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ABSTRACT

To study the long-run effect of dividend taxation on aggregate capital accumulation, we build a dynamic general equilibrium model in which there is a continuum of firms subject to idiosyncratic productivity shocks. We find that a dividend tax cut raises aggregate productivity by reducing the frictions in the reallocation of capital across firms. Our baseline model simulations show that when both dividend and capital gains tax rates are cut from 25 and 20 percent, respectively, to the same 15 percent level permanently, the aggregate long-run capital stock increases by about 4 percent.

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1 Introduction

Dividends are taxed at both the corporate and personal levels in the United States. This double taxation of dividends may distort investment efficiency. Partly motivated by this consideration, the United States Congress enacted the Jobs and Growth Tax Relief Reconciliation Act (JGTRRA) in 2003. This act reduced the tax rates on dividends and capital gains and eliminated the wedge between these two tax rates through 2008. Because one primary goal of JGTRRA is to promote long-run capital formation, these tax cuts could be made permanent. In this paper, we ask the following question: What is the quantitative long-run effect of the 2003 dividend tax reform on aggregate capital accumulation?

This question is of significant interest to both economists and policymakers. Economists disagree about the economic effects of dividend taxation on investment. Two views are prevalent.[1] The key consideration is the marginal source of investment finance. Under the "new view," firms use internal funds to finance investment and do not raise new equity. Thus, dividend taxation does not influence the user cost of capital and investment (Auerbach (1979a,b), Bradford (1981), and King (1977)). Under the "traditional view," the marginal source of funds is new equity and the return to investment is used to pay dividends. A dividend tax cut reduces the user cost of capital and hence raises investment. Empirical evidence on these two views is inconclusive. For example, Poterba and Summers (1983, 1985) find evidence supporting the traditional view using data from the UK, and Desai and Goolsbee (2004) find evidence supporting the new view using data from the US. However, Auerbach and Hassett (2002) show that in US data firms behave according to both views, an indication of substantial heterogeneity in the data.

Our paper builds on the existing literature on dividend taxation in two distinct ways. First, we embed the traditional single-firm model used in empirical studies in a computable dynamic general equilibrium framework.[2] Second, we incorporate a continuum of heterogeneous

[1] There is the third "tax irrelevance" view proposed by Miller and Scholes (1978, 1982). According to this view, marginal investors do not face differential tax rates on dividends and capital gains. Thus, dividend taxation has no effect on investment. This view has been generally rejected by empirical evidence. See Auerbach (2002), Gordon and Dietz (2006), or Poterba and Summers (1985) for an exposition of the three views.

[2] See Auerbach (1979a) for an early overlapping generations model of dividend taxation with a single firm. See Auerbach and Kotlikoff (1987) for an important comprehensive study of fiscal policy in dynamic general equilibrium models. Also see Barro (1989) and Baxter and King (1993) for a general equilibrium analysis of government purchases and the financing of these purchases.

firms in the model. These firms are subject to idiosyncratic productivity shocks.[3] This firm heterogeneity plays a key role in our analysis. Specifically, at any point in time, depending on its productivity and its capital stock, a firm finds itself in one of three finance regimes. In the equity issuance regime, the marginal source of finance is new equity, which reflects the traditional view of dividend taxation. In the dividend distribution regime, the marginal source of finance is retained earnings, which reflects the new view of dividend taxation. Finally, in the liquidity constrained regime, the firm's investment is limited to the amount of retained earnings. Importantly, because of firm heterogeneity, at any point in time different firms may be in different finance regimes, and hence respond to the dividend tax cut in different ways.

We show that if there were a representative firm in the economy, dividend taxation would have no effect on long-run capital accumulation, and this highlights the importance of heterogeneity to our results. A representative firm would, in a deterministic steady state, behave according to the new view of dividend taxation and would use internal funds rather than equity as its source of financing. We document empirical evidence that firms' investment and financing patterns are different in different finance regimes, and that the distribution of firms across different finance regimes changed following the 2003 tax reform. This evidence supports our model mechanism.

We use our calibrated model to provide a quantitative evaluation of the long-run effects of the dividend and capital gains tax cuts enacted in 2003.[4] We assume that the benchmark tax system in the initial steady state reflects the federal statutory tax rates in 2003 before the tax cuts. Because the redistributive effect of the tax cuts is not our focus of study, we assume that there is a representative household who owns all firms in the model. This household has an average income which falls in the 25 percent federal income tax bracket in 2003. It then faces the 25 percent dividend tax rate and the 20 percent capital gains tax rate under the 2003 tax system before the tax cuts.[5] In our baseline model, we suppose that the 2003 tax cuts are permanent, lowering both dividends and capital gains tax rates to the 15 percent level. In this

[3] In the empirical industrial organization literature, many researchers have found firm level productivity differences are large and persistent (see Bartelsman and Dunne (2001) for a survey).

[4] The Congressional Budget Office (CBO) uses several models to evaluate JGTRRA. CBO's (2003) estimates are based on an average of model results using two sets of model inputs with one set reflecting the traditional view and the other set reflecting the new view.

[5] Although dividend taxes are skewed towards upper income households, our calibrated 25 percent tax rate is not too low since a large share of equity is held by low-tax institutional investors such as pension funds (see Poterba (2004)).

case, the long-run aggregate capital stock rises by about 4 percent. When we restrict the tax cut to dividends alone, the effect is much smaller: A permanent reduction of the dividend tax rate from 25 to 20 percent raises the long-run capital stock by about 0.5 percent. We show that these increases may be smaller when we extend the baseline model to incorporate a revenue-neutral shift from dividend taxation to labor income taxation, debt financing, transactions costs of external finance, and share repurchases.

We find that a dividend tax cut has a reallocation effect that generates productivity gains because the dividend tax acts as a friction in the allocation of capital. The intuition is that after a dividend tax cut, some previously liquidity constrained firms move to the equity issuance regime. These firms are more productive, issue new equity, and invest in more capital. Removing the wedge between the tax rate on dividends and the tax rate on capital gains makes the allocation of factors across firms more efficient.

The general equilibrium price feedback effect is important for our results. Specifically, the increase in aggregate capital raises the aggregate demand for labor and hence raises the equilibrium wage. The increased wage lowers profits and the returns to investment and thus dampens the positive effect of the dividend and capital gains tax cuts. To assess the dampening effect of general equilibrium price movements quantitatively, we fix the wage rate at its level prior to the tax cuts and show that the increase in aggregate capital after the tax cuts in partial equilibrium could be six times larger than that in general equilibrium.

Our paper is related to a vast literature on investment and dividend taxation in public finance, corporate finance, and macroeconomics. To our knowledge, our paper provides the first computable dynamic general equilibrium model with firm heterogeneity to evaluate the 2003 dividend tax cut. We show both heterogeneity and general equilibrium price movements are critical to a proper quantitative assessment of this issue. Our model framework is related to Gomes (2001), who analyzes the issue of investment-cash flow sensitivity,[6] although, in contrast to our work, he does not address taxation or tax policy. We extend his model to incorporate both personal and corporate taxation as well as adjustment costs. While both models feature three finance regimes, the three finance regimes in our model are generated through differential tax treatments on dividends and capital gains, as opposed to transaction costs of external

[6] There is a large empirical literature on the investment-cash flow sensitivity (e.g., Cooper and Ejarque (2003), Fazzari et al. (1988), Gilchrist and Himmelberg (1995), Hennessy and Whited (2007), and Moyen (2004)). This literature argues that external finance is costly because of taxes, asymmetric information, and transactions costs.

financing modeled in Gomes (2001).

Our paper is also related to House and Shapiro (2006), who analyze the quantitative effects of the timing of the tax rate changes enacted in 2001 and 2003. Unlike our paper, they assume a representative firm in the model and do not consider the question we analyzed here. Korinek and Stiglitz (2008) provide a partial equilibrium model to study the effects of dividend taxation on investment. They show that firm heterogeneity implies that a dividend tax cut has a small effect on aggregate investment. Unlike our model, their model lacks the general equilibrium mechnasim.

The remainder of the paper is organized as follows. Section 2 documents evidence on the changes in corporate behavior after the 2003 dividend tax cut. Section 3 sets up the model. Section 4 analyzes a single firm's decision problem and the effects of dividend taxation in partial equilibrium. Section 5 provides quantitative results. Section 6 considers several extensions. Section 7 concludes. Technical details regarding model solution and data construction are relegated to appendices.

2 Empirical Evidence on Corporate Behavior from the 2003 Dividend Tax Cut

The 2003 JGTRRA makes two major changes in tax law. First, the capital gains tax rate is reduced from the previous 20 percent for individuals in the top four tax brackets (facing marginal tax rates of 25, 28, 33 and 35 percent) to 15 percent. It is reduced from the previous 10 percent for individuals in the lower two tax brackets (facing marginal tax rates of 10 and 15 percent) to 5 percent. Second, dividends are taxed at the same rate as capital gains. In particular, dividends are taxed at the rate of 15 percent for individuals in the top four tax brackets. Dividends were previously taxed as regular income. In this section, we document empirical evidence on the effects of the 2003 dividend tax cut on corporate investment and financing behavior. This evidence complements the findings of Chetty and Saez (2005). Our data are drawn from the COMPUSTAT database. Appendix A describes the construction of our data in detail.

We sort firms according to their finance regimes: firms distributing dividends (dividend distribution regime), firms issuing new equity but not paying dividends (equity issuance regime), and firms neither issuing new equity nor paying dividends (liquidity constrained regime). Because many firms in our data issue very small amounts of equity, we say that a firm issues new equity if the ratio of equity issuance to the capital stock is greater or equal to 2%.[7] We find that about 20 percent of firms in our data in any given year both distribute dividends and issue new equity. This behavior is puzzling for the standard theory based on taxes, since it implies that there exists a profitable opportunity to reduce both dividends and equity issuance. As Bond and Meghir (1994) argue, the observed behavior may be explained by transactions costs or signaling theory (e.g., Bhattacharya (1979)). Since the objective of our study is not on the preceding "dividend puzzle," we group these firms into the dividend distribution regime.

We compute the investment-to-capital ratio in any year for firms in each finance regime as their total investment in that year divided by their total capital in that year. Similarly, we compute ratios of earnings to capital and Tobin's q in a year for firms in each finance regime. Table 1 presents the average across years from 1988 to 2002 before the dividend tax cut.

Table 1. Distribution of firms across finance regimes in the data (average over 1988-2002). The share of firms for a regime is equal to the total number of firms in that regime divided by the total number of firms in all regimes. The share of capital (resp. investment) for a regime is equal to the total capital stock (resp. investment) of the firms in that regime divided by aggregate capital stock (resp. investment) of all firms. The earnings-capital ratio for a regime is equal to the earnings of the firms in that regime divided by their total capital stock, i.e. it is capital-weighted. The investment-capital ratio and Tobin's q are computed in a similar way.

	Equity issuance regime	Liquidity constrained regime	Dividend distribution regime
Share of firms	0.230	0.297	0.474
Share of capital	0.028	0.059	0.913
Share of investment	0.039	0.057	0.904
Earnings-capital ratio	0.567	0.275	0.355
Investment-capital ratio	0.290	0.193	0.194
Tobin's q	3.768	1.784	2.837

Table 1 reveals that, on average, about half of the firms pay dividends. The rest is divided into two approximately equal-sized groups: firms which issue equity, and firms which do not.

[7] Changing this threshold to 1% does not affect our results significantly.

Consistent with the existing literature (e.g., Loughran and Ritter (1997) and Lyandres, Sun, and Zhang (2007)), this table shows that firms issuing equity are significantly more productive than the rest, as measured by the earnings-to-capital ratio. These firms are small (measured by capital) and have high Tobin's q. Apparently, these "growth firms" are productive, have good investment opportunities, and require external finance to make investments. The two other groups have similar investments, but the firms paying dividends have higher Tobin's q and higher productivity.

