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Growth and Welfare Effects of Fiscal Policy in an Endogenous Growth Model with Public Investment

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Abstract

In this paper we analyze growth and welfare effects of fiscal policy in an endogenous growth model along the balanced growth path. As to the model we assume that sustained per capita growth results from public investment. The government uses its tax income for investment in public capital, for investment subsidy and for transfer payments. It is shown that there exists a growth maximizing income tax rate and a growth maximizing investment subsidy whereas increasing transfer payments always reduces economic growth. Further, a tax on consumption raises the balanced growth rate if the additional tax income is used for public investment. Moreover, we demonstrate that maximizing economic growth is not equivalent to maximizing welfare and we derive the values of the fiscal parameters which maximize welfare.

JEL: O41, H20, E62

Keywords: Public Capital, Endogenous Growth, Fiscal Policy, Welfare

1 Introduction

One strand in the endogenous growth literature deals with models in which the government undertakes productive public investments which positively influence the macroeconomic production function. That approach goes back to the seminal work by Arrow and Kurz (1970). Those authors, however, only analyze growth models with an exogenously determined growth rate. The first model in which productive government spending determines the long-run growth rate is the one by Barro (1990). In this setting, productive public spending raises the marginal product of private capital and, as a consequence, brings about sustained positive per capita growth. In contrast to Arrow and Kurz, Barro assumes that government spending as a flow variable shows positive effects, whereas the former suppose that only the stock of public capital positively influences the productivity of private capital. An interesting extension of Barro's model is provided by Futagami et.al. (1993) who combine this model with the Arrow and Kurz assumption that government spending does not directly influence the macroeconomic production function but only indirectly via the stock of public capital which, for its part, positively influences marginal productivity of private capital. A frequently cited empirical study is the one by Aschauer (1989) in which it is shown that the stock of public capital is indeed dramatically more important than the flow of government spending. The importance of public capital for economic growth is also emphasized by a great many other studies (for a survey of these studies, see Gramlich, 1994, and for a survey of the empirical literature Pfähler et.al., 1996).

In this paper we present an endogenous growth model which extends the one presented by Futagami et.al. (1993) in which sustained per capita growth results from investment in public capital. In contrast to the former, however, we assume that productive government spending can be divided up between investment in infrastructure and subsidies for private investment (as in Judd, 1985). Moreover, we suppose that a certain part of the tax income is used for lump-sum transfers to the household. The goal of this paper then is to analyze how the long-run balanced growth rate reacts to changes in fiscal parameters like the tax rate or the amount of investment subsidy paid per unit of private investment and to increases in lump-sum transfers to individuals. Further, we also want to investigate how the effects of varying a distortionary income tax differ from those of a non-distortionary tax on consumption. Besides the effects of those policy measures on the growth rate, we also investigate how social welfare reacts to fiscal policy.

The rest of the paper is organized as follows. In section 2, the basic model with income taxation is presented and it is shown that there exists at most one unique balanced growth path (BGP) with endogenous growth, which is a saddle path. In section 3 we analyze the effects of fiscal policy on the long-run balanced growth rate within our framework and study growth effects with the distortionary income tax replaced by a non-distortionary tax on consumption. In section 4 we study welfare effects of fiscal policy and section 5 concludes the paper.

2 The Model

Our economy consists of one representative infinitely lived household whose goal is to maximize the discounted stream of utility:

$$J[C(t)] \equiv \max_{\{C(t)\}} \int_0^\infty e^{-rt} C(t)^{1-\sigma}/(1-\sigma)dt. \tag{1}$$

$C(t)$ denotes private consumption, r the subjective constant discount rate and σ is the inverse of the intertemporal elasticity of substitution, which is assumed to be constant. For $\sigma = 1$ the utility function is replaced by the natural logarithm ln . The labour supply is inelastic and assumed to be constant and we set $L(t) \equiv 1$, so that all variables give per capita quantities.

