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Supply-side economics and endogenous growth

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In a simple convex model of endogenous growth, the expansionary effects of a deficit-financed tax cut are often strong enough to allow the government debt to be paid off in the long run without the need for subsequent tax increases. A permanent and substantial reduction in marginal rates of income taxation can provide for both vigorous real economic growth and long-run government budget balance.

Key words: Taxation; One-sector growth model

JEL classification: E62; O41

1. Introduction

Convex models of endogenous economic growth have proven useful as analytic laboratories for the evaluation of fiscal policy experiments. Unlike the basic neoclassical growth model of Solow (1956) and Cass (1965), which attributes cross-economy differences in growth rates to differences in rates of exogenous technological progress, these newer models isolate channels through which public policy can influence long-run growth. In particular, Jones and Manuelli (1990), King and Rebelo (1990), Rebelo (1991), and Jones, Manuelli, and Rossi (1993) find that tax policies have potentially large effects on long-run

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growth rates, both in the simplest convex growth model and in generalized versions featuring multiple capital and consumption goods.

A strong message from contemporary growth theory, then, is that tax policy ranks high on the list of determinants of long-run growth rates. Nevertheless, recent proposals for pro-growth tax cuts in the United States have been widely opposed by policy-makers on the grounds that they will expand the already massive federal deficit and therefore require even larger tax hikes in the future. This paper addresses the policy-maker's concerns by examining the effects of a deficit-financed tax cut using a simple convex model of endogenous growth.

Given a predetermined path for government expenditures, a reduction in marginal tax rates does lead to massive deficits in the short run. Often, however, the government's debt can be paid off in the long run without the need for subsequent tax increases. This striking result obtains because the economy faces a dynamic Laffer curve: a reduction in tax rates today increases the growth rate of aggregate output, thereby expanding the tax base sufficiently in the long run to generate larger total tax revenues even at the lower marginal tax rate.

The model suggests that raising taxes to balance the government's budget in the short run may not be a welfare-improving policy. Tax cuts, rather than tax increases, may be desirable even if they give rise to huge deficits in the short run.

These ideas are formalized in the context of the model specified in section 2. The fiscal policy experiment is described in section 3, where it is demonstrated that for certain parameter values, a deficit-financed tax cut in the model economy need not be followed by a subsequent tax increase. Section 4 concludes with a numerical example.

2. A simple model of endogenous growth

During each period $t=0,1,2,\ldots$, output Y_t of a single consumption good is produced using capital K_t according to the constant returns to scale technology,

$$Y_t = AK_t, \qquad A > 0. \tag{1}$$

The assumption of constant returns to scale is justified by regarding the capital stock as being a composite of both physical and human capital; if these two types of disaggregated capital are not perfect substitutes in production, there can be decreasing returns in either type of capital alone but constant returns in both applied together [Barro (1990)]. King and Rebelo (1990) and Rebelo (1991) demonstrate that this simple linear model captures, both qualitatively and quantitatively, nearly all of the long-run policy implications of more general convex models of endogenous growth in which the accumulation of multiple capital goods is considered explicitly. The aggregate capital stock depreciates at rate δ and is augmented through private investment I_t in each period t. Hence,

$$K_{t+1} = (1 - \delta)K_t + I_t. \tag{2}$$

The set of infinitely-lived agents in this economy consists of a large number of identical consumers, each of whom seeks to maximize the additively time separable CES utility function

$$U(\{c_t\}_{t=0}^{\infty}) = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1 - \sigma}, \qquad \beta \in (0,1), \quad \sigma > 0. \tag{3}$$

The constant size of the population is normalized to unity, so that aggregate and per-capita quantities coincide.

At each date t, the government levies a proportional income tax τ_t and provides each consumer with the lump-sum transfer G_t. The government can finance a deficit in any period t by issuing one-period pure discount bonds; these sell for B_{t+1}/R_t (in terms of time t consumption) in period t and pay off B_{t+1} (in terms of time $t+1$ consumption) in period $t+1$, where R_t is the gross real rate of interest between t and $t+1$. Consumers' income from these bonds is assumed to be tax-free.