Turn to the corporate behavior after the 2003 dividend tax cut. We find that aggregate dividends increased significantly as documented by Chetty and Saez (2005). According to the National Income and Product Accounts, the ratio of dividends to GDP increased from 3.86 percent (the average over 1988-2002) to 5.29 percent (the average over 2003-2006). In our COMPUSTAT sample, the aggregate dividend-capital ratio jumped up in 2004, as displayed in the top left panel of Figure 1. The other three panels in the figure reveal that aggregate equity issuance, aggregate investment, and aggregate earnings (all normalized by the aggregate capital stock) rose significantly, following the 2003 dividend tax cut. In addition, the four panels in Figure 1 show that the aggregate dividend-to-capital ratio is relatively smooth, but the aggregate equity issuance-to-capital, investment-to-capital, and earnings-to-capital ratios are procyclical and highly volatile.

[Insert Figure 1 here]

We finally consider the cross-sectional statistics after the dividend tax cut for the sample period from 2004 to 2006. Table 2 presents the results. We see that the number of firms issuing equity rose after the 2003 dividend tax cut. These firms account for a larger share of aggregate investment. In addition, the number of firms paying dividends also rose. This evidence is consistent with the empirical findings of Chetty and Saez (2005).

Table 2. Distribution of firms across finance regimes in the data (average over 2004-2006) The share of firms for a regime is equal to the total number of firms in that regime divided by the total number of firms in all regimes. The share of capital (resp. investment) for a regime is equal to the total capital stock (resp. investment) of the firms in that regime divided by aggregate capital stock (resp. investment) of all firms. The earnings-capital ratio

for a regime is equal to the earnings of the firms in that regime divided by their total capital stock, i.e. it is capital-weighted. The investment-capital ratio and Tobin's q are computed in a similar way.

	Equity issuance regime	Liquidity constrained regime	Dividend distribution regime
Share of firms	0.283	0.173	0.544
Share of capital	0.034	0.070	0.896
Share of investment	0.044	0.057	0.900
Earnings-capital ratio	0.784	0.336	0.455
Investment-capital ratio	0.231	0.148	0.182
Tobin's q	3.396	1.913	2.876

Figure 2 plots the shares of firms in each finance regime since 1988. Following the 2003 dividend tax cut, the share of firms in the liquidity constrained regime fell and the shares of firms in the equity issuance and dividend distribution regimes rose. In the next section, we will present a model that produces this effect. We will show that the change in the firm distribution across finance regimes is important for understanding our model mechanism.

[Insert Figure 2 here]

3 The Model

We embed a standard investment model with adjustment costs widely used in the literature of dividend taxation (e.g., Desai and Goolsbee (2004), Fazzari et al. (1988), and Poterba and Summers (1983, 1985)) in a general equilibrium framework similar to Gomes (2001). The model economy consists of a continuum of corporate firms, a representative household, and a government. Time is discrete and denoted by $t = 0, 1, 2, ...$ Assume that there is no aggregate uncertainty and that firms face idiosyncratic productivity shocks. By a law of large numbers, all aggregate quantities and prices are deterministic over time, although at the firm level each firm still faces idiosyncratic uncertainty. We will focus on steady-state stationary equilibrium in which all aggregate variables are constant over time.

3.1 Firms

We begin by describing the firms' decision problem. Firms are ex ante identical and are subject to idiosyncratic productivity shocks. They differ ex post in that they may experience different histories of productivity shocks. Assume that these shocks are generated by a Markov process with transition function given by $Q : Z \times \mathcal{Z} \rightarrow [0,1]$, where $(Z, \mathcal{Z})$ is a measurable space.

In order to focus on the key issue of dividend taxation in the simplest possible way, we make two assumptions. First, we consider flat taxes with full loss offset provisions as in most papers in the literature. In particular, we assume that firms face corporate income tax at the constant rate τ_c, while individuals face constant tax rates τ_d on dividends, τ_i on labor and interest income, and τ_g on accrued capital gains.[8] Second, we abstract from debt and assume that firms are all equity financed as in Auerbach and Hassett (2002), Desai and Goolsbee (2004), and Poterba and Summers (1985). Incorporating debt financing would complicate our analysis since we would need to include debt as an additional state variable in the dynamic programming problem (8) below. A simple way to incorporate debt financing is to assume that a fixed fraction of capital is financed by debt as in Poterba and Summers (1983). We will consider this extension in Section 6.2.

Because all firms are ex ante identical, we first consider a single firm's decision problem and then study aggregation. In order to formulate this problem, we first derive the firm's equity valuation equation. Let the ex-dividend equity value be P_t at date t. In equilibrium, the following no arbitrage equation must hold:

$$R_t = \frac{1}{P_t} E_t \left[(1 - \tau_d) \, d_{t+1} + (1 - \tau_g) \left(P_{t+1}^0 - P_t \right) \right], \tag{1}$$

where $E_t [\cdot]$ denotes the expectation operator conditional on the firm's history of idiosyncratic shocks, R_t denotes the required return to equity, d_{t+1} is the firm's dividend payment, and P_{t+1}^0 is the period $t+1$ value of equity outstanding in period t. The firm may issue new shares or repurchase old shares. Thus, equity value at date $t+1$ satisfies $P_{t+1} = P_{t+1}^0 + s_{t+1}$, where s_{t+1} denotes the value of issued new shares (repurchases) if $s_{t+1} \geq (<) \, 0$. Many researchers argue that external equity financing is costly due to asymmetric information or transactions costs. In the baseline model here, we do not consider such costly external financing. Instead, we consider this issue in Section 6.3.

We will show later that since there is no aggregate uncertainty, the steady-state equilibrium required return to equity satisfies:

$$R_t = (1 - \tau_i) \, r. \tag{2}$$

[8] In the U.S., capital gains are taxed on realization rather than on accrual. Incorporating a realization-based capital gains tax would complicate our analysis significantly and is not important in this context.

where r is the steady-state equilibrium interest rate. Using equations (1)-(2), we can derive:

$$P_t\left[\left(1-\tau_i\right)r+1-\tau_g\right]=E_t\left[\left(1-\tau_d\right)d_{t+1}+\left(1-\tau_g\right)\left(P_{t+1}-s_{t+1}\right)\right]. \tag{3}$$

We define the cum-dividend equity value V_{t+1} as:

$$V_{t+1}=P_{t+1}-s_{t+1}+\frac{1-\tau_d}{1-\tau_g}d_{t+1}. \tag{4}$$

Using (3), we can then show that

$$V_t=\frac{1-\tau_d}{1-\tau_g}d_t-s_t+\frac{E_t\left[V_{t+1}\right]}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}. \tag{5}$$

We will use this equation to formulate the firm's dynamic programming problem.

The firm combines labor and capital to produce output. Suppose the firm has a decreasing-returns-to-scale production function given by $F\left(k,l;z\right)$, where k, l, and z denote capital, labor and productivity shock, respectively. Assume that $F\left(\cdot\right)$ is strictly increasing, strictly concave, and satisfies the usual Inada conditions. We can then derive the operating profit function $\pi\left(k,z;w\right)$ by solving the following static labor choice problem:

$$\pi\left(k,z;w\right)=\max_{l\geq0}\left\{F\left(k,l;z\right)-wl\right\}, \tag{6}$$

where w denotes the wage. This problem gives the labor demand $l\left(k,z;w\right)$ and the output supply $y\left(k,z;w\right)=F\left(k,l\left(k,z;w\right);z\right)$.

The firm can also make investments x to increase its capital stock so that the capital stock in the next period k' satisfies:

$$k'=\left(1-\delta\right)k+x, \tag{7}$$

where $\delta\in(0,1)$ denotes the depreciation rate. Investments incur adjustment costs. For simplicity, we consider the quadratic adjustment cost function, $\psi x^2/\left(2k\right)$, widely used in the empirical investment literature (e.g., Cooper and Haltiwanger (2006)). The firm's problem is then to choose investment and financial policies so as to maximize its equity value.

Let $V\left(k,z;w\right)$ denote equity value at the state (k,z) given that the equilibrium steady-state wage rate is w. Then by (5), $V\left(k,z;w\right)$ satisfies the following Bellman equation:

$$V\left(k,z;w\right)=\max_{k',x,s,d}\frac{1-\tau_d}{1-\tau_g}d-s+\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}\int V\left(k',z';w\right)Q\left(z,dz'\right), \tag{8}$$

subject to (7) and

$$x+\frac{\psi x^2}{2k}+d=\left(1-\tau_c\right)\pi\left(k,z;w\right)+\tau_c\delta k+s, \tag{9}$$

$$d \geq 0, \tag{10}$$

$$s \geq 0. \tag{11}$$

Equation (9) describes the flow of funds condition for the firm. The source of funds consists of after-tax profits, depreciation allowances, and new equity issuance. The use of funds consists of investment expenditure, adjustment costs, and dividend payments.[9] Dividend payments cannot be negative. We thus impose constraint (10). There may be further constraints on dividend payments. For example, one may assume that the firm should pay a fraction of earnings as dividends (e.g., Auerbach (2002) and Poterba and Summers (1983)). The motivation for a constraint like this typically comes from asymmetric information problems or agency problems between managers and shareholders, and lies outside the purpose of our present investigation.

While share repurchases are allowed in the United States, there are several reasons to think that share repurchases are either effectively constrained or costly. Regular share repurchases may lead the IRS to treat the repurchases as dividends, thus erasing their tax advantage. Additional repurchase costs may arise as a result of asymmetric information (see, e.g., Brennan and Thakor (1990) and Barclay and Smith (1988)). For simplicity, we follow most papers in the literature to impose constraint (11).[10] Because we rule out share repurchases, the baseline model here cannot address the "dividend puzzle" which asks why firms pay dividends given the tax advantage of share repurchases. In Section 6.4, we will relax this assumption and follow Poterba and Summers (1985) to impose a constraint that share repurchases are bounded by some maximal amount. We refer the reader to Gordon and Dietz (2006) for a survey of models of the dividend puzzle.

By a standard dynamic programming argument (e.g., see Hennessy and Whited (2005), or Stokey and Lucas (1989), one can show that there is a unique value function V satisfying the Bellman equation (8). Also V is continuous, strictly increasing, and strictly concave in k. Thus, there exist unique decision rules denoted by

$$x = x(k, z; w), \ k' = g(k, z; w), \ s = s(k, z; w), \ d = d(k, z; w). \tag{12}$$

[9] Note that we treat the adjustment cost as part of investment expenditures so that it is not tax deductible. One may treat the adjustment cost as part of wage bill so that it is tax deductible. This alternative modeling does not change our key insights.

[10] See, for example, Auerbach (1979b, 2002), Gomes (2001), Bond and Meghir (1994), Desai and Goolsbee (2004), Hennessy and Whited (2005).

3.2 Stationary Distribution and Aggregation

Because there is a continuum of firms that are subject to idiosyncratic shocks, there is a cross sectional distribution μ of firms over the state (k, z). By Stokey and Lucas (1989), the law of motion for the firm distribution is given by:

$$\mu'(A \times B) = \int \mathbf{1}_{g(k,z;w)\in A} Q(z, B)\, \mu(dk, dz), \tag{13}$$

where $\mathbf{1}$ is an indicator function, and A and B are Borel sets. Note that we suppress the dependence of distributions on the wage w. When $\mu' = \mu = \mu^*$, we call μ^* the stationary distribution. Given the stationary distribution μ^*, we can compute the following aggregate quantities:

- aggregate output supply,

$$Y(\mu^*; w) = \int y(k, z; w)\, \mu^*(dk, dz), \tag{14}$$

- aggregate labor demand,

$$L^d(\mu^*; w) = \int l(k, z; w)\, \mu^*(dk, dz), \tag{15}$$

- aggregate investment,

$$I(\mu^*; w) = \int x(k, z; w)\, \mu^*(dk, dz), \tag{16}$$

- aggregate adjustment cost,

$$\Psi(\mu^*; w) = \int \frac{\psi x(k, z; w)^2}{2k} \mu^*(dk, dz). \tag{17}$$

3.3 Household

The representative household derives utility from consumption and leisure according to the standard time-additive utility function:

$$\sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{18}$$

where β is the discount factor, C_t denotes consumption, L_t denotes labor supply, and U satisfies $U_1 > 0$, $U_{11} < 0$, $U_2 < 0$, $U_{22} < 0$, and the Inada conditions. The household owns all firms and trades firms' shares. In addition, the household also trades a risk-free bond in zero net supply. He pays dividend taxes, personal income taxes, and capital gains taxes.[11] Thus, the budget constraint is given by:

$$\begin{aligned} & C_t + \int P_t \theta_{t+1} d\mu_t + b_{t+1} \\ = & \int \left[(1-\tau_d) d_t + P_t^0 - \tau_g \left(P_t^0 - P_{t-1} \right) \right] \theta_t d\mu_t + (1 + (1-\tau_i) r_t) b_t + (1-\tau_i) w_t L_t + T_t, \end{aligned} \tag{19}$$

where θ_t denotes the shares owned by the household, b_t denotes bond holdings, r_t denotes the interest rate, and T_t denotes the transfer from the government. In equilibrium, $\theta_t = 1$ and $b_t = 0$.

