Anticipated Tax Reforms and Temporary Tax Cuts: A General Equilibrium Analysis

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Abstract. Macroeconomic studies of tax policy in dynamic general equilibrium usually assume that reforms hit the economy unexpectedly and last forever. Here, we explore how previous results change when we allow policy changes to be pre-announced and of finite duration and when these facts are anticipated by households and firms. Quantitatively we demonstrate a headstart advantage from pre-announcement that is never caught up by a surprising reform. The welfare gain stemming from a 5-year announcement phase of a corporate tax cut, for example, is estimated to be around 10 percent of the total gain from the reform. We show that impulse responses of important variables like firm value, dividends, and investment differ qualitatively depending on whether the reform comes expected or not. We are also able to demonstrate a genuine welfare gain from temporary tax cuts. Impulse responses generated by our numerical method can be retraced by phase diagram analysis, which facilitates explanation and interpretation of the produced results.

Keywords: tax reform, anticipation effects, investment, economic growth, welfare, corporate finance, capital taxation.

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1. Introduction

While economic research has not yet definitely settled whether and how taxes affect long-term economic growth it is indisputable that the design of the tax law has real effects on the levels of important macroeconomic aggregates such as consumption, investment, income per capita, and welfare. A recent empirical literature has argued that macroeconomic effects of tax policy may be larger than previously thought (e.g. Romer and Romer, 2008, Mountford and Uhlig, 2008) and tax alleviation is high on the policy agenda in many OECD countries. The present article continues the literature that tries to assess the quantitative impact of tax reform on macroeconomic aggregates by calibrating and simulating a dynamic general equilibrium.[1]

Usually this literature assumes that a change of taxes hits the economy unexpectedly and is then expected to last forever. While this might be true in some cases, in reality a tax reform is frequently pre-announced and thus expected quite a while before it actually comes into effect (see the discussion in Alvarez et al., 1998 and Domeij and Klein, 2005). Likewise tax cuts are sometimes temporary. They are announced and thus expected to expire after a certain time. This is, for example, true for the tax relief acts during the Bush administration from 2001 and 2003 of which many measures were announced to end at a certain date between 2007 and 2010. These observations have motivated the present work, which tries to assess within the dynamic general equilibrium paradigm the macroeconomic consequences of anticipated tax reforms and temporary tax cuts.

Anticipated and/or temporary tax changes are analyzed in a small micro-economic literature on firm investment.[2] There, dynamics are driven by adjustment costs (and perhaps additionally by different tax treatment of old and new capital). While the micro-research has produced many interesting insights it cannot be used to assess how aggregate macroeconomic performance is affected by tax policy. The partial-equilibrium approach treats wages and interest rates as given and thus neglects important feedbacks through factor price adjustments. Also, since there are no households, the consequences of tax policy on welfare cannot be explored.

Our work shares probably most with two articles by Judd (1985, 1987) that investigate anticipated and temporary tax changes in a dynamic general equilibrium model and which, like the

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[1]An incomplete list includes Lucas (1990), King and Rebelo (1990), Greenwood and Huffman (1991), Cooley and Hansen (1992), Baxter and King (1993), McGrattan (1994), Stokey and Rebelo (1995), Laitner (1995), Mendoza et al. (1997), Kim (1998), Mendoza and Tesar (1998), Grüner and Heer (2000), Strulik (2003), McGrattan and Prescott (2005).

[2]Summers (1981), Abel (1982), Auerbach (1989), Alvarez et al. (1998), and Gourio and Miao (2007).

present paper, explain adjustment dynamics by the desire of households to smooth consumption. In fact, our model can be conceptualized as an extension of Judd's by a corporate sector and a decision problem of firm finance. Within a somewhat simpler institutional framework Judd computes in a quite sophisticated way the savings and welfare effects of tax reform analytically. That way he is able to obtain welfare effects of *marginal* tax changes.[3]

Yet, tax reforms in reality are non-marginal and in fact sometimes quite drastic. Taking adjustment dynamics properly into account their (non-marginal) quantitative impact on welfare and other aggregates cannot be assessed analytically. Here, we thus propose a new numerical method for their assessment. The method is in detail described in Trimborn et al. (2008) and the general idea of it will be briefly reviewed later in the present paper. Our approach allows us to solve a dynamic general equilibrium model for non-marginal, anticipated or temporary tax changes. The numerical method has a one-to-one correspondence to phase diagram analysis and is thus very intuitive. It nowhere requires a linearization or other approximation of the economic model and allows to obtain impulse responses up to an arbitrarily small, user-specified error.

The concrete framework that we use for our investigation consists of a neoclassical growth model with explicit consideration of a corporate sector and a firm finance decision. For our purpose this setup combines several advantages. It allows for the introduction of a rich set of tax parameters and a discussion of real and financial impacts of tax reform and it is still simple enough to be reduced to a two-dimensional dynamic system, and anticipation effects can be understood qualitatively by phase diagram analysis.[4]

The next section describes the model and the implementation of anticipation effects. Section 3, using phase diagrams, investigates anticipated enactment and termination of tax reforms qualitatively. Section 4 explains how our numerical method exploits the principles derived from phase diagram analysis, Section 5 presents our results, the quantitative impact of anticipation on adjustment dynamics of several macroeconomic aggregates and on welfare. Section 6 concludes.

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[3]Anticipated tax changes in dynamic general equilibrium are also investigated in Howitt and Sinn (1989) and Domeij and Klein (2005). These articles, however, are pursuing different questions than the present one. Domeij and Klein explore how results on optimal capital taxation are modified when tax changes are anticipated. Howitt and Sinn investigate gradual tax reforms where the tax rate changes continuously and converges towards a final value. Their problem could perhaps best be conceptualized as an un-anticipated tax reform that introduces a whole path of future tax changes, which are then, once the whole reform is known, anticipated.

[4]Tax policy in this framework has been investigated by Turnovsky (1982, 1990), Sinn (1987), Osterberg (1989), and Strulik (2003). None of the earlier literature has been concerned with pre-announced and temporary tax policy.

2. The Model

2.1. **Firms.** We consider a continuous time, infinite horizon model of a corporation maximizing present value of the firm (as in Sinn, 1987, Auerbach, 2001) augmented by costly debt (as in Strulik, 2003). Let V denote the value of the firm, S the flow of funds from the issue of new shares, and D dividends. Following the standard literature (the "new view", Auerbach 2001) we focus on both D and S being non-negative, i.e. we exclude share repurchases.[5] Let furthermore r denote the gross interest rate on bonds, τ_d the tax rate on dividends, τ_p the tax rate on private interest income and τ_c the tax rate on capital gains. All variables are generally functions of time but for notational convenience we omit a time index unless necessary for understanding. Tax rates are treated parameterically since they change either only occasionally (at discrete events) or not at all.

No-arbitrage at capital market equilibrium requires that the after-tax return of bonds equals the return obtained from investment in shares consisting of after tax earnings from capital gains and dividends.

$$(1 - \tau_p)rV = (1 - \tau_c)(\dot{V} - S) + (1 - \tau_d)D \tag{1}$$

Integrating equation (1) and applying the terminal condition that discounted firm value converges to zero yields present value of the firm.

$$V(t) = \int_t^\infty \left(\frac{1 - \tau_d}{1 - \tau_c} D - S \right) e^{-\int_t^v \frac{1 - \tau_p}{1 - \tau_c} r(s) ds} dv \,. \tag{2}$$

The implementation of tax depreciation follows Sinn (1987). A proportion z of a unit of investment can be deducted immediately and the remainder is tax-deductible over time with the rate of economic depreciation (δ). Additionally to preferential tax treatment of depreciation other subsidies may directly reduce the cost of investment. In order to be brief we subsume all investment specific allowances in z as *investment tax credit*. Let T_r denote the tax on corporate income at rate τ_r, Π accounting profits, I net investment and $\dot{B}$ new debt. Gross dividends are then defined by

$$D = \Pi + \dot{B} + S - I(1 - z\tau_r) - T_r \,. \tag{3}$$

Firms face an exogenously growing level of technology A and produce with constant returns to scale with respect to capital K and labor in efficiency units AL. The production function F

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[5]Our results nowhere hinge on this assumption, we make it only in order to avoid distracting case differentiation.

has positive and decreasing marginal returns. Each unit of labor receives a wage w. Firms face unit costs of debt which consist of the market interest rate and a further cost depending on their debt ratio (B/K), which may best be thought of as agency costs of debt. Both costs are tax deductible. Because the corresponding costs function $a(B/K)$ is not explicitly micro-founded, we merely require that its curvature ensures an interior solution of the maximization problem.[6]

Accounting profits are given by $\Pi = F(K, AL) - wL - \delta K - rB - a(B/K)B - \tau_r zI$ and the corporate tax is given by $T_r = \tau_r \Pi$. Inserting these expressions into (3) we get gross dividends (4).

$$D = (1 - \tau_r) \left[F(K, AL) - wL - \delta K - rB - a(B/K)B - \tau_r zI + \frac{\dot{B} + S - (1 - \tau_r z)I}{1 - \tau_r} \right] . \quad (4)$$

The corporations part of the model is completed by the law of motion for capital (5).

$$I = \dot{K} . \quad (5)$$

The Hamiltonian for maximization of (2) subject to (4)-(5) and $D \geq 0$ and $S \geq 0$ is:

$$\begin{aligned}
\mathcal{H} =& (1 - \tau_r) \left(\mu_D + \frac{1 - \tau_d}{1 - \tau_c} \right) \times \\
& \left\{ F(K, AL) - wL - \delta K - rB - a(B/K)B - \tau_r zI + (\dot{B} + S - (1 - \tau_r z)I)/(1 - \tau_r) \right\} \\
& - S + q_K I + q_B \dot{B} + \mu_S S
\end{aligned}$$

where q_K and q_B denote the costate variables associated with capital and debt and μ_D and μ_S are the slack variables associated with dividends and share issue. Let capital per labor in efficiency units be defined as $k := K/(AL)$, the debt ratio as $b := B/K$, and production per effective labor as $f(k) := F(k, 1)$, $f'(k) > 0$, $f''(k) < 0$. The first order conditions for an optimal choice of investment (I) and employment (L), share issue (S) and new debt $(\dot{B})$ are summarized in (6).