As sources of funds at time t, a representative consumer has the output AK_t, the depreciated capital stock $(1-\delta)K_t$, the bonds B_t, and the transfer G_t. As uses of funds, the consumer has the tax bill $\tau_t AK_t$, consumption c_t, and the capital K_{t+1} and bonds B_{t+1}/R_t to be carried into the following period. His time t budget constraint is therefore

$$(1 - \tau_t)AK_t + (1 - \delta)K_t + B_t + G_t \geq c_t + K_{t+1} + B_{t+1}/R_t. \tag{4}$$

Although any individual consumer is permitted to sell both capital and bonds short in any given period, nobody is allowed to borrow more through these tactics than he can ever repay. This condition enters into the representative consumer's problem through the terminal constraint

$$\lim_{T \to \infty} \left[\frac{K_{T+1} + B_{T+1}/R_T}{\prod_{s=0}^{T-1} R_s} \right] = 0, \tag{5}$$

which guarantees that the period-by-period budget constraints (4) can be combined into an infinite horizon, present value budget constraint. The individual's nonnegativity constraint $c_t \geq 0$ and the aggregate nonnegativity constraint $K_{t+1} \geq 0$ need not be considered explicitly; both are guaranteed to hold because

(3) implies that the marginal utility of consumption goes to infinity as c_t approaches zero. Consumers take their initial stocks of capital $K_0 > 0$ and bonds $B_0 = 0$ as well as the sequences $\{\tau_t\}_{t=0}^{\infty}$, $\{G_t\}_{t=0}^{\infty}$, and $\{R_t\}_{t=0}^{\infty}$ as given when maximizing (3) subject to (4) and (5).

The government, meanwhile, is assumed to have committed itself to providing a sequence $\{G_t\}_{t=0}^{\infty}$ of transfers to the public. It can finance these transfers either through taxation or by issuing bonds; that is, it faces the constraints

$$\tau_t AK_t + B_{t+1}^s / R_t \geq G_t + B_t^s, \tag{6}$$

where B_t^s denotes the face value of bonds maturing in period t. The government's ability to issue debt is constrained by the terminal condition

$$\lim_{T \to \infty} \left[\frac{B_{T+1}^s / R_T}{\prod_{s=0}^{T-1} R_S} \right] = 0, \tag{7}$$

which guarantees that the period-by-period constraints (6) can be combined into an infinite horizon, present value budget constraint. The government takes the initial conditions $K_0 > 0$ and $B_0^s = 0$ and the sequences $\{K_{t+1}\}_{t=0}^{\infty}$ and $\{R_t\}_{t=0}^{\infty}$ as given.

The representative consumer's first-order conditions imply that the growth rate γ_t of consumption, output, and capital between dates t and $t+1$ is

$$\gamma_t = (\beta R_t)^{1/\sigma}, \tag{8}$$

where

$$R_t = (1 - \tau_{t+1}) A + (1 - \delta). \tag{9}$$

The economy's growth rate depends inversely on the marginal tax rate τ_{t+1}. If the tax rate is constant over time, with $\tau_t = \tau$ for all t, then consumption, output, and capital all grow at the constant rate $\gamma = \{\beta[(1-\tau)A + (1-\delta)]\}^{1/\sigma}$ [King and Rebelo (1990)]. The representative consumer's lifetime utility, given by eq. (3), is finite only when the model's parameters are such that $\beta\gamma^{1-\sigma} < 1$; this condition holds in each of the examples considered below.

3. A supply-side experiment

Consider a special case of the economy described above in which the initial capital stock is given by $K_0 = 1$ and in which the tax rate τ_t is a constant τ^0 for all t. If the government is balancing its budget period-by-period, then $B_t^s = 0$ for all t and

$$G_t = \tau^0 AK_t = \tau^0 A\{\beta[(1-\tau^0)A+(1-\delta)]\}^{t/\sigma}. \tag{10}$$

That is, government expenditures increase over time so as to make them a constant fraction τ^0 of aggregate output.

The supply-side experiment asks whether there exists a lower tax rate $\tau^1 < \tau^0$ that can finance the same sequence of expenditures $\{G_t\}_{t=0}^{\infty}$ given by (10), perhaps through short-term deficit financing, while still allowing the government to balance its budget in the long run. In other words, the supply-side experiment asks whether this economy has access to a dynamic Laffer curve, permitting it to lower its marginal tax rate and still raise a stream of total tax revenues with the same present value as before. If so, then the government can cut taxes, leave expenditures alone, and still balance its present value budget constraint without ever raising taxes again.

