Dividend and Capital Gains Taxation under Incomplete Markets*

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Abstract

Motivated by the Jobs and Growth Tax Relief Reconciliation Act of 2003, we study the effects of capital income tax cuts in a framework where firms make investment decisions to maximize their market value and households are subject to uninsurable labor income risk. We find that the effects of capital gains tax cuts are qualitatively similar to those found in the absence of household heterogeneity. However, dividend tax cuts surprisingly lead to a reduction in aggregate investment. This is because they increase the market value of the existing capital. In equilibrium, households then require a higher return to hold this additional wealth, leading to a lower capital stock. This also implies that dividend tax cuts are welfare reducing in the long run, not only because of the traditional reasons of redistribution from poor to rich, but also because of a fall in long run aggregate output and consumption. Taking into account the transition mitigates the losses but the JGTRRA tax cuts still lead to a welfare reduction equivalent to a 0.5% drop in consumption. In line with empirical evidence, the model also predicts substantial increases in dividends and stock prices following the tax cuts.

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1 Introduction

In 2003, the Bush Administration introduced the Jobs and Growth Tax Relief Reconciliation Act (JGTRRA) which, amongst other reforms, lowered dividend and capital gains taxes. This act had a sunset provision that stipulated its expiry by the end of 2010, but it was recently extended for two more years by the current administration. Whether it should be made permanent or not remains an important subject of political debate. This paper contributes to the current debate on this issue by analyzing the quantitative effects of these capital income tax changes in a dynamic stochastic general equilibrium model calibrated to US data.

Discussions on tax policy, especially capital income tax policy, have always been politically divisive. One of the reasons is that economic theory provides sound arguments for both sides of the discussion. On the one hand, reductions in capital taxes are viewed as providing incentives for investment and, hence, leading to higher economic growth. Indeed, one of the primary objectives of the JGTRRA reform was to promote capital formation. On the other hand, reductions in capital taxes are viewed as negative because of the resulting increase in budget deficits as well as inequality. Although there seems to be a presumption that reductions in capital taxes would disproportionately favor the wealthiest part of the distribution, it is well known that those relying mainly on labor income could also see substantial benefits arising from the general equilibrium effects of increased investment on wages and employment.

Although the non-academic discussion tends to treat all kinds of capital income taxes as though they have similar effects, the academic community has long recognized the difference between taxing returns to investment (e.g. corporate profits, capital gains) and taxing distributions in the form of dividends. Indeed, a growing literature subscribes to the so-called new view of dividend taxation, according to which constant dividend taxes do not distort investment incentives.[1] This paper's main contribution lies in re-examining the differential effects of dividend and capital gains taxes in an incomplete markets environment. The aim is to contribute to our understanding of these taxes theoretically and to provide a quantitative analysis of the size of the costs and benefits associated with the JGTRRA.

To that end, we build a general equilibrium model in which households face uninsurable idiosyncratic labor income risk. In addition to risky labor income, households receive capital income from owning shares in firms. Both labor and capital income are taxed by the government. An important assumption is that the government taxes dividends and capital gains at potentially different rates. Firms in our model undertake investment with a view

[1] A detailed discussion of the literature is provided in Section 2.

to maximizing shareholder value. As shown by Cárceles-Poveda and Coen-Pirani (2009), shareholder unanimity with respect to this objective can be ensured, despite the presence of shareholder heterogeneity and market incompleteness, by assuming constant returns to scale production and no short-selling constraints. We calibrate our model to US data and compute both long run steady states and transitions.

Our results regarding steady states are as follows. A reduction in dividend tax rates has the surprising effect of reducing aggregate investment and capital stock. To understand the reason, first note that the dividend tax change does not directly affect the cost of capital. Its only effect is to raise the market valuation of the existing capital stock and hence aggregate wealth. If markets were complete, there would be no other effects and we would obtain the well-known neutrality of dividend taxation under the new view. However, changes in wealth do matter for household decisions because markets are incomplete. Specifically, households demand a higher return in order to hold the additional wealth. In equilibrium, firms respond by reducing the capital stock and this increases the marginal product of capital and, thus, the rate of return.[2] Capital gains taxes have the opposite effect. We find that a reduction in capital gains tax rates, increases capital stock and investment. Contrary to the dividend tax, the capital gains tax directly affects the cost of capital and therefore acts as a standard capital income tax, effectively reducing the after tax return on investment. At the same time, a fall in the capital gains tax reduces the market valuation of the existing capital stock and, for the reasons explained above, it also leads to an increase in the capital stock. When dividend and capital gains taxes are reduced simultaneously to the levels of the JGTRRA reform, the dividend tax cut effects dominate for two reasons. First, the reduction in the dividend tax stipulated by the JGTRRA was much larger than the one for capital gains taxes. Second, there are no capital gains in the steady state of our model economy, so the capital gains tax rate only affects the steady state through an indirect channel. Thus, in the long run, the reform reduces investment and the capital stock. At the same time dividends, stock prices and returns increase substantially, which is consistent with the experience of the US economy following the reform.[3]

To evaluate the welfare consequences of the reform, it is important to complement these long run results with the short run effects of the tax reform. We therefore analyze the effects of the tax reform taking into account the transition. Starting at the steady state of the pre-

[2]Note that this is the exact opposite effect on investment to the one intended by the proponents of the JGTRRA tax reform. A similar point, albeit for different reasons, is made in Korinek and Stiglitz (2008).

[3]Evidence that a decrease in dividend taxes raises dividend payments can be found in Chetty and Saez (2005) and Poterba (2004). Blouin, Raedy and Shackelford (2004) also find an increase in payout but provide some qualifications for the result. The effect of dividend taxes on investment is difficult to establish, as discussed by Chetty and Saez (2005).

reform economy, taxes change unexpectedly and permanently and the economy is simulated until convergence to the post-reform steady state. The transition is characterized by a monotonically decreasing aggregate capital. Aggregate consumption initially increases as the economy starts dissaving, but eventually falls below the pre-reform level as production is reduced due to lower investment. Based on a utilitarian welfare criterion, we find an average welfare reduction of approximately 0.5% (in terms of consumption equivalents). This arises from significant long run welfare costs mitigated by short run welfare gains due to the temporary increase in aggregate consumption.

Additional insight into the reasons for these costs and gains can be obtained by decomposing welfare effects into "aggregate" and "distributional" components, following the methodology proposed by Domeij and Heathcote (2004). The aggregate component refers to the welfare effect arising from a change in aggregate consumption for a given distribution of consumption across households. The distributional component is defined as the residual. The decomposition reveals a positive aggregate effect arising from the immediate consumption hike, but a larger negative distributional effect. The distributional component captures the effect of changes in the distribution of consumption. A reduction in dividend and capital gains taxes benefits households in the upper tail of the wealth distribution and hurts those in the lower tail. The marginal utility of the latter is higher (and there are more of them) so the utilitarian welfare function is negatively affected.

This negative redistribution has been pointed out in existing studies of capital income tax reforms.[4] The dividend tax cut makes this effect more pronounced than in previous studies, because the bottom of the wealth distribution, which relies mostly on labor income, now faces a negative general equilibrium effect on wages due to the fall in the aggregate capital stock. The finding that the aggregate component is positive is also consistent with existing studies. Note, however, that the reasons are different. In those studies, the aggregate component is positive following a capital income tax cut, because the long run increase in aggregate consumption dominates the temporary decrease. In contrast, following our dividend tax cut experiment, aggregate consumption temporarily increases and this dominates the long run decrease. In terms of winners and losers, we find that individuals at the low end of labor productivity and those holding zero or very few stocks stand to lose from the reform, whereas those holding a lot of stocks stand to gain. Overall, we find that only 20% of the population experiences a welfare improvement, which indicates limited political support.

The rest of the paper is organized as follows. Section 2 points out related articles, discusses some interesting implications of our result and addresses potential caveats. Section 3 presents the model. Section 4 discusses the theoretical effects of the tax cuts and provides

[4]See e.g. Aiyagari (1995), Domeij and Heathcote (2004) and Ábrahám and Cárceles-Poveda (2010).

intuition for the results. In Section 5, we calibrate the model to US data and provide a quantitative evaluation of the welfare implications of the Bush tax reforms both in the long run and along the transition. Section 6 conducts some sensitivity analysis and Section 7 summarizes and concludes.

2 Related Literature and Discussion

From a theoretical perspective, this paper can be seen as bridging the gap between two strands of literature. The first strand includes articles that analyze tax reform and optimal taxation in the presence of household heterogeneity and uninsured idiosyncratic risk. This is done in an infinite horizon framework by Aiyagari (1995), Domeij and Heathcote (2004) and Ábrahám and Cárceles-Poveda (2010) among others, and in a setting with overlapping generations by Imrohoroglu (1998), Conesa and Krueger (2006) and Conesa, Kitao and Krueger (2009). Our paper is most closely related to the former, in the sense that we use an infinite horizon setting. A purely cosmetic difference lies in our choice of modelling firms as the owners of the capital stock, which we view as the most natural setup in which to think of dividend and capital gains taxes.[5] The crucial difference is that we explicitly model dividend and capital gains taxes as opposed to assuming a general capital income tax on the return to capital.

The second strand of the literature is the one focusing on the effects of dividend taxes on capital accumulation and the stock market in a framework with no heterogeneity. McGrattan and Prescott (2005), Gourio and Miao (2008), Santoro and Wei (2009a) and Conesa and Dominguez (2010) show that, in such a setting, a constant flat tax rate on dividends only affects stock prices, leaving all other equilibrium quantities such as investment and dividends unaffected.[6] We add household heterogeneity and find that dividend taxes affect all equilibrium quantities.

Our paper also contributes to the long standing debate in the public finance literature about the effects of dividend taxes on the cost of capital and investment. The debate is centered around two views, the 'traditional' view and the 'new' view. The aforementioned articles belong to the new view, in the sense that dividend taxes have no effects on capital formation. In contrast, according to the traditional view, dividend taxes reduce the capital stock because they increase the cost of capital. In a framework with no household hetero-

[5] An equivalent formulation assuming static firms that rent capital from consumers is available upon request. See also Cárceles-Poveda and Coen Pirani (2010) for a general equivalence result between the two settings with incomplete markets but no taxes.

[6] Conesa and Dominguez (2010), in particular, study optimal corporate and dividend taxes in a framework similar to the one in McGrattan and Prescott (2005).

geneity, the work of Poterba and Summers (1983), Auerbach and Hassett (2003) and, more recently, of Gourio and Miao (2011) has shed light on the implicit assumptions underlying each view, specifically with regard to the marginal sources and uses of funds. Within that framework, if the sources and uses of funds are the same, then the firm is unaffected by the dividend tax and it conforms to the 'new' view. However, if the sources and uses of funds are asymmetric, then the dividend tax distorts capital formation. The most common scenario of the latter case would involve funds raised through equity issuance and the resulting returns to investment being paid out as dividends in the future.