$$w = A[f(k) - f'(k)k] \quad (6a)$$

$$1 - \frac{1 - \tau_d}{1 - \tau_c} = \mu_D + \mu_S \quad (6b)$$

$$\left(\mu_D + \frac{1 - \tau_d}{1 - \tau_c} \right) (1 - \tau_r^2 z) = q_K \quad (6c)$$

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[6]A micro-foundation of agency costs could be integrated into the model at the expense of further formal complication and notational clutter, see Strulik (2008).

$$\frac{1 - \tau_d}{1 - \tau_c} = q_B + \mu_D \tag{6d}$$

$$(1 - \tau_r)\left(\mu_D + \frac{1 - \tau_d}{1 - \tau_c}\right)\left[f'(k) - \delta + a'(b)b^2\right] = q_K r \frac{1 - \tau_p}{1 - \tau_c} - \dot{q}_K \tag{6e}$$

$$-(1 - \tau_r)\left(\mu_D + \frac{1 - \tau_d}{1 - \tau_c}\right)\left[r + a(b) + a'(b)b\right] = q_B r \frac{1 - \tau_p}{1 - \tau_c} - \dot{q}_B \ . \tag{6f}$$

We assume (and confirm numerically below) that our representative firm distributes regular dividends, i.e. $D > 0$, such that the complementary slackness condition, $\mu_D D = 0$ requires $\mu_D = 0$. According to the US tax system (before 2003) $\tau_d > \tau_c$. This implies that according to (6b) $\mu_S > 0$ such that $S = 0$ implying that firms issue (regularly) no new shares and retained profits are the preferred method of accumulating equity capital. This, however, does not imply that firms will *never* issue new shares. If tax rates faced by the corporation sector change, firms may want to adjust their equity capital instantaneously. But since output and profits are flows, retained earnings cannot jump so that firms have to rely on $S > 0$ in order to increase their equity instantaneously. This way, the "new view" is compatible with the empirical observation of occasional issues of new shares.

According to (6c), marginal costs of investment from shareholders' perspective equal marginal value of investment (measured by q_K). Condition (6d) requires that the marginal value of new debt equals its marginal costs: substituting one Dollar of retained earnings by new debt increases dividends by $(1 - \tau_d)/(1 - \tau_c)$. The left hand side of (6e) gives net marginal returns on capital allocated within the firm from shareholders' perspective. It equals net marginal returns on capital outside the firm (net interest payments plus depreciation of value). Note that an additional unit of capital does not only increase output by $f'(k) - \delta$ but also has an additional positive effect by lowering the debt ratio. The left hand side of (6f) gives marginal costs of debt within the firm consisting of interest costs plus marginal leverage costs, which equal the marginal returns on debt outside the firm (net returns on bonds plus depreciation of value).

The necessary conditions are sufficient and an interior solution is – if it exists – unique, if the non-maximized Hamiltonian is strictly concave in states and controls. With respect to capital and debt strict concavity of the Hamiltonian requires that total costs of leverage, $a(B/K)B$, are strictly convex in K and B, implying:

$$2a'(b) + a''(b)b > 0 \ , \tag{7}$$

which is assumed to hold henceforth. Finally, we assume that the tax burden is higher when investment is financed by equity than when it is financed by debt:

$$(1 - \tau_p) > (1 - \tau_c)(1 - \tau_r) \ . \tag{8}$$

The assumption ensures that firms are always realizing an interior solution for financial structure, i.e. that they are never completely equity financed. A tax advantage of debt finance is empirically supported for the US and many other OECD countries (OECD,1991, Graham, 2000, 2006).

From the first order conditions (6) we derive the optimal debt ratio as an implicit function of the capital labor ratio and the tax law.

$$0 = f'(k) - \delta + a'(b)b^2 - \left[\frac{(1 - \tau_r^2 z)(1 - \tau_p)}{(1 - \tau_p) - (1 - \tau_c)(1 - \tau_r)} \right] (a(b) + a'(b)b). \tag{9}$$

2.2. **Households.** Households maximize intertemporal utility from consumption C according to

$$\max \int_0^\infty \frac{C^{1-\sigma}}{1 - \sigma} e^{-\rho t} dt \tag{10}$$

where ρ is the time preference rate and $1/\sigma$ the intertemporal elasticity of substitution. Households supply one unit of labor, receive a wage w_t, pay a tax on wage income at rate τ_w, and receive lump-sum government transfers, T. Their financial wealth, W, consists of equity holdings, V, and bond holdings, B^H, and their budget constraint is given by

$$\dot{B}^H = (1 - \tau_w)w + (1 - \tau_p)rB^H + \theta D + T - S - \tau_c(\dot{V} - S) - C \ .$$

After inserting $\dot{B}^H$ and $\dot{V}$ from (1) into $\dot{W} = \dot{V} + \dot{B}^H$ the budget constraint reads

$$\dot{W} = (1 - \tau_w)w + (1 - \tau_p)rW + T - C \ . \tag{11}$$

The first-order conditions for maximizing (10) given (11) provide the Ramsey rule

$$\frac{\dot{C}}{C} = \frac{(1 - \tau_p)r - \rho}{\sigma}. \tag{12}$$

2.3. **Capital market equilibrium.** Generally, a capital market equilibrium requires $W = V + B$. The interesting case here occurs at those occasional events when a tax reform triggers a restructuring of firm capital. These instantaneous movements of financial funds change debt and equity holdings of firms and thus the value of firms but they cannot change aggregate

wealth W if the tax change was pre-announced and thus expected. Aggregate wealth is a stock variable that cannot jump at the moment of an *unexpected* event. Intuitively, an expected jump of wealth would indicate arbitrage opportunities. These, however, are ruled out by the no-arbitrage condition. Thus at the point of time of financial restructuring, denoted by $\tilde{t}$,

$$\Delta B^H(\tilde{t}) = \Delta V(\tilde{t}) \tag{13}$$

However, if we allow for a discrete financial restructuring at $\tilde{t}$, firms may issue a mass of new shares at $\tilde{t}$ or pay exceptional dividends at $\tilde{t}$. We denote this change by $S(\tilde{t})$ and $D(\tilde{t})$, respectively, and consider it for firm value by applying the Dirac delta function.[7] Accordingly, firm value modifies to

$$V(t) = \int_t^\infty \left(\frac{\theta(D + \delta_{\tilde{t}}(v)D)}{1-\tau_c} - (S + \delta_{\tilde{t}}(v)S) \right) e^{-\int_t^v \frac{1-\tau_p}{1-\tau_c} r(s)ds} dv. \tag{14}$$

But by how much does firm value change? To answer that question we calculate firm value over a small interval $[\tilde{t}, \tilde{t} + \Delta t]$ according to equation (14).

$$V(\tilde{t} + \Delta t)e^{-\int_{\tilde{t}}^{\tilde{t}+\Delta t} \frac{1-\tau_p}{1-\tau_c} r(s)ds} - V(\tilde{t}) =$$

$$\int_{\tilde{t}}^{\tilde{t}+\Delta t} -\frac{\theta(D(s) + \delta_{\tilde{t}}(s)D(s))}{1-\tau_c} e^{-\int_{\tilde{t}}^s \frac{1-\tau_p}{1-\tau_c} r(u)du} ds$$

$$+ \int_{\tilde{t}}^{\tilde{t}+\Delta t} (S(s) + \delta_{\tilde{t}}(s)S(s))e^{-\int_{\tilde{t}}^s \frac{1-\tau_p}{1-\tau_c} r(u)du} ds.$$

Consider first instantaneous restructuring through issues of new shares S. For $\Delta t \to 0$ the first integral at the right hand side converges to zero since D remains to be a flow and $D(\tilde{t}) = 0$. With contrast, S has a discrete mass at point $\tilde{t}$ so that the second integral at the right hand side converges to $S(\tilde{t})$. Likewise, if there is restructuring through dividends, the second integral converges to zero for $\Delta t \to 0$ whereas D has positive mass and the first integral converges towards $-\theta D(\tilde{t})/(1-\tau_c)$. Summarizing we have

$$\Delta V(\tilde{t}) = \begin{cases} S(\tilde{t}) & \text{if } \Delta V(\tilde{t}) > 0 \\ -\frac{\theta}{1-\tau_c} D(\tilde{t}) & \text{if } \Delta V(\tilde{t}) < 0. \end{cases} \tag{15}$$

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[7] We denote the Dirac delta function by the symbol δ. The function is defined by $\delta_{\tilde{t}}(t) = \begin{cases} +\infty, & t = \tilde{t} \\ 0, & t \neq \tilde{t} \end{cases}$ and $\int_{-\infty}^\infty \delta_{\tilde{t}}(t)\, dt = 1$, see Li and Wong (2008) and the citations therein.

Equations (13) and (15) describe the general equilibrium effects of financial restructuring and its consequence on firm value. In words, if firms restructure by paying exceptional dividends, households reinvest income by buying additional bonds. If firms issue new shares, households adjust by selling bonds.

2.4. **Government and General Equilibrium.** Government revenues are completely paid out to households in form of either transfers or interest payments on government bonds. Using Ricardian equivalence, the path of government debt necessary to balance the current budget is represented by a time series of lump sum income transfers.

