Firm Heterogeneity and the Long-Run Effects of Dividend Tax Reform*

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Abstract

What are the long-run effects of dividend taxation on aggregate capital accumulation and welfare? To address this question, we build a dynamic general equilibrium model in which there is a continuum of firms subject to idiosyncratic productivity shocks. We show that at any point in time, a firm may lie in one of three finance regimes: dividend distribution regime, liquidity constrained regime, and equity issuance regime. These finance regimes may change over time in response to idiosyncratic productivity shocks. Firms in different finance regimes respond to dividend taxation in different ways. We calibrate our model to the US data from COMPUSTAT and use this calibrated model to provide an initial quantitative evaluation of the Bush government dividend tax reform in 2003. 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 3 percent and welfare measured by consumption increases by about 0.6 percent. This result is robust to small changes of parameter values and to several extensions of our baseline model.

JEL Classification: E22, E62, G31, G35, H32

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1 Introduction

Dividends are taxed at both the corporate level and the personal level. This double taxation of dividends is under debate both among academics and among policymakers. Dividend taxation reflects the tradeoff between efficiency and equity. On the one hand, taxing dividend income may be desirable for redistribution of income from the rich to the poor. On the other hand, taxing dividend income may distort investment efficiency because it may change the user cost of capital. In this paper, we focus on the efficiency issue. In particular, we ask the following question: What are the long-run effects of a permanent dividend tax cut on aggregate capital accumulation and welfare?

To answer this question, we build a dynamic general equilibrium model in which there is a continuum of corporate firms subject to idiosyncratic productivity shocks. This firm heterogeneity plays a key role in our analysis.[1] Specifically, at any point in time, a firm may be in one of three finance regimes: equity issuance regime, dividend distribution regime, and liquidity constrained regime. These finance regimes are important for investment decisions because retained earnings and dividends are taxed at different rates. In the equity issuance regime, the marginal source of finance is new equity, which corresponds to the traditional view of dividend taxation. In this regime, the dividend tax cut lowers the user cost of capital and hence raises investment. In the dividend distribution regime, the marginal source of finance is retained earnings, and hence the dividend tax cut has no effect on investment. This corresponds to the new view of dividend taxation (Auerbach (1979a,b), Bradford (1981), and King (1977)).[2] 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. By contrast, we show that if all firms were identical or if there were a representative firm in the economy, then dividend taxation would have no effect on the long-run capital accumulation in a deterministic steady state. This is because the representative firm in the

[1]In the empirical industrial organization literature, many researchers (e.g., Syverson (2005)) have found firm-level productivity differences are large and persistent.

[2]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 Poterba and Summers (1985) or Auerbach (2002) for an exposition of the three views. Also see Gordon and Dietz (2006) for a recent survey.

steady state would behave in the same way as described by the new view of dividend taxation.

We use our model to conduct policy experiments for the Bush government dividend tax cut in 2003. The Jobs and Growth Tax Relief Reconciliation Act of 2003 has made two major changes in tax law. First, the capital gains tax is reduced from the previous 20 percent rate 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 rate 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. The tax cut is effective through 2008, but could be made permanent by the second Bush administration.

To evaluate this dividend tax reform, we calibrate our model to match some cross-sectional moments from COMPUSTAT and use these calibrated parameter values to provide quantitative results. As an initial step, we focus on the long-run effects when the tax cut is permanent. Since we do not study the redistributive effect of the dividend tax reform, we assume that there is a representative household who owns all the firms in the model. This household has an average income which falls in the 25 percent federal income tax bracket. Since dividends are taxed at the personal income tax rate, the household faces the 25 percent dividend tax rate.[3] In addition, he faces the 20 percent capital gains tax rate. We show that for reasonably calibrated parameter values in a baseline model with exogenous leisure, when both dividend and capital gains tax rates are cut to the 15 percent level permanently, the steady-state aggregate capital stock rises by about 3 percent. In addition, welfare measured by consumption rises by about 0.6 percent. We also show that these results are robust to small changes of parameter values and to several extensions of the baseline model when incorporating share repurchases, costly external finance, and endogenous leisure.

We emphasize that 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 tax cut. To assess this dampening effect quantitatively, we fix the wage rate at the level prior to the tax reform and show that the increase in aggregate capital after the tax reform in partial equilibrium could be five to ten

[3] Although dividend taxes are skewed towards upper income households, this 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)).

times larger than that in general equilibrium, depending on different parameter values and different model assumptions. Similarly, the increase in consumption in partial equilibrium could be ten times to twenty times larger than that in general equilibrium.

Our paper is related to the literature on the relation between dividend taxation and investment. Miller and Modigliani (1961) show that, in a frictionless world without taxation, transaction costs, and asymmetric information, dividend policy is irrelevant for firm value, and financial and investment policies are independent. Because in reality dividends and retained earnings or capital gains are taxed at different rates, outside equity finance is more costly than internal finance. Thus, the marginal source of investment finance is important for understanding the impact of dividend taxation on investment. Many researchers have used econometric methods to analyze this impact. However, empirical evidence is inconclusive. For example, Poterba and Summers (1985) find evidence supporting the traditional view of dividend taxation using the UK data. Desai and Goolsbee (2004) find evidence supporting the new view of dividend taxation using the US data. Auerbach and Hassett (2003) find that in the US data there are both firms behaving according to the new view and firms behaving according to the traditional view. Thus, there is substantial heterogeneity in the data. To our knowledge, our paper provides the first dynamic general equilibrium model of dividend taxation with firm heterogeneity.[4]

In a related paper, House and Shapiro (2006) build a dynamic general equilibrium model to 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. In addition, they do not consider the firm's financial policy and its interaction with the investment policy.

Our paper is also related to the literature of investment under costly external finance. Many researchers argue that external finance is costly because of transactions costs and asymmetric information. Thus, investment may be sensitive to cash flows (see, e.g., Cooper and Ejarque (2003), Fazzari et al. (1988), Gilchrist and Himmelberg (1995), Gomes (2001), Hennessy and Whited (2006), and Moyen (2004)). Our paper is not about the issue of the investment-cash flow sensitivity. In our model, outside equity is costly because of the tax differential between

[4]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.

dividends and retained earnings. We focus on the effects of the change in the tax differential on investment. In terms of modelling, we embed a standard investment model with adjustment cost and taxation (e.g., Desai and Goolsbee (2004), Fazzari et al (1988), and Poterba and Summers (1985)) in a general equilibrium framework similar to Gomes (2001). However, unlike Gomes (2001), we abstract from entry and exit in order to stay close to a neoclassical growth model. Unlike our paper, Gomes (2001) does not consider taxes.

The remainder of the paper is organized as follows. Section 2 sets up the model. Section 3 analyzes a single firm's decision problem and the effects of dividend taxation in partial equilibrium. This analysis generalizes Auerbach (1979b), Edwards and Keen (1984), and Poterba and Summers (1985) by incorporating adjustment cost. Section 4 provides quantitative results. Section 5 considers several extensions. Section 6 concludes. Technical details and data construction are relegated to appendices.

2 The Model

We embed a standard investment model with adjustment cost widely used in the literature of dividend taxation in a general equilibrium framework. 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. Thus, by a law of large numbers, all aggregate quantities and prices are deterministic over time, although at the firm level each firm faces idiosyncratic uncertainty. We will focus on steady-state stationary equilibrium in which all aggregate variables are constant over time.

2.1 Firms

We begin by describing (corporate) firms' decision problems. 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 $Q : Z \times \mathcal{Z} \to [0, 1]$, where $(Z, \mathcal{Z})$ is a measurable space.

For simplicity, we assume flat taxes with full loss offset provisions. Firms face corporate income tax at the rate τ_c, while individuals face distinct tax rates τ_d on dividends and $\tau_g \leq \tau_d$ on accrued capital gains. In reality, capital gains are taxed on realization rather than on accrual. Incorporating a realization-based capital gains tax would complicate our analysis and is not important in this context. Since debt has tax advantage, firms may have incentives to issue debt. However, incorporating debt financing would also complicate our analysis and is not critical for our key insights. Thus, we do not consider debt financing and assume that firms are all equity financed.

