, F, ϕ_0	0.251	0.280	0.001	0.520	0.156	0.682	5,176.118
ψ, F, ϕ_0, ϕ_1	0.248	0.245	-0.074	0.454	0.092	0.615	5,886.717

floatation. Reasons for the poor fit are many. Most obviously, the model maybe misspecified or the moments poorly chosen. An additional reason is the way in which I estimate the model. By using the 2-stage estimation, I tie my hands when estimating the frictions. In contrast, both Hennessy and Whited (2007) and Cooper and Ejarque (2003) estimate the firm's profit function and the production process as part of the SMM procedure.[12] The third reason the models may not fit well is because the tax rates are not calibrated correctly. As discussed in Section 4.1, there may be large differences between statutory and effective tax rates. Estimating the effective tax schedule as part of the estimation, as in Hennessy and Whited (2007), may improve the model fit considerably.

In spite of the caveats above, I use the best fitting model to conduct two policy experiments in the next section.

6 Policy Experiments

Using the parameter estimates from the best fitting model ($\psi = 0.565$, $F = 0.031$, and $\phi_0 = 0.212$), I calculate the long-run impact of two unanticipated changes in tax policy. The first is the change in policy brought forth in the Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA). Second, I calculate the effects of the tax proposal made by President Obama during his campaign. I calculate the steady-state values of the aggregates under the

[12] Cooper and Haltiwanger (2006) give an argument as to why estimating the profit function with the frictions may be important. While their argument mostly applied to models where the non-convexities come from disruption costs (as opposed to the fixed costs in my model), there is still the potential for the results of the Stage 1 estimation to be biased in non-convexities are present. In light of this concern, I present the 2-stage estimation here, as it makes the SMM estimation faster and less susceptible to returning local minima, a concern with the larger parameter space necessary to estimate the profit function, productivity process, and frictions simultaneously.

Table 11: Long Run Impact of JGTRRA

Aggregate	Change From Pre-2003
%Δ Capital	6.817
%Δ Output	1.797
%Δ Cons.	2.578
%Δ Wage	1.963
%Δ Adj. Costs	12.065

three tax regimes (pre-JGTRRA, post-JGTRRA, post-Obama) and compare the values of these aggregates across regimes.

6.1 JGTRRA

The JGTRRA made two important changes in tax policy. The act reduced the marginal tax rate on capital gains from 20% to 15% for those in the top four tax brackets (those facing marginal tax rates of 25, 28, 33, and 35 percent). In addition, the act changed the taxation of dividend income. Previously, dividend income was taxed as ordinary income. Following the JGTRRA, dividend income is taxed at the same rate as capital gains. Thus for the representative household in the model, τ_d fell from 25% to 15% and τ_g fell from 20% to 15% as a result of the JGTRRA. Notably, the JGTRRA both reduced tax rates and eliminated the tax wedge between internal and external financing.

Table 11 reports the percent change in the equilibrium values of the aggregates following the JGTRRA. The response of the the aggregate capital stock to the change in tax policy is large. In fact, the value of 6.817 is over 75% larger than the value reported in Gourio and Miao (2008). The main difference between the model I use to generate this result and model Gourio and Miao (2008) use lies in the frictions. I find important non-convexities in the real and financial costs. These non-convexities result in tax policy affecting both the intensive and extensive margins of firms. Investment is highly responsive to tax policy in my model.

While promoting capital formation, the JGTRRA does not increase welfare, which is measured by consumption, by such a large percentage. Increases in investment translate into more output, but more of the output is used towards the adjustment costs incurred when undertaking investment.

Table 12: **Long Run Impact of Obama's Tax Proposal**

Aggregate	Change From Pre-2003	Change from JGTRRA
%Δ Capital	3.973	-2.662
%Δ Output	1.155	-0.630
%Δ Cons.	2.099	-0.466
%Δ Wage	1.325	-0.625
%Δ Adj. Costs	10.225	-1.642

6.2 The Obama Plan

President Obama's fiscal plans include increasing the tax rate on capital gains and dividend income from 15% to 20% for those in the top two tax brackets (Burman, Khitatrakun, Leiserson, Rohaly, Toder, and Williams (2008)). In this subsection, I analyze the long run effects of such changes in tax policy. I compare the stationary equilibrium values of the aggregate capital stock, output, consumption, wage rate, and adjustment costs to their equilibrium values under the pre-2003 tax regime and their equilibrium values under the JGTRRA tax rates.

Relative to the tax rates on capital gains and dividends in the pre-JGTRRA world, Obama proposes marginal rates of equal or lesser value. Obama plans to tax capital gains and dividends at a rate of 20% for those in the top four tax brackets. Thus under Obama, as under the JGTRRA, there is no tax wedge between internal and external funding. The second column of Table 12 displays the percent changes in the aggregates under Obama's plan, using the pre-2003 tax rates as a baseline. Obama's plan increases capital formation and output, but not as much as the JGTRRA cuts. In third column, one can see the differences between the long run values of the aggregates under the the JGTRRA tax plan and under the Obama tax plan. The first two rows show the lower capital formation and output under the Obama plan. However, the Obama plan dominates the JGTRRA tax plan on welfare grounds. Obama's plan does not encourage as much investment as the JGTRRA rates, but the fall in consumption is not as large as the drop in investment.

7 Conclusion and Suggestions for Further Research

This paper analyzes the extent to which the aggregate effects of tax policy depend on real and financial frictions in a general equilibrium model with heterogenous firms. Understanding how tax policy affects the investment decisions of firms is important, since the government, should it decide to tax capital, has many tools from which to choose. I determine how frictions interact with three of these tools: taxes on dividend income, taxes on capital gains, and taxes on corporate income. In addition, I estimate the actual frictions faced by firms and use the results to evaluate changes in tax policy; one recent and one proposed.

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 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.

Others suggest the investment behavior of firms, and, in particular, the intermittent pattern of investment and the lack of sensitivity of the investment rate to Q, reflect *either* imperfections in capital markets *or* non-convexities in the costs of adjustment. I allow for both non-convexities in the cost of adjustment and financial frictions. The estimation results support a view where both real and financial frictions play a significant role in explaining the investment and financing behavior of firms.

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 heterogenous 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 also suggests several directions for future research. Contrary to the model presented here, changes in tax policy are often predictable. 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 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:

$$\left[\frac{-4\sigma}{\sqrt{1-\rho^2}}, \frac{4\sigma}{\sqrt{1-\rho^2}}\right] \tag{A.1.1}$$

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

$$\left[\underline{\mathrm{k}}..., (1-\delta)\bar{k}, (1-\delta)^{1/2}\bar{k}, (1-\delta)^{1/3}\bar{k}, (1-\delta)^{1/4}\bar{k}, \bar{k}\right], \tag{A.1.2}$$

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