An important implication of our model is that this intimate connection between sources and uses of funds and the two views is broken when we introduce household heterogeneity. In our model, firms do not use equity issuance to finance investment. Instead, the marginal source of financing is retained earnings (i.e. a reduction in dividends) and the resulting profits are distributed as dividends in the future. In the above taxonomy, our firm would thus conform to the new view, since the sources and uses of funds are symmetric. However, it does not conform to the spirit of the new view, since dividend taxes have real effects on investment and dividends. This should raise concerns about tests of the new versus the traditional view based on theoretical implications of representative agent models. Empirical evidence of an increase in dividend payments in response to a decrease in dividend taxes is often seen as evidence in favor of the traditional view and, specifically, of the idea that the marginal source of funds is equity issuance. This seems to contradict the observation that the overwhelming majority of investment is carried out by mature firms who use internal funds to finance their investment.[7] Our model provides a reconciliation of these two pieces of evidence. In our environment, dividends respond strongly and positively to a decrease in dividend taxes, even though investment is financed exclusively using internal funds.[8] The implication is that one should be cautious when using empirical tests based on the response of dividends to distinguish between the two views.

Both the preceding discussion of the literature and our model in the main body of the paper assume that the tax reform is unexpected and perceived as permanent. These assumptions are not innocuous. If individuals face a non-constant dividend tax rate profile, as would be the case if the reform was temporary or expected, then the dividend tax will affect

[7] Using Compustat data, Gourio and Miao (2010) find that firms which distribute dividends and use retained earnings to finance investment undertake more than 90% of investment and hold more than 90% of the capital stock. In earlier work using the Survey of Current Business and Federal Reserve Bulletins, Sinn (1991) concludes that "*...most corporate equity capital is generated by internal investment rather than new share issues*". The recent theoretical literature studying the effects of dividend and capital gains taxes seems to have adopted this view at least as a benchmark.

[8] A similar result is obtained by Chetty and Saez (2010) in an agency model of the firm.

investment even in the absence of heterogeneity.[9] We discuss each of those assumptions in turn.

There are good reasons to believe that the reform was unexpected. It was not part of Bush's 2001 election platform, it was first suggested in January 2003 and seemed to lose momentum several times in the following months until it was signed into law in May 2003. Thus, the window of opportunity for anticipation effects to matter was short. This is confirmed in Chetty and Saez (2005), who provide empirical evidence supporting the idea that the tax cuts were unexpected.

Whether the reform was perceived as temporary or permanent is more controversial. While the JGTRRA included a sunset provision, it was clear at the time that this was not introduced because the tax reform was intended to be temporary, but rather as a means of circumventing the Byrd rule and avoiding having the act blocked in the Senate. In fact, a statement published in 2003 by a panel of economists opposing the tax cuts states this perception explicitly: "...Regardless of how one views the specifics of the Bush plan, there is wide agreement that its purpose is a permanent change in the tax structure...The permanent dividend tax cut, in particular, is not credible as a short-term stimulus...". Auerbach and Hassett's (2005) work also seems to support the idea that markets perceived this tax change as fairly permanent. To the extent that markets perceived the reform as temporary, both Korinek and Stiglitz (2008) and Gourio and Miao (2011) have shown that the dividend tax cut would tend to increase dividend payments and decrease investment. In this sense, our results would be further strengthened in that case.

The article most closely related to ours is the one by Gourio and Miao (2010). They investigate the effects of the JGTRRA in a general equilibrium model with firm heterogeneity.[10] Firm heterogeneity is something we have abstracted from in this paper and which, interestingly, leads to opposite conclusions about the effects of the reform. Gourio and Miao (2010) find that the reform could lead to an increase in investment through several channels. First, the decrease in capital gains taxes reduces the cost of capital for all firms, making it easier to invest. This mechanism is also present in our model, albeit dominated by the wealth effect of the dividend tax cut. Second, there are reallocation effects which are absent from our study. In particular, their model features firms that can be in one of three finance regimes: liquidity constrained, equity issuing or dividend paying. The last two types, and particularly the equity issuing firms, are the ones that are most productive and hence carry out the majority of investment in that model. The reform has the effect of moving

[9] A non-constant dividend tax profile is introduced by Korinek and Stiglitz (2009), McGrattan (2010), by Gourio and Miao (2011) and, indirectly, by Santoro and Wei (2009b).

[10] Korinek and Stiglitz (2009) do this in a partial equilibrium framework.

firms from the liquidity constrained stage to the equity issuing (and to the dividend paying) stage and, hence, increases aggregate investment through reallocation. Additionally, because the sources and uses of funds are asymmetric for equity issuing firms, the dividend tax cut directly reduces the cost of capital for those firms which also raises investment. These considerations suggest that the JGTRRA tax cuts might have generated opposite forces affecting aggregate investment, which only changed moderately following the tax cuts, as documented in Desai and Goolsbee (2004). We view our results as complementary to those in Gourio and Miao (2010).[11] From a quantitative perspective, given that mature firms hold the majority of capital and undertake the majority of investment in the US economy, we view our focus on mature firms as a reasonable abstraction.

3 The Model

We consider an infinite horizon economy with endogenous production and uninsurable labor income risk. The economy is populated by a continuum (measure 1) of infinitely lived households that are indexed by i, a representative firm that maximizes its market value and a government that maintains a balanced budget. Time is discrete and indexed by $t = 0, 1, 2, ...$

3.1 Households

Households have identical additively separable preferences over sequences of consumption $c_i \equiv \{c_{it}\}_{t=0}^{\infty}$ of the form:

$$U(c_i) = E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}), \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor and E_0 denotes the expectation conditional on information at date $t = 0$. The period utility function $u(\cdot) : \mathbb{R}_+ \to \mathbb{R}$ is assumed to be strictly increasing, strictly concave and continuously differentiable, with $\lim_{c_i \to 0} u'(c_i) = \infty$ and $\lim_{c_i \to \infty} u'(c_i) = 0$.

Each period, households can only trade in stocks of the firm to insure against uncertainty. We denote by s_{it-1} the number of stocks held at the beginning of period t. Stocks can be traded between households at a competitive price p_t and the ownership of stocks entitles the shareholder to a dividend per share of d_t. We assume that there is no aggregate uncertainty, implying that dividends, the stock price and hence the return on the stock are certain.

[11] Since we introduce household heterogeneity, we need to abstract from firm heterogeneity in order to maintain computational tractability.

In addition to asset income, household i earns labor income. We assume that all households supply a fixed amount of labor (normalized to one) but their productivity, ϵ_{it}, varies stochastically. This productivity is i.i.d. across households and follows a Markov process with transition matrix $\Pi(\epsilon'|\epsilon)$ and S_ϵ possible values. Individual labor income is thus equal to $w_t\epsilon_{it}$, where w_t is the aggregate wage rate.

The government levies proportional taxes on labor income, dividend income and capital gains income at rates of τ_l, τ_d and τ_g respectively**.** Households can use their after-tax income from all sources to purchase consumption goods or to purchase additional stocks. The households' budget constraint can be expressed as:

$$c_{it} + p_t s_{it} = (1-\tau_l) w_t \epsilon_{it} + ((1-\tau_d) d_t + p_t)\, s_{it-1} - \tau_g\,(p_t - p_{t-1})\, s_{it-1}. \tag{2}$$

Note that we have simplified by assuming capital gains taxes are paid on an accrual basis and that capital losses are subsidized at the same rate.[12] At each date, household i also faces a no short-selling constraint on stocks:

$$s_{it} \geq 0 \tag{3}$$

The presence of this constraint will allow us to have a well-defined firm objective on which all the shareholders agree, despite the market incompleteness. Individuals choose how much to consume and how many stocks to buy in each period given prices, dividends and tax rates $\{p_t, w_{t,} d_{t,} \tau_d, \tau_l, \tau_g\}_{t=0}^{\infty}$.

Before proceeding with the description of the firm, we derive the relationship between stock prices and future dividends, which we call the price dividend mapping. We will use this mapping in the following subsection to define the value of the firm and to derive the relationship between physical capital and the stock price.

The optimal choice of stocks by an unconstrained household i with $s_{it} > 0$ requires the following optimality condition to hold:

$$p_t u_{c,it} = \beta E_t u_{c,it+1} \left[(1-\tau_d)\, d_{t+1} + p_{t+1} - \tau_g\,(p_{t+1} - p_t)\right] \tag{4}$$

where $u_{c,it}$ denotes the marginal utility of the agent. As usual, the expected intertemporal marginal rates of substitution for all unconstrained households are equalized and they are equal to the reciprocal of the gross return from the stock between t and $t+1$

$$1 + r_{t+1} \equiv \frac{\left[(1-\tau_d)\, d_{t+1} + p_{t+1} - \tau_g\,(p_{t+1} - p_t)\right]}{p_t} = \frac{u_{c,it}}{\beta E_t u_{c,it+1}} \tag{5}$$

[12] For a way to model capital gains taxes on a realization basis see Kydland, Gavin and Pakko (2007).

Using this relationship, the absence of aggregate uncertainty and assuming that there are no-bubbles, the stock price can then be written as a function of dividends as follows[13]

$$p_t = \sum_{j=1}^{\infty} \left(\prod_{i=0}^{j-1} \frac{1}{1 + \frac{r_{t+1+i}}{1-\tau_g}} \right) \frac{1-\tau_d}{1-\tau_g} d_{t+j} \tag{6}$$

3.2 The Firm

The representative firm owns the capital stock K_t, hires labor and combines these two inputs to produce consumption goods using a constant returns to scale technology:

$$Y_t = AF(K_t, L_t)$$

where K and L are the aggregate capital and effective labor, while A is the total factor productivity, which is assumed to be constant. The total number of stocks outstanding is normalized to one and we assume that the firm has no access to additional sources of external finance, namely, it cannot issue new equity or debt. Thus the total wage bill and investment as well as the distributions of dividends to shareholders have to be financed solely using internal funds.[14] The firm's financing constraint is therefore:

$$d_t + K_{t+1} - (1-\delta) K_t + w_t L_t = AF(K_t, L_t) \tag{7}$$

where $\delta \in [0, 1]$ is the capital depreciation rate.

The firm's objective is to maximize its market value for the shareholders. In general, when markets are incomplete, maximizing the value of the firm is not an objective to which all shareholders would agree. However, Cárceles-Poveda and Coen-Pirani (2009) show that, even under incomplete markets, shareholder unanimity can be obtained if the technology exhibits constant returns to scale and short-selling is not allowed. We maintain these two assumptions throughout the paper. Using the price-dividend mapping (6), the value of the firm at t can be written as:

$$V_t = \frac{1-\tau_d}{1-\tau_g} d_t + p_t = \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j-1} \frac{1}{1 + \frac{r_{t+1+i}}{1-\tau_g}} \right) \frac{1-\tau_d}{1-\tau_g} d_{t+j}$$

[13] The derivation of the expressions in this section can be found in Appendix A.

[14] We do not allow firms to use repurchases as a means of distributing profits. See Gordon and Dietz (2009) for a discussion of alternative ways to ensure firms pay dividends.

Maximizing this objective subject to (7) leads to the aggregate labor demand equation:

$$w_t = AF_L\left(K_t, L_t\right) \tag{8}$$

Optimal investment dynamics are described by the capital Euler equation:

$$1 = \frac{1}{1 + \frac{r_{t+1}}{1-\tau_g}}\left(1 - \delta + AF_K\left(K_{t+1}, L_{t+1}\right)\right) \tag{9}$$

As shown in Appendix A, this last expression together with (6) implies the following relation between aggregate capital and the stock price:

$$p_t = \frac{1-\tau_d}{1-\tau_g} K_{t+1} \tag{10}$$

Differences between dividend and capital gains tax rates create a wedge between the physical capital stock and its market valuation. Crucially for the results that will follow, changes in the ratio $\frac{1-\tau_d}{1-\tau_g}$ will cause movements in the total wealth held by households, even keeping the capital stock constant.