The household's problem is to choose consumption, labor supply, and trading strategies to maximize his utility (18) subject to (19). We consider the household problem in a stationary equilibrium in which the interest rate r_t, the wage rate w_t, and aggregate quantities are constant over time. As in Gomes (2001), one can show that in a stationary equilibrium the intertemporal marginal rate of substitution (the pricing kernel) is equal to β. Thus, the interest rate satisfies:

$$\beta \left(r \left(1 - \tau_i \right) + 1 \right) = 1, \tag{20}$$

and the required return to equity is given by (2). In addition, in the steady state, the household's problem can be simplified to the following static problem:

$$\max_{C,L} U \left(C, L \right) \tag{21}$$

subject to

$$\begin{aligned} C = & (1-\tau_d) \int d(k,z;w) \mu^* (dk,dz) - (1-\tau_g) \int s(k,z;w) \mu^* (dk,dz) \\ & + (1-\tau_i) wL + T(w,\mu^*), \end{aligned} \tag{22}$$

where $T(w,\mu^*)$ is the steady-state transfer. This problem gives decision rules for consumption $C(w,\mu^*,T(w,\mu^*))$ and labor supply $L^s(w,\mu^*,T(w,\mu^*))$.

3.4 Government

Because the focus of the paper is on the distortionary effect of dividend taxation on investment, we assume that tax revenues collected by the government are rebated to the household in a

[11] According to the U.S. tax system, capital losses are tax deductible within some limit. For tractability, we ignore this limit in our model.

lump-sum manner. Thus, we abstract from other distortionary effects associated with using distortionary taxation to finance government spending on goods and services. Incorporating government spending would complicate our analysis since a tax cut must eventually be financed with some combination of other tax increases or spending cuts. We also do not consider government debt. The analysis of how the dividend and capital gains tax cut is financed is beyond the scope of the present paper and is left for future research. In Section 6.1, we extend our model to allow for revenue-neutral tax reform by shifting from dividend taxation to labor income taxation.

Because the government collects corporate income taxes, dividend taxes, personal income taxes, and capital gains taxes, and transfers these tax revenues to the household, the government budget constraint is given by:

$$\begin{aligned} T &= \tau_c \int \left(\pi\left(k,z;w\right) - \delta k\right) \mu\left(dk,dz\right) + \tau_d \int d\left(k,z;w\right) \mu\left(dk,dz\right) \\ &\quad + \tau_i w L - \tau_g \int s\left(k,z;w\right) \mu\left(dk,dz\right). \end{aligned} \tag{23}$$

3.5 Stationary Equilibrium

A stationary equilibrium consists of a constant wage rate w, a stationary distribution of firms μ^*, aggregate quantities, $C(\mu^*;w)$, $I(\mu^*;w)$, $\Psi(\mu^*;w)$, $Y(\mu^*;w)$, $L^d(\mu^*;w)$, $L^s(\mu^*;w)$, $T(w,\mu^*)$, and decision rules, $k' = g(k,z;w)$, $x = x(k,z;w)$, $s = s(k,z;w)$, $d = d(k,z;w)$, such that (i) the decision rules solve the firm's problem (8); (ii) $C(w,\mu^*,T(w,\mu^*))$ and $L^s(w,\mu^*,T(w,\mu^*))$ solve the problem by (21); (iii) μ^* satisfies equation (13) and aggregate quantities satisfy equations (14)-(17); (iv) $T(w,\mu^*)$ satisfies the government budget constraint (23); and (v) markets clear,

$$L^d(\mu^*;w) = L^s(\mu^*;w), \tag{24}$$

$$C(\mu^*;w) + I(\mu^*;w) + \Psi(\mu^*;w) = Y(\mu^*;w). \tag{25}$$

4 Analysis of A Single Firm's Decision Problem

In order to analyze the general equilibrium effects of a dividend tax cut, we first analyze a single firm's decision problem in partial equilibrium. We thus fix the wage rate and suppress the variable w throughout this section.

It proves more convenient to rewrite the dynamic programming problem (8) as the following sequence problem:

$$\max_{x_t,k_{t+1},s_t} E\left[\sum_{t=0}^{\infty}\frac{1}{\left(1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)\right)^t}\left(\frac{1-\tau_d}{1-\tau_g}d_t-s_t\right)\right], \tag{26}$$

subject to

$$x_t+\frac{\psi x_t^2}{2k_t}+d_t=\left(1-\tau_c\right)\pi\left(k_t,z_t\right)+\tau_c\delta k_t+s_t, \tag{27}$$

$$k_{t+1}=\left(1-\delta\right)k_t+x_t, \tag{28}$$

$$d_t\geq 0, \tag{29}$$

$$s_t\geq 0. \tag{30}$$

Let q_t, $\lambda_t^d\geq 0$ and $\lambda_t^s\geq 0$ be the Lagrange multipliers associated with the constraints (28)-(30), respectively. As is well known, q_t can be interpreted as the shadow price of capital and is referred to as the marginal q. Using equation (27) to eliminate d_t, we obtain the following first-order conditions:

$$s_t:\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d+\lambda_t^s=1, \tag{31}$$

$$x_t:q_t=\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d\right)\left(1+\frac{\psi x_t}{k_t}\right), \tag{32}$$

$$k_{t+1}\quad:\quad q_t=\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}E_t\left\{q_{t+1}\left(1-\delta\right)+\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_{t+1}^d\right)\left[\left(1-\tau_c\right)\pi_1\left(k_{t+1},z_{t+1}\right)+\tau_c\delta+\frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2\right]\right\}. \tag{33}$$

We also have the usual transversality condition and the complementary slackness condition, which are omitted here for simplicity.

4.1 Financial Policy

We start by analyzing the firm's financial policy, holding the investment policy fixed. This financial policy is determined by equation (31), which has the following interpretation. Raising one unit of new equity to pay dividends relaxes the dividend constraint and the share repurchase constraint. In addition, the shareholder receives $\left(1-\tau_d\right)/\left(1-\tau_g\right)$ units of after-tax dividends. Thus, the expression on the left side of (31) represents the marginal benefit to the shareholder.

On the other hand, one unit increase in new share lowers equity value by one unit and hence the expression on the right side of (31) gives the marginal cost to the shareholder. Equation (31) requires that the preceding marginal benefit and marginal cost must be equal at optimum.

If $\tau_d = \tau_g$, then there is no tax differential between dividends and retained earnings. Equation (31) implies that $\lambda_t^d = \lambda_t^s = 0$. In this case, the firm's financial policy is irrelevant. That is, it does not matter for firm value and investment policy how much earnings to retain for use as internal finance, rather than distributing dividends and raising new equity in the external equity market. More formally, in the firm's problem (26), the payout $d_t - s_t$ can be determined. However, dividends d_t and new equity s_t are indeterminate. This is the celebrated Miller and Modigliani (1961) dividend policy irrelevance theorem.

However, if $\tau_d \neq \tau_g$, then the firm's financial policy matters. Before the 2003 dividend tax cut, the tax rate on dividends in the United States was higher than the tax rate on capital gains, so we assume that $\tau_d > \tau_g$. In this case, it follows from (31) that we cannot have $\lambda_t^d = \lambda_t^s = 0$. That is, it is not optimal for the firm to simultaneously issue new equity and distribute dividends. The intuition is simple. New equity or share repurchases change equity value and hence capital gains. Thus, they are taxed at the capital gains rate τ_g. By contrast, dividends are taxed at a higher rate τ_d. To maximize equity value, the firm should reduce dividends, but repurchase shares to the extent possible. This implies that one of the constraints (10) and (11) must be binding. This observation gives us three cases to consider. Each case corresponds to a different *finance regime* (also see Hennessy and Whited (2005) and Stiglitz (1973)).

In the first case, $d_t > 0$ and $s_t = 0$. We call this case the *dividend distribution regime.* In this regime, the firm has enough retained earnings to finance investment and to distribute dividends. In addition, the firm has exhausted opportunities to repurchase shares so that the share repurchase constraint binds, $s_t = 0$. This regime corresponds to the "new view" of dividend taxation. In the second case, $d_t = 0$ and $s_t > 0$. We call this case the *equity issuance regime.* In this regime, the firm does not have enough internal funds to distribute dividends. Instead, the firm reduces dividends to the extent possible so that the nonnegative dividend constraint binds, $d_t = 0$. In addition, the firm has unused opportunities to repurchase shares in that $s_t > 0$. The marginal source of investment finance is the external equity market. This regime reflects the traditional view of divided taxation. In the third case, $d_t = 0$ and $s_t = 0$.

We call this case the *liquidity constrained regime*. In this regime, the firm exhausts all internal funds to finance investment and hence does not distribute dividends. In addition, the firm does not issue new equity because the marginal return to investment does not justify the reduction in equity value due to share dilution. In this regime, a windfall addition to current earnings, which conveys no information about the firm's future profitably, will raise investment. The presence of firms in this regime may account for the excess sensitivity of investment to measures of internal funds.

We should emphasize that finance regimes may change over time because of the stochastic productivity shocks and the intertemporal investment policy. As will be discussed later, this implies that we cannot simply do comparative statics based on the current source of marginal finance only. In addition, in the cross section with firm heterogeneity, different firms may lie in different finance regimes. We next turn to the firm's investment policy.

4.2 Investment Policy

We first derive a q-theoretic investment equation and then derive the user cost of capital. Based on this derivation, we analyze the effect of dividend taxation on investment in partial equilibrium. This analysis generalizes Auerbach (1979b), Edward and Keen (1984), and Poterba and Summers (1985) to include adjustment costs.

4.2.1 q Theory

Using equation (32), we can derive the investment equation:

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(\frac{q_t}{\frac{1-\tau_d}{1-\tau_g} + \lambda_t^d} - 1\right). \tag{34}$$

This equation is a simple variant of the estimation equation widely used in the q-theory literature on dividend taxation (Desai and Goolsbee (2004) and Poterba and Summers (1983, 1985)). It highlights the key difference between the traditional and the new views of dividend taxation.

According to the traditional view, the marginal source of finance is new equity. In this case, $\lambda_t^d > 0$, $\lambda_t^s = 0$ and $s_t > 0$ for all t. Using equation (31), we can then derive:

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(q_t - 1\right). \tag{35}$$

Thus, investment is determined by the point at which the shareholder is indifferent between holding a dollar inside or outside the firm. That is, the firm stops investment when q_t is equal to 1. According to the new view, the marginal source of finance is retained earnings. In addition, the firm distributes dividends and hence $\lambda_t^d = 0$ for all t. Equation (34) reduces to:

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(\frac{1-\tau_g}{1-\tau_d} q_t - 1\right). \tag{36}$$

Thus, the shareholder will stop investing when he is indifferent between receiving dividends, with value $(1-\tau_d)$, and having the dollar invested, yielding $(1-\tau_g)\, q_t$. That is, he will stop investing when $q_t = (1-\tau_d) / (1-\tau_g) < 1$.

Given equations (35)-(36), a natural empirical strategy to test the traditional and the new views of dividend taxation is to test which one of these two equations fits the data better (e.g., Desai and Goolsbee (2004) and Poterba and Summers (1983, 1985)). We should emphasize that the assumption underlying the standard q-theory approach to estimation (Hayashi (1982)) is violated here since we have assumed decreasing returns to scale. Thus, the substitution of average for marginal q produces a measurement error (see Gomes (2001)). As pointed out by Cooper and Ejarque (2003), this misspecification of q-theory based models implies that any inferences about the size of the quadratic adjustment cost or the significance about financial variable may be invalid.