With $\tau_t = \tau^1 < \tau^0$ for all t and $K_0 = 1$, (8) and (9) indicate that

$$K_t = \{\beta[(1-\tau^1)A+(1-\delta)]\}^{t/\sigma} \tag{11}$$

and

$$R_t = (1-\tau^1)A+(1-\delta). \tag{12}$$

Eqs. (6) and (7) imply that the government's present value budget constraint is satisfied if and only if

$$\sum_{t=0}^{\infty}\left[\prod_{s=0}^{T-1} R_S\right]^{-1}\left[\tau^1 AK_t - G_t\right] \geq 0. \tag{13}$$

Substituting the new values for K_t and R_t given by (11) and (12) and the old values for G_t given by (10) into eq. (13) indicates that the government's present value budget constraint will be satisfied under the lower tax rate τ^1 if and only if

$$\sum_{t=0}^{\infty}\left[\frac{\tau^1 A\{\beta[(1-\tau^1)A+(1-\delta)]\}^{t/\sigma} - \tau^0 A\{\beta[(1-\tau^0)A+(1-\delta)]\}^{t/\sigma}}{[(1-\tau^1)A+(1-\delta)]^t}\right] \geq 0. \tag{14}$$

The reduction in the marginal tax rate from τ^0 to τ^1 has three effects on the government's budget constraint. First, the direct effect of the lower tax rate decreases total tax revenues. Second, the lower tax rate increases the rate of capital accumulation as shown in eq. (11); this effect increases the size of the tax base and hence increases total tax revenues. These two effects are captured by the first term in the numerator in (14). Third, the lower tax rate increases the real rate of interest as shown in eq. (12) and thereby decreases the present value of the government's future receipts and expenditures. This final effect is captured by the denominator in (14).

The total effect of the tax cut on the government's budget can be measured by writing eq. (14) more compactly as

$$L(\tau^1, \tau^0, A, \beta, \delta, \sigma) \equiv \frac{\tau^1 A}{R^1 - (\beta R^1)^{1/\sigma}} - \frac{\tau^0 A}{R^1 - (\beta R^0)^{1/\sigma}} \geq 0 \,, \tag{15}$$

where

$$R^1 = (1 - \tau^1) A + (1 - \delta) \quad \text{and} \quad R^0 = (1 - \tau^0) A + (1 - \delta) .$$

The function L is generally monotonic in δ and σ only, so it is not possible to determine analytically the range of parameter values for which $L \geq 0$ and hence for which the supply-side experiment is feasible. It is possible, however, to evaluate L numerically when specific values are chosen for the parameters and to see how the function changes as one of its arguments varies while the others are held constant.

A set of parameters is chosen, following King and Rebelo (1990), so that with $\sigma = 1$, $\delta = 0.1$, and $\tau_t = 0.20$ for all t, the model economy's after-tax real rate of interest R is 3.2% and its growth rate γ is 2% per period. With one period in the model identified as one year in real time, these figures are representative of the after-tax real interest rates and growth rates experienced in the postwar U.S. economy. To match the two statistics, $A = 0.165$ and $\beta = (1.02/1.032)$. Using these parameter values, the feasibility of a permanent tax cut from 20% to 15% will be assessed.

Each of figs. 1–6 starts with

$$\begin{gathered} \tau^1 = 0.15, \quad \tau^0 = 0.20, \quad A = 0.165, \\ \beta = (1.02/1.032), \quad \delta = 0.1, \quad \sigma = 1 \,, \end{gathered} \tag{16}$$

and evaluates the function L at various values of one parameter, holding the other parameters constant at their initial levels. A positive value for L, labelled the 'budget effect' in the figures, indicates that the supply-side experiment is feasible under the given set of parameter values. The figures also show the 'growth effect' of the supply-side tax cut. Denoting the economy's growth rates under the constant tax rates τ^0 and τ^1 by γ^0 and γ^1, the effect of the tax cut on