3.3 Government

In each period t, the government consumes an exogenous, constant amount G and taxes labor, dividend and capital gains income at rates τ_l, τ_d and τ_g respectively. We assume that the government has a balanced budget. The government budget constraint is given by

$$G = \tau_d d_t + \tau_l w_t L_t + \tau_g (p_t - p_{t-1}) \tag{11}$$

3.4 Recursive Competitive Equilibrium

In the present framework, the aggregate state of the economy is given by the aggregate capital stock K together with the joint distribution Ψ of consumers over individual stock holdings s and idiosyncratic productivity ϵ. Households perceive that Ψ evolves according to:

$$\Psi' = \Gamma\left(K, \Psi\right)$$

where Γ represents the transition function from the current aggregate state into tomorrow's stock-productivity distribution. The aggregate capital stock evolves according to:

$$K' = \Phi\left(K, \Psi\right)$$

Since the individual state vector consists of individual labor productivity and stock holdings (ϵ, s), the relevant state variables for a household are summarized by the vector $(\epsilon, s; \Psi, K)$.[15]

Definition: Given the transition matrix Π, as well as initial values for the aggregate capital stock K_0 and for the distribution over stocks and productivity Ψ_0, a *recursive competitive equilibrium* relative to a government policy $(\tau_d, \tau_g, \tau_l, G)$ consists of laws of motion Γ and Φ, stock price and wage functions $p(K')$ and $w(K)$, firm choices K', $L(K)$ and $d(K, K')$ and individual household policy functions $c(\epsilon, s; K, \Psi)$ and $s(\epsilon, s; K, \Psi)$, as well as associated value functions $V(\epsilon, s; K, \Psi)$ such that:

- *Optimal Household Choice:* Given prices and aggregates, the individual policy functions $c(\epsilon, s; K, \Psi)$, $s(\epsilon, s; K, \Psi)$ and the value function $V(\epsilon, s; K, \Psi)$ solve the problem of the household:

$$V(\epsilon, s; K, \Psi) = \max_{c, s'} \left\{ u(c) + \beta \sum_{\epsilon'|\epsilon} \Pi(\epsilon'|\epsilon) V(\epsilon', s'; K', \Psi') \right\} \text{ s.t.} \tag{12}$$

$$\begin{aligned} c + p(K')(s' - s) &= (1 - \tau_l) w(K) \epsilon + (1 - \tau_d) d(K, K') s - \tau_g (p(K') - p(K)) s \\ s' &\geq 0 \end{aligned}$$

$$\begin{aligned} \Psi' &= \Gamma(K, \Psi) \\ K' &= \Phi(K, \Psi) \end{aligned}$$

- *Firm Value Maximization:* Given prices, K', $L(K)$ and $d(K, K')$ satisfy firm optimality and the firm's financing constraint:

$$\begin{aligned} p(K') &= \frac{1 - \tau_d}{1 - \tau_g} K' \\ w(K) &= A F_L(K, L(K)) \\ d(K, K') &= A F(K, L(K)) + (1 - \delta) K - K' - w(K) L(K) \end{aligned}$$

- *Government Budget Balance:* Government spending equals government revenue:

$$G = \tau_l w(K) L(K) + \tau_d d(K, K') + \tau_g (p(K') - p(K))$$

[15] Note that, contrary to a framework were households own the capital directly, the aggregate capital K contains additional information on top of Ψ. The additional information consists essentially of the past stock price, which could equivalently be used as a state variable instead of K.

- *Market Clearing:* Prices are such that all markets clear:

$$\int s(\epsilon, s; K, \Psi) d\Psi(\epsilon, s) = 1$$

$$\int \epsilon d\Psi(\epsilon, s) = L(K)$$

$$\int c(\epsilon, s; K, \Psi) d\Psi(\epsilon, s) + K' + G = AF(K, L(K)) + (1 - \delta)K$$

- *Consistency:* Γ and Φ are consistent with the agents' optimal decisions.

4 Qualitative Analysis

A key result of this paper is that, in the presence of uninsured idiosyncratic risk, a reduction in dividend taxes reduces the capital stock. This section explains why this has to be the case theoretically, while the following section evaluates the quantitative importance of this effect in the context of the 2003 tax reform both in the long run and throughout the transition. Our discussion in this section focuses on steady states.

To understand the effects of taxes on distributions on the capital stock, the three key equations are the stock Euler equation (5), the capital Euler equation (9) and the price-capital relationship (10). This is directly analogous to a standard Aiyagari economy. In fact, using a simple change of variable will make this analogy clear and help with the intuition. Let a_{it+1} denote the (value of) assets acquired by individual i at time t

$$a_{it+1} \equiv p_t s_{it} \tag{13}$$

Using the definition of the after tax return r_t given in (5), the budget constraint (2) can be written as:

$$c_{it} + a_{it+1} = (1 - \tau_l) w_t \epsilon_{it} + (1 + r_t) a_{it}. \tag{14}$$

This makes it clear that what matters for household consumption and savings decisions is the after tax return r_t as opposed to p_t and d_t separately. Equation (5) represents an individual's demand for assets and aggregating across i we obtain the aggregate demand for assets Ea_{t+1} as a function of the after tax return r. When markets are incomplete, this aggregate demand for assets is increasing in r and tends to infinity as the return approaches the time preference rate $\frac{1}{\beta} - 1$ because of the precautionary savings motive. We call this curve equity demand and denote it by A_h.[16]

[16] This is what Aiyagari calls the capital supply curve. There is no guarantee that this curve is smooth in

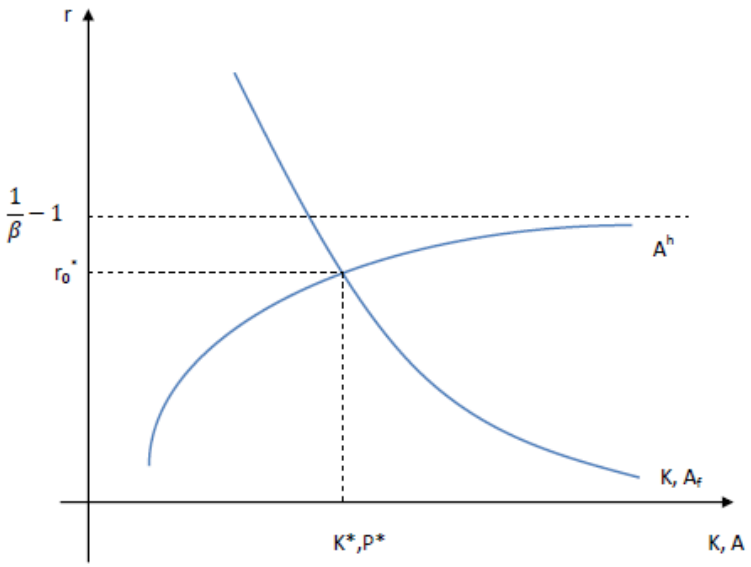

Figure 1: Equilibrium in an Aiyagari (1994) model where $q = 1$.

Equations (9) and (10) will be used to provide the equity supply curve. The first one describes the firm's desired capital stock K as a function of r. The second one describes the relationship between assets inside the firm (the capital stock) and assets outside the firm (the market value of stocks). This last relationship states that one unit of capital inside the firm is valued at $q = \frac{1-\tau_d}{1-\tau_g}$ by investors. The aggregate supply of assets is equal to the market value of all stocks, $p = qK$. This is given as a function of r by combining (9) and (10). We call this curve equity supply and denote it by A_f.

In equilibrium, aggregate asset demand has to equal the stock value, $Ea_{t+1} = qK$. If there are no taxes on capital gains and dividends, or if these two taxes are the same, then $q = 1$. This implies that the value of capital inside the firm is equal to the value of the firm's equity. In that case, our model is equivalent to a standard incomplete markets economy like the one in Aiyagari (1994). The equilibrium can then be represented as in Figure (1).

When $q = 1$, $p = K$ and the equity supply curve A_f coincides with the familiar downward sloping marginal product of capital schedule, as in a standard Aiyagari economy. The equilibrium return r^* and the equilibrium value of assets held p^* are found at the intersection of the equity supply curve A_f and the equity demand curve A_h, while the equilibrium level of the capital stock can be read off the K curve once r^* is known.

Now suppose there is a difference in dividend and capital gains tax rates and suppose, for

general, but this turns out to be the case in our numerical experiments.

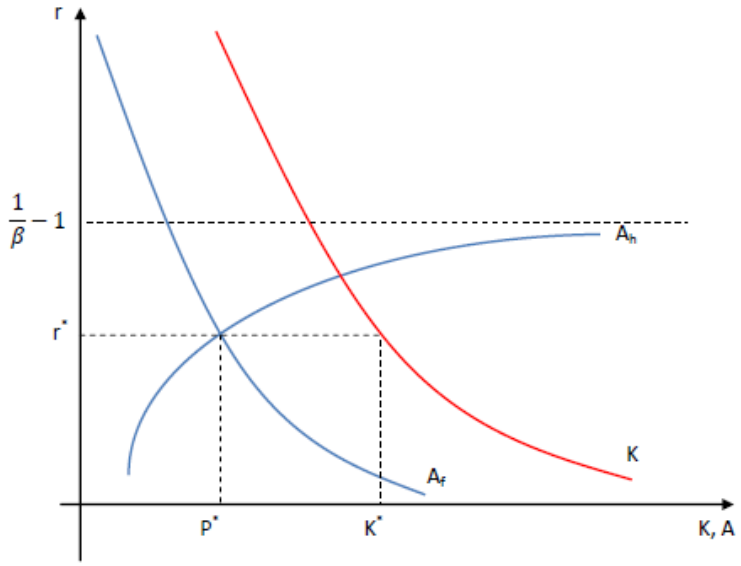

Figure 2: Equilibrium in our model where $q < 1$.

the sake of exposition, that $\tau_d > \tau_g$ so that $q < 1$. This has been the case historically for the US and will be assumed for the pre-reform steady state in our quantitative experiments. A unit of capital in the firm is now worth less than one unit to the shareholders. As a result, the value of stocks p and the physical capital K held by the firm will not be the same. Figure 2 shows how to obtain the equilibrium return in the stock market and the implied capital stock in such an economy. Similarly to the previous case, the equity demand curve A_h is simply a depiction of the demand for wealth Ea_{t+1} given by the aggregated stock Euler equation (5). To obtain the equity supply curve A_f, the first step is the same as before, namely, we plot the capital stock K given in (9). But when we translate this into the supply of assets by multiplying it by q, the equity supply curve A_f is now below the K curve because $q < 1$. The equilibrium in the stock market is (r^*, p^*) and the implied capital stock is $K^* = \frac{1-\tau_g}{1-\tau_d} p^*$.

Consider now a decrease in τ_d, keeping τ_g fixed. This has no effect on the K and A_h schedules but it does increase q and therefore shifts the A_f schedule to the right. The new A_f curve is the dashed line shown in Figure 3.[17] A decrease in dividend taxes raises the rate of return and, interestingly, has opposite effects on the stock price and the aggregate capital stock, raising the former and reducing the latter. The intuition is straightforward. At the prevailing rate r^*, households want to hold the same wealth as before and firms want to invest the same capital stock as before. But this capital stock is now valued more so that

[17] The graphical depiction assumes that q increases but remains below 1. In the experiment of the next section, q increases to exactly 1, which leads qualitatively to the same effects.