The economy consists of a continuum of households and a continuum of firms both of measure one. GDP is used for private consumption, investment and agency costs

$$Y = C + I + \delta K + a(b)B = F(K, AL).$$

Inserting this into (5) and dividing by K we obtain growth of aggregate capital as:

$$\dot{K}/K = [f(k)/k - a(b)b] - C/K - \delta. \tag{16}$$

Next, we introduce the consumption-capital ratio $c = C/K$ and assume that technology grows at constant rate γ. Using (12) and (16), the economy is represented as the following system in k and c.

$$\dot{k}/k = f(k)/k - a[b(k)]b(k) - c - \delta - \gamma \tag{17a}$$

$$\dot{c}/c = [(1 - \tau_p)r(k) - \rho]/\sigma - (\gamma + \dot{k}/k). \tag{17b}$$

The main deviation from the standard neoclassical growth model is that the interest rate is not explicitly given by capital productivity but "only" implicitly determined on the financial market. To see this clearly, derive from (9) financial structure b as an implicit function of firm size k. Then conclude from (6d) and (6f) $r + a(b) + a'(b) = r(1 - \tau_p)/[(1 - \tau_c)(1 - \tau_r)]$, which expresses the interest rate implicitly as a function of firm leverage. It can be shown that leverage and interest rates are positively correlated ($\mathrm{d}r/\mathrm{d}b > 0$) and that larger firms are relatively less indebted ($\mathrm{d}b/\mathrm{d}k < 0$). This provides, as for the standard neoclassical growth model, a negative correlation between capital stock and returns $\mathrm{d}r/\mathrm{d}k < 0$ and ensures a unique and saddlepoint-stable equilibrium (See Strulik, 2003, for a proof of these claims).

Given the saddlepoint property, obtaining adjustment dynamics after a permanent, *non-anticipated* tax reform is straightforward. At the time of the tax change, the state variable k cannot jump and consumption jumps on the stable manifold along which the economy travels towards the new steady-state, determined by the after-reform tax law. Generally, growth and welfare effects of these kinds of tax changes have been investigated in many articles and in particular, for the current model in Strulik (2003). If the tax change is anticipated and/or known to be non-permanent, however, assessing adjustment dynamics is somewhat more involved.

3. Anticipated Tax Policy: Qualitative Analysis

In the real world, people may know both the point in time when a tax policy comes into effect and the point in time when it terminates – if it terminates. For better understanding, however, it is useful to investigate the effects that arise from pre-announcement and from known expiry separately. Linguistically, we may distinguish an anticipated *tax reform*, i.e. a policy that is regarded to be permanent and which will become operative in the future at a certain pre-announced date (like, for example, elements of Germany's "Agenda 2010") from a *temporary tax cut*, which is enacted more or less spontaneously and known to be terminated at a certain date in the future (like many elements of the 2001 and 2003 tax relief acts of the Bush administration).[8]

3.1. **Anticipated Tax Reform.** Consider, as an illustration, an anticipated and permanent cut of the corporate tax rate which is announced at time t_0 and which becomes effective at a future date $\tilde{t} > t_0$. At time t_0 the economy is assumed to rest at the pre-reform steady-state. Because firms and households know in advance that the reform will happen, they use the opportunity to adjust their behavior already from time t_0 onwards.
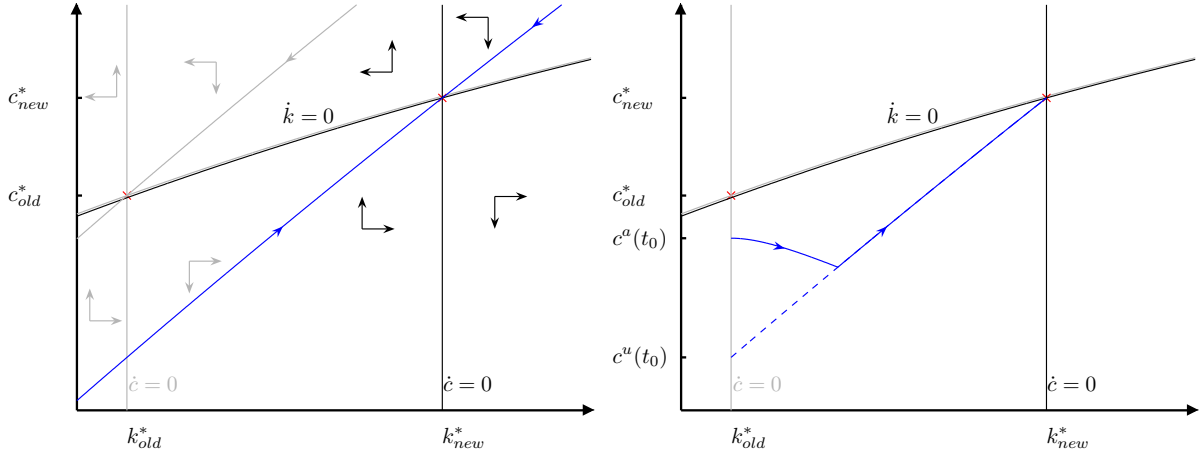
Adjustment dynamics can be conveniently analyzed in a phase diagram. In Figure 1 the panel on the left introduces the pre- and after reform equilibria and general movements within the phase diagram. The panel on the right shows adjustment dynamics of the specific reform. Initially the economy is situated at (k^*_{old}, c^*_{old}). Grey curves show the initial isoclines and grey arrows indicate the direction of motion of trajectories around the steady-state. A cut of the corporate tax rate τ_r increases the incentive to take up more debt in order to finance additional

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[8]We ignore elements of uncertainty stemming, for example, from commitment problems or (unexpected) change of the incumbent party. For a related paper on policy uncertainty, see Alvarez et al. (1998).

investment. Thus at the after-reform steady-state both k^* and $b(k^*)$ will be higher. The $\dot{c}=0$–curve moves to the right because of higher capital accumulation (lower marginal return on capital) and the $\dot{k}=0$–curve shifts downward because of higher agency costs of debt. Black lines indicate the new isoclines and the black vector field indicates the direction of movement of trajectories associated with the new equilibrium.[9]

FIGURE 1: PRE-ANNOUNCED TAX REFORM: PHASE DIAGRAM

The basic intuition for the understanding of adjustment dynamics is that there can only be a jump of household wealth and thus of consumption at the moment of an unexpected event. As explained above, the assumption of no-arbitrage rules out jumps if everything is expected and thus correctly anticipated by households and firms. If agents would not expect the tax reform, the economy would rest at the initial steady-state from t_0 to $\tilde{t}$. At $\tilde{t}$ households and firms would rearrange their decision plans such that the economy would immediately jump on the stable manifold associated with the after-reform steady-state, represented by a dashed line on the right panel of Figure 1. This behavior follows stringently from the logic of the first order conditions and the transversality condition requiring that the economy converges towards the steady-state. Because there cannot be any further jumps, and because any trajectory not starting on the stable manifold will never arrive at the steady-state, the economy has to be on the manifold at $\tilde{t}$.

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[9]Theoretical analysis identifies a higher capital stock at the new equilibrium but leaves the change of steady-state consumption indeterminate. In line with our numerical results below Figure 1 assumes that the shift caused by interest rates (i.e. through the savings channel) is more pronounced than the shift caused by agency costs of debt (through the credit channel) such that consumption is actually higher at the new equilibrium.

When households and firms anticipate the tax reform they choose already a different pattern of investment and consumption during the time between first knowledge and coming into effect of the policy, i.e. during $[t_0, \tilde{t}]$. At time $\tilde{t}$, there is no new information so that households' wealth evolves continuously. Hence, the shadow price of wealth and consumption evolves continuously as well. For this to be the case, households choose an initial value of consumption $c^a(t_0)$, such that the resulting trajectory implied by the vector field meets the stable manifold at $\tilde{t}$. This path is represented in the panel on the right hand side of Figure 1 by a solid line.

In order to understand the movement of transitional dynamics, note that until $\tilde{t}$ the grey vector field associated with the pre-reform steady-state applies whereas the black vector field associated with the after-reform steady-state applies from $\tilde{t}$ onwards. A higher level of consumption compared with the old steady-state level at $\tilde{t}$ would result in a trajectory leading in north-westward direction. This trajectory would radiate from the new stable manifold and, hence, could not meet it at time $\tilde{t}$. Therefore, consumption has to jump down at t_0.
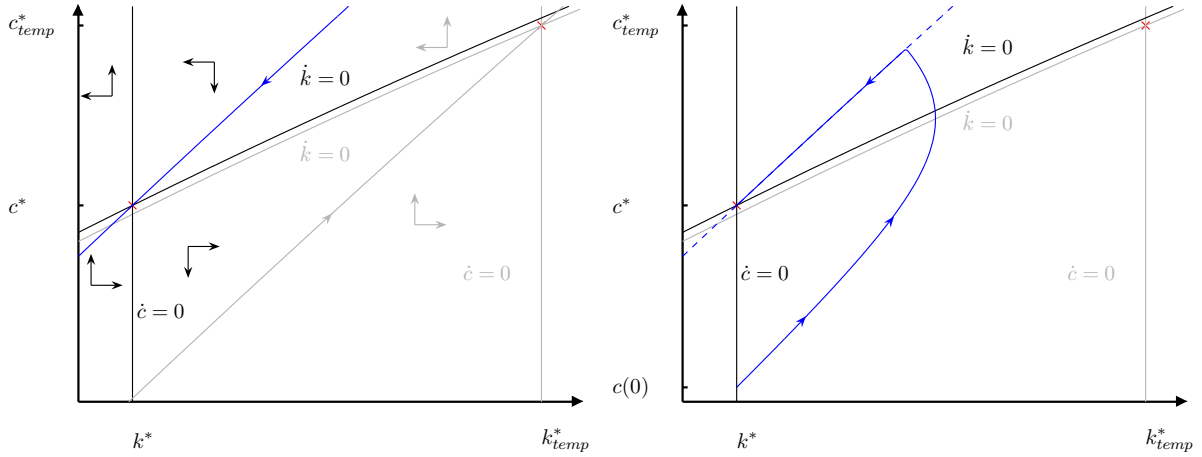
This downward shift of consumption means that the announcement of the tax cut already spurs investment before the reform actually comes into force. We can also conclude that the downward jump of consumption has to be smaller than for an unanticipated reform. Trajectories starting with $c < c^*_{old}$ under the old tax regime point to the south-east. Hence, any $c^a(t_0)$ lower than $c^u(t_0)$ would result in a trajectory leading away from the new stable manifold. The economy would never arrive at the after-reform steady-state.