What seems counterintuitive is that under the traditional view tax parameters do not enter (35), but they appear in (36). In fact, the intuition is easy to explain. Solving equation (33) recursively forward and using the law of iterated expectation and the transversality condition, we obtain:

$$q_t = E_t\left[\sum_{j=1}^{\infty} \frac{(1-\delta)^{j-1}\, mpk_{t+j}}{\left(1 + r\,(1-\tau_i) / (1-\tau_g)\right)^j}\right], \tag{37}$$

where

$$mpk_{t+j} = \left(\frac{1-\tau_d}{1-\tau_g} + \lambda_{t+j}^d\right)\left[(1-\tau_c)\,\pi_1\left(k_{t+j}, z_{t+j}\right) + \tau_c \delta + \psi x_{t+j}^2 / \left(2k_{t+j}^2\right)\right]. \tag{38}$$

This equation simply says that marginal q reflects the firm's marginal valuation. Thus, a change in dividend tax rate changes q and hence influences investment under the traditional view. However, under the new view, dividend taxes are fully capitalized in equity value ($\lambda_{t+j}^d = 0$ for all j), and thus the dividend tax parameter in q fully offsets the factor $(1-\tau_g) / (1-\tau_d)$ in (36). This implies that dividend taxation has no effect on marginal investment.

To formalize the above intuition more transparently, we use equations (32)-(33) to obtain the optimality condition for investment:

$$\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d\right)\left(1+\frac{\psi x_t}{k_t}\right)=\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}\times \tag{39}$$

$$E_t\left\{\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_{t+1}^d\right)\left[\left(1-\tau_c\right)\pi_1\left(k_{t+1},z\right)+\tau_c\delta+\frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2+\left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)\right]\right\}.$$

The expression on the left side of (39) represents the marginal cost of investment, while the expression on the right side represents the marginal benefit from investment.

From equation (39), we can see clearly that if the marginal source of finance does not change in two adjacent periods, i.e., $\lambda_t^d=\lambda_{t+1}^d$, then dividend tax does not influence investment policy at date t, *ceteris paribus*, since the factors $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_t^d$ and $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_{t+1}^d$ cancel out in equation (39).[12] Thus, the condition that the current marginal source of finance is retained earnings is not necessary for the new view of dividend taxation to hold true. Even if the current marginal source of finance is new equity, dividend taxation has no effect on the current marginal investment if the return to investment is used to reduce equity issuance in the next period. This point has been made by Edwards and Keen (1984) in a model without adjustment costs.

When the current marginal source of finance is new equity, i.e., $\lambda_t^d>0$ and $\lambda_t^s=0$, but the return to investment is used to pay dividends, i.e., $\lambda_{t+1}^d=0$, then $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_t^d=1$ and $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_{t+1}^d=\left(1-\tau_d\right)/\left(1-\tau_g\right)$ in equation (39). Thus, a decrease in the dividend tax rate τ_d raises the after-tax marginal return to investment and hence raises the current investment x_t, *ceteris paribus*. This result reflects the traditional view of dividend taxation.

When the current marginal source of finance is retained earnings, i.e., $\lambda_t^d=0$, but the return to investment is used to reduce equity issuance in the next period, i.e., $\lambda_{t+1}^d>0$ and $\lambda_{t+1}^s=0$, then $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_t^d=\left(1-\tau_d\right)/\left(1-\tau_g\right)$ and $\left(1-\tau_d\right)/\left(1-\tau_g\right)+\lambda_{t+1}^d=1$ in equation (39). Thus, a decrease in the dividend tax rate τ_d raises marginal cost and hence reduces investment x_t, *ceteris paribus*. This result seems counterintuitive. In fact, if the firm uses current retained earnings to finance an additional \$1 of investment, then the shareholder

[12] We should emphasize that the firm's investment policy is dynamic and thus the date t investment x_t depends on the date $t+1$ investment x_{t+1}. Here we focus on the effect on x_t (or k_{t+1}) by holding x_{t+1} constant. A similar remark applies to the other related analysis within this section.

loses $\$(1-\tau^d)$ of dividends. Thus, a dividend tax cut makes this cost higher, but does not change the benefit if the return to investment is used to reduce equity issuance in the next period.

Finally, when the firm is in the liquidity constrained regime, we have $\lambda_t^d > 0$ and $\lambda_t^s > 0$. Then the firm does not raise new equity or pay dividends. Investment is constrained to be the retained earnings, $x_t = (1-\tau_c)\,\pi\,(k_t, z_t) + \tau_c \delta k_t$, which do not depend on dividend taxation.

Figure 3 illustrates the determination of the optimal investment policy for the case without adjustment cost ($\psi = 0$). When the investment demand is low, as with the MB1 schedule, investment spending can be financed from internal funds, at the expense of extra dividends. The marginal cost is equal to $(1-\tau_d)/(1-\tau_g)$. By contrast, for high investment demand, as with the MB3 schedule, the firm raises new equity and the marginal cost is equal to 1. For an intermediate level of investment demand, as with the MB2 schedule, the firm is constrained to invest at the amount of retained earnings $(1-\tau_c)\,\pi\,(k,z) + \tau_c \delta k$.

[Insert Figure 3 Here]

4.2.2 User Cost of Capital

We can also analyze the effects of dividend taxation on investment using the user cost of capital framework following Jorgenson (1963). To simplify the analysis, we consider the deterministic case only. We generalize Abel's (1990) and Jorgenson's (1963) definition of the user cost of capital to include adjustment cost and dividend taxation. We define the user cost of capital as the cost u_t such that it is equal to the after-corporate-tax marginal cash flow of an additional unit of capital, i.e.,

$$u_t = (1-\tau_c)\,\pi_1\,(k_{t+1}) + \frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2. \tag{40}$$

Using (33), we can derive that

$$u_t = \left(\frac{1-\tau_d}{1-\tau_g} + \lambda_{t+1}^d\right)^{-1}\left[q_t\left(r\,(1-\tau_i)\,/\,(1-\tau_g) + \delta\right) - \Delta q_t\,(1-\delta)\right] - \delta\tau_c, \tag{41}$$

where $\Delta q_t = q_{t+1} - q_t$. Thus, the user cost of capital is equal to the sum of the tax-adjusted interest rate, physical depreciation, and the capital loss, minus depreciation allowance. Importantly, it depends on the firm's dynamic finance regimes as reflected by the marginal q and the first factor in equation (41).

Substituting equation (32) into (41) yields:

$$\begin{aligned} u_t &= \left(\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d\right)\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_{t+1}^d\right)^{-1}\left(1+\frac{\psi x_t}{k_t}\right)\left(1+\frac{r\left(1-\tau_i\right)}{1-\tau_g}\right) \\ &\quad -\left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)-\tau_c\delta. \end{aligned} \tag{42}$$

Removing the expectation operator in equation (39) and using equation (40), we observe that equations (42) and (39) are equivalent. Thus, we may derive essentially identical results based on the effects of dividend taxation on the user cost of capital. Specifically, if the firm's finance regime does not change in two adjacent periods, then the dividend tax cut does not change the user cost of capital and hence does not change the current investment, as predicted by the new view of dividend taxation. If the firm's finance regime changes from the equity issuance regime to the dividend distribution regime, then the dividend tax cut reduces the user cost of capital and hence raises the current investment, as predicted by the traditional view of dividend taxation. By contrast, if the firm's finance regime changes from the dividend distribution regime to the equity issuance regime, then the dividend tax cut raises the user cost of capital and hence lowers the current investment.

We have pointed out before that if $\tau_d = \tau_g$, then the Miller-Modigliani dividend irrelevance theorem holds and $\lambda_t^d = \lambda_{t+1}^d = 0$. We can then use equation (42) to show that a cut of the common tax rate $\tau_d = \tau_g$ lowers the user cost of capital and hence raises investment for a firm in any finance regime. This result is useful for understanding our policy experiments in Section 5.

4.3 Importance of Firm Heterogeneity

To understand the importance of heterogeneity in determining the steady-state effect of the dividend tax reform, we consider the case where there is only one representative firm in the model described in Section 3. Also we suppose there is no uncertainty. Because aggregate consumption in a steady state is constant over time, equation (20) determines the interest rate. In addition, equations (31)-(33) still describe the representative firm's first-order conditions, except that we remove the shock variable z_t and the expectation operator. Because $k_t = k_{t+1}$, $x_t = \delta k_t$, and $\lambda_t^d = \lambda_{t+1}^d$ for all t in a deterministic steady state, it follows from (39) that the steady-state capital stock k^* satisfies:

$$1+\psi\delta = \frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}\left[\left(1-\tau_c\right)\pi_1\left(k^*\right)+\tau_c\delta+\psi\delta^2/2+\left(1+\psi\delta\right)\left(1-\delta\right)\right]. \tag{43}$$

This equation implies that in a model without firm heterogeneity, dividend taxation does not influence the steady-state capital stock. This is because the representative firm can finance its investment using retained earnings in the deterministic steady state and its finance regime does not change over time. By contrast, in our model with firm heterogeneity, because of idiosyncratic productivity shocks, firms face different finance regimes and respond to a dividend tax cut in different ways. Thus, a dividend tax cut will influence the steady-state capital stock. In the next section, we analyze its quantitative effects.

5 Quantitative Results

We now turn to the general equilibrium model presented in Section 3. Because this model does not permit a closed-form solution for the stationary equilibrium, we resort to a numerical method to compute the approximate equilibrium. Appendix B details our numerical method.

5.1 Baseline Parametrization

To solve the model numerically, we need to specify functional forms for utility and technology. We also need to assign parameter values. We assume a time period in the model corresponds to one year. We calibrate our baseline model to match some moments obtained from the COMPUSTAT database. The sample period ranges from 1988 to 2002, which corresponds to the period before the dividend tax cut. Appendix A describes the data construction.

Tax system. It is delicate to calibrate tax rates since in reality they are nonlinear and change each year, while we have assumed constant and flat rates in our model. In order to evaluate the 2003 dividend tax reform, we suppose that the initial steady state tax rates are given by the federal statutory rates in 2003 before the tax reform. We thus set the corporate income tax rate $\tau_c = 0.34$. Dividend tax rate, personal income tax rate, and capital gains tax rate depend on the individual's income tax bracket. We suppose the representative household has an average income in the US, which falls into the lowest of the top four tax brackets at the personal income tax rate $\tau_i = 0.25$. This household faces the capital gains tax rate $\tau_g = 0.20$. Because dividends are taxed at the personal income tax rate, we set $\tau_d = 0.25$.

Preferences. We take the utility function:

$$U(c, L) = \ln(c) - \frac{hL^2}{2}, \tag{44}$$

where $h > 0$ is the weight on leisure. This utility function has a unit Frisch elasticity of labor supply, which is reasonable for macro models as argued by Hall (2008). We choose the discount factor β such that the interest rate r is equal to 0.04 using equation (20). We choose the parameter h to match the equilibrium labor supply of 0.3, which is the average fraction of time spent on market work.

Technology. We choose the Cobb-Douglas production function with decreasing returns to scale, $F(k, l; z) = zk^{\alpha_k} l^{\alpha_l}$, where $0 < \alpha_k, \alpha_l < 1$ and $\alpha_k + \alpha_l < 1$. We assume that the productivity shock follows the process,

$$\ln z_t = \rho \ln z_{t-1} + \varepsilon_t, \tag{45}$$

where ε_t is i.i.d. and normally distributed with mean zero and variance σ^2. In appendix C, we detail the procedure for calibrating the parameter values α_k, α_l, ρ, and σ. We find $\rho = 0.767$, $\sigma = 0.211$, $\alpha_k = 0.311$, and $\alpha_l = 0.650$. These estimates are similar to those in Cooper and Haltiwanger (2006), Gomes (2001), or Hennessy and Whited (2005). We set the depreciation rate to match the aggregate investment-capital ratio, which is equal to 0.095 according to the National Income and Product Accounts.