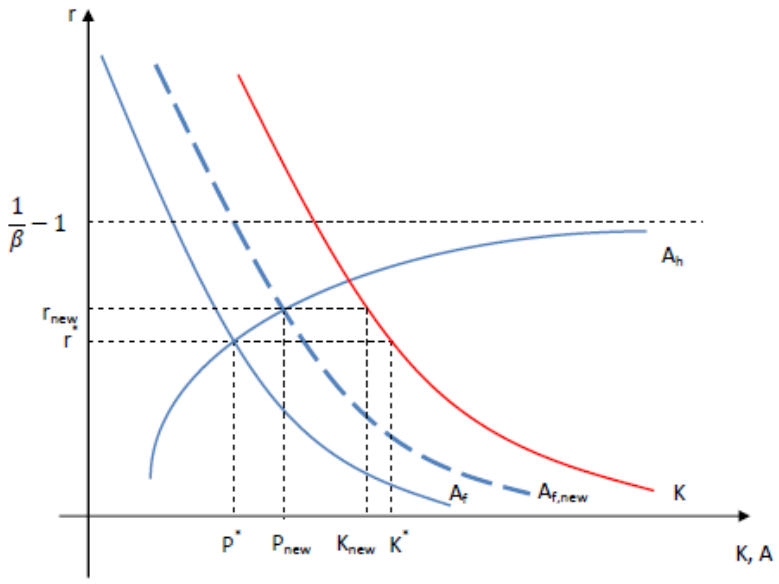

Figure 3: The effect of an increase in q in our model.

the supply of wealth is now higher. In order to induce households to hold more wealth, the return on stocks has to increase and this increase serves as the signal to the firm to start reducing the capital stock.

This result suggests that using a cut in dividend taxes as a way to promote investment can actually have negative effects on the capital stock and achieve the exact opposite effect. A crucial aspect required to yield this result is that the desired wealth held by households is not perfectly elastic, as it would be in a complete markets infinite horizon economy. The equilibrium with complete markets is depicted in Figure 4. After a decrease in the dividend tax, the stock price increases proportionally to the change in the tax. Wealth held by individuals is now higher than before, but agents are content to hold this higher amount of wealth as long as the return remains equal to the time preference rate. The end result is an increase in stock prices but no change in capital (or any other variable). This is the essence of Proposition 2 in McGrattan and Prescott (2005) and Proposition 1 in Santoro and Wei (2009a) and the sense in which dividend taxes are not distortionary under the new view.

An alternative extreme would be to postulate that the desired wealth schedule A_h is perfectly inelastic. Indeed, this would be a formalization of the intuition given by Poterba and Summers (1983), who argue that " *If the desired wealth-to-income ratio is fixed, then an increase in the dividend tax, which reduces each capital good's market value, will actually* increase *equilibrium capital intensity*". This intuition is not borne out of their model, which conforms to the standard infinite horizon complete markets model and therefore predicts no

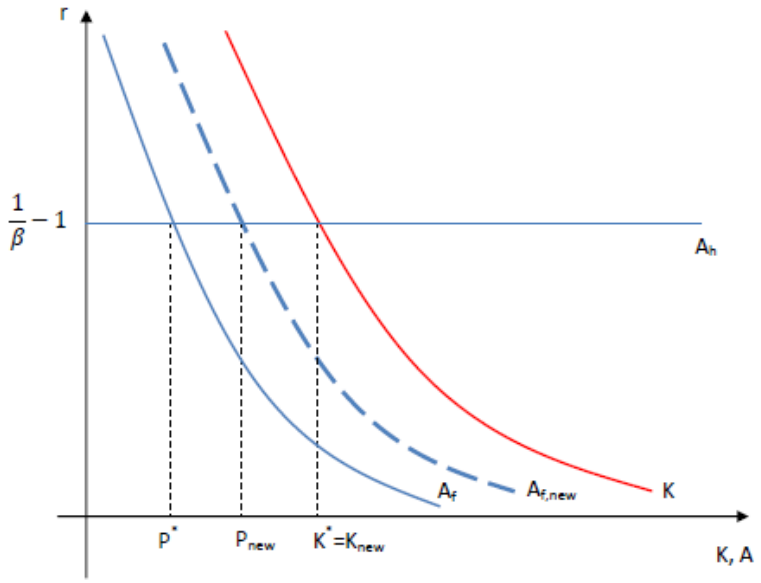

Figure 4: The effect of an increase in q in a representative agent model.

effects of dividend taxes on the capital stock. Our Bewley economy delivers this intuitive result, by allowing both the desired level of wealth and the long run rate of return to be endogenously determined.

The preceding discussion essentially analyzes the effects of an increase in q. This can arise through any combination of changes in τ_d and τ_g that increases $\frac{1-\tau_d}{1-\tau_g}$. However, there are two important differences between the two tax changes. First, a reduction in τ_g reduces q and leads to the exact opposite effects to those discussed above. In particular, a decrease in τ_g, will raise the capital stock but reduce the stock price, ceteris paribus. Second, when τ_d falls but τ_g is kept fixed, the dividend tax change does not directly affect the cost of capital in the sense that it does not distort the capital Euler equation. This means that τ_d affects the equilibrium only through its effect on q. By contrast, a change in τ_g directly distorts the capital Euler equation and therefore has additional effects that are more closely related to the standard effects of capital taxes. In particular, a decrease in the capital gains tax rate reduces the cost of capital $\frac{r}{1-\tau_g}$ and this has the direct effect of shifting the K curve outwards. The implied wealth provided by the firm is therefore also shifted outward, keeping q fixed. So, the capital stock increases for two reasons after a decrease in τ_g, but the stock price could go either way depending on which effect is stronger.

To summarize, in our economy, a reduction in dividend taxes reduces the capital stock and increases the stock price but a reduction in capital gains taxes increases the capital

stock and has ambiguous effects on the stock price. In the tax reform experiment of the next section, both taxes fall, but τ_d falls by more than τ_g leading to a rise in q. This effect will thus be present but there are additional effects arising from the change in τ_g. The overall effect of a reform that reduces both is, thus, theoretically ambiguous and can only be determined by quantifying these mechanisms. This is the objective of the following two sections.

5 Quantitative Results

This section uses a calibrated version of our model to study the effects of the 2003 capital tax reforms. First, we discuss the calibration and solution method for the benchmark economy. Next, we study the effects of a reduction in taxes both in the long run and during the transition.

5.1 Calibration

The time period is assumed to be one year. Preferences are of the CRRA class, $u(c) = \frac{\left[c^{1-\mu}-1\right]}{1-\mu}$, with a risk aversion of $\mu = 2$. The production function is Cobb-Douglas, $F(K,L) = AK^{\alpha}L^{1-\alpha}$ with $\alpha = 0.32$ and the technology parameter A is normalized so that output is equal to one in the steady state of the deterministic version of our economy. We choose a discount factor $\beta = 0.92$ to match an average capital to output ratio of 2.8. The depreciation rate is set to $\delta = 0.103$**.** Although this depreciation rate implies a very high investment to output ratio, it is chosen to match the average dividend to GDP ratio of 2.8% observed in NIPA data up to 2002.[18]

Table 1: Earnings Process

$$\boldsymbol{\epsilon} = \begin{bmatrix} 1.00 & 5.29 & 46.55 \end{bmatrix}$$

$$\boldsymbol{\Pi}^{*} = \begin{bmatrix} 0.498 & 0.443 & 0.059 \end{bmatrix}$$

$$\boldsymbol{\Pi}(\epsilon'|\epsilon) = \begin{bmatrix} 0.992 & 0.008 & 0.000 \\ 0.009 & 0.980 & 0.011 \\ 0.000 & 0.083 & 0.917 \end{bmatrix}$$

[18] In a previous version of the paper we calibrated the capital depreciation rate to match the investment to GDP ratio which resulted in a much higher dividend to GDP ratio. This, in turn, led to much larger effects of changes in dividend taxation. In this sense, our current calibration biases the quantitative significance of our results downwards.

The idiosyncratic labor productivity process is taken from Davila, Hong, Krusell and Ríos-Rull (2007). They construct the process so as to generate inequality measures for earnings and (endogenously) wealth that are close to US data using a very parsimonious model.[19] As shown in Table 1, this is achieved with a three-state Markov chain with transition matrix $\mathbf{\Pi}(\epsilon'|\epsilon)$ exhibiting very strong persistence and productivity values $\boldsymbol{\epsilon}$ that assign productive individuals 46 times the productivity of unproductive individuals. The resulting stationary distribution is denoted by $\mathbf{\Pi}^*$ and is also displayed in Table 1.

We take our tax rates from Feenberg and Coutts (1993).[20] These are Federal plus State marginal tax rates for wages, qualified dividends and long term capital gains respectively. For our benchmark economy we use $\tau_l = 0.28$, $\tau_d = 0.31$ and $\tau_g = 0.24$, which are the values reported for 2002.[21] With these taxes, the implied government spending to output ratio before the reform is equal to 20%, which is very close to the government to output ratio of 19% in the US. Feenberg and Coutts report marginal tax rates of 18.42 and 19.64 for dividends and capital gains respectively for 2003. Since the intention of the reform was to equalize the two tax rates, and since the case of equal tax rates is the standard theoretical benchmark with $p = K$, it seems natural to choose equal rates after the reform. Thus we assume dividend and capital gains tax rates are reduced to $\tau_d = \tau_g = 0.19$. In our main reform experiment, the labor tax rate adjusts to balance the budget but we also consider an alternative reform where the foregone government revenue is recovered using lump sum taxes.

5.2 Solution Method

To solve the model, we use a policy function iteration algorithm that is described in detail in Appendix B. In order to evaluate the welfare effect of tax reforms, we have also computed the transition of our economy between the stationary distributions of the pre reform and the post reform steady states. The extra difficulty of this exercise is that factor prices and the distribution of individuals over asset holdings and labor income change during the transition.

[19] For details on this see also Diaz, Pijoan-Mas, Ríos-Rull (2003) and Castaneda, Diaz-Gimenez and Ríos-Rull (2003).

[20] The data we use can be downloaded from http://www.nber.org/taxsim.

[21] Using an average of the tax rates for years 1997 to 2002 gives essentially the same numbers.

5.3 Tax Reform Experiments

5.3.1 Long Run

We begin with an analysis of the long run implications of revenue neutral tax reforms that reduce dividend and (or) capital gains taxes at the expense of higher labor income taxes. To isolate the effects of each of these tax changes, we start by analyzing a reduction in dividend taxes and capital gains taxes separately. First, we consider the effects of a reduction in the dividend tax rate while maintaining the capital gains tax at $\tau_g = 0.24$ (reform 1).[22] Next, we consider a reform that reduces capital gains taxes while keeping dividend taxes at the original level of $\tau_d = 0.31$ (reform 2). Finally, we consider the full tax reform in which both the dividend and the capital gains taxes are reduced to 19% (reform 3). In all the reforms we consider, the government is required to maintain a balanced budget for the same level of government spending as in the benchmark economy. This implies that labor taxes have to be adjusted upwards unless the reform is self-financing (see reform 2).