Financial structure of firms, with contrast, does not change discontinuously at the time when the reform is *announced*, i.e. at time t_0. For given macroeconomic aggregates and constant policy the structure of finance depends solely on current taxes and the stock of capital. Implicitly differentiating (9) we find $\partial b / \partial \tau_r > 0$. Thus, financial structure of firms changes discontinuously in favor of equity when the reform becomes operative, i.e. at time $\tilde{t}$. Because of no-arbitrage this financial restructuring must not affect aggregate wealth (and consumption) of households. Qualitatively, we know from equations (13) and (15) that firms issue new shares at $\tilde{t}$ such that expenditure by households (S) equals the gain in aggregate firm value (ΔV). The quantitative impact, however, that an anticipated tax reform has on financial structure, capital accumulation, consumption, and welfare, is unknown. It will be investigated in Section 5.

3.2. **Non-permanent Tax Policies.** Consider now the opposite case and suppose that a tax law becomes known at the moment when it becomes effective (for example, because it is known

that a proposal once it has passed legislature will be retroactively applied) and that the law changes the tax rate only for a finite period of time, which is known by the economic agents. Afterwards, the original policy applies again. Typical examples are many traditional Keynesian policies, like temporary investment tax credits and accelerated depreciation rules. As an illustration we thus consider a non-anticipated increase of z which is known to last for $\tilde{t}$ time periods.

FIGURE 2: TEMPORARY RISE OF INVESTMENT TAX CREDIT: PHASE DIAGRAM

An increase of the investment tax credit z makes investment more attractive and leads to higher capital accumulation and lower interest rates. It shifts the $\dot{c} = 0$-curve to the right. The $\dot{k} = 0$-curve shifts down a little because $b(k^*)$ and the entailed agency costs of debt are higher at the new steady-state. However, the policy change is known to be only temporary. In Figure 2 black isoclines and vector fields are associated with the initial equilibrium, which is also the terminal equilibrium. Grey isoclines and vector fields are associated with the equilibrium towards which the economy temporarily converges (k^*_{temp}, c^*_{temp}). General dynamics are introduced in the panel on the left. Dynamics of the specific policy are shown in the right panel.

For the construction of adjustment dynamics note that at the time when the temporary tax credit becomes effective the grey vector field applies while at the time when the policy expires the economy must have reached the stable manifold leading to the old (i.e. the permanent) steady-state. This behavior follows the same logic as explained above. Economic agents receive no new information at the time when the policy expires because the expiry date is already known

in advance. Consequently, no-arbitrage rules out a jump of aggregate wealth implying that the associated shadow price of wealth and consumption cannot jump as well.

Because the policy is temporarily expansive, adjustment along the stable manifold has to be from above as indicated in the panel on the right of Figure 2. In order to reach the manifold along a path that obeys the grey vector field, the initial jump of consumption must be in direction of lower c. The policy implies a steep spontaneous increase of investment with subsequently falling investment rates. Note that the inherent logic of adjustment dynamics also implies that the trajectory describing the optimal consumption strategy crosses the $\dot{k} = 0$ isocline from below before it reaches the manifold. Otherwise, the economy would never return to the initial steady-state. The model thus predicts that investment falls below its initial level at a time when the favorable investment credit is still effective. Finally, observe that consumption reaches its highest level at the moment when the temporary policy is terminated.

Generally, phase diagrams of anticipated reforms have already been analyzed elsewhere (Summers, 1981, Abel, 1982, Judd, 1985). We have been reviewing these principles in such a detailed manner because we are exploiting them with our numerical solution technique, the application of which to anticipated tax reform and temporary tax relief is the major innovation of the present paper.

4. Method and Calibration

4.1. **Method.** For calculating adjustment dynamics we apply the relaxation algorithm as introduced by Trimborn et al. (2008). The principle of relaxation is to construct a large set of non-linear equations, the solution of which represents the desired trajectory. This is achieved by a discretization of the involved differential equations on a mesh of points in time. The set of differential equations is augmented by algebraic equations representing equilibrium conditions or (static) no-arbitrage conditions at each mesh point. Finally, equations representing the initial and final boundary conditions are appended. The whole set of equations is solved simultaneously.

The special property of our optimization problem is that the size of the jumps fulfilling (13) and (15) follows from the continuity of capital (k), wealth (W), consumption (C) and the respective shadow prices. A jump in financial structure is thus optimal according to (13) and (15)

if it is accompanied by a continuous movement of consumption, capital, and wealth. The relaxation algorithm is demanding just this property by treating differential and algebraic variables conceptually differently. For differential variables there are differential equations present (e.g. for k) whereas this is not the case for algebraic variables (e.g. for b). The distinction is important because it implies that differential variables are connected along time through difference equations whereas no such connection exists for algebraic variables. This feature allows algebraic variables to jump whereas differential variables have to be continuous (potentially with corners). Thus, while the algorithm forces W to evolve continuously, its components V and B can exhibit interior jumps of the same magnitude, but with opposite signs. This way the algorithm reveals the extraordinary payout of dividends (or the extraordinary issue of shares) at the time when a policy comes into effect and firms adjust financial structure.[10]

4.2. **Calibration.** We calibrate the model with U.S. data. We use a Cobb-Douglas production function and set the capital share α to $1/3$. Instead of imposing a linear or quadratic form for the unit costs of debt, we try to find parameters of the isoelastic function $a(b) = a_0 b^{a_1}$ such that the simulated behavior of the representative firm generates the correlation between taxation and leverage estimated for the average U.S. firm by Gordon and Lee (2001, 2007). We set $\tau_r = 0.35$ according to the marginal tax rate applying for U.S. corporations at the highest tax bracket. For tax rates on private capital income we tried to calibrate the initial steady-state such that it reflects the U.S. tax law before the (mostly temporary) tax cuts of the Bush administration. Following Gourio and Miao (2010) we set $\tau_p = 0.25$, $\tau_d = 0.25$, $\tau_r = 0.35$ and the statutory capital to 0.20. The tax on capital gains is an effective rate and following Poterba (2004) we set $t_c = 0.2/4$. Finally we set τ_w to the value of 0.36, which has been estimated by Carey and Tchilinguirian (2000) as the average effective tax rate on labor income, and — following the approach in Sinn (1987, pp. 57-60) — $z = 0.4$. From various other calibration studies we adopt $\rho = 0.02$ and $\gamma = 0.015$.

The remaining parameters are determined in the following way. Eqs. (9), and (17) evaluated at the steady state are required to yield $b^* = 0.194$ (the average debt ratio according to Gordon and Lee), a long-run capital output ratio of $k^{*1-\alpha} = 2.16$, and a long-run gross investment ratio of $(I + \delta K)/K \cdot (K/Y) = (\delta + \gamma)k^{*1-\alpha} = 0.17$ (both values according to Mendoza and

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[10]A detailed description of the numerical method is available at: `http://kaldor.vwl.uni-hannover.de/???`. The MATLAB code is available upon request.

Tesar, 1998). This implies a net investment ratio I/K of 3.24 and determines $\delta = 0.064$ and $\sigma = 2.8$. Finally, the parameters of the debt cost function are determined by requiring $a(b) = 0$ for $b = 0$ and that our benchmark economy reproduces Gordon and Lee's (2001) estimate that a five percentage point increase in τ_r raises the debt ratio by about 1.8 percentage points. This provides the estimates $a_0 = 7.3$ and $a_1 = 4.7$.[11]

5. Anticipated and Temporary Tax Policy: Quantitative Analysis

5.1. **Pre-Announced Corporate Tax Reform.** Many OECD countries have recently enacted quite drastic cuts of corporate taxes or are planning them for the future. Corporate tax reforms are frequently known several years in advance (Alvarez et al, 1998, Domeij and Klein, 2005). In line with these observations we assume a tax cut of τ_r of 10 percentage points and start our investigation at year 0, from which onwards it is known that in year 5 there will be a corporate tax reform.

In Figure 3 we show the consequences for major economic variables: capital stock (k), consumption (c), aggregate wealth (W), debt ratio (b), firm value (V), net investment rate I/Y, dividends per share (D/V), tax revenue, and economic growth of per capita output (g_y). Values for macroeconomic aggregates are detrended and expressed relative to their pre-reform steady-state values. Values for economic rates (i.e. b, I/Y, and g_y) are expressed in percentage points. In each panel the after-reform steady-state value to which the economy eventually converges is indicated by a circle. Solid lines show adjustment dynamics for the pre-announced reform. For comparison, dashed lines show adjustment dynamics when the same reform hits the economy unexpectedly at $t = 5$.