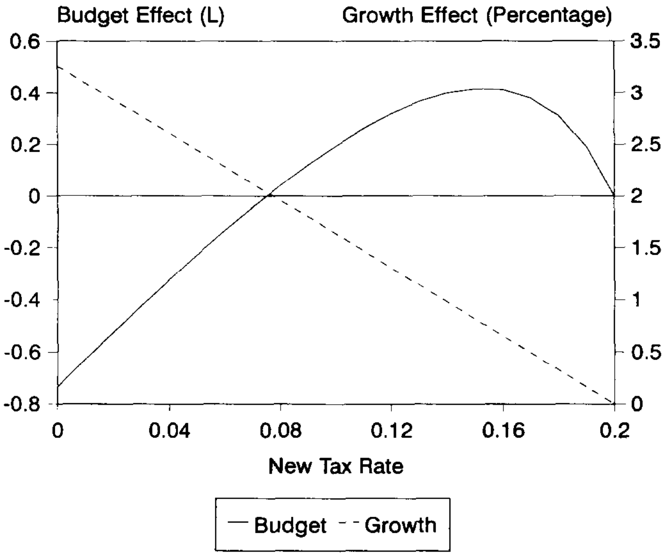

Fig. 1. The effects of a deficit-financed tax cut for various new tax rates τ^1.

All other parameter values are given in eq. (16); in particular, the initial tax rate is $\tau^0 = 0.20$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut from τ^0 to τ^1 is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

growth is measured in percentage points as

$$\begin{aligned} 100(\gamma^1 - \gamma^0) = {} & 100\{\beta[(1 - \tau^1)A + (1 - \delta)]\}^{1/\sigma} \\ & - 100\{\beta[(1 - \tau^0)A + (1 - \delta)]\}^{1/\sigma}. \end{aligned} \tag{17}$$

Since an increase in the size of the tax base allows the government to balance its budget under a lower marginal tax rate, a significant growth effect is crucial for the supply-side experiment's success. On the other hand, a set of parameter values may be dismissed as unrealistic if the implied growth effect of the tax cut seems unreasonably large.

Fig. 1 shows that with the other parameters fixed at their values given in eq. (16), the budget effect L is positive for all new tax rates τ^1 greater than 0.076. Thus, the marginal tax rate can be cut from 20% to any rate greater than 7.6% while still balancing the government's present value budget constraint. The figure also shows that larger tax cuts give rise to bigger growth effects. The economy's growth rate increases by 0.8% when $\tau^1 = 0.15$, by about 2% when $\tau^1 = 0.076$, and by more than 3.25% when $\tau^1 = 0$.

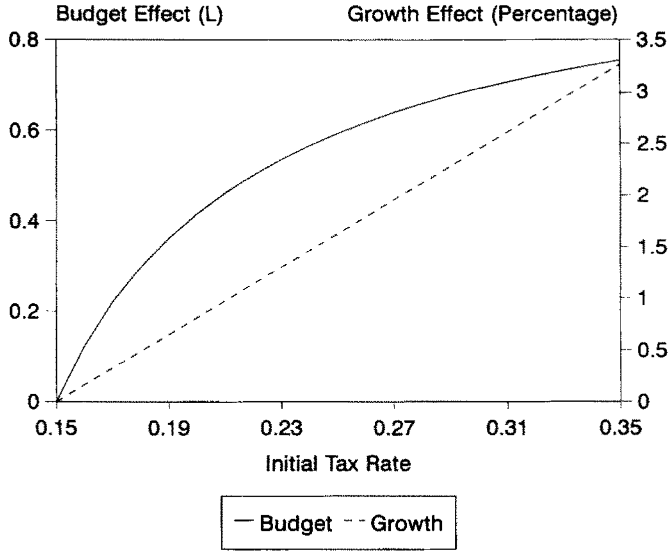

Fig. 2. The effects of a deficit-financed tax cut for various initial tax rates τ^0.

All other parameter values are given in eq. (16); in particular, the new tax rate is $\tau^1 = 0.15$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut from τ^0 to τ^1 is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

In fig. 2, the budget effect is positive for all initial tax rates τ^0 between 0.15 and 0.35. Thus, starting from any marginal tax rate between 15% and 35%, taxes can be lowered to 15% and still generate enough revenue to balance the present value budget constraint. Like fig. 1, fig. 2 shows that the magnitude of the growth effect increases with the size of the tax cut $\tau^0 - \tau^1$; again, the tax cuts considered can increase the economy's growth rate by as much as 3.25%.