Table 2 reports steady state results for the three experiments. The first column displays results for the benchmark economy and the other three columns display the resulting long run steady state values after each of the reforms. The different rows correspond to the tax rates (τ_d, τ_g, τ_l), the stock return r, the level of output Y, the aggregate capital K, the stock price p, the aggregate wage rate and dividends before taxes (w, d) and after taxes $((1-\tau_l)\,w, (1-\tau_d)\,d)$ as well as three measures of the long run welfare effects of the reform. We compute the welfare change λ, in consumption equivalent (ce) terms, based on a utilitarian social welfare function. Following Domeij and Heathcote (2004), we also decompose the total welfare change into an aggregate component $\hat{\lambda}$ and a distributional component $\tilde{\lambda}$.[23]

Table 2: Long run effects of tax reforms

[22] The aim of this experiment is to provide a decomposition of the effects of lowering different taxes. However, it should be pointed out that these tax rates could generate tax arbitrage if raising new equity were allowed. In this case, firms would be able to raise \$1 of new equity at a cost of $1-\tau_g$ and then use these funds to pay dividends, with a gain of $(1-\tau_d)-(1-\tau_g)>0$ to the shareholders.

[23] The exact computations used are given in Appendix C. See also Domeij and Heathcote (2004) for more details.

	Benchmark	Reform 1	Reform 2	Reform 3
(τ_d, τ_g, τ_l)	$(0.31, 0.24, 0.28)$	$(0.19, 0.24, 0.29)$	$(0.31, 0.19, 0.28)$	$(0.19, 0.19, 0.29)$
r	0.7	1.3	0.55	1.2
Y	1.36	1.32 (−3%)	1.38 (+1.5%)	1.33 (−1.8%)
K	3.82	3.46 (−9.4%)	3.99 (+4.2%)	3.62 (−5%)
p	3.47	3.69 (+6%)	3.40 (−2.3%)	3.62 (+4%)
w	0.166	0.160 (−3.6%)	0.168 (+1.2%)	0.163 (−1.8%)
$(1-\tau_l)w$	0.119	0.114 (−4.4%)	0.121 (+1.7%)	0.116 (−2.4%)
d	0.038	0.062 (+39%)	0.027 (−31%)	0.052 (+36%)
$(1-\tau_d)d$	0.026	0.050 (+48%)	0.019 (−27%)	0.042 (+62%)
ce total λ	0	−3.0%	0.9%	−1.9%
ce aggregate $\hat{\lambda}$	0	−0.8%	0.2%	−0.5%
ce distribution $\tilde{\lambda}$	0	−2.3%	0.7%	−1.4%

Reform 1 reduces τ_d from 0.31 to 0.19. Despite the large reduction in the tax rate, the effect on the government budget is quite small because we have calibrated our economy so that dividend income is a small percentage of GDP. As a result, the government can balance its budget using a very small increase in the labor tax rate, from 0.28 to 0.29. As described in the previous section, the decrease in τ_d raises the market value of capital and thus the value of the assets held by individuals. This leads to an increase in the rate of return and a decrease in the capital stock. In addition, there is a secondary channel through which the capital stock is reduced. The reform leads to a change in the composition of income, with labor income, which is risky, becoming a smaller fraction of the total. This is both because of taxation shifting from capital to labor and because of the endogenous response of before-tax wages and dividends. Both mechanisms increase capital income and reduce labor income, thus reducing the amount of risk faced by households and, consequently, reducing precautionary savings. Overall, the capital stock falls by more than 9% while, at the same time, the stock price rises by 6%.

Comparing welfare measures across steady states we find that total welfare is reduced by 3%. This can be decomposed into an aggregate and a distributional component following Domeij and Heathcote (2004). Whereas they find a positive aggregate effect and a negative distributional effect of a reduction in capital income taxes, our finding is that both components are negative. The negative aggregate welfare effect is a direct result of the reduction in the capital stock which, in the long run, reduces output and aggregate consumption. The distributional effect is negative for reasons similar to those found in the previous literature on capital taxation. As labor income is reduced relative to capital income, individuals at the

low end of the wealth distribution suffer welfare losses whereas those at the high end enjoy welfare gains. Given a utilitarian welfare function, and a strictly decreasing marginal utility, the loss of the wealth-poor section of the population is reflected more strongly in the aggregate welfare measure. In sum, the reduction in the dividend tax increases the stock price, decreases the aggregate capital stock and reduces total welfare due to negative aggregate and distributional effects.

In many respects, the capital gains tax rate reduction works in the opposite direction. Focusing on the results from reform 2, we find an increase in the capital stock and a decrease in the rate of return. The stock price falls, because the effect from the decrease in q dominates the counteracting effect of the decrease in the cost of capital, which pushes the capital demand schedule (and thus the price) upwards. As the capital stock increases, that also implies an increase in the marginal product of labor which increases labor income. Notice that the labor tax rate is effectively unchanged which reflects the fact that the government collects no revenues from taxing capital gains at steady state. Thus, the reduction in the capital gains tax rate does not cause a deterioration in the government's budget. In fact, because wages increase as a result of the reform, the tax base increases and the labor tax rate that balances the budget is slightly lower (not seen up to the second digit reported). This reform is therefore self-financing at steady state. Overall, the welfare effects of the capital gains tax decrease are positive but smaller than in the case of dividend taxes. This largely reflects the fact that the capital gains tax rate falls by less than the fall in the dividend tax in the first reform. In sum, the decrease in the capital gains tax decreases the stock price, increases the aggregate capital stock and raises total welfare due to positive aggregate and distributional effects.

Once the two separate changes have been understood, the full reform (reform 3) follows easily. The effects of the reform are qualitatively the same as the dividend tax cut, but quantitatively less strong because the capital gains tax rate reduction partly mitigates these effects. Quantitatively, we find a 5% reduction in the long run capital stock, a 4% increase in stock prices and a negative long run welfare effect equivalent to a 2% permanent reduction in consumption, arising both from reduced aggregate consumption and from reverse redistribution.

It is perhaps too early to assess whether these long run effects can be seen in the data. Initial evidence, however, seems to be consistent with the theoretical prediction on stock returns**.** Consider, for example, the average after tax return, which is equal to $r = \frac{d(1-\tau_d)}{p} = \frac{d(1-\tau_g)}{K}$ in the present model. Using the average dividend to capital ratios $\frac{d}{K}$ before and after 2003 from NIPA data, and letting τ_g fall from 0.24 to 0.19 as in the theoretical experiment, we obtain an increase in the stock return from 0.72 to 1.23. Comparing to Table 2, the

first value coincides with the level of returns in our benchmark calibration by construction. Remarkably, the second value also coincides with the predicted after tax return following reform 3. The fact that the dividend-to-capital ratio has increased following the JGTRRA is also confirmed by Gourio and Miao (2010) and by DeBacker (2009) using Compustat data. A more thorough examination of the data, as in e.g. Chetty and Saez (2005) and Poterba (2004), also seems to suggest there was a significant increase in dividends following the reform.

Looking at steady states allows us to clarify the intuition for our results and understand the qualitative mechanisms taking place in our model. However, for obtaining a quantitative assessment of the welfare effects of the tax reform it is imperative that we consider the transition. It is well known that results about the long run are often mitigated, and sometimes even reversed, when the short run effects are included. In our case, it is clear that this could be so. After all, the predicted reduction in the long run capital stock will reduce aggregate consumption in the long run but increase aggregate consumption in the short run. We investigate this further in the next section.

5.3.2 Transition

We focus on the transitional paths for the full reform (reform 3) only. We assume that the economy begins at a steady state with dividend taxes that are equal to 31% and capital gains taxes that are equal to 24%. These taxes are unexpectedly and permanently reduced to 19% and 19% respectively and the economy is simulated until convergence to the new steady state. Labor taxes are adjusted in every period of the transition to keep the government's budget balanced.

The paths for some of the key aggregate variables, expressed as a percentage of their initial value, are displayed in Figures 5 and 6. The transition paths are as expected. Aggregate capital decreases monotonically to the new steady state. Stock prices increase by almost 10% on impact, as q has suddenly risen but the capital stock has not had time to adjust. As the economy reduces its capital stock, stock prices gradually fall towards a new steady state, which is higher than the old one. The aggregate wage rate follows a decreasing path, similar to the one of the aggregate capital stock. The same is true for the after tax wage, but the decrease in the latter is larger due to the higher labor income tax rate.[24] Per share dividends rise sharply on impact as investment is reduced and after tax dividends rise even more because the tax rate has fallen. The subsequent downward adjustment in the capital

[24]Since the reform is unexpected, it creates large capital gains in the initial period. In turn, these create a one time upward jump in stock returns. In addition, these imply a much lower labor tax income needed to balance the budget in the first period and higher after tax labor income. These three variables are plotted here from period two onwards for expositional purposes.

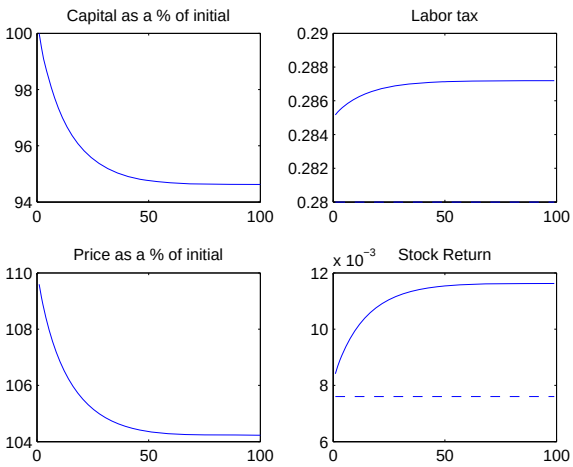

Figure 5: Aggregate Variable Transition Paths

stock brings dividends down, although they remain significantly above the pre-reform level even in the long run.

The sharp initial increase in after-tax dividends resulting from lower investment is also reflected in the path for aggregate consumption displayed in the upper panel of Figure 7. The initial increase is approximately 3%, but aggregate consumption starts falling as the capital stock decreases. Eventually, aggregate consumption falls below the original steady state and, in the long run, settles at a level approximately 0.5% below the pre-reform level. This lower level of aggregate consumption in the long run is what leads to a negative aggregate component of welfare in the long run (see Table 2).

The overall welfare effects along the transition are depicted in the lower panel of Figure 7. The decrease in welfare when the transition effects are taken into account is just above 0.5% of consumption. This is much less than the long run decrease of 1.9% because of the temporary increase in aggregate consumption. In fact, the time path of welfare gains follows closely the time path of aggregate consumption. Performing a decomposition of the welfare gains reveals positive aggregate welfare gains of approximately 1.8% when the transition is taken into account. This is because the decrease in long run consumption is dominated by the temporary increase in consumption in the short run. The distributional component on the other hand is negative and larger, -2.3%.