The final parameter to be calibrated is the adjustment cost parameter ψ. Because the volatility (standard deviation) of the investment rate is very sensitive to this parameter, we choose a value to match the cross-sectional volatility of the investment rate in our data, which is 0.156. More specifically, for any given value of ψ, we solve the model numerically and obtain the stationary distribution of firms. Using this stationary distribution, we compute the cross-sectional standard deviation of the investment rate in the model. If there were no adjustment cost, our model would imply excessive sensitivity of investment to variations in productivity shocks, which is inconsistent with empirical evidence. Our calibrated value of ψ is equal to 1.080, which is similar to the estimates reported by Cummins, Hassett and Hubbard (1994), Gilchrist and Himmelberg (1998), and Gilchrist and Sim (2006). However, this value is higher than the value (0.049) estimated by Cooper and Haltiwanger (2006) and is lower than the value (about 20) estimated in the early investment literature.

In summary, we list the calibrated parameter values in Table 3. In Section 5.6, we conduct a sensitivity analysis for parameters ρ, σ and ψ since these parameter values are important for our quantitative results.

Table 3. Baseline parametrization

	Parameter	Value
Corporate income tax	τ_c	0.340
Personal income tax	τ_i	0.250
Dividend tax	τ_d	0.250
Capital gain tax	τ_g	0.200
Exponent on capital	α_k	0.311
Exponent on labor	α_l	0.650
Shock persistence	ρ	0.767
Shock standard deviation	σ	0.211
Depreciation rate	δ	0.095
Discount factor	β	0.971
Weight on leisure	h	6.616
Adjustment cost	ψ	1.080

5.2 Baseline Model Results

We suppose that the economy under the parameter values in Table 3 before the tax cuts has reached the steady state. We solve for this steady state numerically. Before reporting aggregate and cross sectional moments, it proves useful to consider first the finance regimes for the firms in the cross section. As analyzed in Section 4.2, firms in different finance regimes may respond to the dividend tax cut in different ways. Figure 4 illustrates these regimes for the baseline model and reveals a few interesting features similar to those in Gomes (2001). First, firms that are either very small or very productive tap the equity market and do not distribute dividends. They are in the equity issuance regime. Second, firms that are either very large or less productive use internal funds to finance investment and also distribute dividends. They are in the dividend distribution regime. Finally, the remaining firms do not distribute dividends and do not issue new equity. They are in the liquidity constrained regime. Unlike the Gomes (2001) model in which these different finance regimes arise due to transactions costs of external financing, our model generates these finance regimes because of the differential tax treatment on dividends and capital gains.

[Insert Figure 4 Here]

We next turn to the aggregate and cross-sectional results. Table 4 reports these results. From this table, one can see that our baseline model matches most aggregate and cross-sectional moments reasonably well. However, the model overpredicts the ratio of aggregate dividends to aggregate earnings, perhaps because we abstract from share repurchases, another way of distribution. The model also underpredicts the standard deviation of the ratio of earnings to capital. This could be due to the fact that there are shocks to earnings other than productivity in the data that our model does not capture.

Table 4. Aggregate and cross-sectional moments in the baseline model. The investment rate is computed from the National Income Accounts and the other data moments are computed using COMPUSTAT. See Appendix B for the variable definition. Model moments are computed using parameter values listed in Table 3.

Variable	Data	Model
Investment rate	0.095	0.095
Aggregate dividends/earnings	0.137	0.353
Aggregate new equity/investment	0.130	0.148
Volatility of investment rate	0.156	0.156
Autocorrelation of investment rate	0.596	0.648
Volatility of earnings/capital	0.623	0.175
Autocorrelation of earnings/capital	0.791	0.658

Table 5 reports the distribution of firms across finance regimes. This table reveals that there is only a small fraction (20.1 percent) of firms in the equity issuance regime in the steady state. These firms are smaller than average, since they account for only 10.8 percent of total capital. However these firms account for quite a lot of investment. These results reflect the fact that most firms do not tap the equity market since equity issuance is costly due to the different tax treatment of capital gains and dividends. In addition, those firms that tap the equity market are small and productive, and hence have higher Tobin's q and make more investment. These patterns are qualitatively consistent with the empirical evidence reported in Table 1. Quantitatively, the model matches well the fraction of firms across the three finance regimes, and matches roughly the patterns for earnings, investment, and Tobin's q. We think this is a reasonable success of our model given that our model is very parsimonious. In particular, the shock process and returns-to-scale parameters are estimated from the data and are not picked to match the firm distribution. The only "free" technology parameter is the adjustment cost parameter.

Table 5. Distribution of firms across finance regimes in the baseline model. The share of firms for a regime is equal to the total number of firms in that regime divided by the total number of firms in all regimes. The share of capital (resp. investment) for a regime is equal to the total capital stock (resp. investment) of the firms in that regime divided by aggregate capital stock (resp. investment) of all firms. The earnings-capital ratio for a regime is equal to the earnings of the firms in that regime divided by their total capital stock, i.e. it is capital-weighted. The investment-capital ratio and Tobin's q are computed in a similar way. Parameter values are listed in Table 3.

	Equity Issuance Regime	Liquidity Constrained Regime	Dividend Distribution Regime
Share of firms	0.201	0.342	0.457
Share of capital	0.108	0.229	0.663
Share of investment	0.402	0.436	0.161
Earnings-capital ratio	0.431	0.264	0.170
Investment-capital ratio	0.354	0.181	0.023
Average Tobin's q	2.633	1.941	1.348

We notice that our model underpredicts the earnings and investments of firms in the dividend distribution regime, compared to the data. As shown in Figure 4, firms in the dividend distribution regimes may have large capital stocks, but low productivity, relative to firms in other finance regimes. Thus, firms in the dividend distribution regime have a low Tobin's q, low investments, and large distributions. Introducing other shocks such as shocks to profits to induce these firms to make more investments may remedy this defect somewhat. Our model does not match well the shares of capital and investment reported in Table 1. In the data, firms in the equity issuance regime are very small. While our model captures this feature qualitatively, it does not match it quantitatively. This is because the size distribution has less dispersion in the model than in the data. Nevertheless, because our model matches well the distribution of firms across finance regimes reported in Table 1 and also matches well the aggregate equity issuance reported in Table 4, which are the key statistics for understanding the effects of the dividend tax reform, we view our model as a reasonable starting point for policy analysis.

5.3 Effects of Dividend Tax Reform

To estimate the quantitative long-run effects of the 2003 dividend and capital gains tax cuts as discussed in Section 2, we consider four policy experiments. Our experiments assume that the tax rate changes are permanent in order for us to study the long-run steady-state effects. To help understand the model mechanism, we begin by the first hypothetical experiment in which we fix the capital gains tax rate at the 20 percent level, while the dividend tax rate is cut to the 22 percent level. Column 2 of Table 6 reports the aggregate results. Because dividends are taxed at a lower rate in this experiment, firms distribute more dividends. Because $(1-\tau_d)/(1-\tau_g)<1$ after the dividend tax cut in this experiment, outside equity finance is still more costly than internal finance. However, the tax wedge is narrowed. Thus, as revealed in Column 2 of Table 6, firms raise more equity to finance investment after the dividend tax cut.

Table 6. Aggregate effects of the dividend tax reform in the baseline model. When we change the dividend and capital gains tax rates, we fix all other parameter values as in Table 3. All results are measured in percentage change from the initial steady state before the reform.

	$\tau_d = 0.22$ $\tau_g = 0.20$	$\tau_d = 0.20$ $\tau_g = 0.20$	$\tau_d = 0.15$ $\tau_g = 0.15$	$\tau_d = 0$ $\tau_g = 0$
Capital	0.27	0.52	4.26	13.95
Output	0.58	1.00	2.15	5.04
Consumption	0.38	0.63	1.30	2.91
Dividends	6.23	N/A	N/A	N/A
Equity Issuance	40.05	N/A	N/A	N/A
Wage	0.48	0.82	1.72	3.95
Firm value	3.40	5.78	10.52	24.09
Welfare	0.31	0.52	1.04	2.27

Column 2 of Table 6 also reveals that the long-run aggregate capital stock, output, consumption, and wage all increase following the dividend tax cut. However, the increase is quite small. This implies that the welfare effect of the dividend tax cut is also small, even though the increase in dividends and firm value is relative large. The welfare benefit can be measured by the equivalent increase in consumption holding leisure constant, which is only 0.31 percent.

Turn to the effect of the dividend tax cut on the wage rate. After the dividend tax cut there are more firms in the equity issuance regime and these firms are profitable. These firms invest more and demand more labor causing the aggregate demand for labor to rise. In addition, labor supply falls because the household receives higher payouts and hence is wealthier. Thus, the equilibrium wage rate should go up. Consistent with this intuition, Column 2 of Table 6 reveals that the wage rate is increased by 0.48 percent after the dividend tax cut. The effect on the equilibrium labor is ambiguous, depending on the relative magnitude of changes in the labor supply and the labor demand. In all of our numerical experiments, the change in labor demand dominates so that the equilibrium employment rises after the dividend tax reform.

To understand the effect on aggregate capital accumulation, we recall that firm heterogeneity plays a key role. As shown in Section 4.3, if there were no firm heterogeneity, dividend taxes would have no effect on the steady-state capital stock. Table 7 illustrates the importance of firm heterogeneity. Compared with Table 5, Table 7 reveals that after the dividend tax cut, fewer firms are constrained. That is, some firms in the liquidity constrained regime move to the equity issuance regime and some firms move to the dividend distribution regime. The firms in the equity issuance regime account for most of the increase in investment. These firms' behavior is consistent with the traditional view of dividend taxation. These changes in the cross-sectional distribution of firms are consistent with the empirical results reported in Section 2.

Table 7. Distribution of firms across finance regimes for $\tau_d = 0.22$ and $\tau_g = 0.20$. The share of firms for a regime is equal to the total number of firms in that regime dividend by the total number of firms in all regimes. The share of capital (resp. investment) for a regime is equal to the total capital stock (resp. investment) of the firms in that regime divided by aggregate capital stock (resp. investment) of all firms. The earnings-capital ratio for a regime is equal to the earnings of the firms in that regime divided by their total capital stock, i.e. it is capital-weighted. The investment-capital ratio and Tobin's q are computed in a similar way. Except for τ_d and τ_g, other parameter values are listed in Table 3.

	Equity issuance regime	Liquidity constrained regime	Dividend distribution regime
Share of firms	0.248	0.259	0.493
Share of capital	0.138	0.169	0.693
Share of investment	0.517	0.325	0.158
Earnings-capital ratio	0.415	0.264	0.171
Investment-capital ratio	0.357	0.183	0.022
Average Tobin's q	2.620	2.001	1.406

We next consider the second policy experiment in which we fix the capital gains tax rate at the 20 percent level, while the dividend tax rate is cut further to this level. As a result, firms do not face the tax differential cost of external equity finance. Because there is no other friction associated with external equity finance in the baseline model, the celebrated Miller and Modigliani dividend policy irrelevance theorem holds, as analyzed in Section 4.1. Thus, in Column 3 of Table 6, the values of aggregate dividends and new equity are indeterminate (marked as "N/A"). Because firms do not face any financing frictions after the second policy experiment, the long-run aggregate capital stock, output, consumption, and wage all increase more than that in the first policy experiment. In particular, aggregate capital is raised by 0.52 percent, and aggregate output is raised by 1.00 percent. The welfare increase measured by the increase in aggregate consumption is still small, equal to 0.52 percent.

We now consider the third policy experiment in which both the capital gains tax rate and the dividend tax rate are cut permanently to the same level of 15 percent. These tax cuts are implemented by JGTRRA. Column 4 of Table 6 reports the results. Comparing with the second policy experiment reported in Column 3, we can see that the increases in aggregate capital, output, consumption, and wage are higher. In particular, aggregate capital and welfare increase by 4.26 and 1.04 percent, respectively. This larger effect is caused by a different channel in addition to the preceding reallocation channel. From (8) or (26), we can see that the after-tax interest rate is given by $r\left(1-\tau_i\right)/\left(1-\tau_g\right)$. Thus, a decrease in $\tau_g = \tau_d$ lowers the after-tax interest rate and hence the user cost of capital for all firms, as analyzed in Section 4.2.2. Our numerical experiments illustrate that this channel has a larger impact than the reallocation channel.