Capital is unproductive when the technology parameter A equals zero. In this limiting case, changes in tax rates have no effect on either the growth rate of the economy (which is negative) or the government's tax receipts (which are zero). When A is close to zero, changes in tax rates have very little effect on the marginal return to capital and the aggregate growth rate. Thus, a tax cut when A is very small does not generate a sufficient expansion of the tax base to offset the decline in revenue resulting from a lower marginal tax rate. For all values of A greater than 0.076, however, fig. 3 reveals that L is positive. The growth effects of the cut in taxes from 20% to 15% are very large for values of A exceeding 0.4; when $A = 1$, for instance, the tax cut increases the economy's growth rate by almost 5%. Still, the figure indicates that the supply-side experiment is feasible for more reasonable values of A ranging from 0.076 to 0.4.

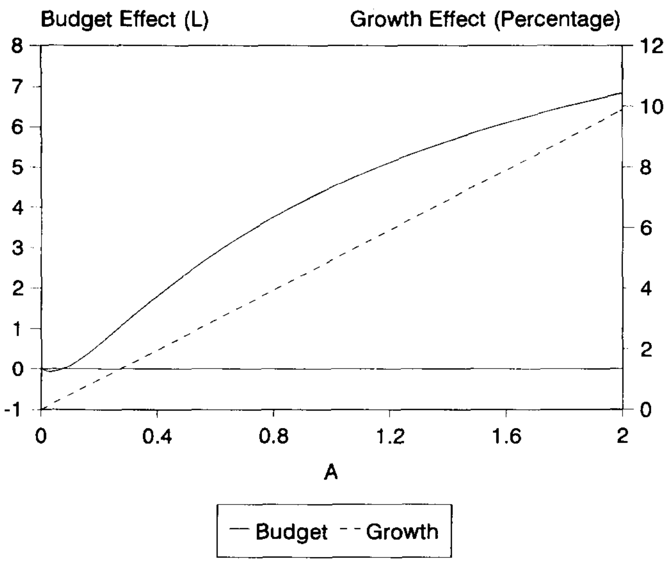

Fig. 3. The effects of a deficit-financed tax cut for various values of the technological parameter A. All other parameter values are given in eq. (16); the tax cut is from the initial rate $\tau^0 = 0.20$ to the new rate $\tau^1 = 0.15$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

As β approaches unity, consumers become more patient and hence more willing to take advantage of the saving opportunities provided by a tax cut. For β above 0.977, therefore, fig. 4 shows that the cut in taxes from 20% to 15% increases the size of the tax base fast enough to balance the government's present value budget constraint. In the limit as β goes to zero, agents consume the entire capital stock in period 0, a cut in taxes has no effect, and L approaches zero from below. The tax cut increases the economy's growth rate by about 0.8% for any value of β between 0.90 and 0.99.

Fig. 5 shows that L is positive for all possible values of δ. A decrease in taxes has a larger proportional effect on the marginal product of capital when the depreciation rate is high than when the depreciation rate is low. Thus, the impact of a tax cut on the growth rate of the tax base increases with δ, so that L slopes upward as a function of the depreciation rate. While the proportional growth effect of the tax cut increases with δ, eq. (17) and fig. 5 indicate that with $\sigma = 1$ the absolute growth effect does not depend on δ; in all cases, the tax cut increases the economy's growth rate by about 0.8%.

Eq. (8) indicates that the elasticity of the growth rate γ with respect to the after-tax return on capital R is $1/\sigma$. Thus, fig. 6 shows that the size of the growth

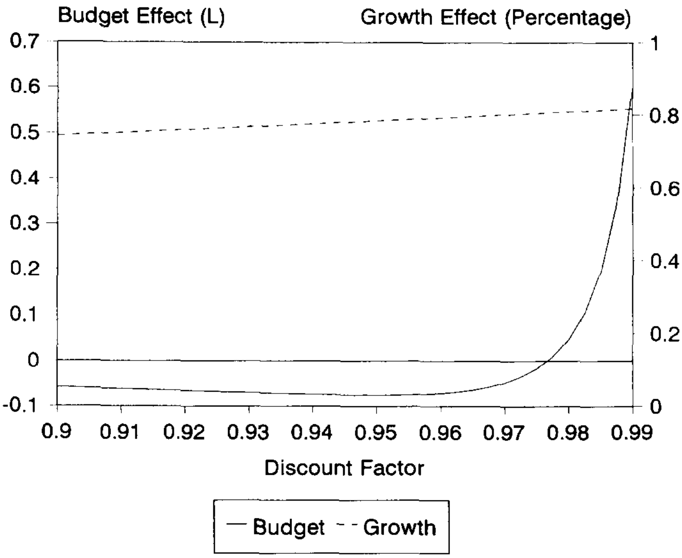

Fig. 4. The effects of a deficit-financed tax cut for various values of the discount factor β.