Decomposing the welfare gains across individuals provides further insights into the effects of the reform. Such a decomposition is provided in Figure 8, which shows individual welfare gains for different combinations of productivity (labor income) and asset levels. An examination of this figure will reveal two things: who gains and who loses from the reform

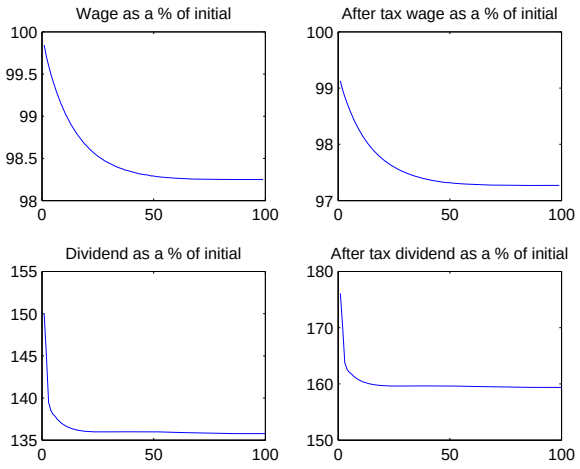

Figure 6: Aggregate Variable Transition Paths

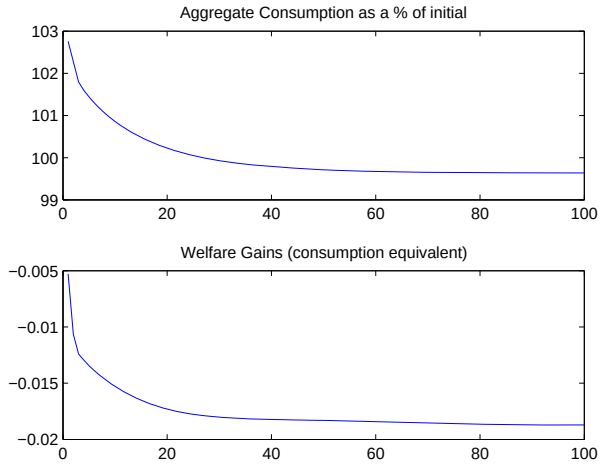

Figure 7: Aggregate Consumption and Welfare Gains in the Full Reform

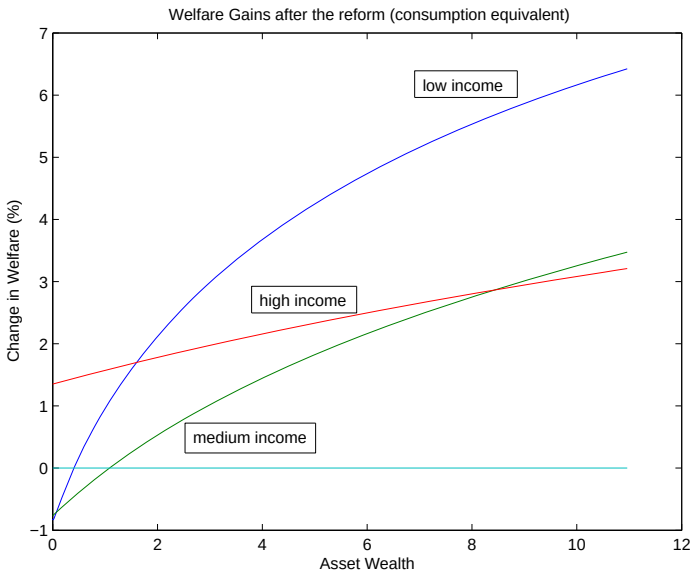

Figure 8: Individual Welfare Gains in the Full Reform

and whether the reform could have public support or not. A couple of important observations emerge from the figure. First, welfare gains are increasing in the amount of asset wealth held by an individual. Indeed, most individuals holding stocks gain from this reform and only some individuals holding no stocks (and some holding very few stocks) lose. This is not surprising, since the reform reduces the taxation of asset wealth and increases the stock return**.** Second, given a large amount of asset wealth, welfare gains are higher for low productivity individuals. This is because among agents with the same asset level, agents with lower productivity rely less on labor income compared to asset income. Therefore, the increase in labor income taxes and the decrease in wages hurts them the least. However, given little or no wealth, welfare gains are lower (or rather, welfare losses are larger) for low productivity individuals. This is because those agents enjoy very low levels of consumption anyway and their marginal utility is very high. In addition, given the persistence of the labor productivity process, they are unlikely to benefit from low asset taxation in the future either.

In terms of support for the reform, individuals at the low end of the wealth distribution and with low labor productivity would not support the reform. It turns out that the bulk of the distribution is actually concentrated in this region. When we aggregate over the population across asset levels and productivity levels using the stationary distribution of the pre-reform steady state, we find that the overall political support for the reform is 20 percent. In sum, this reform would not get wide political support, mostly because of strong

redistribution effects from the poor to the rich.

6 Robustness

To conduct the quantitative analysis of the preceding section, we have had to make specific modelling and parameter choices. Here, we investigate the robustness of our results to changes in those choices. We consider, in turn, lump sum taxes to balance the budget instead of adjusting labor taxes after the reform, varying the degree of households' risk aversion, endogenous labor supply, progressive labor income taxes, and corporate profits taxes. We mostly focus on long run effects.

6.1 Using Lump Sum Taxes

Our tax reform experiments in Section 5 assume that the government has a fixed exogenous spending level G and maintains a balanced budget. Reductions in the taxation of dividends and capital gains are financed by increasing labor income taxes. Here, we consider an alternative scenario, in which labor income taxes are kept fixed after the reform and the extra revenue is raised through the use of lump sum taxes. The results of this experiment are shown in Table 3. The second column (labelled 'Benchmark') is simply a repetition of the equilibrium values before the reform from Table 2. The third column shows the new steady state in this alternative experiment.

Table 3: Long Run Effects of Tax Reform with Lump Sum Taxes

	Benchmark	After Reform
(τ_d, τ_g, τ_l)	$(0.31, 0.24, 0.28)$	$(0.19, 0.19, 0.28)$
r	0.7	1.1
Y	1.36	1.34 (-1.4%)
K	3.83	3.67 (-4.2%)
p	3.48	3.67 ($+5.5\%$)
w	0.166	0.164 (-1.2%)
$w*(1-\tau_l)$	0.119	0.118 (-1%)
d	0.038	0.049 ($+28\%$)
$d*(1-\tau_d)$	0.026	0.039 (-50%)
ce total λ	0	-4.8%
ce aggregate $\hat{\lambda}$	0	-0.3%
ce distributional $\tilde{\lambda}$	0	-4.5%

Qualitatively, this alternative reform does not change the result of the previous section. The capital stock falls by slightly less and the stock price increases by slightly more. The most significant difference is in the welfare loss resulting from the reform, which is now much larger due to a much larger distributional effect. To understand why this happens, it is important to notice that labor supply is exogenous, so the labor income tax rate does not distort the supply of labor. In the absence of heterogeneity, this tax would be equivalent to a lump sum tax. In our economy with heterogeneity however, both the labor tax and the lump sum taxes affect allocations by changing the distribution of income. The question is which one has a stronger effect and why. An increase in labor tax rates has negative distributional effects in the sense that poorer households rely more heavily on labor income and are therefore hurt relatively more. Since these households have higher marginal utility, the effect on aggregate welfare is negative. However, this tax is proportional to a household's labor income so, the level of taxes raised from poorer households is less than that raised from richer households. If instead the reform is financed by lump sum taxes that are equally spread across households, this negative distributional welfare effect is even stronger. This explains the difference that we see in Table 3.

We have also considered financing the reduction in capital taxes through an individual specific lump sum tax. This tax was constructed so that, at the pre-reform prices and allocations, each household ends up with the same tax bill after the reform as before the reform. This completely neutralizes any effects dividend taxes might have, except for the wealth effect operating through the change in q. The increase in q still leads to a fall, albeit a smaller one, in the capital stock and welfare.

6.2 Varying Risk Aversion

It should be clear from the discussion in Section 4 that the slope of the A_h schedule is crucial for determining the magnitude of the wealth effect on the capital stock. The effect is zero when the slope is zero and it is maximized when the slope is infinite. Recall, in addition, that the reduction in the capital gains tax has a second effect on the capital stock that is actually positive and that survives a perfectly elastic A_h schedule. It follows that in the extreme case where A_h is perfectly elastic, this positive effect on the capital stock should dominate the negative wealth effect, whereas when A_h is very steep, the negative wealth effect should dominate. It turns out that the level of risk aversion has a direct effect on this slope. As the level of risk aversion is decreased, the asset demand schedule A_h moves to the left and the equilibrium capital stock is reduced. Importantly, the relevant section of the demand schedule, i.e. the section that lies to the right of the complete markets level

of wealth, becomes flatter. In the limit, as $\mu \to 0$, the demand for assets approaches the complete markets demand schedule, which is perfectly elastic at $r = \frac{1}{\beta} - 1$. At that limiting point, the equilibrium level of the capital stock is simply the modified golden rule and there are no precautionary savings. The negative effect working through the change in wealth is not present anymore and the reform increases the capital stock. When the level of risk aversion is increased above a threshold, the negative effect dominates and the capital stock falls as a result of the reform. This reduction in the capital stock becomes larger as risk aversion is further increased. This intuition is borne out in the quantitative experiment described below.

Table 4 displays the effect on the main variables of interest arising due to the reform in three different economies. The three economies differ in their level of risk aversion. We consider a case with low ($\mu = 0.5$) and a case with high ($\mu = 5$) risk aversion and compare to our benchmark economy ($\mu = 2$).[25]

Evidently, the effect of the reform on the capital stock is larger, the larger is the value of μ. The threshold μ, at which the capital stock actually rises is below 0.5. The effect on the stock price changes sign, from an increase in the stock price for low and medium risk aversion to a decrease in the stock price when risk aversion is relatively high. At that extreme, the fall in the capital stock is so large that the increase in the valuation q of this capital is not enough to raise the price.

Table 4: Long run effects of tax reform for different risk aversion

μ	$\mu = 0.5$	$\mu = 0.5$	$\mu = 2$	$\mu = 2$	$\mu = 5$	$\mu = 5$
τ_l	0.28	0.285(+0.05)	0.28	0.287(+0.02)	0.28	0.29(+0.01)
r	0.7	0.8(+0.1)	0.7	1.1(+0.5)	0.7	1.6(+0.9)
Y	1.074	1.071(−0.2%)	1.35	1.33(−1.4%)	2.05	1.98(−3.4%)
K	3.02	2.99(−0.9%)	3.82	3.62(−5.2%)	5.78	5.13 (−11%)
p	2.74	2.99(+9.2%)	3.47	3.62(+4.3%)	5.24	5.13(−2%)
w	0.153	0.153(+0.2%)	0.165	0.162(−1.8%)	0.25	0.24(−4%)
$(1-\tau_l)w$	0.11	0.109(−1.5%)	0.119	0.116(−1.7%)	0.18	0.17(−5.5%)
d	0.037	0.032(+5.5%)	0.038	0.052(+36%)	0.059	0.101(+71%)
$(1-\tau_d)d$	0.021	0.026(+24%)	0.026	0.042(+61%)	0.04	0.08(+101%)

[25] For each μ, the pre-reform economy is recalibrated to meet the calibration targets described in Section 5. Specifically, we modify the discount factor to obtain the same capital output ratio of 2.8.

6.3 Labor Leisure Choice and Progressive Labor Taxes

In this section we investigate whether adding an endogenous labor leisure choice or progressive labor income taxes affects our results.[26] To do this, we assume a standard Cobb-Douglas specification for the period utility function:

$$U(c) = \frac{\left(c^{\gamma}(1-l)^{1-\gamma}\right)^{1-\mu}}{1-\mu}$$

We set $\mu = 2$ for comparison with our previous framework and γ such that, on average, labor is one-third of the time endowment.

First, we investigate the effects of an endogenous labor leisure choice in the presence of a flat labor income tax rate. Subsequently, we add progressive labor income taxes. In this case, we denote individual taxable labor income by $y = wl\epsilon$, where l is individual labor supply. Total taxes are given by the function

$$T(y;\kappa) = \kappa_0 \left(y - \left(y^{-\kappa_1} + \kappa_2\right)^{-\frac{1}{\kappa_1}}\right)$$

where $\kappa = (\kappa_0, \kappa_1, \kappa_2)$ is a vector of parameters. This functional form was first proposed by Gouveia and Strauss (1994) and has been used by several authors such as Castañeda, Díaz-Giménez, and Ríos-Rull (1999), Conesa and Krueger (2006) and Conesa et al. (2009). With such a function, the average tax rate is roughly controlled by κ_0, while κ_1 governs the degree of progressivity. When $\kappa_1 \to 0$ there is no progressivity (flat tax rate).