We finally conduct the fourth experiment in which both dividend and capital gains taxes are eliminated permanently. We find a much larger impact on the economy, because there is a large decrease in the user cost of capital for all firms in the economy. In particular, aggregate capital increases by 13.95 percent and welfare increases by 2.27 percent.

5.4 Productivity Gains

We have shown that a dividend tax cut stimulates long-run capital formation in our model with firm heterogeneity. In our model, firms with high productivity but with little capital issue new equity. These firms are primarily responsible for the increase in investment after the dividend tax cut. When the dividend tax is reduced, some liquidity constrained firms move to the equity issuance regimes and they attract more capital and labor. Hence, the allocation of capital and labor is more efficient, which generates productivity gains.

To gauge the productivity gains quantitatively, we use two measures, aggregate labor productivity (Y/L) and total factor productivity ($Y/(K^{\alpha_k}L^{\alpha_l})$). To focus on the effect of dividend taxes alone, we consider the changes of τ_d from 0.25 to 0.22 and 0.20, and fix all other parameter values as in Table 3. Table 8 reports the results. Row 2 of this table reveals that total factor productivity (TFP) increases following the decrease in the dividend tax rate. To see the intuition, we use the Cobb-Douglas production function to derive TFP as follows:

$$\begin{aligned} TFP &= \frac{Y}{K^{\alpha_k}L^{\alpha_l}} = \frac{\left[\int (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}}\,\mu(dk,dz)\right]^{1-\alpha_l}}{\left[\int k\mu(dk,dz)\right]^{\alpha_k}} = \frac{E_\mu\left[z^{\frac{1}{1-\alpha_l}}k^{\frac{\alpha_k}{1-\alpha_l}}\right]^{1-\alpha_l}}{(E_\mu[k])^{\alpha_k}} \\ &= \frac{\left(E_\mu\left[z^{\frac{1}{1-\alpha_l}}\right]E_\mu\left[k^{\frac{\alpha_k}{1-\alpha_l}}\right]+Cov_\mu\left[z^{\frac{1}{1-\alpha_l}},k^{\frac{\alpha_k}{1-\alpha_l}}\right]\right)^{1-\alpha_l}}{(E_\mu[k])^{\alpha_k}}, \end{aligned} \tag{46}$$

where E_μ and Cov_μ denote, respectively, the expectation and covariance operators for the stationary distribution of firms μ. The covariance term represents the reallocation effect, which captures the fact that capital may move among firms with different productivity shocks. If there were no reallocation effect, the covariance term would be zero. If, in addition, production had constant returns to scale $\alpha_k = 1-\alpha_l$, then TFP would be equal to $E_\mu\left[z^{1/\alpha_k}\right]^{\alpha_k}$, which would not change following a change in the dividend tax rate. However, we have assumed decreasing returns to scale in our model.[13] In addition, Row 4 of Table 8 reveals that the correlation between capital and productivity shock is positive and increases following a decrease in the dividend tax rate. Clearly, the higher this correlation, the more efficient the allocation of capital across firms. Row 5 shows that the slope coefficient in a regression of log capital on

[13] Jermann and Quadrini (2003) use a model with financial frictions and decreasing returns to scale in production to explain the productivity gains in the 1990s. Unlike our model with taxation, they assume financial frictions are generated by the enforcement problem of lending contracts.

log firm productivity also increases, reflecting that firms with high productivity have relatively more capital. Thus, we should expect that TFP will increase if the dividend tax rate is lowered. This intuition is confirmed in Row 2 of Table 8.

Table 8: Productivity gains from the dividend tax cut. When we change the dividend tax rate, we fix all other parameter values as in Table 3.

	$\tau_d = 0.25$	$\tau_d = 0.22$	$\tau_d = 0.20$
Percentage change in TFP	0.00	0.479	0.721
Percentage change in Y/L	0.00	0.430	0.818
Correlation between $\ln k$ and $\ln z$	0.438	0.450	0.457
Regression coefficient of $\ln k$ on $\ln z$	1.203	1.268	1.312

We now turn to Row 3 of Table 8, which reveals that labor productivity (Y/L) increases as the dividend tax rate decreases. To see the intuition, we use the Cobb-Douglas production function to compute labor productivity as follows:

$$\frac{Y}{L} = \frac{\int \left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}} \mu\left(dk, dz\right) \left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}}}{\int \left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}} \mu\left(dk, dz\right) \left(\frac{\alpha_l}{w}\right)^{\frac{1}{1-\alpha_l}}} = \frac{w}{\alpha_l}. \tag{47}$$

From this equation, we can see clearly that the increase in labor productivity is due to the increase in wage. The increase in wage is in turn due to the increase in capital since the latter increase raises the marginal product of labor.

Table 8 also reveals that the magnitude of the productivity gain from the dividend tax cut is not large. Since most of the output increase is due to an increase in productivity (TFP), rather than to an increase in the stock of capital, this may explain why our simulated welfare effect of the 2003 dividend tax reform is small, as reported in Table 6. We note that the magnitude of the reallocation effect depends on the size of the adjustment cost. If adjustment costs are smaller, the effect of a dividend tax cut on capital accumulation and productivity will be larger since it is less costly to reallocate capital.

5.5 General Equilibrium Effect

To appreciate our general equilibrium model, we conduct a hypothetical experiment by shutting down the price feedback effect. Specifically, we fix the wage rate at its level before the tax reform. At this wage, we use labor demand to determine aggregate employment by ignoring the labor market-clearing condition (24). After solving the firm's problem, we can derive aggregate investment and aggregate output. We then use the resource constraint to solve for aggregate consumption.

We find that the increase in capital stock, output, and consumption in partial equilibrium after the tax reform is much higher than that in general equilibrium. In particular, when the tax rates on dividends and capital gains are cut to 15 percent, the increase in capital in partial equilibrium is about 6 times larger than in general equilibrium, and the increase in consumption in partial equilibrium is about 26 times larger than in general equilibrium. This experiment demonstrates that using a partial equilibrium model to conduct policy evaluation can be quite misleading.

To understand the remarkable difference between the partial and the general equilibrium results, we derive the profit function as follows:

$$\pi(k, z; w) = (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}} \left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}} (1 - \alpha_l). \tag{48}$$

We note that the wage rate rises after the tax reform in general equilibrium as reported in Table 6. The preceding equation reveals that the increased wage lowers a firm's profits and hence its returns to investment. This equilibrium price feedback effect dampens the increase in investment and hence output in general equilibrium. Our numerical experiments demonstrate that the equilibrium price feedback is quantitatively significant.

5.6 Sensitivity Analysis

Because the parameters of persistence ρ, volatility σ, and adjustment cost ψ are potentially important for our quantitative results, we now conduct sensitivity analysis by changing these parameter values. When we change one of the parameters, we fix the other parameters at the baseline values given in Table 3.

Table 9 reports aggregate and cross-sectional results for different parameter values. From this table, we find the following results: When the volatility σ is increased, firms face larger shocks to productivity, which leads them to go more frequently to the equity market and hence raise more new equity. In addition, investment and earnings become more volatile and less persistent since capital adjustment is faster.

An increase in the persistence parameter ρ raises the autocorrelation of the investment rate and the earnings/capital ratio. It also raises the cross-sectional volatility of the investment rate and the earnings/capital ratio. This is because the unconditional variance of the productivity shock, $\sigma^2/\left(1-\rho^2\right)$, is also increased when ρ is increased. Thus, firms issue more new equity to finance investment.

The most notable effect of an increase in the adjustment cost parameter ψ is to lower the volatility of the investment rate. When ψ is increased from 0.5 to 1.5, the standard deviation of the investment rate is lowered from 0.254 to 0.127. The increase in ψ also raises the persistence of the investment rate since firms adjust capital gradually.

Table 9. Moments for different parameter values. When we change one parameter value, we fix other parameter values as in Table 3.

	Data	$\rho = 0.65$	$\rho = 0.85$	$\sigma = 0.1$	$\sigma = 0.3$	$\psi = 0.5$	$\psi = 1.5$
Aggregate dividends/earnings	0.137	0.290	0.435	0.296	0.413	0.481	0.315
Aggregate new equity/investment	0.130	0.007	0.340	0.010	0.294	0.419	0.069
Volatility of investment rate	0.156	0.098	0.224	0.076	0.208	0.254	0.127
Autocorrelation of investment rate	0.596	0.566	0.683	0.690	0.603	0.588	0.668
Volatility of earnings/capital	0.623	0.160	0.176	0.080	0.273	0.157	0.186
Autocorrelation of earnings/capital	0.791	0.557	0.732	0.720	0.588	0.647	0.662

Table 10 reports the results when the tax rates are cut to $\tau_d = \tau_g = 0.15$. This table reveals that our estimates of the effects on capital, output and consumption in the baseline model are not very sensitive to the choice of parameter values. In particular, for a wide range of parameter values, the steady-state capital stock and output increase by 3 to 6 percent and 1 to 3 percent, respectively. Notably, the steady-state increase in consumption is almost always below 2 percent. When the adjustment cost parameter is small ($\psi = 0.5$), the reallocation effect and productivity gains from the tax cut are large, as discussed in Section 4.4. In this case, the resulting increases in aggregate output, capital and consumption are relatively large.

Table 10. Sensitivity analysis of dividend tax reform for different parameter values. When we change one parameter value, we fix other parameter values as in Table 3. All results are measured in percentage change from the initial steady state.

	Capital	Output	Consumption	Wage
Baseline	4.26	2.15	1.30	1.72
$\rho = 0.65$	3.58	1.34	0.78	1.08
$\rho = 0.85$	5.40	2.32	1.38	1.86
$\sigma = 0.1$	3.57	1.48	0.88	1.19
$\sigma = 0.3$	5.36	2.34	1.39	1.88
$\psi = 0.5$	5.72	2.85	1.72	2.28
$\psi = 1.5$	4.06	1.89	1.15	1.50

6 Extensions

In this section, we consider extensions of our baseline model by relaxing some of our previous assumptions. First, we consider a revenue-neutral tax reform. Second, we introduce debt financing. Third, we consider the effect of transaction costs of equity issuance. Finally, we allow for share repurchases. When we relax one assumption, we hold everything else constant as in the baseline model. We show that our estimates of the benefit from the 2003 dividend tax cut will be reduced in these extensions.

6.1 Revenue-Neutral Tax Reform

Our baseline model assumes tax revenues are rebated back to the household. Tax revenues must decrease after a dividend and capital gains tax cut. This means that the household receives smaller lump-sum transfers from the government. If the government tries to keep tax revenues constant after a dividend and capital gains tax cut, it must raise other taxes. If the taxes which are increased are distortionary, the benefit from a dividend and capital gains tax cut will be reduced.

To illustrate this point quantitatively, we consider an experiment in which the government raises the personal (labor) income tax rate to keep tax revenues identical to the level before the tax cut. We find that the equilibrium tax revenues are reduced by 3.1 percent after the dividend and capital gains tax rates are cut to $\tau_d = \tau_g = 0.15$ from their baseline values. To restore tax revenues to their level before the tax cut, the government must raise the tax rate on labor income to $\tau_i = 0.266$, 1.6 percentage point higher than the level before the tax cut. This higher labor income tax rate distorts labor supply and thus reduces the benefit from the dividend and capital gains tax cut. In particular, we find that aggregate capital, output, and consumption increase by 3.23, 1.16, and 0.30 percent, respectively. These numbers are all smaller than the corresponding values (4.26, 2.15, and 1.30 percent) in our baseline model.