The trajectory obtained for consumption confirms our earlier results from qualitative analysis. If the policy is anticipated, consumption falls already as soon as the reform becomes known indicating that households (shareholders) are eager to smooth consumption (wealth) and react to the expected lower taxes in the future by initiating an investment spurt today. The anticipation effect is quantitatively significant. If the tax reform comes unexpected, consumption stays at its initial level for the next 5 years and then falls by about twice as much as for the anticipated reform. In terms of current consumption (and thus instantaneous utility) ignorant households
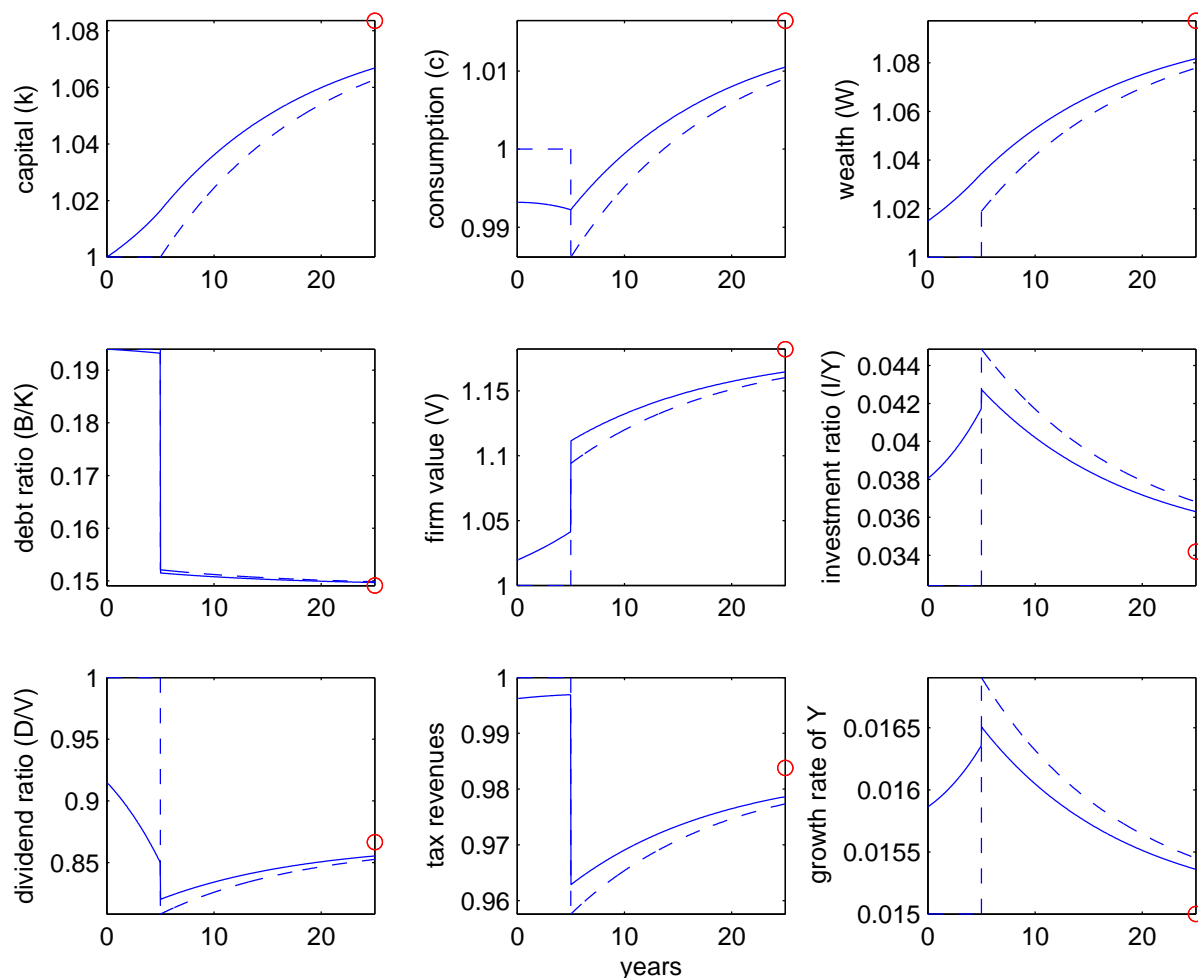
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[11]An even larger effect of corporate taxes on firm finance than suggested by Gordon and Lee's estimate has recently been found by Djankov et al. (2000) in a cross-country study. They estimate that a 10 percentage point increase of the corporate tax rate raises the debt to equity ratio by 45 percentage points.

are better off during the first five years and worse off afterwards when they have to adjust towards the new steady-state from a much lower level.

FIGURE 3: ANTICIPATED VS. UN-ANTICIPATED CORPORATE TAX REFORM

Adjustment paths for a 10 percentage point cut of the corporate tax rate that comes into effect in year 5. Solid lines: announcement at year 0. Dashed lines: unexpected reform. Macroeconomic aggregates measured in relative deviation from pre-reform steady-state; macroeconomic rates measured in percentage points.

As a consequence of anticipation the capital stock adjusts very smoothly. There is almost no kink visible at the time when the reform becomes operative. At the moment when the policy is enacted the capital stock is already about 2 percent above its pre-reform steady-state. This head-start advantage over the ignorant case is caught up only eventually when the economy reaches the new steady-state implying that pre-announcement of the reform makes firms bigger over the whole adjustment path.The finding of a size-effect from pre-announcement has been

obtained previously in partial equilibrium (Summers, 1981) and is here confirmed in general equilibrium.

With contrast to real variables, adjustment behavior of financial structure is much more abruptly when the reform comes into effect and almost insensitive to pre-announcement. Firms react to the new tax law by replacing debt with equity thereby, as explained in Section 2, issuing new shares. This way the model can explain the occasional observation of new share issues. The model explains these issues as optimal reaction on tax reforms, which also happen only occasionally (or, generally, as optimal reaction to rare events that are exogenous to the single firm). Optimal financial policy is determined by capital stock and the tax system (and not by the shareholders' desire to smooth consumption). Thus the prior knowledge that a reform will happen has little effect. The only, almost invisible, movement of the debt ratio during the announcement phase is caused by the increasing capital stock.

More capital and less debt implies that firms have to cut back dividends per share (D/V). The total value of shares, however, increases because of the increasing firm size. If the tax cut is pre-announced share value increases already before the reform.

As a consequence of increasing share value, households hold more shares and accumulate more wealth. Household wealth jumps at the moment when surprised firms adjust their financial structure by issuing new shares. For the pre-announced reform this happens immediately, at the moment of announcement. For the non-announced reform it happens at the moment of enactment. As consequence, consumption falls for the pre-announced reform already during the announcement phase, indicating the incentive to save and invest already before the policy comes into effect..

The early investment spurt is also visible in the I/Y-panel. If the reform is anticipated, most of the total increase of investment happens already in the pre-reform phase with only a small jump when the reform comes into effect. It is beneficial for firms to accumulate capital stock in advance, which allows for high profits at the time when the tax on retained profits is reduced. If the reform comes unexpectedly, the jump of investment at reform time is much higher and it remains to be higher after reform. Nevertheless, as inspection of the k panel has made clear, the head-start advantage from pre-announcement with respect to capital stock (and profits) is only recovered as time goes to infinity.

Behavior of investment translates one-to-one into behavior of the growth rate of output per capita. Output per capita growth is predicted to be higher for an unanticipated reform. Again, this does not indicate at all a benefit from ignorance. Higher growth after the enactment of the reform is insufficient to make up for the higher growth before reform that is taking place when the reform comes expectedly.
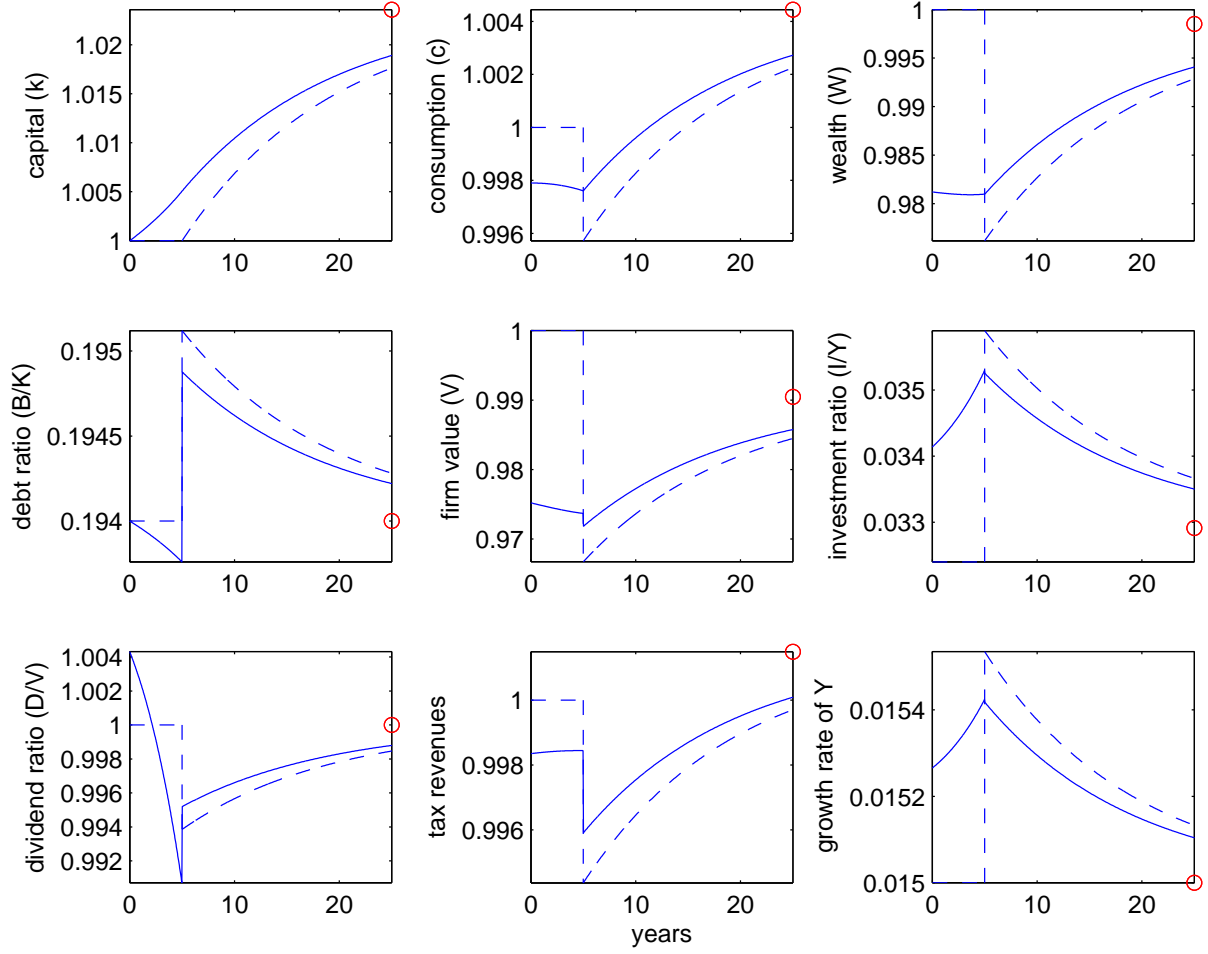
************* Finally, we consider tax revenue. The model predicts that the tax cut leads in the end, after considering all adjustment processes, to (slightly) higher tax revenue as compared to the pre-reform steady-state. During the adjustment phase, of course, tax revenue is temporarily lower. If the reform is anticipated, tax revenue falls already during the announcement phase because of lower revenue from dividend taxation. But the earlier expansion of the economy under an anticipated reform helps the economy to break even earlier with the pre-reform tax revenue. The pre-reform revenue is reached in year 15, i.e. 10 years after the reform comes into force as compared to 13 years for the unexpected reform. In any case, the reform becomes self-financing quite rapidly.