Since 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 conditional expectation operator, 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 shares outstanding in period t. The firm may issue new shares or repurchase old shares. Thus, equity value at date $t+1$ satisfies

$$P_{t+1} = P_{t+1}^0 + s_{t+1}, \tag{2}$$

where s_{t+1} denotes 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 costly external financing. Instead, we consider this issue in Section 5.2.

We will show later that since there is no aggregate uncertainty, the required return in a steady-state equilibrium is given by

$$R_t = (1-\tau_i)\, r, \tag{3}$$

where τ_i is the personal income tax rate to the representative household and r is the constant interest rate. Using equations (1)-(3), we can derive

$$P_t \left[(1-\tau_i)\, r + 1 - \tau_g \right] = E_t \left[(1-\tau_d)\, d_{t+1} + (1-\tau_g) \left(P_{t+1} - s_{t+1} \right) \right]. \tag{4}$$

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

$$V_{t+1} = P_{t+1} - s_{t+1} + \frac{1-\tau_d}{1-\tau_g} d_{t+1}. \tag{5}$$

Using (4), we can then show that

$$V_t = \frac{1-\tau_d}{1-\tau_g} d_t - s_t + \frac{E_t\left[V_{t+1}\right]}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}. \tag{6}$$

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 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 condition. We can then derive the operating profit function by solving the following static labor choice problem

$$\pi\left(k,z;w\right) = \max_{l\geq 0}\left\{F\left(k,l;z\right) - wl\right\}, \tag{7}$$

where w denotes the wage. We can also derive the labor demand

$$l\left(k,z;w\right) = \arg\max_{l}\left\{F\left(k,l;z\right) - wl\right\}, \tag{8}$$

and output supply

$$y\left(k,z;w\right) = F\left(k,l\left(k,z;w\right);z\right). \tag{9}$$

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

$$k' = \left(1-\delta\right)k + x, \tag{10}$$

where $\delta \in (0,1)$ denotes the depreciation rate. Investments incur adjustment cost. For simplicity, we consider the quadratic adjustment cost function, $\psi x^2/\left(2k\right)$, widely used in the empirical investment literature. 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 (6), $V\left(k,z;w\right)$ satisfies the following Bellman equation:

$$V\left(k,z;w\right) = \max_{k',x,s,d} \frac{1-\tau_d}{1-\tau_g} d - s + \frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)} \int V\left(k',z';w\right) Q\left(z,dz'\right), \tag{11}$$

subject to (10) and

$$x + \frac{\psi x^2}{2k} + d = \left(1-\tau_c\right)\pi\left(k,z;w\right) + \tau_c \delta k + s, \tag{12}$$

$$d \geq 0, \tag{13}$$

$$s \geq 0. \tag{14}$$

Equation (12) 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 cost, and dividend payments.[5] Dividend payments cannot be negative. We thus impose constraint (13).

There may also be effective restriction on share repurchases. In some countries such as the United Kingdom, share repurchases are explicitly banned. In the United States, share repurchases are allowed. However, regular repurchases may lead the IRS to treat repurchases as dividends. Also repurchases may be costly. These costs may be associated with asymmetric information.[6] For simplicity, we follow most papers in the literature to impose constraint (14).[7] Since we rule out share repurchases, the model here cannot address the "dividend puzzle" which asks why firms pay dividends given the tax advantage of share repurchases. In Section 5.1, we will relax this assumption and follow Poterba and Summers (1985) to impose a constraint that share repurchases are bounded by some maximal amount.[8]

By a standard dynamic programming argument as in Stokey and Lucas (1989), one can show that there is a unique value function V satisfying the Bellman equation (11). Also V is continuous, strictly increasing, and strictly concave in k. Thus, there exist unique decision rules denoted by

$$x = x(k, z; w), \ k' = g(k, z; w), \ s = s(k, z; w), \ d = d(k, z; w). \tag{15}$$

2.2 Stationary Distribution and Aggregation

Since 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). The law of motion for the firm distribution is given by

$$\mu'(A \times B) = \int P((k, z), A \times B)\, \mu(dk, dz), \tag{16}$$

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

[6] See, for example, Brennan and Thakor (1990) and Barclay and Smith (1988).

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

[8] See Gordon and Dietz (2006) for a survey of models for the dividend puzzle.

where the transition function P satisfies

$$P\left(\left(k,z\right),A\times B\right)=Q\left(z,B\right)\mathbf{1}_{A}, \tag{17}$$

and

$$\mathbf{1}_{A}=\begin{cases}1 & \text{if } g\left(k,z;w\right)\in A\\ 0 & \text{otherwise}\end{cases}. \tag{18}$$

Here A and B are Borel sets. 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

$$Y\left(\mu^{*};w\right)=\int y\left(k,z;w\right)\mu^{*}\left(dk,dz\right), \tag{19}$$

- aggregate labor demand

$$L^{d}\left(\mu^{*};w\right)=\int l\left(k,z;w\right)\mu^{*}\left(dk,dz\right), \tag{20}$$

- aggregate investment

$$I\left(\mu^{*};w\right)=\int x\left(k,z;w\right)\mu^{*}\left(dk,dz\right), \tag{21}$$

- aggregate adjustment cost

$$\Psi\left(\mu^{*};w\right)=\int\frac{\psi x\left(k,z;w\right)^{2}}{2k}\mu^{*}\left(dk,dz\right). \tag{22}$$

2.3 Household

For simplicity, we assume that the representative household supplies labor inelastically at $\bar{L}$. We will consider endogenous leisure in Section 5.3 and show that our results are robust to this extension. The representative household derives utility from consumption according to the standard time-additive utility function

$$\sum_{t=0}^{\infty}\beta^{t}U\left(C_{t}\right), \tag{23}$$

where β is the discount factor, C_t denotes consumption, and U satisfies $U'>0$, $U''<0$, and the Inada condition. 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. Thus, the budget constraint is given by

$$\begin{aligned} & C_t + \int P_t \theta_{t+1} d\mu_t + b_{t+1} \\ = & \int \left[(1-\tau_d) d_t + P_t^0 - \tau_g \left(P_t^0 - P_{t-1} \right) \right] \theta_t d\mu_t + (1 + (1-\tau_i) r_t) b_t + (1-\tau_i) w_t \bar{L} + T_t, \end{aligned} \tag{24}$$

where θ_t denotes the shares owned by the household, b_t denotes the amount of bond, 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 and trading strategies to maximize his utility (23) subject to (24). We consider the household problem's in a stationary equilibrium in which interest rate r_t and aggregate consumption C_t are constant over time. As in Gomes (2001), one can show that in a stationary equilibrium the intertemporal marginal rate of substitution is equal to β. Also the interest rate satisfies

$$\beta (r (1-\tau_i) + 1) = 1. \tag{25}$$

In addition, the required return to equity is given by (3), and hence equity value satisfies (4).

As in Gomes (2001), in the steady state, the household solves a static problem

$$\max U(C) \tag{26}$$

subject to

$$\begin{aligned} C = & (1-\tau_d) \int d(k,z;w) \mu^* (dk,dz) - (1-\tau_g) \int s(k,z;w) \mu^* (dk,dz) \\ & + (1-\tau_i) w \bar{L} + T \end{aligned} \tag{27}$$

From this problem, we can derive the consumption demand function $C(\mu^*; w)$.