All other parameter values are given in eq. (16); the tax cut is from the initial rate $\tau^0 = 0.20$ to the new rate $\tau^1 = 0.15$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

effect decreases as a function of σ. The budget effect L is positive, so that the supply-side tax cut is feasible, for all values of σ less than 1.3. In general, L is decreasing as a function of σ.

The figures show that when A and β are sufficiently large and σ is sufficiently small, a deficit-financed cut in marginal tax rates need not be followed by subsequent tax increases. For many sets of parameter values, the supply-side experiment is successful even though it increases the economy's growth rate by less than 1%. In fact, the parameter values used by King and Rebelo (1990) to get this model to match key features of the U.S. data satisfy the necessary restrictions, suggesting that the analysis is relevant in considering fiscal policy for the U.S. economy.

4. A numerical example

With the parameter values as given in eq. (16) and with $K_0 = 1$, eq. (10) indicates that government expenditures are 20% of total product in period 0 and increase by 2% annually thereafter. A permanent cut in tax rates from

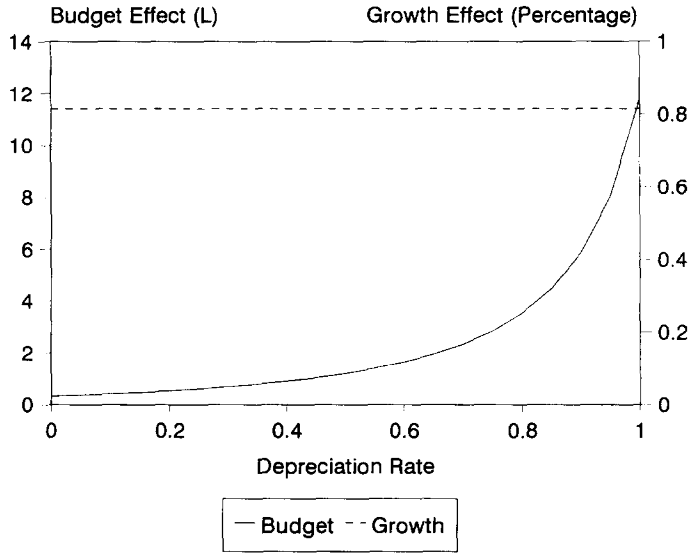

Fig. 5. The effects of a deficit-financed tax cut for various values of the depreciation rate δ.

All other parameter values are given in eq. (16); the tax cut is from the initial rate $\tau^0 = 0.20$ to the new rate $\tau^1 = 0.15$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

20% to 15% increases the common annual growth rate of consumption, output, and capital from 2.0% to 2.8%.

Fig. 7 shows that to finance the stream of expenditures given by eq. (10) at the lower tax rate, the government must run deficits for 37 years, after which the tax base has expanded sufficiently to yield a surplus (the deficit is computed in fig. 7 as $G_t - \tau^1 AK_t$ and therefore does not include interest payments). Government debt outstanding, also shown in fig. 7, grows to exceed 100% of GNP (measured by Y_t), but is completely paid off after 96 years. In fact, the government eventually begins to accumulate private assets (i.e., B_t^s eventually becomes negative), indicating that with a constant tax rate of 15%, the government can actually finance more expenditures than it could at the higher rate of 20%.