6.2 Debt Financing

Our baseline model assumes that the only source of outside financing is equity. However, firms also rely on debt to finance investment (either through the bond market or through bank loans). In this section we introduce debt financing in the model to study how it affects our results. We follow Poterba and Summers (1983) and assume that debt is risk-free and is equal to a fixed fraction of capital: $b_t = \xi k_t$. This assumption may be motived by a binding collateral constraint as in Kiyotaki and Moore (1997).[14] As a firm accumulates more capital, it raises its debt capacity in that capital is tantamount to collateral. This simple formulation simplifies our numerical solution since we still solve the dynamic programming problem (8), but the flow of funds constraint (9) is modified to be:

$$x + \frac{\psi x^2}{2k} + d + (1 + (1 - \tau_c) r) b = (1 - \tau_c) \pi (k, z; w) + \tau_c \delta k + s + b', \tag{49}$$

$$b = \xi k, \ b' = \xi k'. \tag{50}$$

To illustrate how our results are affected by this modification, we keep the same parameter values as in Table 3, and set $\xi = 0.5$. This number is in the range of estimates reported by Ramey and Shapiro (2001) and is close to the estimates of Hennessy and Whited (2005). We find that equity issuance becomes smaller, because firms can access to debt financing rather than using internal funds or equity issuance only: The ratio of equity issuance to investment is 5.0 percent rather than 14.8 percent. In addition, there are fewer firms issuing equity (14.9 percent rather than 20.1 percent).

We next analyze the effects of the dividend tax cut by conducting experiments similar to Table 6. We find that the effects on the wage, consumption, and equity issuance are smaller than in the baseline model. This is because the reallocation effect is smaller with debt financing. We also find that the increase in capital in the model with debt financing is a little larger than in the baseline model when we reduce τ_d alone to 0.20 (0.71 percent versus 0.52 percent), but is a little smaller than in the baseline model when we reduce both τ_g and τ_d to 0.15 (2.81 percent versus 4.26 percent). The intuition appears to be the following: On the one hand, when firms

[14] In the case with occasionally binding collateral constraint as in Hennessy and Whited (2005) and Gourio and Miao (2007), debt is an additional state variable. Our dynamic programming problem becomes three dimensional, which is harder to solve numerically.

can issue debt, they rely less on equity financing. Thus, reducing dividend taxes should have a smaller effect than in the baseline model without debt financing. On the other hand, an increase in capital in the model with debt relaxes the collateral constraint and allows firms to take on more debt, thereby stimulating more capital accumulation. For small tax changes, the second effect dominates, but for large tax changes, the first effect dominates.

6.3 Costly External Finance

So far, we have assumed that external equity finance is costly only because of the differential tax treatment on capital gains and dividends. Many researchers argue that outside equity markets are costly because of asymmetric information or transactions costs. When there is a cost of issuing equity, there is an additional wedge between internal and external funds. Thus, one should expect the aggregate effects to be smaller even though the tax wedge is eliminated in our previous policy experiments. We have confirmed this intuition numerically using a model with linear cost of issuing equity (see Gomes (2001) and Hennessy and Whited (2005)). For instance, when the cost of equity issuance is 3 percent of the value of issued equity, a decrease in the dividend tax rate to $\tau_g = 0.20$ raises capital by only 0.33 percent, and a decrease in dividend and capital gains tax rates to 0.15 raises capital by 3.91 percent (as compared to 0.52 and 4.26 percent, respectively, in the baseline model).

6.4 Share Repurchases

Share repurchases are allowed in the US. However, repurchases are not free. First, regular repurchases may lead the IRS to treat repurchases as dividends. Second, there may be asymmetric information and transactions costs. To model the costly share repurchases in a simple way, we follow Poterba and Summers (1985) and assume that there is an upper bound on repurchases in that $s \geq \underline{s}$, where $\underline{s}$ is a negative number. Note that after one uses this constraint to replace (11), the analysis in Section 4 still goes through with small notational changes. In particular, firms still face three finance regimes: dividend distribution regime ($d > 0, s = \underline{s}$), equity issuance regime ($d = 0, s > \underline{s}$), and liquidity constrained regime ($d = 0, s = \underline{s}$). Moreover, the effect of the dividend tax cut is qualitatively the same.

Compared to the baseline model without share repurchases, the model here implies that firms can avoid the more costly dividend distribution by repurchasing shares to the extent possible. Thus, one should expect that firms pay smaller dividends. We show numerically that, holding everything else constant, when the share repurchase constraint is gradually relaxed, aggregate output, capital, consumption, equity issuance, and earnings are increased, but aggregate dividends are reduced. The intuition is the following. When firms can use the returns on investments to repurchase shares, as opposed to distributing dividends which are more highly taxed, the benefits of investment effectively rise. Thus, firms have incentives to make larger investments and issue more new equity to finance the investment, if possible.

We also find numerically that the effects of the dividend tax reform are smaller when firms can repurchase shares. The intuition is the following. If both dividend and capital gains tax rates are cut down to the same level, then allowing for share repurchases does not change the equilibrium allocations in the economy after the tax cut. This is because the firm's financial policy is irrelevant when there is no tax differential between dividends and capital gains, by the Miller and Modigliani Theorem. Thus, given our discussion in the preceding paragraph, aggregate capital, consumption, and output in the model with share repurchases should increase less than those in the baseline model. In the extreme case where we remove the share repurchase constraint (11) so that firms can completely avoid dividend payments, dividend taxes have no real effect on the economy. However, when the tax rates on both dividends and capital gains are reduced to $\tau_d = \tau_g = 0.15$ as in JGTRRA, these tax cuts still have real effects through the user cost of capital channel discussed in Section 4.2.2. We find that aggregate output, capital and consumption increase by 1.14, 3.72, and 0.66 percent, respectively.

7 Conclusion

In this paper, we build a dynamic general equilibrium model to analyze the long-run effects of the dividend tax reform on aggregate capital accumulation. Firm heterogeneity in productivity and general equilibrium play a key role in our analysis. This firm heterogeneity implies that firms still face idiosyncratic productivity shocks, even though the economy-wide aggregates are constant over time in the long run. Thus, firms may lie in different finance regimes over time and respond to dividend taxation in different ways. In particular, some firms behave according to the traditional view of dividend taxation and other firms behave according to the new view of dividend taxation. This is in sharp contrast to a model with a representative firm, which implies that dividend taxation has no effect on aggregate capital accumulation in the deterministic steady state as predicted by the new view. We also show that general equilibrium is important for policy analysis. Using a partial equilibrium model may provide very misleading quantitative estimates.

We use our calibrated model to provide an initial quantitative evaluation of the 2003 dividend tax reform. Our simulations suggest that cutting the dividend tax rate alone raises the long-run capital stock by a small magnitude. In addition, it raises total factor productivity and labor productivity. This result is primarily generated by the reallocation effect in our model with tax frictions and decreasing returns to scale in production. When both dividends and capital gains tax rates are cut down to the same level, aggregate effects are much larger. The reason is that the user costs of capital for all firms are reduced and this reduction has a larger effect on capital formation. Our baseline model simulations show that when both dividend and capital gains tax rates are cut from 25 and 20 percent, respectively, to the same 15 percent level permanently, the aggregate long-run capital stock increases by about 4 percent. This estimate may be viewed as an upper bound because it will be reduced when we incorporate several extensions of our baseline model including revenue-neutral tax reform, debt financing, costly external financing, and share repurchases.

While we have considered several extensions of our model, it would be still interesting to generalize it along a few directions. First, our modeling of debt precludes a change in the debt-capital ratio. It would be interesting to relax this assumption as in Gourio and Miao (2007), Hennessy and Whited (2005, 2007), Miao (2005), and Moyen (2004), among others. Second, given the fact that a dividend tax cut may be temporary, it would be interesting to analyze both its temporary and permanent effects. We study this issue in Gourio and Miao (2007). Third, we have assumed a representative agent in the model. Incorporating household heterogeneity would allow us to provide a more interesting welfare analysis. Finally, we may consider that the government collects taxes and issues debt to finance expenditures. We can then analyze how the dividend tax reform affects budget deficits.

Appendices

A Data Construction

We use the COMPUSTAT Industrial Annual data set from 1988 to 2002 and use the following standard criteria to drop data (see, e.g., Hennessy and Whited (2005)). First, we delete observations of firms whose primary SIC classification is between 6000 and 6999 or between 4900 and 4999, since our model is inappropriate for regulated or financial firms. Second, we delete observations of firms with negative or zero values of book value of capital (item 8), sales (item 12), or assets (item 6). To avoid rounding errors, we also delete observations with book value of capital less than one million dollars or assets less than two million dollars. Third, we delete observations of firms with missing data for assets (item 6), book value of capital (item 8), sales (item 12), operating income before depreciation (item 13), investment (item 30), dividends (item 21 plus item 19), equity issuance (item 108), and equity repurchases (item 115). Because a large share of equity issuance is done by small firms which may not be present in all the years that we cover, we prefer not to balance the panel. We end up with 11,945 firms and a total of 77,906 firm-year observations.

We measure earnings using item 13. To reduce the impact of extreme observations, we also "winsorize" two variables (investment over capital and earnings over capital), using the 5th and 95th percentiles as thresholds. To compute total equity issuance over total investment, we use the gross equity issuance, i.e. the aggregate of item 108, over the aggregate of item 30.

B Numerical Method

To solve the model numerically, we proceed in three steps. First, for a given wage, we compute the firm's optimal decision rules. Next, we compute the stationary distribution. Finally, we check whether the labor market equilibrium condition holds; if not, we adjust the wage and go back to the first step.[15] We now provide more details about each step.

Step 1. Starting with a guess of wage, solve the firm's dynamic programming problem by value function iteration on a grid. We use a grid with 300 points for capital and 10 points for productivity. The grid for capital is finer for low capital values. The lower bound for capital

[15] Our programs are available at the following web address: `http://people.bu.edu/fgourio/research.html`

is 0.001 and the upper bound is chosen so that it binds with very small probabilities in a stationary equilibrium. Changes in the grid do not affect the result significantly. The grid for productivity is taken from Joao Gomes' program, which implements the usual Tauchen and Hussey (1991) approximation for an AR(1) process.

Step 2. After obtaining decision rules from step 1, we solve for the stationary distribution of firms $\mu^*(k, z; w)$. To do so, we simply iterate on equation (13) defined in the main text, starting from a uniform distribution over (k, z).

Step 3. After obtaining the stationary distribution of firms, we obtain the aggregate labor demand $L^d(w) = \sum_{k,z} \mu^*(k, z; w) l(k, z; w)$. We then check whether the labor market clears. There are two cases. If labor supply is fixed, we need to check that $L^d(w) = 0.3$. If labor supply is elastic, we check the equation, $U_2(C, L)/U_1(C, L) = (1 - \tau_i)w$, where aggregate consumption C is deduced from the resource constraint and the stationary distribution. If the equilibrium condition is not satisfied, we use the bisection method to update the wage rate and go back to step 1.

Because we solve the model on a grid, the policy function $g(k, z; w)$ is necessarily discontinuous in the Euclidean norm. Hence labor demand can be discontinuous: a small change in the wage can create a discrete jump in $g(k, z; w)$ and thus in $\mu^*(k, z; w)$. This implies we may not be able to make the equilibrium condition hold with arbitrary precision. However, the error in this equilibrium condition is very small for our computations, typically around 10^{-5}.

C Calibration of the Production Function and Shock Process

We follow an approach similar to that in Fuentes, Gilchrist and Rysman (2006), Gilchrist and Sim (2006), and Moyen (2004), and estimate the production function parameters and shock processes directly using the COMPUSTAT database. We choose these estimates as our calibrated parameter values. Because our paper does not focus on structural estimation, we do not use the simulated method of moments or indirect inference to estimate these parameters as in Cooper and Ejarque (2003), Cooper and Haltiwanger (2006), or Hennessy and Whited (2005, 2007).

We now describe our estimation procedure. By (48), we have the following expression for profits:

$$\pi(k, z) = k^{\frac{\alpha_k}{1-\alpha_l}} z^{\frac{1}{1-\alpha_l}} \times \text{constant}.$$

Our regression is based on this equation. To recover the exponents on the production function, we run a simple regression of log real profits (item 13) on log real capital (item 8):

$$\ln \pi_{it} = a + b \ln k_{it} + \delta_t + e_{it}. \tag{C.1}$$

This regression incorporates time fixed effects which capture variation in aggregate productivity, as well as aggregate inflation. Note that we do not incorporate firm fixed effects in this regression. One reason is that our model has no fixed effect. Another one is that in a relatively short sample, the fixed effect is likely to absorb some of the dynamics, biasing the estimate of the shock process. Finally we find intrinsic permanent differences in firms' productivity hard to square with the evidence on the turnover of the largest firms (see, for instance, Comin and Philippon (2005)). We recognize, however, that the absence of firm fixed effects may increase the endogeneity problem in this production function estimation.