2.4 Government

Since the focus of the paper is on the distortionary effect of dividend taxation, we assume that the tax revenue collected by the government is rebated to the household in a lump-sum manner. Thus, we abstract away from the wealth effects associated with using distortionary taxation to finance government spending on goods and services. Since the government collects corporate income taxes, dividend taxes, personal income taxes and capital gains taxes, and transfers these tax revenues to the household,[9] the government budget constraint is given by

$$\begin{aligned} T &= \tau_c \int \left(\pi\left(k,z;w\right)-\delta k\right)\mu\left(dk,dz\right)+\tau_d \int d\left(k,z;w\right)\mu\left(dk,dz\right) \\ &\quad +\tau_i w\bar{L}-\tau_g \int s\left(k,z;w\right)\mu\left(dk,dz\right). \end{aligned} \tag{28}$$

2.5 Stationary Equilibrium

A stationary equilibrium consists of a constant wage rate w, a stationary distribution of firms μ^*, aggregate quantities $C\left(\mu^*;w\right),\ I\left(\mu^*;w\right),\ \Psi\left(\mu^*;w\right),\ Y\left(\mu^*;w\right),\ L^d\left(\mu^*;w\right)$, and decision rules $k'=g\left(k,z;w\right),\ x=x\left(k,z;w\right),\ s=s\left(k,z;w\right),\ d=d\left(k,z;w\right)$ such that (i) the decision rules solve the firm's problem (11); (ii) $C\left(\mu^*;w\right)$ solves the household's problem (26); (iii) μ^* satisfies equation (16) and aggregate quantities satisfy equations (19)-(22); and (iv) markets clear,

$$L^d\left(\mu^*;w\right)=\bar{L}, \tag{29}$$

$$C\left(\mu^*;w\right)+I\left(\mu^*;w\right)+\Psi\left(\mu^*;w\right)=Y\left(\mu^*;w\right). \tag{30}$$

3 Analysis of A Single Firm's Decision Problem

In order to analyze the general equilibrium effects of 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 (11) as the following sequence problem:

$$\max_{x_t,k_{t+1},s_t} E\left[\sum_{t=0}^{\infty}\frac{1}{\left(1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)\right)^t}\left(\frac{1-\tau_d}{1-\tau_g}d_t-s_t\right)\right], \tag{31}$$

subject to

$$x_t+\frac{\psi x_t^2}{2k_t}+d_t=\left(1-\tau_c\right)\pi\left(k_t,z_t\right)+\tau_c\delta k_t+s_t, \tag{32}$$

$$k_{t+1}=\left(1-\delta\right)k_t+x_t, \tag{33}$$

$$d_t\geq 0, \tag{34}$$

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

$$s_t \geq 0. \tag{35}$$

Let q_t, $\lambda_t^d \geq 0$ and $\lambda_t^s \geq 0$ be the Lagrange multipliers associated with the constraints (33)-(35), 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 (32) to eliminate d_t, we obtain the following first-order conditions:

$$s_t : \frac{1-\tau_d}{1-\tau_g} + \lambda_t^d + \lambda_t^s = 1, \tag{36}$$

$$x_t : q_t = \left(\frac{1-\tau_d}{1-\tau_g} + \lambda_t^d \right) \left(1 + \frac{\psi x_t}{k_t} \right), \tag{37}$$

$$k_{t+1} \quad : \quad q_t = \frac{1}{1 + r\left(1-\tau_i\right) / \left(1-\tau_g\right)} E_t \Bigg\{ q_{t+1}\left(1-\delta\right) + \tag{38}$$
$$\left(\frac{1-\tau_d}{1-\tau_g} + \lambda_{t+1}^d \right) \left[\left(1-\tau_c\right) \pi_1\left(k_{t+1}, z_{t+1}\right) + \tau_c \delta + \frac{\psi}{2} \left(\frac{x_{t+1}}{k_{t+1}} \right)^2 \right] \Bigg\}.$$

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

3.1 Financial Policy

We start by analyzing the firm's financial policy, holding the investment policy fixed. This financial policy is determined by equation (36), which has the following interpretation. Raising one unit of new equity to pay dividends relaxes the dividend constraint and the no-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 (36) 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 (36) gives the marginal cost to the shareholder. Equation (36) 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 (36) 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 (31) 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. Since according to the US tax system before the 2003 dividend tax cut the dividend tax rate is higher than the capital gains tax rate, we assume that $\tau_d > \tau_g$. In this case, it follows from (36) 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_c. 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 (13) and (14) must be binding. This observation gives us three cases to consider. Each case corresponds to a different *finance regime*.

In the first case, $\lambda_t^d > 0$ and $\lambda_t^s = 0$. By the complementary slackness condition, $d_t = 0$, and $s_t > 0$. We call this case the *equity issuance regime*. In this regime, the firm does not have enough internal funds to make investment and distribute dividends. Hence the marginal source of investment finance is the external equity market. This regime reflects the traditional view of divided taxation. Using (36) and (12), we have

$$\frac{1-\tau_d}{1-\tau_g} + \lambda_t^s = 1, \tag{39}$$

$$s_t = -\left[(1-\tau_c)\,\pi\,(k_t, z_t) + \tau_c \delta k_t - x_t - \frac{\psi x_t^2}{2k_t} \right] > 0. \tag{40}$$

In the second case, $\lambda_t^d = 0$ and $\lambda_t^s > 0$. The complementary slackness condition implies that $d_t > 0$ 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. The firm does not need to go to the equity market. This regime corresponds to the "new view" of dividend taxation.

In the third case, $\lambda_t^d > 0$ and $\lambda_t^s > 0$. The complementary slackness condition implies that $d_t = 0$ and $s_t = 0$. We call this 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.

3.2 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 cost.

3.2.1 q Theory

Using equation (37), we can derive the investment equation:

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(\frac{q_t}{\frac{1-\tau_d}{1-\tau_g} + \lambda_t^d} - 1\right). \tag{41}$$

This equation is a simple variant of the estimation equation widely used in the q-theory literature. It also highlights the key difference between the traditional and 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 (39), we can then derive

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(q_t - 1\right). \tag{42}$$

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 (41) reduces to

$$\frac{x_t}{k_t} = \frac{1}{\psi}\left(\frac{1-\tau_g}{1-\tau_d} q_t - 1\right). \tag{43}$$

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 $q_t = (1-\tau_d)\,/\,(1-\tau_g) < 1$.

What seems counterintuitive is that under the traditional view tax parameters do not enter (42), but they appear in (43). In fact, the intuition is easy to explain. Solving equation (38) recursively forward and using the law of iterated expectation and the transversality condition, we obtain

$$q_t = E_t\left[\sum_{j=1}^{\infty} \frac{(1-\delta)^{j-1}\, mpk_{t+j}}{\left(1 + r\,(1-\tau_i)\,/\,(1-\tau_g)\right)^j}\right], \tag{44}$$

where

$$mpk_{t+j} = \left(\frac{1-\tau_d}{1-\tau_g} + \lambda_{t+j}^d\right)\left[(1-\tau_c)\,\pi_1\,(k_{t+j}, z_{t+j}) + \tau_c\delta + \psi x_{t+j}^2 / \left(2k_{t+j}^2\right)\right]. \tag{45}$$

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 (43). This implies that dividend taxes have no effect on marginal investment.

To formalize the above intuition more transparently, we use equations (37)-(38) to obtain the optimality condition for investment

$$\left(\frac{1-\tau_d}{1-\tau_g} + \lambda_t^d\right)\left(1 + \frac{\psi x_t}{k_t}\right) = \frac{1}{1 + r\,(1-\tau_i)\,/\,(1-\tau_g)} \times \tag{46}$$

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

The expression on the left side of (46) represents the marginal cost of investment, while the expression on the right side represents the marginal benefit from investment.

From equation (46), 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*, and the following equation determines the optimal investment policy[10]

$$1+\frac{\psi x_t}{k_t}=\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}\times \tag{47}$$
$$E_t\left[\left(1-\tau_c\right)\pi_1\left(k_{t+1},z\right)+\tau_c\delta+\frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2+(1-\delta)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)\right].$$

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 tax has no effect on the current marginal investment if the return to investment is used to reduce the next period equity issuance. This point has been made by Edwards and Keen (1984) in a model without adjustment cost.