The individual's budget constraint is written as:

$$C(t) + \dot{K}(t) = K(t)^{1-\alpha} G(t)^{\alpha} (1-\tau) + \theta \dot{K}(t) + T_P(t), \tag{2}$$

with $K(t)$ physical capital and $G(t)$ stock of public capital, which is a non-rival and non-excludable public good[1]. $K(t)^{1-\alpha}G(t)^{\alpha}$ gives the macroeconomic production output and $1-\alpha \in (0,1)$ is the capital share in the production function[2]. $\tau \in (0,1)$ denotes the income tax rate, $\theta \in (0,1)$ stands for the investment subsidy in terms of consumption good per unit of gross investment and $T_P(t)$ are lump-sum transfer payments to the representative individual, which it takes as given in solving its optimization problem. It should be noted that we assume that depreciation of both private and public capital is zero. Further, we suppose that the stock of public capital positively influences the productivity of private capital instead of the flow of government spending since this seems to be of higher relevance, as mentioned in the introduction.

The government in our economy is assumed to collect taxes from income it then uses for lump-sum transfers, $T_P(t)$, on the one hand, and for investment in infrastructure, $\dot{G}(t)$, and the investment subsidy $\theta\dot{K}(t)$, on the other hand. The government can fix how much of its resources it uses for transfer payments, for investment in public capital, or as investment subsidy. But it is supposed to run a balanced budget at any moment in time. Denoting with $T(t)$ the tax income at t, the budget constraint can be written as $T(t) = \dot{G}(t) + T_p(t) + \theta\dot{K}(t) = \dot{G}(t) + \varphi T(t) + \theta\dot{K}(t)$, with $T_P(t) = \varphi T(t)$, $\varphi \in (0,1)$. This means that φ gives that part of the tax income which is used for transfer payments. Knowing that $T(t) = \tau K(t)^{1-\alpha}G(t)^{\alpha}$ holds, the budget constraint may be rewritten as $\tau K(t)^{1-\alpha}G(t)^{\alpha} = \dot{G}(t) + \varphi\tau K(t)^{1-\alpha}G(t)^{\alpha} + \theta\dot{K}(t)$.

As to the governmental decision rules, we do not try to find out the second best optimal level for the income tax rate or the amount of the investment subsidy nor the socially optimal decisions for consumption and the fiscal parameters. Instead, we only consider how the growth rate and welfare reacts to fiscal policy. This seems to be of more relevance for real world economies with a democratic government because government behaviour may be hampered by bureaucracy and by political or institutional constraints (as to this argumentation see also van Ewijk and van de Klundert (1993)).

[1] As usual, the dot over a variable denotes the derivative with respect to time.

[2] It should be noted that the solution to this problem is equivalent to the solution of a decentralized economy with a productive sector which behaves competitively.

Before we go on and use necessary conditions to describe the solution to the optimization problem of the representative individual, we first investigate whether there exists a solution at all. Here we can state the following proposition.

Proposition 1 *Assuming that $K(t)$ and $G(t)$ are bounded by a function growing with e^{gt}, where $g > 0$ and $g(1-\sigma) < r$, there exists a unique solution for (1) subject to (2).*

The proof proceeds in analogy to the existence proof in Greiner and Semmler (1996). It consists in checking that the conditions of the theorem developed by Romer (1986) are fulfilled.

With this proposition at hand we can use Pontryagin's maximum principle to describe the optimal solution. The current-value Hamiltonian for our problem is written as[3], $H(\cdot) = C^{1-\sigma}/(1-\sigma)+\gamma(-C+K^{1-\alpha}G^{\alpha}(1-\tau)+T_P)/(1-\theta)$. The necessary optimality conditions are then given by

$$\begin{aligned}
\gamma &= C^{-\sigma}(1-\theta), \\
\dot{\gamma} &= \gamma r - \gamma\left(\frac{1-\tau}{1-\theta}\right)(1-\alpha)K^{-\alpha}G^{\alpha}, \\
\dot{K} &= \frac{-C + K(t)^{1-\alpha}G(t)^{\alpha}(1-\tau) + T_P}{1-\theta}.
\end{aligned}$$

The necessary optimality conditions are also sufficient if the limiting transversality condition $\lim_{t\to\infty} e^{-rt}\,\gamma(K-K^*) \geq 0$, is satisfied with K^* denoting optimal values of capital (see Seierstad and Sydsaeter, p. 234/235).