In Figure 4 we present impulse responses to a pre-announced vs. unexpected increase of the investment tax credit by 20 percentage points. In many ways adjustment dynamics resemble those obtained for the corporate tax reduction albeit at smaller size, initially as well as eventually. Yet there are also qualitative differences between both reforms discernable.

To begin with, firms get more into debt when the higher tax credit comes into effect. This effect operates only temporarily in order to finance the higher investment triggered by the reform. While conventional wisdom would have probably predicted that investment will be delayed until the investment tax credit becomes operative, we observe, again, an investment spurt during the announcement phase.

This at first sight puzzling behavior is explained by costly debt. Firms anticipate that there will be large investments when the investment tax credit is granted. The entailed investment costs cannot be served spontaneously by retained earnings since profits are a flow variable. Issue of shares is also no option since the policy (with contrast to the corporate tax cut) leaves the financial structure desired in *the long-run* unaffected. Thus higher investment cost are expected to be served by higher debt. The implied higher leverage will increase the cost of debt. In order to mitigate the cost-effect from higher leverage, firms invest, i.e. accumulate capital, already

FIGURE 4: ANTICIPATED VS. UN-ANTICIPATED INCREASE OF INVESTMENT TAX CREDIT

Adjustment dynamics after a 20 percentage point increase of z that comes into effect in year 5. Solid lines: announcement at year 0. Dashed lines: unexpected reform. Macroeconomic aggregates measured in relative deviation from pre-reform steady-state; macroeconomic rates measured in percentage points.

in the announcement phase. During this period they pay less dividends and retain earnings in order to display a lower debt ratio (B/K) when the reform comes into effect.

While the dividend ratio returns to its pre-reform value, total firm value is (with contrast to the corporate tax cut) predicted to be lower after the reform. Because long-run financial structure remains unchanged, permanently higher total investment has to be financed by both higher debt and higher equity. A higher stock of equity is accumulated through more retained earnings i.e. less dividends, which is reflected by a lower total value of firms (leaving the dividend ratio D/V unchanged).
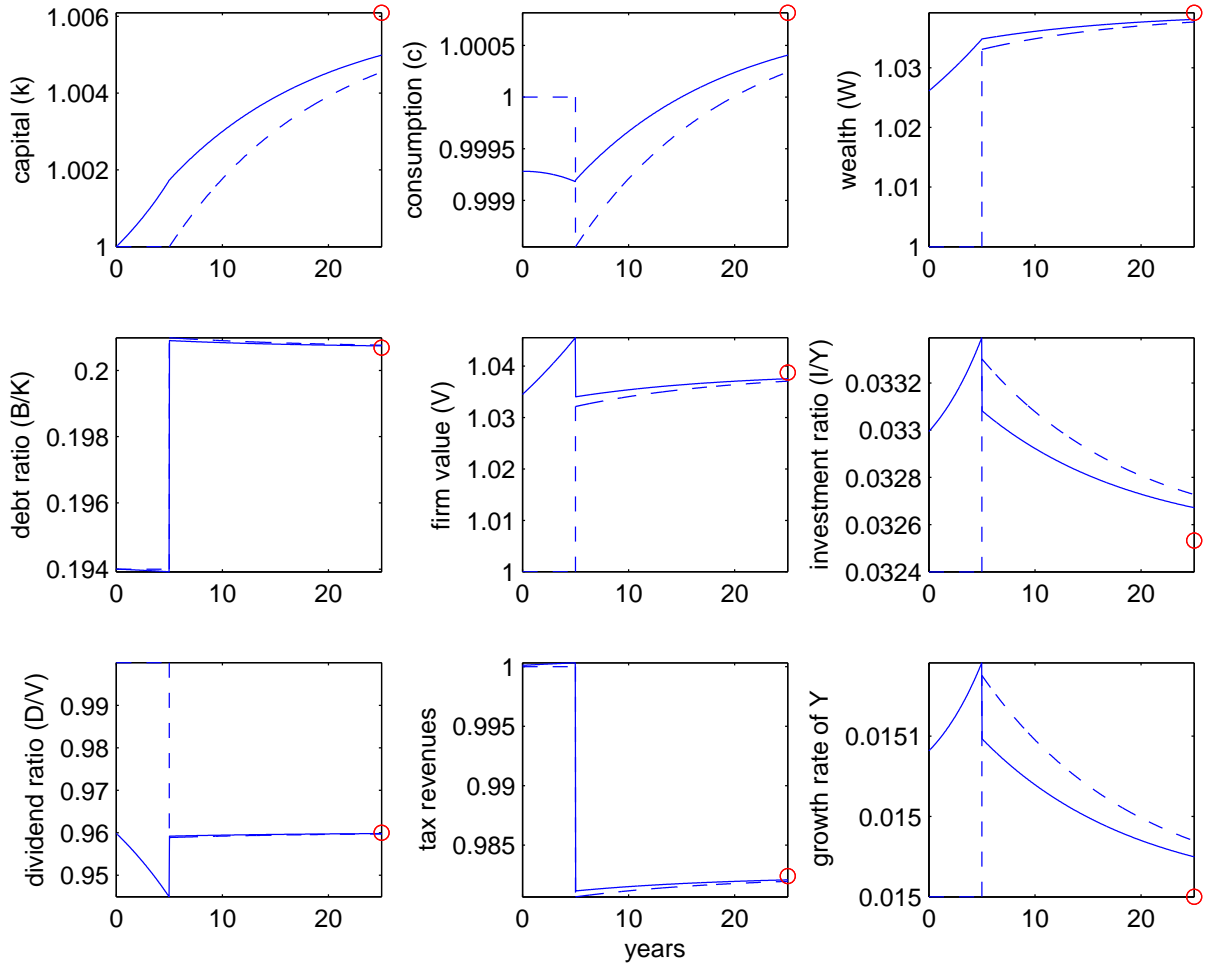
Interestingly, the model predicts for anticipated and unexpected reform diametrically opposed behavior of dividends when the reform comes into effect. If the reform arrives unexpectedly firms adjust by both higher debt and lower dividends in order to finance the higher investment needs. If the reform was anticipated, however, firms have already adjusted through lower dividends during the announcement phase and start to pay higher dividends (compared to last period, not compared to initial steady-state) when the reforms comes into effect.

Again, the reform generates enough expansive power to be self-financing in the end and produces even a mild surplus of tax revenue. During transition, however, tax revenue is below its pre-reform value for a much longer time than observed for the corporate tax cut. If the reform was announced in advance, tax revenue breaks even after about 25 years. As for other variables as well, adjustment dynamics for the unexpected reform lag behind indicating, again, a genuine welfare gain from announcement.

In Figure 5 we consider an anticipated vs. unexpected reduction of the tax rate on private capital income (including dividends) by 10 percentage points at time $t = 5$. Roughly speaking, results are less favorable than those obtained for the corporate tax reform. This is at first sight surprising since a reduction of τ_p is the only tax instrument that increases the net return on capital in the long-run. We can distinguish an interest rate channel inducing households to save more and a credit channel inducing households to hold a higher share of wealth in the form of bonds. Both effects are initiated simultaneously if the reform hits the economy unexpectedly. If the reform is anticipated, the credit channel operates mainly at the time when the reform comes into effect whereas the interest rate channel operates right from announcement onwards.

The head-start advantage from pre-announcement is again visible. When it becomes known that taxes on capital income will be lower in the future, households and firms immediately start to save and to invest. Again, early investment generates a size-effect from announcement that is only caught up as time goes to infinity if the reform hits the economy unexpectedly. During the announcement phase investment is mainly financed through retained earnings, i.e. lower dividends. When the reform comes into effect the tax advantage of debt increases and induces firms to raise their debt ratio and thus, in financial market equilibrium, induce households to hold a larger share of their wealth in bonds. When the reform comes into effect, firms do not

FIGURE 5: ANTICIPATED VS. UN-ANTICIPATED REFORM OF CAPITAL INCOME TAX

Adjustment Paths for a 10 percentage point reduction of τ_p comes into effect in year 5. Solid lines: announcement at year 0. Dashed lines: unexpected reform. Macroeconomic aggregates measured in relative deviation from pre-reform steady-state; macroeconomic rates measured in percentage points.

only adjust by demanding more debt but also by paying higher dividends, which in turn implies that total firm value is lower after the reform.[12]

The most interesting differences between anticipated and unexpected reform are observed for consumption and investment. If the reform comes anticipated, almost all of the expansive power of the reform has already taken place during the announcement phase. As a consequence the model predicts for the time when the reform becomes operative a small drop of the investment

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[12]Note that the one time payment of a special dividend at $t = 5$ is not visible in Figure 5, which shows just the flow of regular dividends. According to (14) we compute a one time increase of dividends by 11% in the year when the reform becomes operative. Comparatively, the impact of the reform on special dividends is much larger than its impact on regular dividends.

rate (compared to the previous period not compared to the pre-reform state). The opposite is true for the unexpected reform that unfolds its highest momentum when the reform comes into effect. In that case the model predicts a fall of aggregate consumption and an increase of the investment rate and economic growth rate at time $t = 5$.