When the current marginal source of finance is new equity, i.e., $\lambda_t^d>0$ and $\lambda_t^s=0$ ($d_t=0, s_t>0$), but the return to investment is used to pay dividends, i.e., $\lambda_{t+1}^d=0$ ($d_{t+1}>0, s_{t+1}=0$), then (46) reduces to

$$1+\frac{\psi x_t}{k_t}=\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)}\frac{1-\tau_d}{1-\tau_g}\times \tag{48}$$
$$E_t\left[\left(1-\tau_c\right)\pi_1\left(k_{t+1},z\right)+\tau_c\delta+\frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2+(1-\delta)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)\right].$$

This equation implies that a decrease in dividend tax rate τ_d raises the after-tax marginal return to investment and hence raises 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., $\lambda_t^d=0$ ($d_t>0, s_t=0$), but the return to investment is used to reduce equity issuance in the next period, i.e., $\lambda_{t+1}^d>0$ and $\lambda_{t+1}^s=0$ ($d_{t+1}=0, s_{t+1}>0$), then equation (46) reduces to

$$\frac{1-\tau_d}{1-\tau_g}\left(1+\frac{\psi x_t}{k_t}\right)=\frac{1}{1+r\left(1-\tau_i\right)/\left(1-\tau_g\right)} \tag{49}$$
$$E_t\left[\left(1-\tau_c\right)\pi_1\left(k_{t+1},z\right)+\tau_c\delta+\frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2+(1-\delta)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)\right].$$

Thus, a decrease in dividend tax rate τ_d raises marginal cost and hence reduces investment x_t, *ceteris paribus*.

[10] 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.

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:

$$x_t = (1 - \tau_c)\,\pi\,(k_t, z_t) + \tau_c \delta k_t, \tag{50}$$

which do not depend on dividend taxation.

Figure 1 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 $(1 - \tau_c)\,\pi\,(k, z) + \tau_c \delta k$. This financing hierarchy may be familiar in the public finance literature (see, e.g., Fazzari et al. (1988) or Auerbach (2002)).

[Insert Figure 1 Here]

3.2.2 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 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 addition unit of capital, i.e.,

$$u_t = (1 - \tau_c)\,\pi_1\,(k_{t+1}) + \frac{\psi}{2}\left(\frac{x_{t+1}}{k_{t+1}}\right)^2. \tag{51}$$

Using (38), we can derive that

$$u_t = \left(\frac{1 - \tau_d}{1 - \tau_g} + \lambda_{t+1}^d\right)^{-1} \left[q_t \left(r\,(1 - \tau_i)\,/\,(1 - \tau_g) + \delta\right) - \Delta q_t\,(1 - \delta)\right] - \delta \tau_c, \tag{52}$$

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.

Substituting equation (37) into (52) yields

$$u_t = \left(\frac{1-\tau_d}{1-\tau_g}+\lambda_t^d\right)\left(\frac{1-\tau_d}{1-\tau_g}+\lambda_{t+1}^d\right)^{-1}\left(1+\frac{\psi x_t}{k_t}\right)\left(1+\frac{r\left(1-\tau_i\right)}{1-\tau_g}\right) - \left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)-\tau_c\delta. \tag{53}$$

Ignoring the liquidity constrained regime, we can see from this equation that there are three cases corresponding to the three cases analyzed earlier. In the first case, if the marginal source of finance does not change in two adjacent periods, i.e., $\lambda_t^d = \lambda_{t+1}^d$, then the user cost of capital is given by

$$u_t = \left(1+\frac{\psi x_t}{k_t}\right)\left(1+\frac{r\left(1-\tau_i\right)}{1-\tau_g}\right) - \left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)-\tau_c\delta, \tag{54}$$

which does not depend on dividend taxation.

In the second case where $\lambda_t^d > 0$ and $\lambda_{t+1}^d = 0$, the user cost of capital is given by

$$u_t = \frac{1-\tau_g}{1-\tau_d}\left(1+\frac{\psi x_t}{k_t}\right)\left(1+\frac{r\left(1-\tau_i\right)}{1-\tau_g}\right) - \left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)-\tau_c\delta. \tag{55}$$

Thus, a decrease in dividend tax rate τ_d lowers the user cost of capital and hence raises investment at date t, *ceteris paribus.*

In the third case where $\lambda_t^d = 0$ and $\lambda_{t+1}^d > 0$, the user cost of capital is given by

$$u_t = \frac{1-\tau_d}{1-\tau_g}\left(1+\frac{\psi x_t}{k_t}\right)\left(1+\frac{r\left(1-\tau_i\right)}{1-\tau_g}\right) - \left(1-\delta\right)\left(1+\frac{\psi x_{t+1}}{k_{t+1}}\right)-\tau_c\delta. \tag{56}$$

Thus, a decrease in dividend tax rate τ_d raises user cost of capital and hence lowers investment at date t, *ceteris paribus.*

Finally, 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 (53) to show that a cut of the common tax rate $\tau_d = \tau_g$ will lower the user cost of capital and hence will raise investment. This result will be useful for understanding our policy experiments in Section 4.

3.3 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 2. Also we suppose there is no uncertainty. Because aggregate consumption in a steady state is constant over time, equation (25) determines the interest rate.

In addition, equations (36)-(38) still describe the representative firm's first-order conditions, except that we remove the shock variable z_t and the expectation operator. Since $k_t = k_{t+1}$, $x_t = \delta k_t$, $\lambda_t^d = \lambda_{t+1}^d$ for all t in a deterministic steady state, it follows from (46) that the steady-state capital stock k^* satisfies

$$1 + \psi\delta = \frac{1}{1 + r(1-\tau_i)/(1-\tau_g)} \left[(1-\tau_c)\,\pi_1(k^*) + \tau_c\delta + \psi\delta^2/2 + (1+\psi\delta)(1-\delta) \right]. \quad (57)$$

This equation implies that in a model without firm heterogeneity dividend taxation does not influence the steady-state capital stock. This is because, when there is a representative firm, in the deterministic steady state the firm can finance its investment using retained earnings 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 the dividend tax cut in different ways. Thus, the dividend tax cut will influence the steady-state capital stock. In the next section, we analyze its quantitative effects.

4 Quantitative Results

We now turn to the general equilibrium model presented in Section 2. Since 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 A details our numerical method.

4.1 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 dividend tax cut. We do not consider other periods since our tax parameters are not relevant for those periods. Appendix B describes the data construction.

Tax system. It is delicate to calibrate tax rates since tax rates in reality are nonlinear and changes in each year, while we have assumed constant and flat rates in our model. In order to evaluate the Bush government's dividend tax reform in 2003, we suppose tax rates in each year are given by the federal statutory rates in 2003. 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 at $\tau_g = 0.20$. Since dividends are taxed at the personal income tax rate, we set $\tau_d = 0.25$.

Preferences. Since we focus on stationary equilibrium and assume fixed labor, preferences do not play an important role in our analysis. Specifying any period utility function U that satisfies the assumption in Section 2.3 does not change our analysis. We choose the discount factor β such that the interest rate r is equal to 0.04 using equation (25). As is standard in the macroeconomics literature, we set $\bar{L} = 0.3$, which is the average fraction of time spent on market work.

Technology. We choose the following Cobb-Douglas production function:

$$F(k, l; z) = zk^{\alpha_k} l^{\alpha_l}, \tag{58}$$

where $0 < \alpha_k, \alpha_l < 1$. We assume that the productivity shock follows the AR(1) process,

$$\ln z_t = \rho \ln z_{t-1} + \varepsilon_t, \tag{59}$$

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. Following Cooper and Ejarque (2003), Gilchrist and Himmelberg (1995), Hennessy and Whited (2006), we simply set the depreciation rate $\delta = 0.15$.

The final parameter to be calibrated is the adjustment cost parameter ψ. Since the volatility of the investment rate is very sensitive to this parameter, we choose a value to match the standard deviation of the investment rate, which is 0.194 in our data. 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.[11]

In summary, we list the calibrated parameter values in Table 1. In Section 4.6, we conduct a sensitivity analysis for parameters ρ, σ and ψ since these parameter values are important for our quantitative results.

[11] See Cooper and Haltiwanger (2005) for an estimation of adjustment cost using establishment-level data.