Using the definition $T_P = \varphi\tau K^{1-\alpha}G^{\alpha}$ as well as the equation giving the evolution of public capital, which is obtained from the budget constraint for the government, the economy is completely described by the following set of differential equations

$$\frac{\dot{C}}{C} = \frac{1}{\sigma}\left(-r + (1-\alpha)\left(\frac{1-\tau}{1-\theta}\right)K^{-\alpha}G^{\alpha}\right), \tag{3}$$

$$\frac{\dot{K}}{K} = -\frac{C}{K}\frac{1}{1-\theta} + \frac{1-\tau(1-\varphi)}{1-\theta}K^{-\alpha}G^{\alpha}, \tag{4}$$

$$\frac{\dot{G}}{G} = K^{1-\alpha}G^{\alpha-1}\left(\tau(1-\varphi) - \frac{\theta}{1-\theta}\left(1-\tau(1-\varphi)\right)\right) + \frac{\theta}{1-\theta}\frac{C}{G}. \tag{5}$$

[3] From now on we suppress the time argument t if it is dispensable.

It is obvious that sustained per capita growth is only feasible if the decline of the marginal product of physical capital, brought about by increases in that stock, is made up for by investment in public capital. Let us assume that this holds for our economy so that sustained per capita growth is possible and that the rate of growth is bounded by $g(1-\sigma) < r$.[4] Then, system (3)-(5) does not have a rest point because growth is unbounded, and the usual procedure of determining this stationary point and examining the steady states properties fails. So, to be able to analyze our system further, we first have to perform a change of the variables. Defining $x = G/K$ and $c = C/K$ and differentiating with respect to time yields the new dynamic system as $\dot{x}/x = \dot{G}/G - \dot{K}/K$ and $\dot{c}/c = \dot{C}/C - \dot{K}/K$. A rest point of this system then corresponds to a balanced growth path (BGP) of the original system (3)-(5) where all variables grow with the same constant rate.

To further investigate our economy we explicitly write down the dynamic system governing its evolution. It is given by

$$\dot{x} = x^\alpha \left(\tau(1-\varphi) - \frac{\theta}{1-\theta}(1-\tau(1-\varphi)) \right) + \frac{c(\theta + x)}{1-\theta} - \left(\frac{1-\tau(1-\varphi)}{1-\theta} \right) x^{\alpha+1}, \tag{6}$$

$$\dot{c} = \frac{c}{\sigma}\left(-r + (1-\alpha)\left(\frac{1-\tau}{1-\theta}\right) x^\alpha \right) + \frac{c^2}{1-\theta} - c\left(\frac{1-\tau(1-\varphi)}{1-\theta} \right) x^\alpha. \tag{7}$$

In proposition 2 we demonstrate that there exists at most one BGP and that this path is saddle path stable.

Proposition 2 *For this model there exists at most one BGP with endogenous growth and the Jacobian matrix of (6)-(7) has one positive and one negative real root, i.e. the rest point of (6)-(7) is a saddle path.*

Proof: The proof is contained in an appendix available on request. It proceeds as follows: First, set $\dot{c} = 0$ giving $c = c(k, \cdot)$. Inserting $c(k, \cdot)$ in $\dot{x} \equiv q(x, \cdot)$ shows that $q(0, \cdot) > 0$ and $\partial q(x, \cdot)/\partial x < 0$. Saddle path stability is shown by calculating $\det J$ and using $\dot{G}/G$ and that $q(x, \cdot) = 0$ holds on a BGP. □

[4] The assumption that growth is bounded by $g(1-\sigma) < r$ is sufficient for the transversality condition to be fulfilled and it guarantees that the functional (1) remains bounded.