Next we evaluate the welfare consequences of tax reforms and, in particular, the extra welfare that can be generated through pre-announcement of a reform. For that purpose we employ the Lucas' (1990) methodology and measure the welfare gain of a tax reform as the constant relative increase in consumption that equates intertemporal utility from remaining in the state before the reform and switching towards the consumption path induced by the reform. Results are reported in Table 1. By way of example we also check for the robustness of results. It is well known that the shape of adjustment dynamics is most drastically affected by the choice for the elasticity of marginal utility σ (see, for example, Barro and Sala-i-Martin, 2004). Our benchmark calibration has estimated $\sigma = 2.8$. We report additionally results when σ assumes values that are 33 percent higher and lower, respectively and where we have adjusted ρ such that the model parameterization in any case implies a steady-state growth rate of 1.5 percent.

The first row in Table 1 shows results for a 10 percentage point reduction of τ_r announced 5 years in advance. The left part shows the total welfare gain of the reform and the right part shows the extra welfare gain stemming from pre-announcement of the reform (compared to an unexpected reform). For a better assessment of results it may be helpful to recall that one percent welfare gain (from abolishing capital taxation) has been appraised as the largest gain that quantitative welfare economics can provide (Lucas, 1990) and that the welfare gained by eliminating all business cycles has been estimated to be somewhere between 0.008 and 0.1 percent (Krusell and Smith, 1999).

The total welfare gain of the corporate tax reform is estimated to be roughly one third of a percentage point, a figure that accords well with earlier results (Strulik, 2003). Compared to the total gain the extra gain from pre-announcement is smaller than one might have expected. The reason is that the extra utility gained along the higher consumption path after reform enactment (as compared to a surprising reform) is to a large degree counterbalanced by lower utility during the anticipation phase. Figuratively speaking, in the consumption panel of Figure 3 the discounted utility differential produced by the large areas between solid and dashed line before and after enactment is of similar size. Then again, a welfare gain from anticipation of

the reform of about 0.04 percent may equally well be assessed as quite large when compared to the gain from eliminating business cycles.

The size of the welfare gain is quite robust against alternative choices of σ. Not surprisingly, the lower σ the higher the welfare gain from tax reform. Interestingly, this result takes over to the additional gain from anticipation. If σ is smaller, the welfare gain from anticipation is somewhat higher as well. Summarizing we can conclude that anticipation of a corporate tax reform increases the welfare gain produced by the reform by roughly 10 percent.

TABLE 1: WELFARE AND ANTICIPATION EFFECTS OF TAX REFORMS

Policy reform	welfare gain			anticipation effect		
	σ low	σ benchmark	σ high	σ low	σ benchmark	σ high
$\Delta\tau_r = -0.1$	0.390	0.364	0.343	0.043	0.040	0.037
$\Delta z = 0.2$	0.092	0.084	0.078	0.013	0.013	0.012
$\Delta z = 0.1$	0.047	0.043	0.040	0.006	0.006	0.005
$\Delta z = 0.3$	0.136	0.124	0.114	0.021	0.019	0.018
$\Delta\tau_p = -0.05$	-0.002	-0.004	-0.006	0.005	0.005	0.005
$\Delta\tau_p = -0.05$ (Ramsey)	0.170	0.155	0.143	0.027	0.026	0.024

Welfare gain measured in consumption equivalents and expressed in percent. See text for further explanations.

Next we report welfare consequences for an increase of the investment tax credit by 20 percentage points. Results are, in principle, similar to the case of corporate tax reduction. While the total welfare gain is smaller the extra gain from anticipation is, relatively speaking, somewhat larger and estimated to be about 15 percent of the total gain of the reform. Assuming lower and higher values of the tax credit we have checked for non-linear size effects, but found (almost) none within a sensible range of Δz. As a rule of thump an x percentage point increase of the tax credit generates an 0.04 percentage point welfare gain.

Finally, we consider a 5 percentage point reduction of the tax rate on private capital income. Although the steady-state effect on consumption (and thus welfare) is mildly positive, taking adjustment dynamics into account the reform causes a mild welfare loss. This loss is produced by the initially low consumption and is further amplified by financial restructuring of firms. Driven by the tax cut, firms hold more debt and cause higher agency costs of debt. The isolated effect of anticipation is, of course, positive. Again the gain from anticipation is, although absolutely small, relatively speaking quite large.
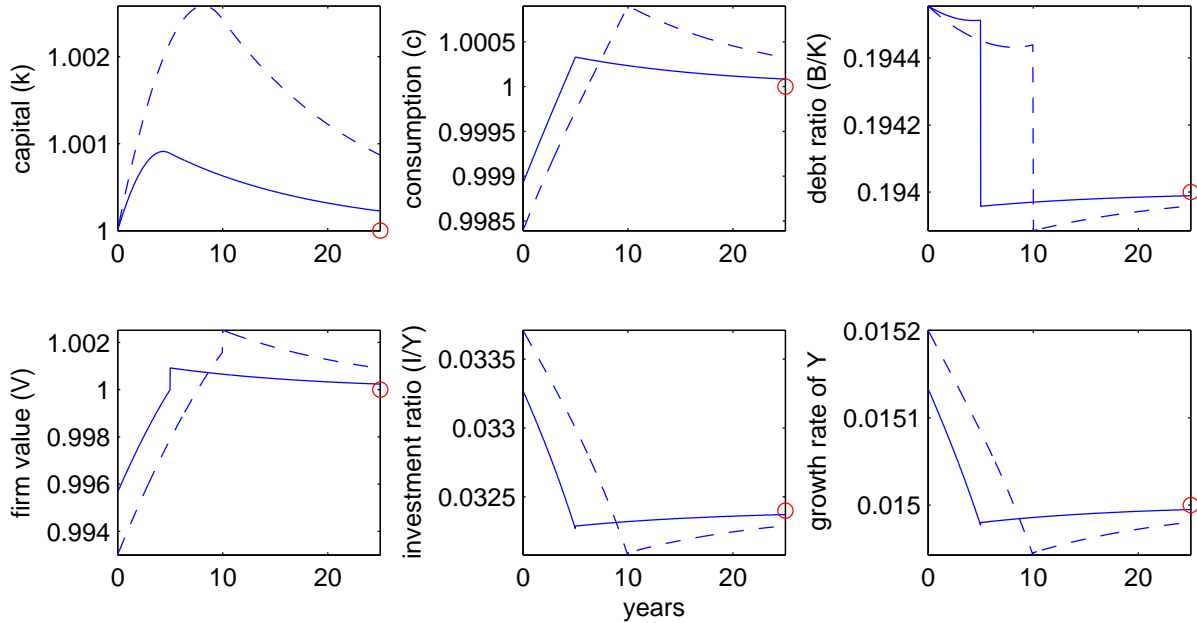
5.2. **Welfare Effects of Temporary Tax Cuts.** In this section we present the macroeconomic consequences predicted for temporary tax cuts. We begin with a temporary rise of the investment tax credit by 20 percentage points which is granted immediately and lasts for 5 years. Since the policy is temporary, the economy returns to its initial steady-state in the long-run. Despite its temporary character the policy may have positive consequences on welfare. For an intuition reconsider the right hand side panel of Figure 2. Consumption drops immediately and – following the logic explained in Section 3 – reaches the "old" manifold in year 5, i.e. when the tax relief expires. Along the manifold it travels from above towards the initial steady-state, which is reached as time goes to infinity. Since the manifold lies everywhere above the initial steady-state we can infer that consumption lies *most of the time* above its initial steady-state level c^*.

The results of our numerical computation, represented by solid lines in Figure 6, confirm this insight. Consumption drops initially in order to free resources for the additional investment triggered by the temporary tax cut. During the implementation phase (i.e. the period where the temporary policy is operative) consumption is on the rise again, breaks even with steady-state consumption after about 3 years and reaches its maximum at year 5 when the temporary tax cut terminates. It then adjusts slowly towards the initial steady-state. 20 years after the policy has terminated consumption is still (slightly) above steady-state level.

To finance the additional investment firms have initially to recur on debt because retained earnings cannot jump. During the implementation phase firms finance the increased investment costs by paying less dividends and consequently firm value drops temporarily. Tax revenue, naturally, drops at the time when the larger tax credit is granted. It subsequently rises because profits and employment rise, and lies above steady-state level after the tax cut expires because the "old" tax rates apply to temporarily higher capital stock, employment, and profits.

Dotted lines in Figure 6 show adjustment dynamics when the higher tax credit is granted for 10 years. Impulse responses are structurally similar but display, non-surprisingly, higher amplitudes. Capital stock is now accumulated for a longer period above steady-state level and consequently it takes longer until the positive effect vanishes after the policy has been terminated. Interestingly, the picture hints at a non-linearity. A doubling of the implementation phase from five to ten years leads to more than a doubling of the maximum amplitude, an effect that is in particular visible for capital stock and consumption. From this, one may infer that doubling the

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FIGURE 6: TEMPORARY INCREASE OF INVESTMENT TAX CREDIT

Adjustment Paths for a 10 percentage point increase of z in year 0. Solid lines: policy is known to end in year 5. Dashed lines: policy is known to end in year 10. Macroeconomic aggregates measured in relative deviation from pre-reform steady-state; macroeconomic rates measured in percentage points.

length of the implementation period is more than twice as good for welfare, a hypothesis that we investigate next.

Table 2 shows the computed welfare gains and verifies that the temporary policy has indeed positive consequences on welfare. The welfare gain is, however, quite small compared to that of a permanent tax cut. If the extra tax credit is granted for 5 years, the model predicts a welfare gain of 0.0023. The figures on the left show that if the policy is extended over a longer time the welfare gain rises indeed in a non-linear fashion. Doubling duration of the implementation phase produces a welfare gain of 0.0155, i.e. the welfare gain is more than six times higher. Again, the result is quite robust against alternative specifications of parameters as exemplarily shown for alternative values of σ.