Table 1. Baseline parametrization

	Parameter	Value
Corporate income tax	τ_c	0.34
Personal income tax	τ_i	0.25
Dividend tax	τ_d	0.25
Capital gain tax	τ_g	0.20
Exponent on capital	α_k	0.30
Exponent on labor	α_l	0.65
Shock persistence	ρ	0.76
Shock standard deviation	σ	0.23
Depreciation rate	δ	0.15
Discount factor	β	0.97
Adjustment cost	ψ	1.15

4.2 Baseline Model Results

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 3, firms in different finance regimes may respond to the dividend tax cut in different ways. Figure 2 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.

[Insert Figure 2 Here]

We next turn to the aggregate and cross-sectional results. Table 2 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 2. Aggregate and cross-sectional moments in the baseline model. The Investment share is taken from the National Income Accounts (BEA) 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 1.

Variable	Data	Model
Investment share I/Y	0.110	0.157
Aggregate dividends/ aggregate earnings	0.142	0.312
Aggregate new equity/aggregate investment	0.160	0.131
Standard deviation of investment rate	0.194	0.199
Autocorrelation of investment rate	0.631	0.609
Standard deviation of earnings/capital	0.914	0.274
Autocorrelation of earnings/capital	0.782	0.625

Table 3 reports the distribution of firms. This table reveals that there is only a small fraction (23.3 percent) of firms in the equity issuance regime in the steady state. These firms are small and account for a small fraction of employment and output. 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 make more investment.

Table 3. Distribution of firms in the baseline model. Relative average size in each regime is computed as the ratio of the average size of the firms whin that regime to the average size of all firms. The model parameter values are listed in Table 1.

	Equity issuance regime	Liquidity constrained regime	Dividend distribution regime
Fraction of firms	0.233	0.390	0.377
Relative average size	0.474	0.577	1.762
Share of investment	0.339	0.351	0.310
Share of labor	0.196	0.234	0.570
Share of output	0.196	0.234	0.570

Note that the last two rows in Table 3 reveal that the share of labor is the same as the share of output for the firms in each finance regime. The intuition is the following. Given the

Cob-Douglas production function specification, we can show that labor demand and output supply for a firm are given by

$$l\left(k,z;w\right)=\left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}}\left(\frac{\alpha_l}{w}\right)^{\frac{1}{1-\alpha_l}},\ y\left(k,z;w\right)=\left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}}\left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}}. \tag{60}$$

Thus, shares of output and labor are determined by the same term $\left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}}$.

4.3 Effects of Dividend Tax Reform

To estimate the quantitative effects of dividend taxation, we consider three policy experiments. These experiments intend to provide an evaluation of the long run effects of the Jobs and Growth Tax Relief Reconciliation Act of 2003. This act makes two major changes in tax law. First, the capital gains tax is reduced from the previous 20 percent rate 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 rate 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.

Our experiments assume that the tax rate changes are permanent and we focus on the long-run steady-state effects. 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 4 reports the aggregate results. Since dividends are taxed at a lower rate after this policy, firms distribute more dividends. This is consistent with economic intuition and empirical evidence reported by Chetty and Saez (2005) and Poterba (2004). Since $\left(1-\tau_d\right)/\left(1-\tau_g\right)<1$ after the dividend tax cut, outside equity finance is still more costly than internal finance. However, the gap between the cost of outside equity finance and the cost of internal finance is narrowed. Thus, as revealed in Column 2 of Table 4, firms raise more equity to finance investment after the dividend tax cut.

Table 4. Aggregate effects of the dividend tax reform in the baseline model. When we change tax rates, we fix all other parameter values as in Table 1. All results are measured in percentage change from the initial steady state before the reform.

	$\tau_d = 0.22, \tau_g = 0.20$	$\tau_d = \tau_g = 0.20$	$\tau_d = \tau_g = 0.15$
Capital	0.30	0.63	3.12
Output	0.43	0.75	1.37
Consumption	0.24	0.39	0.64
Dividends	4.66	indeterminate	indeterminate
Equity issuance	30.83	indeterminate	indeterminate
Wage	0.43	0.75	1.37

Column 2 of Table 4 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. It can be measured as the increase in consumption, which is only 0.24 percent.

To understand the effect on aggregate capital accumulation, we recall that firm heterogeneity plays a key role. As shown in Section 3.3, if there were no firm heterogeneity, dividend taxes would have no effect on the steady-state capital stock. Table 5 illustrates the importance of firm heterogeneity. Compared with Table 3, Table 5 reveals that after the dividend tax cut, 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.

Table 5. Firm distribution for $\tau_d = 0.22$ and $\tau_g = 0.20$. The other parameter values are listed in Table 1.

	Equity issuance regime	Liquidity constrained regime	Dividend distribution regime
Fraction of firms	0.275	0.305	0.420
Relative average size	0.519	0.534	1.652
Share of labor	0.432	0.247	0.320
Share of investment	0.242	0.164	0.594
Share of output	0.242	0.164	0.594

Turn to the effect of the dividend tax cut on the wage rate. Since after the dividend tax cut there are more firms in the equity issuance regime and these firms are profitable as illustrated in Figure 2, they invest more and demand more labor causing the aggregate demand for labor to rise. Since we assume that the labor supply is inelastic, the equilibrium wage rate must rise as illustrated in Figure 3. Consistent with this intuition, Column 2 of Table 4 reveals that the wage rate is increased by 0.42 percent after the dividend tax cut. Note that this increase is the same as that in output. The reason is the following. By (29) and (60), the equilibrium wage is determined by

$$\int l\left(k,z;w\right)\mu^{*}\left(dk,dz\right)=\left(\frac{\alpha_{l}}{w}\right)^{\frac{1}{1-\alpha_{l}}}\int\left(zk^{\alpha_{k}}\right)^{\frac{1}{1-\alpha_{l}}}\mu^{*}\left(dk,dz\right)=\bar{L}. \tag{61}$$

By (60), aggregate output is given by

$$Y=\int y\left(k,z;w\right)\mu^{*}\left(dk,dz\right)=\left(\frac{\alpha_{l}}{w}\right)^{\frac{\alpha_{l}}{1-\alpha_{l}}}\int\left(zk^{\alpha_{k}}\right)^{\frac{1}{1-\alpha_{l}}}\mu^{*}\left(dk,dz\right)=w\bar{L}/\alpha_{l}, \tag{62}$$

where I have used equation (61) to derive the last equality. Since labor supply is fixed at $\bar{L}$, aggregate output is proportional to the wage rate w.

[Insert Figure 3 Here]

We now 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 the same 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 3.1. Thus, in Column 3 of Table 4, the values of aggregate dividends and new equity are indeterminate. 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 0.63 percent, and aggregate output is raised by 0.75 percent. The welfare increase measured by the increase in aggregate consumption is still small at the value of 0.39 percent.

We finally consider the third policy experiment in which both the capital gains tax rate and the dividend tax rate are cut to the same level of 15 percent. Column 4 of Table 4 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 measured by consumption increase by 3.12 and 0.64 percent, respectively. We should point out that when the same tax rate on dividends and capital gains are lowered from 20 percent to 15 percent, the previously discussed "regime changing effect" does not play an important role since for both the second and the third policy experiments there is no tax differential in dividends and capital gains. In fact, the economic effect of the tax cut from $\tau_d = \tau_g = 0.20$ to $\tau_d = \tau_g = 0.15$ is through the after-tax interest rate and hence the user cost of capital. From (11) or (31), we can see that the after-tax interest rate is given by $r(1-\tau_i)/(1-\tau_g)$. Thus, a decrease in $\tau_g = \tau_d$ lowers the after-tax interest rate and hence the user cost of capital, as analyzed in Section 3.2.2.

4.4 Productivity Gains

We have shown that the dividend tax cut stimulates aggregate capital accumulation in general equilibrium. In addition, the change in the dividend tax rate leads to reallocation of capital and labor towards more productive firms. In our model, firms with high productivity but with little capital issue new equity, and may pay dividends later on. These firms are responsible for the increase in investment after the dividend tax cut. In addition, capital and labor are reallocated more to these high productivity firms, generating productivity gains from the dividend tax cut.