From the economic point of view that proposition shows that our model is both globally and locally determinate meaning that there exists a unique value for the level of initial consumption $C(0)$, which can be chosen freely by the economy, such that the economy converges to the BGP in the long run[5]. Thus, our model is completely characterized including its transitional dynamics.

3 Growth Effects of Fiscal Policy

In this section we will first analyze how the balanced growth rate reacts to changes in transfer payments and in the investment subsidy. It should also be mentioned that we exclude the economically meaningless stationary point $x = c = 0$. First, we consider the case of a distortionary income tax.

3.1 Income Taxation

To work out the effects of higher transfer payments we first note that those can be modeled by increases in the parameter φ. A rise in transfer payments to individuals implies a shift of government resources from productive to non-productive use so that economic growth declines. On the other hand, however, higher transfer payments make the representative individual richer, but since these are lump-sum payments this measure does not influence the allocation of private resources so that more transfers only influence growth by changing the ratio $G/K \equiv x$. This ratio will decline and, thus, the marginal product of private capital so that this effect is also expected to reduce economic growth.

As to the impact of raising the investment subsidy θ, we can state that it is composed of two different parts. On the one hand, we see from the condition resulting from the maximum principle, $\gamma = C^{-\sigma}(1-\theta)$, that a higher amount of investment subsidy reduces the marginal utility of a given level of consumption. At the same time, it follows from the budget constraint for the individual, condition (2), that a higher θ makes

[5] For a more detailed definition of global and local indeterminacy see e.g. Benhabib and Farmer (1994), Benhabib, Perli and Xie (1994), or Greiner and Semmler (1996a).

investment cheaper. The combination of these two effects increases the opportunity costs of consumption implying a shift of resources from consumption to investment. On the other hand, a higher θ implies a shift of government resources from investment in public capital to the investment subsidy, which tends to reduce the ratio G/K, and, thus, economic growth. The overall effect, however, cannot be determined in general. Proposition 3 clarifies that question in detail.

Proposition 3 *Increasing transfer payments reduces the balanced growth rate. Moreover, there exists a growth maximizing investment subsidy which is determined by*

$$\frac{\partial x}{\partial \theta}\frac{\theta}{x} = -\frac{\theta}{\alpha(1-\theta)}.$$

Proof: To prove this proposition we denote the balanced growth rate which is given by (3) with g. Differentiating g with respect to φ yields

$$\frac{\partial g}{\partial \varphi} = \frac{\alpha}{\sigma}\left(\frac{1-\tau}{1-\theta}\right)(1-\alpha)x^{\alpha-1}\frac{\partial x}{\partial \varphi}.$$

The derivative of $\partial x/\partial \varphi$ is obtained by implicit differentiation from $q(x,\cdot) = 0$ (see the proof of proposition 2 in the appendix available on request) as

$$\left.\frac{\partial x}{\partial \varphi}\right|_{q(x,\cdot)=0} = -\frac{\partial q(x,\cdot)/\partial \varphi}{\partial q(x,\cdot)/\partial x} = \frac{\tau x^{\alpha}}{\partial q(x,\cdot)/\partial x}.$$

From the proof of proposition 2 we know that $(\partial q(x,\cdot)/\partial x) < 0$ on the BGP so that $(\partial x/\partial \varphi) < 0$ and $(\partial g/\partial \varphi) < 0$.

Differentiating (3) with respect to θ gives

$$\frac{\partial g}{\partial \theta} = \left(\frac{(1-\alpha)(1-\tau)}{\sigma(1-\theta)^2}\right)x^{\alpha}\left(1 + \frac{\alpha(1-\theta)}{\theta}\frac{\partial x}{\partial \theta}\frac{\theta}{x}\right).$$

This shows that

$$\frac{\partial g}{\partial \theta}\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} 0 \Leftrightarrow \frac{\partial x}{\partial \theta}\frac{\theta}{x}\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} -\frac{\theta}{\alpha(1-\theta)}.$$