We estimate the parameters of the tax function using OECD data for the US in 2003, following the procedure of Guvenen, Kuruscu and Ozkan (2010). The OECD tax database provides a calculator that estimates the total labor income tax liability at income levels between one half of average wage earnings and two times average earnings. Using this calculator, we obtain the average labor income tax rate for 31 income levels between 50% and 200% of average earnings. To calculate average tax rates at higher income levels, we use the US top marginal tax rate together with the corresponding top bracket as in Guvenen et al. (2010). Finally, we fit $T(y;\kappa)$ to the constructed data points. The estimated parameters are $\kappa_0 = 0.4143$, $\kappa_1 = 0.8881$ and $\kappa_2 = 1.3447$. To implement the tax reform, we assume these values for κ_0 and κ_1 in the pre-reform economy and we choose κ_2 so that the government spending to output ratio is the same as in our benchmark economy with no endogenous labor choice and flat labor taxes. After the dividend and capital gains taxes are reduced,

[26] The case with progressive dividend taxes is more complicated, since this breaks the unanimity result with shareholder heterogeneity and the value of the firm is no longer well defined. Given this, we have abstracted from this case.

government budget balance is achieved by increasing κ_0.

Table 5 displays the results with endogenous labor leisure choice, for the full reform in which both dividend and capital gains taxes are decreased. The first two columns display the results with flat labor income taxes and the last two columns display the results under progressive labor income taxes. A comparison with the last column of Table 2 indicates that the results for both cases are qualitatively and quantitatively very similar to our benchmark case with no labor leisure choice. Aggregate capital stock decreases and dividends and stock prices increase by roughly the same amounts. The reason is that, in our calibration, the fraction of government revenue raised from taxing capital income is very small. Balancing the budget after a reduction in capital tax rates requires only a minimal change in labor taxes, which, in turn, implies small movements in labor supply. This small (negative) movement in equilibrium labor supply, and the accompanying extra reduction in output, are the only quantitative differences to our benchmark.

Table 5: Long run effects of tax reforms with endogenous labor supply

	Benchmark	Reform	Benchmark	Reform
	Flat Taxes	Flat Taxes	Prog. Taxes	Prog. taxes
	(τ_d, τ_g, τ_l)	(τ_d, τ_g, τ_l)	$(\tau_d, \tau_g, \kappa_0)$	$(\tau_d, \tau_g, \kappa_0)$
	$(0.31, 0.24, 0.28)$	$(0.19, 0.19, 0.289)$	$(0.31, 0.24, 0.414)$	$(0.19, 0.19, 0.431)$
r	0.75	1.1	0.77	1.11
Y	0.47	0.46	0.46	0.44
K	1.34	1.27 (-5.2%)	1.29	1.22 (-5.4%)
p	1.22	1.27 ($+4.1\%$)	1.17	1.22 ($+4.2\%$)
w	0.166	0.163 (-1.8%)	0.165	0.163 (-1.2%)
L	1.958	1.941 (-0.8%)	1.893	1.873 (-1.1%)
d	0.013	0.017 ($+30.7\%$)	0.013	0.016 ($+23\%$)
$(1-\tau_d)d$	0.009	0.014 ($+55\%$)	0.009	0.013 ($+44\%$)

When labor taxes are flat, an increase in labor taxes used to finance the decrease in dividend and capital gains taxes, has negative redistribution effects. Progressive taxes place a disproportionately high burden on individuals with high income and hence an increase in such taxes could, in principle, lead to less negative or even positive redistribution effects. Given our utilitarian welfare criterion, this change in redistribution effects of the reform could overturn our benchmark result about welfare. To check if this is the case, we need to compute the transition. During the transition, we have assumed that the government maintains budget balance every period, which is achieved by adjusting the parameter κ_0 every period. Whereas the aggregate welfare losses are smaller than with flat taxes (-0.25%),

the qualitative finding is the same as with flat taxes. The reform has a negative impact on welfare when the transition is taken into account, because a positive aggregate effect (1.36%) is dominated by a negative distributional effect (−1.59%). Moreover, the implications for different households are very similar to those presented in figure **8.**

6.4 Corporate Profit Taxes

Up to this point, we have abstracted from corporate profit taxes. To investigate the extent to which introducing such taxes affects our results, we have also computed the full reform in the presence of these taxes. In this case, the model of Section 3 needs to be modified as follows. The firm's financing constraint (7) becomes

$$d_t = (1 - \tau_c)\left(AF(K_t, L_t) - w_t L_t - \delta K_t\right) - K_{t+1} + K_t$$

the capital Euler equation (9) becomes

$$1 = \frac{1}{1 + \frac{r_{t+1}}{1-\tau_g}}\left(\left(AF_K\left(K_{t+1}, L_{t+1}\right) - \delta\right)(1 - \tau_c) + 1\right)$$

and the government budget constraint (11) now includes tax revenue from corporate profits

$$G = \tau_d d_t + \tau_l w_t L_t + \tau_g(p_t - p_{t-1}) + \tau_c\left(AF(K_t, L_t) - w_t L_t - \delta K_t\right)$$

where τ_c is the corporate profits tax rate. Following Gourio and Miao (2010), we set $\tau_c = 0.34$. Table 6 reports the results of reducing dividends and capital gains taxes (reform 3) in the presence of corporate profit taxes. The corporate profits tax rate is kept fixed after the reform, since there was no provision to reduce it in the JGTRRA. As shown by the table, the results are very similar to the ones obtained in Section 5, with similar changes for all the variables after the reform is implemented. In other words, introducing corporate profits taxes does not change our main conclusions.

Table 6: Long run effects of reform 3 with corporate profits taxes

	Benchmark	Reform 3
$(\tau_d, \tau_g, \tau_l, \tau_c)$	$(0.31, 0.24, 0.28, 0.34)$	$(0.19, 0.19, 0.29, 0.34)$
r	0.6	0.96
Y	1.34	1.31 (-2.2%)
K	3.70	3.46 (-6.5%)
p	3.36	3.46 $(+2.3\%)$
w	0.164	0.160 (-2.4%)
$(1-\tau_l)w$	0.118	0.115 (-2.5%)
d	0.031	0.041 $(+32\%)$
$(1-\tau_d)d$	0.021	0.033 $(+62\%)$

7 Conclusion

This paper studies the effects of a reduction in dividend and capital gains taxes. Our finding that reductions in these taxes lead to reverse redistribution, and hence are detrimental from the point of view of a utilitarian social welfare function, is in line with previous research on capital tax reforms. The new insight, obtained by disaggregating capital taxes into dividend and capital gains taxes, is that a dividend tax cut can have the exact opposite effect from the one intended, i.e. it can reduce investment instead of increasing it. We explain that this result arises because the increase in stock prices feeds back to household choices through a wealth effect. We also provide a quantitative assessment of the 2003 JGTRRA reform and find it to be welfare reducing, even after positive short run effects are taken into account.

Given that our result on the effect of dividend taxes on investment is surprising, a question that could easily arise is whether this mechanism is borne out by the aftermath of the 2003 reform. Desai and Goolsbee (2004) touch on this issue and find the investment recovery from 2003 onwards to be weaker than previous recoveries. As Kevin Hassett suggests in his discussion of that paper, it is not clear that comparing to previous recoveries is the right metric to be used. Looking at the raw data, there does seem to be an increase in capital expenditures following the 2003 reform. However, it is important to realize that the reform did not only change dividend taxes. Various other provisions, such as the increase in depreciation allowances, the decrease in estate taxes and the decrease in the level and the progressivity of labor taxes, could have spurred investment *despite* the dividend tax decrease.

An attempt at empirically evaluating the effect of dividend taxes on investment would have to separate these effects as well as somehow take into account the business cycle. Unfortunately, estimating the effects of dividend taxes on investment is not a straightforward exercise. To quote Chetty and Saez (2005) " ... the time series of investment is extremely

volatile and of much larger magnitude than dividend payments."[27] Crucially, even if the ceteris paribus effect of the dividend tax cut on investment could be conclusively determined empirically, that effect would only be the result of a combination of different mechanisms. The decrease in dividend taxes exerts a downward pressure on investment because of the mechanism explained in this paper. Additional downward pressure would arise to the extent that the reform is perceived as temporary, as argued in Gourio and Miao (2011) and in Korinek and Stiglitz (2008) . On the other hand, the tax cut exerts an upward pressure in the presence of firm heterogeneity as explained in Gourio and Miao (2010) or in the presence of agency issues as in Chetty and Saez (2010).

Although it would be interesting to have a framework that includes all these mechanisms simultaneously so as to gauge their relative importance, such a model would be computationally challenging if not unfeasible. One can only speculate about the relative importance of these different channels quantitatively. The main mechanisms leading to increased investment as a result of dividend tax cuts that are missing from our model, are those operating through growing, equity issuing firms. These firms account for approximately 10% of the aggregate capital stock and of investment according to Compustat data reported in Gourio and Miao (2010). It seems reasonable to conjecture that the mechanism identified here will have larger effects since it operates through mature firms which account for 90%. This is, however, only a conjecture and there could be interesting interactions of the different mechanisms which could only be gauged in a model combining household and firm heterogeneity. This would be an interesting, but challenging, way forward.

Finally, we focus more closely on the effects of dividend taxes compared to capital gains taxes. Such focus is partly because the change in dividend taxes was of a much larger magnitude but also because we view our treatment of capital gains taxes as less satisfactory. In our model capital gains are taxed on an accrual basis which simplifies the computational burden significantly but is arguably unrealistic. In practice, capital gains are only taxed upon realization and this allows individuals to time the realization of capital gains in their favor. It is often suggested, see for example Poterba (2004) or Sinn (1991), that this could be crudely modelled as an accrual tax at a lower rate. To the extent this is true, our main result of a fall in the capital stock and in welfare should survive such an extension since this would reduce the effects of capital gains taxes. One could also explicitly model realization-based capital gains taxes along the lines of Gavin, Kydland and Pakko (2007), but at a higher computational cost.

[27] Similar statements about the difficulty of assessing these effects can be found in Hassett's discussion of Desai and Goolsbee's article. Poterba's (2004) take on existing evidence on this issue is that it is "controversial".