To gauge the productivity gains quantitatively, we use two measures, aggregate labor productivity (Y/L) and total factor productivity ($Y/(K^{\alpha_k}L^{\alpha_l})$). 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 1. Table 6 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 equation (60) to rewrite TFP as follows

$$\begin{aligned} TFP &= \frac{Y}{K^{\alpha_k}L^{\alpha_l}} = \frac{\left[\int (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}}\mu(dk,dz)\right]^{1-\alpha_l}}{\left[\int k\mu(dk,dz)\right]^{\alpha_k}} = \frac{E_\mu\left[z^{\frac{1}{1-\alpha_l}}k^{\frac{\alpha_k}{1-\alpha_l}}\right]^{1-\alpha_l}}{E_\mu[k]^{\alpha_k}} \\ &= \frac{\left(E_\mu\left[z^{\frac{1}{1-\alpha_l}}\right]E_\mu\left[k^{\frac{\alpha_k}{1-\alpha_l}}\right] + Cov_\mu\left[z^{\frac{1}{1-\alpha_l}}, k^{\frac{\alpha_k}{1-\alpha_l}}\right]\right)^{1-\alpha_l}}{E_\mu[k]^{\alpha_k}}, \end{aligned} \tag{63}$$

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 shock z. 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. In addition, Row 4 of Table 6 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 is, the more efficient the allocation of capital across firms. Thus, we should expect that TFP will increase if the dividend tax rate is lowered. This intuition is confirmed in Row 2 of Table 6.

Table 6: Productivity gains from the dividend tax cut. Other parameter values are listed in Table 1.

	$\tau_d = 0.25$	$\tau_d = 0.22$	$\tau_d = 0.20$
Percentage change in TFP	0.00	0.33	0.55
Percentage change in Y/L	0.00	0.42	0.75
Correlation between $\ln k$ and $\ln z$	0.48	0.49	0.50

We now turn to Row 3 of Table 6, which reveals that labor productivity (Y/L) increases as the dividend tax rate decreases. To see the intuition, we use equation (60) to compute labor productivity as follows

$$\frac{Y}{L} = \frac{\int (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}} \mu(dk, dz) \left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}}}{\int (zk^{\alpha_k})^{\frac{1}{1-\alpha_l}} \mu(dk, dz) \left(\frac{\alpha_l}{w}\right)^{\frac{1}{1-\alpha_l}}} = \frac{w}{\alpha_l}. \tag{64}$$

From this equation, we can see clearly that the increase in labor productivity is due to the increase in wage.[12] The increase in wage is in turn due to the increase in capital since the latter increase raises the marginal product of labor.

Table 6 also reveals that the magnitude of the productivity gain from the dividend tax cut is small. This may explain why our simulated welfare effect of the Bush tax reform in 2003 is small as reported in Table 4. We should emphasize that the importance of the reallocation effect depends on the size of the adjustment cost. For smaller adjustment costs, the effect of dividend tax cut on capital accumulation and productivity should be larger since capital is less costly to be reallocated.

4.5 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 the level before the tax

[12]This equation and the intuition also hold true for the case with endogenous leisure analyzed in Section 5.3.

reform. At this wage, we use labor demand to determine aggregate employment by ignoring the labor market-clearing condition (29). 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.

Table 7 reports the results. Comparing this table with Table 4 reveals 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 as large as that in general equilibrium and the increase in consumption in partial equilibrium is about 23 times as large as that in general equilibrium. This experiment demonstrates that using a partial equilibrium model to conduct policy evaluation can be quite misleading.

Table 7. Aggregate effects in partial equilibrium. The wage rate is fixed at the equilibrium value before tax changes. Other parameter values are listed in Table 1. All results are measured in percentage change from the initial steady state before the tax change.

	$\tau_g = 0.2, \tau_d = 0.22$	$\tau_g = \tau_d = 0.2$	$\tau_g = \tau_d = 0.15$
Capital	4.83	8.23	17.70
Output	4.91	8.36	15.70
Consumption	4.73	8.03	14.97
Employment	4.91	8.36	15.70

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

$$\pi\left(k, z; w\right) = \left(zk^{\alpha_k}\right)^{\frac{1}{1-\alpha_l}} \left(\frac{\alpha_l}{w}\right)^{\frac{\alpha_l}{1-\alpha_l}} \left(1 - \alpha_l\right). \tag{65}$$

Table 7 reveals that labor demand increases in response to the tax cut. Thus, the wage rate should rise after the tax reform in general equilibrium. The preceding equation reveals that the increased wage lowers a firm's profits and hence its returns to investment. This equilibrium wage feedback effect dampens the increase in investment and hence output in general equilibrium. Table 7 illustrates that this feedback effect is quantitatively significantly.

4.6 Sensitivity Analysis

Since the parameters of persistence ρ, volatility σ, and adjustment cost ψ are 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 1. Table 8 reports aggregate and cross-sectional results for different parameter values.

From this table, we can see the following: 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 raises more new equity. In addition, investment and earnings become more volatile and less persistent since the adjustment is then faster.

An increase in the persistence 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 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 0.324 to 0.172. This increase also raises the persistence of the investment rate since firms are reluctant to adjust investment.

Table 8. Moments for different parameter values. When we change one parameter value, we fix other parameter values as in Table 1.

	$\rho = 0.6$	$\rho = 0.8$	$\sigma = 0.1$	$\sigma = 0.3$	$\psi = 0.5$	$\psi = 1.5$
Investment share I/Y	0.181	0.147	0.184	0.139	0.160	0.154
Total dividends/total earnings	0.252	0.349	0.254	0.359	0.426	0.287
Total new equity/total investment	0.007	0.203	0.007	0.226	0.338	0.085
Standard deviation of investment rate	0.110	0.235	0.090	0.248	0.324	0.172
Autocorrelation of investment rate	0.494	0.625	0.657	0.573	0.540	0.624
Standard deviation of earnings/capital	0.251	0.274	0.114	0.381	0.237	0.291
Autocorrelation of earnings/capital	0.492	0.660	0.699	0.569	0.610	0.629

Table 9 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 is 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 about 3 percent and 1 percent, respectively. Notably, the steady-state increase in consumption is below 1 percent. We should also point out that 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. Thus, the resulting increases in aggregate output, capital and consumption are also large.

Table 9. Sensitivity analysis of dividend tax reform for different parameter values. When we change one parameter value, we fix other parameter values as in Table 1. All results are measured in percentage change from the initial steady state.

	Capital	Output	Consumption	Wage
Baseline parametrization	3.12	1.37	0.64	1.37
$\rho = 0.6$	2.79	0.87	0.37	0.84
$\rho = 0.8$	3.43	1.44	0.66	1.44
$\sigma = 0.1$	2.47	0.86	0.36	0.85
$\sigma = 0.3$	3.72	1.47	0.68	1.45
$\psi = 0.5$	4.34	1.88	0.86	1.88
$\psi = 1.5$	2.81	1.18	0.55	1.16

5 Extensions

Our baseline model has a few limitations. First, we do not allow for share repurchases. Second, except for the tax cost, there is no other cost associated with external equity finance. Finally, we assume fixed labor supply. We now relax each of these three assumptions. Our simulations indicate that these extensions do not change our previous quantitative results significantly.

5.1 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 (14), the analysis in Section 3 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 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 less dividends. To illustrate the effects of share repurchases, we conduct experiments by setting $\underline{s} = -0.1, -0.2$, and -0.3. We also fix the other parameter values as in Table 1. We find that 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. Allowing for share repurchases, firms can use the returns from investment to repurchase shares instead of distributing the more costly dividends. This effectively raises the benefit from investment. Thus, firms have incentives to make more investment and issue more new equity to finance the investment if possible.

We now consider the effect of the dividend tax reform when firms can repurchase shares. We observe that, 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 retained earnings, by the Miller and Modigliani Theorem. Thus, given our discussion in the preceding paragraph, aggregate capital, consumption, and output should increase less than those in the baseline model. Table 10 reports the quantitative results.