For this result to make sense, we must have $(\partial x/\partial\theta) < 0$. Using $g = (1/\sigma)(-r + x^{\alpha}(1-\alpha)(1-\tau)/(1-\theta))$ we calculate for $\partial x/\partial\theta$ by implicit differentiation from $q(x,\cdot) = 0$,

$$\frac{\partial x}{\partial\theta} = \frac{g + x^{\alpha}(\theta + x)(1-\alpha)(1-\tau)/(\sigma(1-\theta)^2)}{-g - r\alpha\left(1+\theta/x\right)/\sigma} < 0.$$

□

This proposition demonstrates that increases in transfer payments reduce balanced growth. It is true that higher lump-sum transfers make the individual richer, but this does not change the allocation of private resources so that it has no positive effects on economic growth. Instead, it only reduces investment in public capital which makes economic growth decline.

It should be noted that increases in φ or θ imply a shift of governmental resources from public investment to the respective use, and we saw that shifting resources to non-productive government spending clearly reduces economic growth. For reallocations of resources from investment in public capital to subsidies of private investment, however, this does not necessarily hold. In this case, it may be possible that this measure promotes growth. A positive effect will be observed if the absolute value of the elasticity of the ratio of public to private capital with respect to θ is low, i.e. if a higher θ does not reduce $G/K \equiv x$ to a great extent so that the positive direct effect of shifting resources from private consumption to investment will prevail.

In analogy to variations in θ, we can split up the impact of a change in the income tax rate τ in two separate effects. On the one hand, increases in τ imply a higher taxation of returns to capital meaning a disincentive to save and, therefore, lead to less private investment. This effect tends to decrease economic growth. On the other hand, there is a positive effect because more tax income raises investment in public capital which fosters economic growth. In Proposition 4 we treat this case in detail.

Proposition 4 *The growth maximizing income tax rate τ^* is determined by $\tau^* = \alpha(1+\theta/x)$. It positively varies with φ and θ.*

Proof: To prove that proposition we again denote the balanced growth rate with g and differentiate (3) with respect to τ. This gives

$$\frac{\partial g}{\partial \tau} = \frac{1-\alpha}{\sigma(1-\theta)} x^{\alpha} \left(-1 + \frac{\alpha(1-\tau)}{\tau} \frac{\partial x}{\partial \tau} \frac{\tau}{x} \right) .$$

$\partial x / \partial \tau$ is obtained by implicitly differentiating $q(x,\cdot) = 0$ as

$$\left. \frac{\partial x}{\partial \tau} \right|_{q(x,\cdot)=0} = - \frac{\partial q(x,\cdot)/\partial \tau}{\partial q(x,\cdot)/\partial x} = \frac{x^{\alpha} \left(1 - \varphi + (1-\alpha)(\theta + x)/(\sigma(1-\theta))\right)}{g + r\alpha(1+\theta/x)/\sigma} .$$

Now, we can solve $q(x,\cdot) = 0$ for r yielding,

$$r = x^{\alpha} \left(\frac{(1-\alpha)(1-\tau)}{1-\theta} - \frac{\sigma\tau(1-\varphi)}{\theta + x} \right) .$$

Inserting this r in $\partial x/\partial \tau$ and the resulting expression in $\partial g/\partial \tau$ and solving $(\partial g/\partial \tau) = 0$ leads to[6],

$$\tau^{*} = \alpha \left(1 + \frac{\theta}{x} \right) .$$

The effect of changes in φ and in θ on the growth maximizing tax rate can be calculated by implicit differentiation of $\tau^{*} - \alpha(1 + \theta/x) = 0$. It can easily be seen that this gives

$$\frac{\partial \tau^{*}}{\partial \varphi} = - \frac{\partial x/\partial \varphi}{(\partial x/\partial \tau) + x^{2}/(\alpha\theta)} > 0, \quad \text{and}$$

$$\frac{\partial \tau^{*}}{\partial \theta} = \frac{\alpha\left(x - \theta(\partial x/\partial \theta)\right)}{x^{2} + \alpha\theta(\partial x/\partial \tau)} > 0. \qquad \square$$