APPENDIX

Appendix A: The Relationship between the Stock Price and the Capital Stock

Using the definition of the risk-free return, together with the stock Euler condition (4), we can write the stock price at time t as:

$$p_t\left(1+r_{t+1}\right)=\left[\left(1-\tau_d\right)d_{t+1}+p_{t+1}-\tau_g\left(p_{t+1}-p_t\right)\right]$$

Solving for the current stock price p_t yields

$$p_t=\frac{1}{1+\frac{r_{t+1}}{1-\tau_g}}\left(\frac{1-\tau_d}{1-\tau_g}d_{t+1}+p_{t+1}\right)$$

and repeated forward substitution, along with a no-bubble condition, yields the price dividend mapping (6). The capital Euler condition (9) can be manipulated to write capital as a function of dividends as follows:

$$\begin{aligned}1&=\frac{1}{1+\frac{r_{t+1}}{1-\tau_g}}\left(1-\delta+AF_K\left(K_{t+1},L_{t+1}\right)\right)\Rightarrow\\ K_{t+1}&=\frac{1}{1+\frac{r_{t+1}}{1-\tau_g}}\left(\left(1-\delta\right)K_{t+1}+AF_K\left(K_{t+1},L_{t+1}\right)K_{t+1}\right)\end{aligned}$$

Using the constant returns to scale assumption, we can write:

$$K_{t+1}=\frac{1}{1+\frac{r_{t+1}}{1-\tau_g}}\left(\left(1-\delta\right)K_{t+1}+AF\left(K_{t+1},L_{t+1}\right)-w_{t+1}L_{t+1}\right)$$

and replacing the right hand side from the firm's financing constraint, we obtain:

$$K_{t+1}=\frac{1}{1+\frac{r_{t+1}}{1-\tau_g}}\left(d_{t+1}+K_{t+2}\right)$$

Repeated forward substitution (with the use of the transversality condition) leads to the following expression:

$$K_{t+1}=\sum_{j=1}^{\infty}\left(\prod_{i=0}^{j-1}\frac{1}{1+\frac{r_{t+1+i}}{1-\tau_g}}\right)d_{t+j} \tag{15}$$

Comparing (15) to (6) gives the relationship between capital and stock price in equation (10).

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Appendix B: Numerical Algorithm

B.1 Computing the Stationary Competitive Equilibrium

We use a generalized policy function iteration algorithm, which relies on the first-order conditions (mainly the Euler equation) of the model. We approximate all the relevant policy and value functions with linear interpolation over the grid on assets. To solve the individual problem with policy iterations, we proceed as follows. Given the aggregate capital K, the stock price p, dividends d, the wage rate w and a tax vector (τ_d, τ_g, τ_l), we let h be the vector consisting of the individual policy functions of interest, i.e., $h = [c, s']$. Let T be a non-linear operator such that $T[h; d, K, p, w, \tau_l]$ satisfies the individual optimality conditions given taxes. To approximate the fixed point, we follow the steps below.

Step 1: Guess an initial vector $[h^0; p^0, \tau_l^0]$, where $h^0 = [c^0, s'^0]$. Using p^0 we can calculate d^0, w^0 and K^0.

Step 2: For each iteration $n \geq 1$, use the previous guess h^{n-1} and $[d^{n-1}, K^{n-1}, w^{n-1}, \tau_l^{n-1}, p^{n-1}]$ to compute the new vector h^n that satisfies the individual equilibrium conditions.

Step 3: Using h^n and the distribution for the idiosyncratic shock Π, calculate Ψ, the joint (stationary) distribution of assets and income. Next, use Ψ to calculate the aggregate demand for stocks by the households to get the new stock price p^n.

Step 4: The new tax rate on labor τ_l^n is calculated given Ψ and h^n to satisfy the government's budget constraint.

Step 5: Repeat Steps 2-4 until convergence.

B.2 Computing the Transition Between Steady States

When we calculate the transition between steady states we need to adjust the above procedure in the following way. First, for the sake of exposition, assume that convergence to the new steady state takes place in T periods. Then we follow the steps below.

Step 1: Guess a time series for the variables $\left\{h_t^0;\ K_t^0, p_t^0, d_t^0, w_t^0, \tau_{l,t}^0\right\}_{t=1}^T$, together with the time series for the distribution of individuals $\{\Psi_t^0\}_{t=1}^T$. Again, knowing $\{p_t^0\}_{t=1}^T$ we can calculate $\{K_t^0, d_t^0, w_t^0\}_{t=1}^T$. We then initialize the first period with the stationary distribution of the first steady state ($\Psi_1^0 = \Psi_{SS1}$ and $p_1^0 = p_{SS1}$) and we assume that at time T we are already in the second steady state ($\Psi_T^0 = \Psi_{SS2}$ and $p_T^0 = p_{SS2}$)).

Step 2: For each iteration $n \geq 1$ and for each time period $1 \leq t \leq T-1$, we use the previous guess for the next period h_{t+1}^{n-1} and $[K_t^{n-1}, p_t^{n-1}, d_t^{n-1}, w_t^{n-1}, p_t^{n-1}, \tau_{l,t}^{n-1}]$ to compute the new vector h_t^n that satisfies the individual equilibrium conditions.

Step 3: Using h^n and Π, we calculate Ψ^n_{t+1}, the joint distribution of assets and income and then use Ψ^n_{t+1} to calculate the demand of stocks and the new price p^n_t. These two variables are compared to the initial guesses Ψ^{n-1}_{t+1} and p^{n-1}_t for all $1 \leq t \leq T-1$.

Step 4: The new tax rate on labor for each time period $1 \leq t \leq T-1$ is calculated given Ψ^{n-1}_t and h^n_t to satisfy the government's budget constraint at each period.

Step 5: Repeat Steps 2-4 until convergence for all periods $1 \leq t \leq T-1$.

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Appendix C: Welfare Computation and Decomposition

Transition

The economy begins at an initial steady state (at $t = 0$) with a given, constant level of aggregate capital K^{old} and an initial distribution of stocks Ψ^{old}. The change in the tax system induces a sequence of aggregate capital stocks and distributions $\{K_t, \Psi_t\}_{t=0}^T$ that eventually converges (at time T) to the new steady state K^{new}, Ψ^{new}. Let $x = (\epsilon, s)$ be a point in the individual state space of the economy. Given the sequence of aggregates, the maximized utility (value function) for an individual household with individual state x at time t is denoted by $V_t(x)$. Similarly, denote the corresponding consumption and stock policy functions by $c_t(x)$ and $S_t(x)$ respectively. At steady state, the aggregates are constant and the value functions are time independent. We use $V^{old}(x)$ and $V^{new}(x)$ for the steady state value functions before and after the reform.[28] The welfare of an individual household at any point t along the transition is:

$$V_t(x_t) = \sum_{j=0}^{\infty} \beta^j \sum_{x_{t+j}|x_t} \pi(x_{t+j}|x_t) \frac{c_{t+j}(x_{t+j})^{1-\sigma}}{1-\sigma}$$

where $\pi(x_{t+j}|x_t)$ is the probability of state x_{t+j} given x_t. To be more precise, this value can be represented recursively as

$$V_t(\epsilon_t, s_t) = \frac{c_t(\epsilon_t, s_t)^{1-\sigma}}{1-\sigma} + \beta \sum_{\epsilon_{t+1}|\epsilon_t} \Pi(\epsilon_{t+1}|\epsilon_t) V_{t+1}\left(\epsilon_{t+1}, S_t(\epsilon_t, s_t)\right)$$

This representation can be used to compute $V_0(x_0)$ backwards starting at $V_T(x_T) = V^{new}(x_T)$. Clearly, $V_0(x_0)$ represents the welfare of an individual with individual state x_0 in the economy where the reform takes place. The corresponding welfare in case the reform does not

[28] We do the same for the policy functions.

happen is simply

$$V^{old}(\epsilon_0, s_0) = \frac{c^{old}(\epsilon_0, s_0)^{1-\sigma}}{1-\sigma} + \beta \sum_{\epsilon_1|\epsilon_0} \Pi(\epsilon_1|\epsilon_0) V^{old}\left(\epsilon_1, S^{old}(\epsilon_0, s_0)\right)$$

These individual welfare levels can be aggregated to yield a (utilitarian) measure of aggregate/average welfare using the initial distribution of households Ψ^{old}

$$W^{old} = \sum_{(\epsilon_0, s_0)} \Psi^{old} V^{old}(\epsilon_0, s_0)$$
$$W_0^{new} = \sum_{(\epsilon_0, s_0)} \Psi^{old} V_0(\epsilon_0, s_0)$$

We use W^{old} and W_0^{new} to compare welfare with and without the reform. Specifically, we compute the equivalent variation in consumption, λ, defined as the percent increase in consumption in every date/event of the economy without reform that is required to make the old and the new aggregate welfare equal. Clearly λ satisfies

$$1 + \lambda = \left(\frac{W_0^{new}}{W^{old}}\right)^{\frac{1}{1-\sigma}}$$

If $\lambda < 0$, then consumption in the old equilibrium would need to be decreased, indicating that aggregate welfare is lower in the new equilibrium.

To decompose the overall welfare effect into aggregate and distributional components we follow the idea in Domeij and Heathcote (2004). For the aggregate component, we consider a hypothetical economy that shares all the features of the pre-reform economy, except that consumption is scaled by the ratio of aggregate consumptions in the pre- and post-reform economies. In particular, we maintain the same consumption distribution across households after the reform as the one before the reform. Let aggregate consumptions be denoted by C_t^{new} and C^{old} (note the pre-reform economy is in steady state so aggregate consumption would be constant across time). Then we can compute individual welfare at t in that economy as

$$\hat{V}_t(x_t) = \sum_{j=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{new}}{C^{old}}\right)^{1-\sigma} \sum_{x_{t+j}|x_t} \pi(x_{t+j}|x_t) \frac{c^{old}(x_{t+j})^{1-\sigma}}{1-\sigma}$$

This can be computed backwards using a recursive representation

$$\hat{V}_t(\epsilon_t, s_t) = \frac{c^{old}(\epsilon_t, s_t)^{1-\sigma}}{1-\sigma} \left(\frac{C_t^{new}}{C^{old}}\right)^{1-\sigma} + \beta \sum_{\epsilon_{t+1}|\epsilon_t} \Pi(\epsilon_{t+1}|\epsilon_t) \hat{V}_{t+1}\left(\epsilon_{t+1}, S^{old}(\epsilon_t, s_t)\right)$$

and starting at

$$\begin{aligned}\hat{V}_T(\epsilon_T, s_T) &= \left(\frac{C^{new}}{C^{old}}\right)^{1-\sigma} \sum_{j=0}^{\infty} \beta^j \sum_{x_{t+j}|x_t} \pi(x_{t+j}|x_t) \frac{c^{old}(x_{t+j})^{1-\sigma}}{1-\sigma} \\ &= \left(\frac{C^{new}}{C^{old}}\right)^{1-\sigma} V^{old}(\epsilon_T, s_T)\end{aligned}$$

With $\hat{V}_0(\epsilon_0, s_0)$ in hand, the aggregate component of welfare can be computed just like before as a consumption equivalent using the average welfare measure

$$\hat{W}_0 = \sum_{(\epsilon_0, s_0)} \mu(\epsilon_0, s_0) \hat{V}_0(\epsilon_0, s_0)$$

so that

$$1 + \hat{\lambda} = \left(\frac{\hat{W}_0}{W^{old}}\right)^{\frac{1}{1-\sigma}}$$

Finally, the distributional component $\tilde{\lambda}$ is defined as a residual such that

$$\left(1 + \hat{\lambda}\right)\left(1 + \tilde{\lambda}\right) = (1 + \lambda)$$

Steady States

Comparing steady states is more controversial because of the different distributions associated with the different steady states. We compare steady state welfare making some particular assumptions for illustrative purposes. Specifically, we define the overall average consumption equivalent as

$$1 + \lambda_{ss} = \left(\frac{W^{new}}{W^{old}}\right)^{\frac{1}{1-\sigma}}$$

i.e. by comparing the average welfare level in the two steady states. We also decompose this into aggregate and distributional components. The aggregate component is computed by assuming that the distribution is the same in the two steady states and only adjusting individual consumptions by the ratio of aggregate consumptions. This leads to an aggregate component $\hat{\lambda}_{ss}$ given by

$$1 + \hat{\lambda}_{ss} = \frac{C^{new}}{C^{old}}$$

The distributional component is then defined as a residual just like before.

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