Table 10. The effects of dividend tax reform in the model with share repurchase. We set $\underline{s} = -0.2$. All other parameter values are listed in Table 1. All results are measured in percentage change from the initial steady state before the tax change.

	$\tau_d = \tau_g = 0.20$	$\tau_d = \tau_g = 0.15$
Capital	0.52	2.97
Output	0.53	1.13
Consumption	0.27	0.49
Wage	0.52	1.14

5.2 Costly External Finance

So far, we have assumed that external equity finance is costly only because of the differential tax treatment of retained earnings and dividends. Many researchers argue that outside equity markets are costly because of asymmetric information or transactions cost. We now analyze a model with this sort of costly external finance. Specifically, we assume that equity issuance incurs a fixed cost and a proportional cost as in Gomes (2001). To illustrate the effects of these costs, we run one simulation by choosing small values of the fixed cost parameter $\phi_0 = 0.01$, and the linear cost parameter $\phi_1 = 0.05$. Table 11 reports the results. Comparing this table with Table 4, we can see that the effects of the dividend tax reform on capital, output and consumption are smaller in the model with equity issuance cost. Importantly, unlike the baseline model, the Miller and Modigliani theorem is invalid here even when $\tau_d = \tau_g$ due to the equity issuance cost, and thus there is an optimal dividend policy when $\tau_d = \tau_g$. Table 11 shows that when $\tau_d = \tau_g = 0.20$, new equity is raised by 49.72 percent, and dividends are raised by 4.08 percent. When both rates are further cut down to $\tau_d = \tau_g = 0.15$, dividends are raised by a smaller number of 3.22 percent, while new equity is raised by a larger number of 55.09 percent. The reason is that firms raise more equity and use more retained earnings to finance investment because the after-tax interest rate is lower.

Table 11. The effects of dividend tax reform for the model with costly external finance. We set the parameter values for the fixed and linear equity issuance costs as $\phi_0 = 0.01$ and $\phi_1 = 0.05$. All other parameter values are listed in Table 1. All results are measured in percentage change from the initial steady state.

	$\tau_d = \tau_g = 0.20$	$\tau_d = \tau_g = 0.15$
Capital	0.13	2.34
Output	0.48	0.99
Consumption	0.22	0.38
Dividends	4.08	3.22
Equity Issuance	49.72	55.09

5.3 Endogenous Leisure

We have assumed that labor supply is inelastic in order to flesh out intuition in a simple manner. We now generalize the baseline model to allow for endogenous labor supply. Specifically, we suppose the period utility function takes the form $U(c,l) = \ln(c) + H\ln(1-l)$. We then calibrate the parameters H and ψ to match the hours spent on working at the value 0.3 and the standard deviation of investment rate at the value 0.194 in the initial steady state. We find $H = 1.41$ and $\psi = 1.20$. Using these parameter values and other parameter values listed in Table 1, we solve the model again and conduct policy experiments. Table 12 reports the aggregate effects of the dividend tax reform. Comparing with the results for the baseline model with exogenous leisure reported in Table 4, we find that the qualitative results do not change. In addition, quantitative results have similar magnitude. However, the effects on consumption and output are larger here since the equilibrium employment rises in response to the tax cut. After controlling for changes in labor, we find that welfare measured by consumption increases by 0.43 and 0.72 percent for the two policy experiments in Table 12.

Table 12. Aggregate effects of the dividend tax reform for the model with endogenous leisure. Let $U(c,l) = \ln(c) + H\ln(1-l)$. Set $H = 1.41$ and $\psi = 1.20$. All other parameter values are listed in Table 1. All results are measured in percentage change from the initial steady state.

	$\tau_d = \tau_g = 0.20$	$\tau_d = \tau_g = 0.15$
Capital	0.75	3.53
Output	0.97	1.87
Consumption	0.63	1.14
Employment	0.26	0.54
Labor productivity	0.71	1.32
Wage	0.71	1.32

The mechanism behind the model with endogenous leisure is similar to that behind the model with exogenous leisure. The only difference lies in the labor market behavior. Figure 4 illustrates the labor market equilibrium. In the figure, the L_1^d and L_1^s schedules represent labor demand and supply curves before the tax reform, respectively. After the tax reform, labor demand rises so that L_1^d schedule shifts to the right. Because after the dividend tax reform, the household receives higher dividends, the wealth effect implies that the household will consume more and supply less labor. This implies that the L_1^s schedule shifts to the left. The new equilibrium is determined by the intersection of the L_2^d schedule and the L_2^s schedule. It is clear that the wage rate should go up after the tax cut since the labor demand goes up and the labor supply goes down. However, 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 labor rises after the dividend tax reform.

[Insert Figure 4 Here]

As discussed earlier, the rise in the wage rate after the dividend tax reform in general equilibrium will dampen the increase in the capital stock. To asses this general equilibrium feedback effect, Table 13 reports the results when we fix the wage rate at the value before the dividend tax reform. Comparing to the results with exogenous labor, we see that the dampening effect has a similar magnitude.

Table 13. Aggregate effects of the dividend tax reform for the model with endogenous leisure in partial equilibrium. Let $U(c,l) = \ln(c) + H\ln(1-l)$. Set $H = 1.41$ and $\psi = 1.20$. We fix the wage rate at the equilibrium value before tax changes. All other parameter values are listed in Table 1. All results are measured in percentage change from the initial steady state.

	$\tau_d = \tau_g = 0.20$	$\tau_d = \tau_g = 0.15$
Capital	9.19	19.20
Output	9.37	17.35
Consumption	9.03	16.60
Employment	9.37	17.35

6 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 and welfare. Firm heterogeneity in productivity and general equilibrium play a key role in our analysis. This firm heterogeneity implies that, in the long run, firms still face idiosyncratic productivity shocks, even though the economy-wide aggregates are constant over time. Thus, firms may lie in different finance regimes over time and respond to dividend taxation in different ways. 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. 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 Bush government dividend tax reform in 2003. Our simulations show that under reasonably calibrated parameter values in a baseline model with exogenous leisure, a permanent cut of dividend taxes alone from 25 percent to the same level of 20 percent as the capital gains tax rate has a small effect on the long-run capital accumulation and welfare (less than 1 percent increase). When both dividend and capital gains taxes are cut to the same 15 percent level permanently, the steady-state capital stock and welfare measured by consumption increase by about 3 and 0.6 percent, respectively. Our results are robust to small changes of parameter values and to several extensions of our baseline model when incorporating share repurchases, costly external finance and endogenous leisure. By contrast, when shutting down the price feedback effect in a partial equilibrium model, the increase in capital could be about five to ten times larger and the increase in consumption could be about ten to twenty times larger, depending on different parameter values and different model assumptions.

One limitation of our model is that we abstract from debt financing.[13] Incorporating debt in the model would be interesting. Another limitation of our model is that we do not study transitional dynamics. Given the fact that the dividend tax cut may be temporary, it would be interesting to analyze both of its temporary and permanent effects. We study this issue in Gourio and Miao (2006). Finally, we have assumed a very simple government behavior. In future work, 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 deficit.

[13] See Hennessy and Whited (2005) and Moyen (2004) for partial equilibrium models with debt financing, and Miao (2005) for an industry equilibrium model with debt financing.

Appendices

A Numerical Method

To solve the model, 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.[14]

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 is 0.001 and the upper bound is chosen so that it does not bind. 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 (16) 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. In the benchmark calibration, labor supply is fixed, so we need to check that $L^d(w) = 0.3$. In the extension which allows for elastic labor supply, we check whether $U_2(C, L)/U_1(C, L) = (1 - \tau_i)w$, 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, and is never greater than 10^{-5} in relative term. According to our numerical experiments, a 1 percent change in the wage leads

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

to a change smaller than 10 percent on all the variables. Thus, the precision of our results appears to be no less than 0.01 percent.

B 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.

When computing the statistics in Table 2, 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 for Table 2, we use the gross equity issuance, i.e. the aggregate of item 108, over the aggregate of item 30.