The next row in Table 2 shows that structurally similar results are obtained for a temporary cut of the corporate tax rate. Here, we have assumed that a 10 percentage point cut of τ_r is granted for five or ten years, respectively. Again, the policy arrives unexpectedly but agents know about its temporary character. The temporary tax relief spurs investment implying a temporary loss of consumption. As before, welfare raises because capital, output, and consumption overshoot their

TABLE 2: WELFARE EFFECTS OF TEMPORARY TAX CUTS

Policy reform	5 years tax cut			10 years tax cut		
	σ low	σ benchmark	σ high	σ low	σ benchmark	σ high
$\Delta z = 0.2$	0.0030	0.0023	0.0019	0.0191	0.0155	0.0132
$\Delta \tau_r = -0.1$	0.0542	0.0504	0.0481	0.1208	0.1108	0.1042

steady state values. Since the economy spends much longer time above its steady-state value than below, the gains in consumption outweigh the initial losses due to enhanced investment activities.

The size of the welfare gain from temporary corporate tax cut is larger than for the investment tax credit, but, of course, it has already been found to be much larger in case of a permanent tax reform. The non-linearity appears now at a much smaller scale than for the investment tax credit. If the implementation period of the corporate tax cut doubles to ten years, the welfare gain is about 2.2 times higher.

Finally, we more systematically evaluate how much of the gain from a permanent reform can be produced by an otherwise identical temporary tax policy. In Table 3 we have compiled the welfare gain resulting from a 10 percentage point reduction of the corporate tax cut against the length of duration of the tax relief. In parenthesis we show how large this effect is in percent of the welfare gain produced by a permanent tax cut. For example, if the policy lasts indeed forever (as assumed in the first row), the welfare gain is 0.408 percent, which is, of course, 100 percent of the permanent effect. As a robustness check for our results we calculate again the welfare gain for the same policy change when σ is 33 percent lower or higher than assumed for the benchmark model.

For an assessment note that Table 3 assumes that policies come into effect immediately. A comparison with results from Table 1 reveals that the welfare gain from having the permanent reform immediately is higher than the welfare gain from have the same reform in 5 years from now taking into account the extra welfare gained from announcement. In other words, the fact that announcing a reform in advance is always welfare enhancing ceteris paribus, i.e. holding the date of enactment constant, does not imply that a generally favorable reform should be "artificially" delayed in order to realize this extra gain from announcement.

As expected, if the tax relief lasts for 100 years, the deviation of welfare from the one obtained for a permanent change is very small. If the tax relief is granted for 20 years the deviation is

TABLE 3: WELFARE EFFECT OF TEMPORARY VS. PERMANENT TAX RELIEF

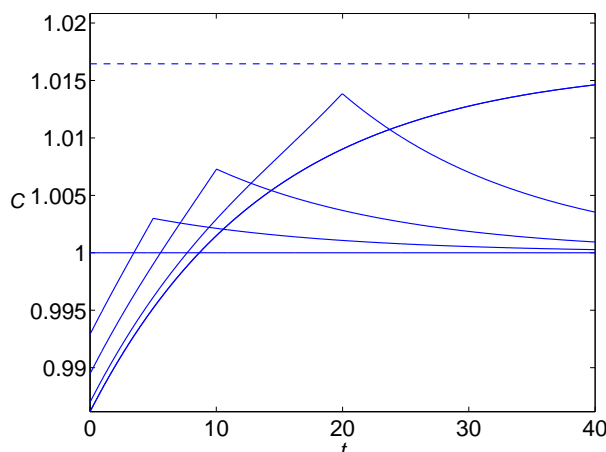| duration of tax relief	welfare gain		
	σ low	σ benchmark	σ high
∞	0.438 (100%)	0.408 (100%)	0.384 (100%)
100	0.433 (99%)	0.403 (99%)	0.380 (99%)
20	0.234 (53%)	0.215 (53%)	0.201 (52%)
10	0.121 (28%)	0.111 (27%)	0.104 (27%)
5	0.054 (12%)	0.050 (12%)	0.0048 (13%)

Policy: corporate tax cut of 10 percentage points. In parenthesis: total welfare gain compared to the one resulting from an everlasting tax relief.

already significant. The welfare gain is 0.22 percent, which is roughly half the gain obtained for the permanent policy. A ten year tax relief yields just about 25 percent of the welfare gain of the respective permanent policy. For a 5 year tax cut the welfare gain melts down to a mere 12 percent. Results are again quite robust against parameter variation.

Welfare gains from permanent tax policy changes have been analyzed by several numerical studies in the past. The question may have been occurred whether the findings could be used to assess the welfare gain resulting from an actual policy change that is known to be non-permanent. This would be very convenient since welfare consequences of permanent policy changes are much easier to compute (which may be actually one reason for why they are more prevalent in the literature). The results compiled in Table 3, however, indicate that we would accept large errors if we treated a temporary tax relief as if being permanent. The error made is, naturally, decreasing in the duration of the actual tax relief.

With Figure 7 we explore the underlying adjustment dynamics. The figure shows the optimal consumption path triggered by a tax relief of different duration. The individual paths are easily identified since we know from phase diagram analysis that consumption peaks when the policy is terminated. The path that peaks at $t = 5$ thus reflect the consumption trajectory provoked by a 5 year tax relief. The path that peaks "outside of the figure" reflects the 100 year policy, and the dashed line shows the steady-state consumption eventually assumed if the tax cut were indeed permanent.The solid horizontal line shows consumption at the old state, i.e. without any tax relief. All numbers are measured relative to initial consumption. Remaining at the initial steady-state thus yields one unit consumption at each period of time forever.

FIGURE 7: TEMPORARY TAX CUTS AND OPTIMAL CONSUMPTION PATHS

Policy: corporate tax cut of 10 percentage points. The curves show consumption optimal paths for alternative duration of the policy. Each curve peaks when the temporary tax relief expires, i.e. after 5, 10, 20, 100 years.

While the initial drop of consumption is of comparable magnitude for all policies, the most striking result visible in Figure 7 is how small the maximum yield of consumption gets when the duration of the tax relief is shortened. The comparatively small welfare gain computed for a temporary tax relief of 5 or 10 years thus originates chiefly from the fact that consumption never – not even for a short time – comes close to the consumption yield that a permanent policy eventually produces. The Figure impressively documents the supply-side mechanism. In the end, everything is driven by supply of capital (or, more generally, factor accumulation). A tax cut of short duration leads to a short spurt of investment activities and a small (and, of course, only temporary) increase of factor endowments. Consequently, it can support only a short and small increase of consumption and welfare. In conclusion, even if a tax cut is quite drastic, it is ill-judged to expect large positive consequences on welfare when the relief is simultaneously of short duration, for example, if it is operative for "only" one legislative period.

6. CONCLUSION

In this paper we have applied a new method to evaluate the quantitative macroeconomic consequences of anticipated tax reforms and temporary tax cuts. The mechanics of the numerical algorithm can be retraced by phase diagram analysis, a fact that facilitates an intuitive explanation of the obtained impulse response behavior.

We have found that adjustment dynamics for anticipated policy reform differs significantly from an unexpected reform. In particular, we have demonstrated that a pre-announced cut of taxes causes a sizeable investment spurt during the announcement phase, i.e. before the reform becomes operative. The investment spurt generates a head-start advantage of the announced reform vis a vis a surprising (but otherwise identical) reform, which is only caught up as time goes to infinity. For a reduction of corporate taxes we predict that a five year lead of pre-announcement generates an extra welfare gain of about 10 percent of the total gain from the reform, which is estimated to be around a third of a percentage point for a ten percentage point tax cut. A structurally similar investment spurt and extra welfare gain arises from pre-announcement of a higher future investment tax credit. Results are less favorable for taxation of private capital income. The again positive announcement effect is not sufficient to turn a generally (mildly) negative welfare effect positive.

Besides these quantitative results we have also found and explained important qualitative differences between pre-announced and surprising tax reforms. These differentiated effects are caused by adjustment of financial structure, which is modelled as endogenous in our setup. For example, the model predicts for a cut of the corporate tax rate that firm values (stock market prices) rise when a pre-announced reform becomes operative while they are predicted to fall in case of a surprising reform. Similarly dividends are predicted to rise when a pre-announced investment tax credit becomes operative but are predicted to fall in case of a surprising policy. In case of a cut of capital income taxes the model predicts investment rates to fall (vis a vis the previous period) when the reform comes into action while they are predicted to rise in case of a surprising policy. With respect to actual policy evaluation these findings suggest that one has to sort out carefully whether a reform came expectedly or surprisingly, in particular, for the interpretation of events around the time when a reform becomes operative.

With respect to tax revenue our model supports generally a quite optimistic view on corporate tax cuts, which is further improved through anticipation. Tax revenue after a 10 percentage point cut of taxes is predicted to break even with pre-reform level after 13 years. This time span is reduced to 10 years if the reform was announced 5 years in advance. In the end the tax cut yields a (mild) surplus of revenue. Similar, though quantitatively less important results are obtained for higher investment tax credits. Again, predictions are pessimistic for a cut of capital income taxes where revenue is predicted to never catch up to pre-reform level.

Finally, we were able to demonstrate a genuine welfare gain arising from a temporary cut of the corporate tax rate and from a temporarily higher investment tax credit. While small initially the gain rises with length of the implementation period. In particular for the investment credit we have found a non-linearity. Doubling the implementation period more than triples the welfare gained. Nevertheless, we have also demonstrated that temporary policy drastically underperformes vis a vis a permanent policy, in particular when the implementation period is short. For example, if the corporate tax cut is granted for five years it generates around 11 percent of the welfare obtained from a permanent tax cut of equal size. This implies that large errors are excepted when a tax policy which is known to be temporary is evaluated as if being permanent.

We have generally found that there is much more variation in impulse responses of important macroeconomic variables than indicated by the aggregated welfare gain. The aggregation over time hides the fact that ups and down of investment, profits and consumption before and after reform are to a large extent counterbalancing each other. We thus expect important intergenerational distribution effects from announcement. An extension of our method towards a Blanchard (1985) – Yaari (1965) setup seems to be a promising project for the future.

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