Following King and Rebelo (1990), the welfare consequences of this supply-side tax cut can be measured by finding the constant ϕ that satisfies

$$U(\{c_t^0(1+\phi)\}_{t=0}^{\infty}) = U(\{c_t^1\}_{t=0}^{\infty}), \tag{18}$$

where $\{c_t^0\}_{t=0}^{\infty}$ is the time path of consumption in an economy with a constant tax rate of $\tau^0 = 0.20$ and $\{c_t^1\}_{t=0}^{\infty}$ is the time path of consumption in an economy

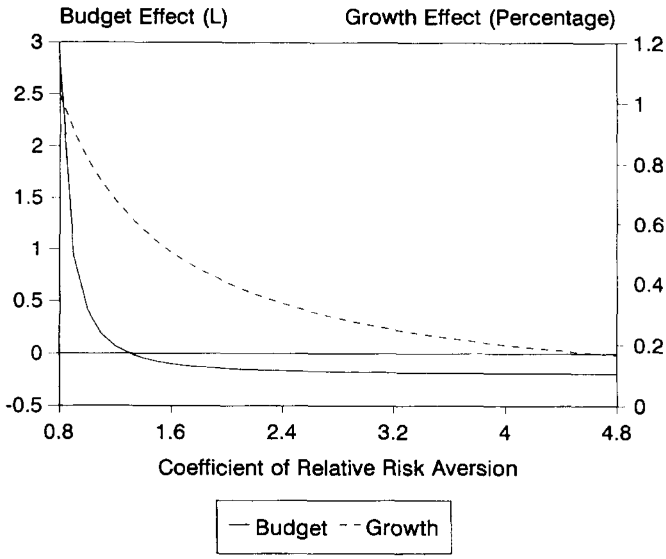

Fig. 6. The effects of a deficit-financed tax cut for various values of the coefficient of relative risk aversion σ.

All other parameter values are given in eq. (16); the tax cut is from the initial rate $\tau^0 = 0.20$ to the new rate $\tau^1 = 0.15$. The budget effect L is given by eq. (15); a positive value for L indicates that the government's budget constraint is satisfied, so that the tax cut is feasible. The growth effect, given by eq. (17), measures the increase in the aggregate growth rate brought about by the tax cut.

with a constant tax rate of $\tau^1 = 0.15$. The number ϕ represents the constant percentage increase in consumption that makes the representative consumer as well off in the high tax economy as he is in the low tax economy. When the parameter values are given by eq. (16), $\phi = 0.39$. That is, the welfare gain from implementing the supply-side tax cut is equivalent to the welfare gain from a permanent increase in consumption of nearly 40%.

This numerical example shows that a permanent decrease in taxes will contribute to larger deficits for many years. However, the example also demonstrates that the expansionary effects of lower taxes can actually generate larger revenues in the long run than if the government balanced its budget period-by-period. To repeat, neither future increases in taxes nor cuts in government spending are necessary. In fact, the expansionary effects of lower taxes may be so strong that the government can actually increase its spending commitments faster when tax rates are permanently lower.

In short, the analysis suggests that a permanent and substantial reduction in marginal tax rates can be the key to both vigorous rates of real growth and long-run government budget balance in the U.S. economy today.

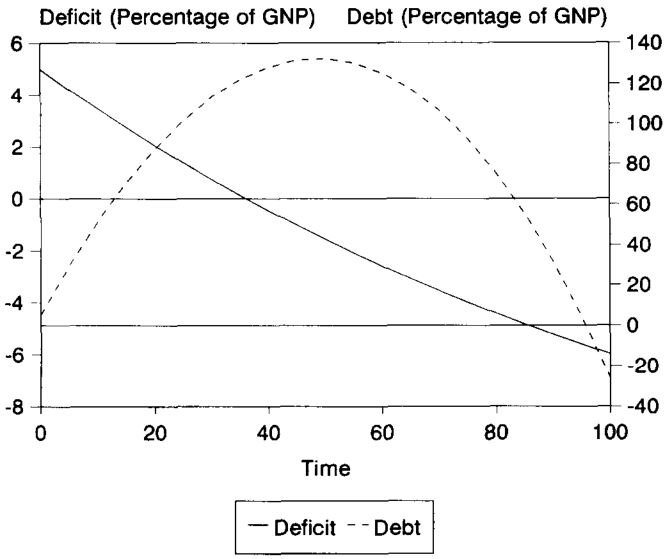

Fig. 7. The effects of a deficit-financed tax cut on the government's deficit and debt as percentages of GNP.

All parameter values are given in eq. (16); the tax cut is from the initial rate $\tau^0 = 0.20$ to the new rate $\tau^1 = 0.15$. Time is measured in years.

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