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. Since 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 (2005), or Hennessy and Whited (2005, 2006).

We now describe our estimation procedure. By (65), 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 deflated by the consumption GDP deflator) on log real capital (item 8 deflated by the investment GDP deflator):

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

Note that we do not incorporate 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, Figure 4 in Comin and Philippon (2005)). We recognize, however, that fixed effects may increase the endogeneity problem in this production function estimation.

Our estimate of b is $\widehat{b} = 0.855$. 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 $\alpha_k : \widehat{\alpha}_k = 0.30$.

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

$$\widehat{\rho} = 0.76, \ \widehat{\sigma} = 0.23.$$

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

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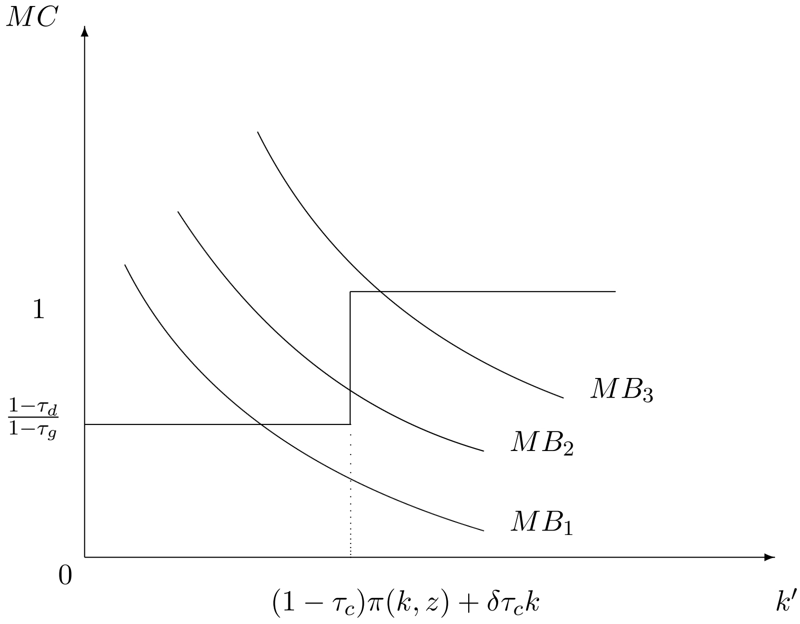

Figure 1: **Determination of optimal investment policy for the case without adjustment cost**

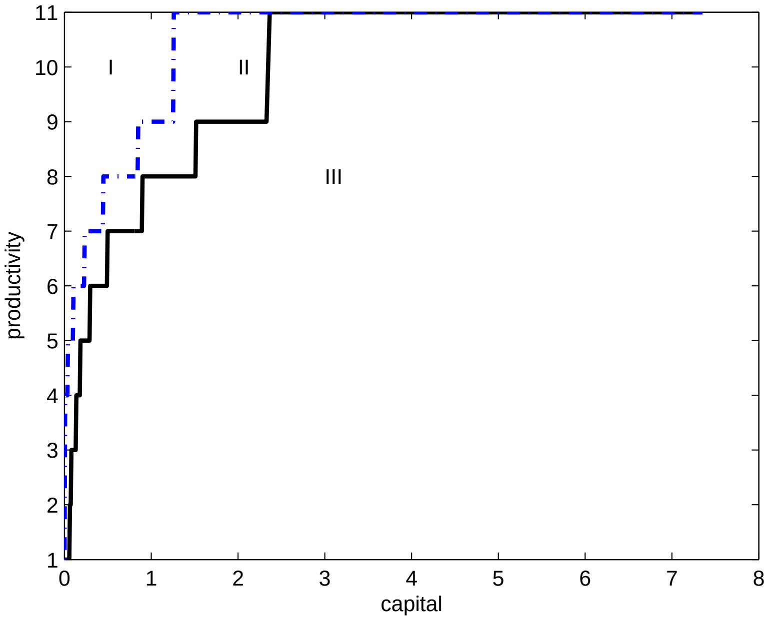

Figure 2: **Finance regimes.** This figure is obtained from the numerical solution for the baseline model with parameter values given in Table 1. It illustrates the three finance regimes for the baseline model. Region I represents the equity issuance regime. Region II represents the liquidity constrained regime and region III represents the dividend distribution regime.

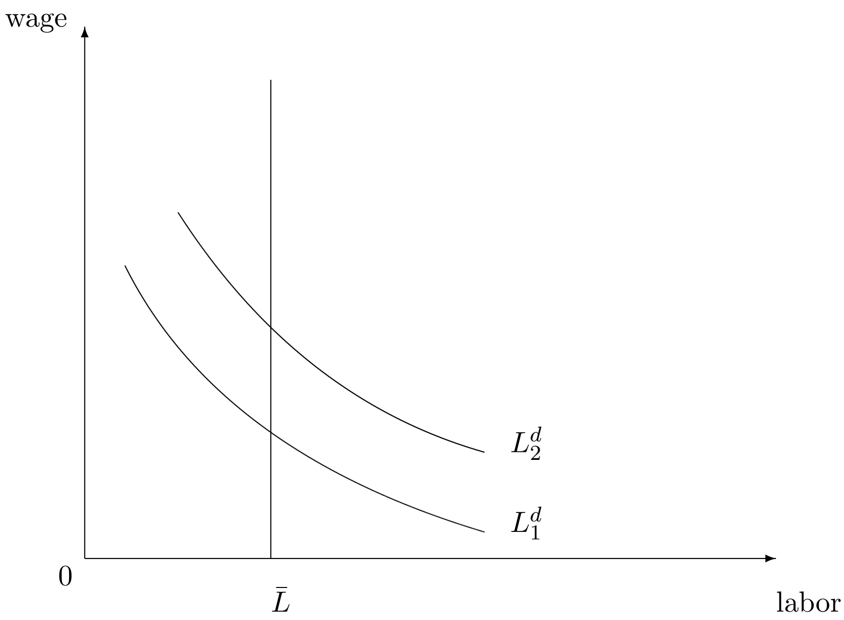

Figure 3: **Labor market equilibrium in the model with exogenous leisure**

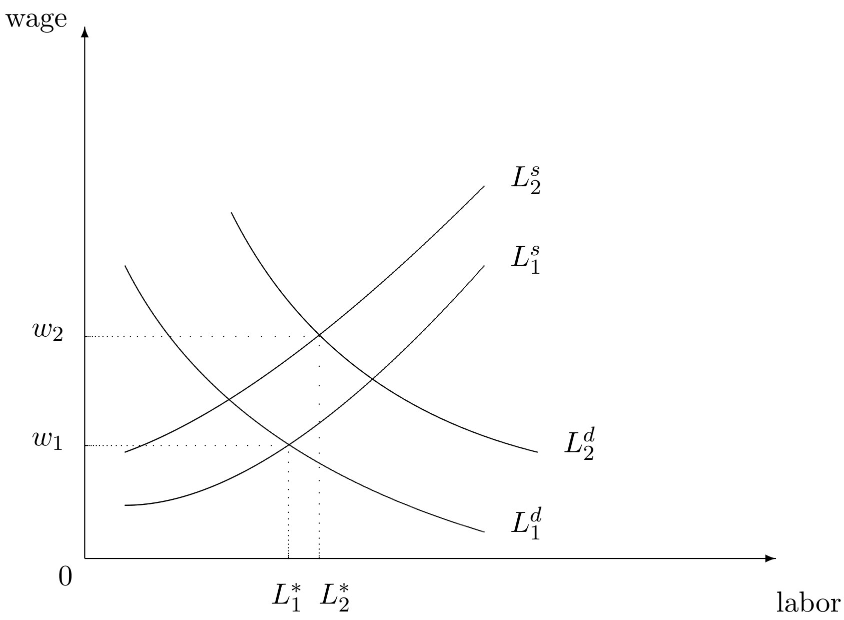

Figure 4: **Labor market equilibrium in the model with endogenous leisure**