Our estimate of b is $\widehat{b} = 0.889$. Following the macroeconomics literature, we set $\alpha_l = 0.65$ since labor share is approximately 65 percent in the US data. Given that $\widehat{b}$ is an estimate of $\alpha_k / (1 - \alpha_l)$, this yields an estimate of $\alpha_k : \widehat{\alpha}_k = 0.311$.

We use the residuals from the regression (C.1) to measure the shock process. We fit an AR(1) to $\eta_{it} = (1 - \alpha_l) e_{it}$:

$$\eta_{i,t} = \rho \eta_{i,t-1} + \sigma \zeta_{it},$$

where ζ_{it} is i.i.d. across i and t and drawn from a standard normal distribution. These estimates imply that the parameters of the shock process z are

$$\widehat{\rho} = 0.767, \ \widehat{\sigma} = 0.211.$$

Overall, our estimates for parameters of the production function and the shock process are quite similar to those in the papers cited above.

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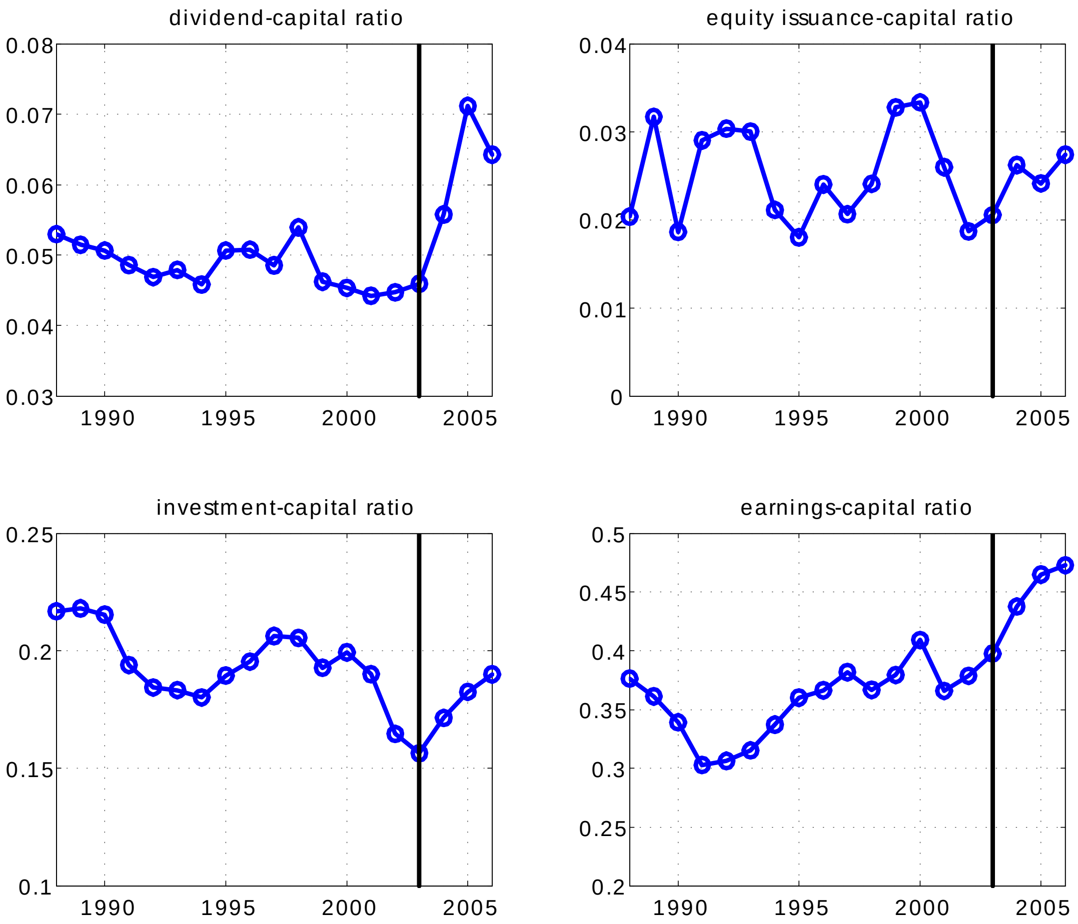

Figure 1: **Time series of aggregate corporate investment and financing behavior in the data.** Our data are drawn from the COMPUSTAT database. The data construction is described in Appendix A.

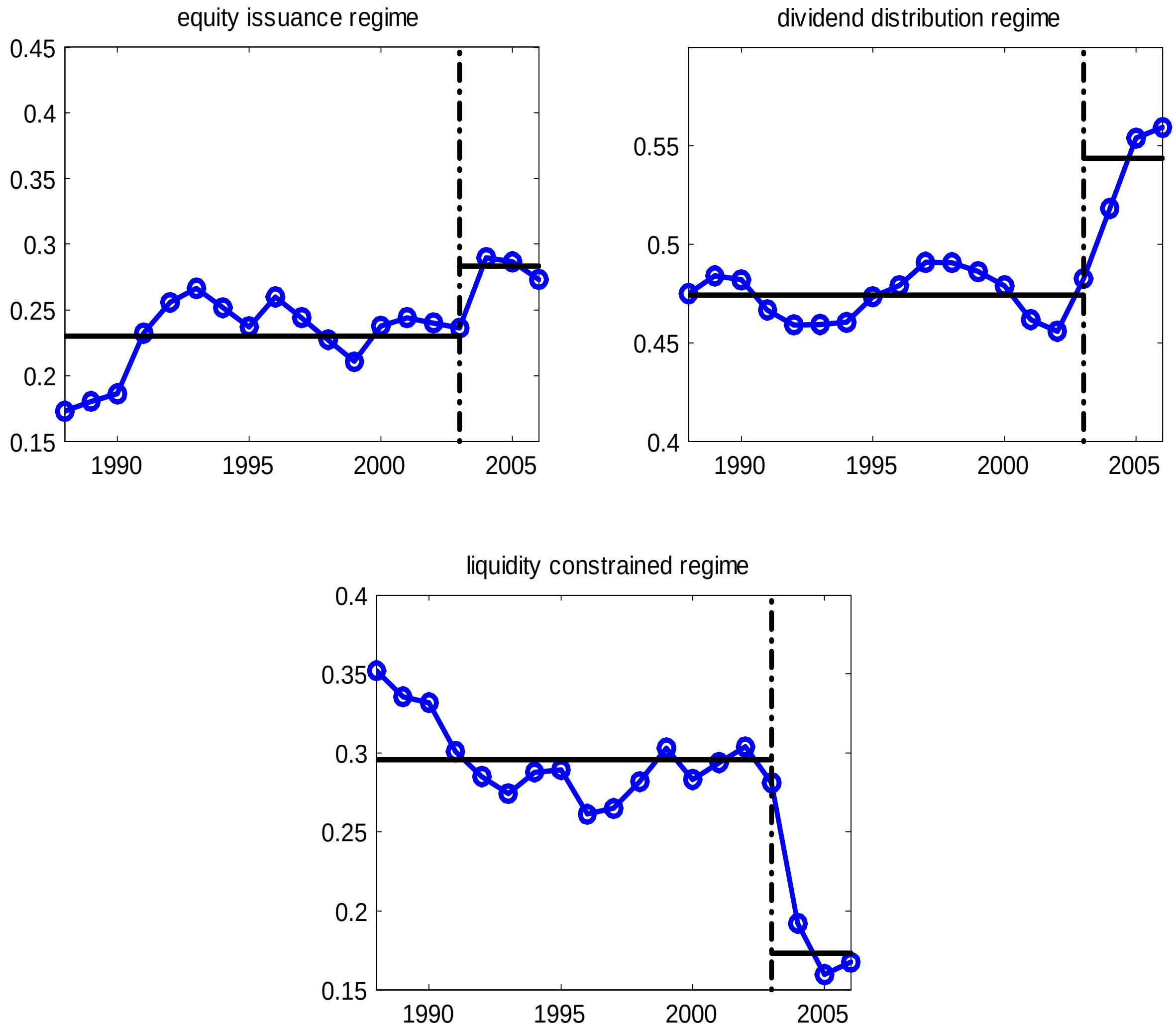

Figure 2: **Changes in firm distribution across finance regimes in the data.** Our data are drawn from the COMPUSTAT database. The data construction is described in Appendix A. The thick black lines represent the sample average over 1988-2002 and 2004-2006, respectively.

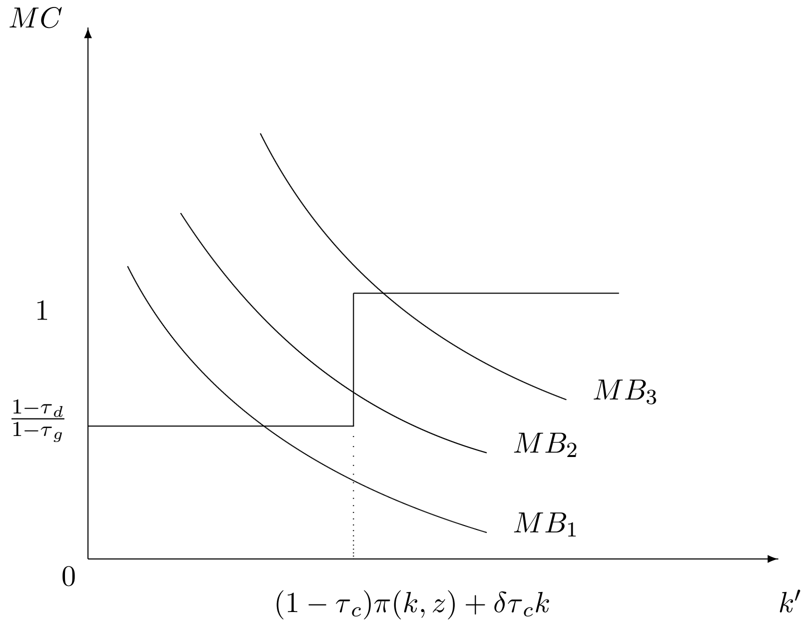

Figure 3: **Determination of optimal investment policy for the case without adjustment cost**

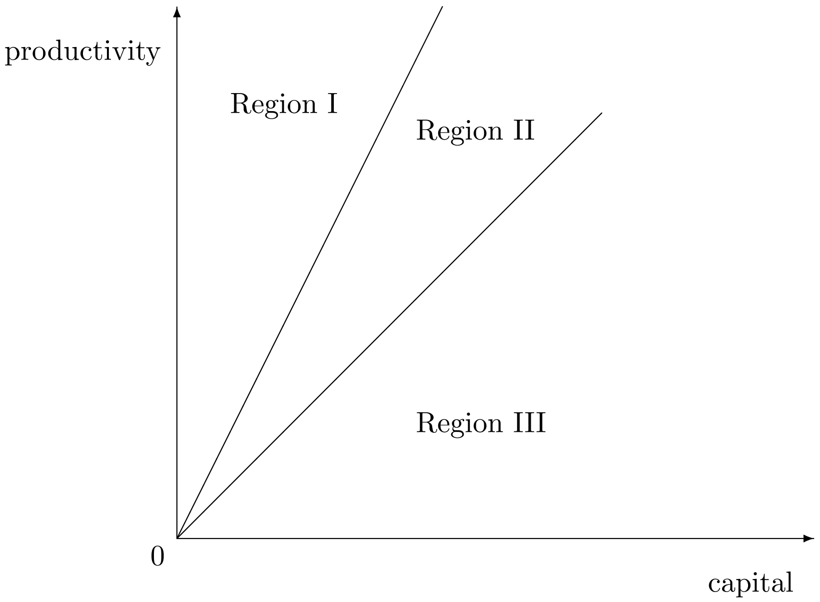

Figure 4: **Finance regimes.** This figure illustrates the three finance regimes. Region I represents the equity issuance regime. Region II represents the liquidity constrained regime and region III represents the dividend distribution regime.