This proposition shows that economies with large non-productive government spending and a high investment subsidy must also have a relatively high income tax rate in order to achieve maximum growth. The economic mechanism behind this result is clear: if a lot of public resources are used for non-productive spending the tax rate has to be high in order to be able to finance productive investment in infrastructure which promotes economic growth. It should be noted that for $\theta = 0$ (no investment subsidy) the growth maximizing income tax rate is the same as the one derived in Barro (1990)

[6]For this step, we used the software Mathematica (see Wolfram Research (1991)).

and Futagami et.al. (1993). Only if the government subsidizes private investment τ^* is larger than the elasticity of aggregate output with respect to public capital α.

It should also be mentioned that propositions 3 and 4 do not say anything about the exact value of the growth maximizing investment subsidy rate and income tax rate. So, boundary solutions cannot be excluded. However, in Greiner (1996) ch. 4.1 numerical examples are presented which illustrate propositions 3 and 4 and show that for realistic parameter values interior solutions exist for θ and τ which maximize economic growth.

In the next section, we analyze our model with the distortionary income tax replaced by a non-disortionary tax on consumption.

3.2 Consumption Tax

In this section, we study our model with the income tax replaced by a tax on consumption. The representative's budget constraint is then written as

$$C(t)(1+\tau_C) + \dot{K}(t) = K(t)^{1-\alpha}G(t)^{\alpha} + \theta\dot{K}(t) + T_P(t), \tag{8}$$

with $\tau_C \in (0,1)$ tax on consumption. Assuming that growth is bounded by $(1-\sigma)g < r$, it can again be shown that a solution to problem (1) subject to (8) exists. The proof proceeds in analogy to the proof of proposition (1). The current-value Hamilltonian is now written as $H(\cdot) = C^{1-\sigma}/(1-\sigma) + \gamma_1(-C(1+\tau_C) + K(t)^{1-\alpha}G(t)^{\alpha} + T_P)/(1-\theta)$, and the necessary optimality conditions are given by

$$\begin{aligned}
\gamma_1 &= C^{-\sigma}\left(\frac{1-\theta}{1+\tau_C}\right), \\
\dot{\gamma}_1 &= \gamma_1 r - \gamma_1\left(\frac{1}{1-\theta}\right)(1-\alpha)K^{-\alpha}G^{\alpha}, \\
\dot{K} &= \frac{-C(1+\tau_C) + K(t)^{1-\alpha}G(t)^{\alpha} + T_P}{1-\theta}.
\end{aligned}$$

The budget constraint of the government is again given by $T = \dot{G} + \varphi T + \theta\dot{K}$. Using $T = \tau_C C$ it can be rewritten as $\dot{G} = (\tau_C C(1-\varphi) + \theta(C - K^{1-\alpha}G^{\alpha}))/(1-\theta)$.

Using the equation giving the evolution of public capital, the economy is completely characterized by the following set of differential equations

$$\frac{\dot{C}}{C} = \frac{1}{\sigma}\left(-r + \left(\frac{1-\alpha}{1-\theta}\right) K^{-\alpha} G^{\alpha}\right), \tag{9}$$

$$\frac{\dot{K}}{K} = -\frac{C}{K}\left(\frac{1+\tau_C(1-\varphi)}{1-\theta}\right) + \frac{1}{1-\theta} K^{-\alpha} G^{\alpha}, \tag{10}$$

$$\frac{\dot{G}}{G} = \tau_C \frac{C}{G}\left(\frac{1-\varphi}{1-\theta}\right) + \frac{\theta}{1-\theta}\left(\frac{C}{G} - \left(\frac{K}{G}\right)^{1-\alpha}\right), \tag{11}$$

In the following, we shall assume that the growth of public capital is high enough to compensate for the decline of the marginal product of private capital brought about by a rising capital stock so that sustained per capita growth is feasible. In this case, system (9)-(11) does not have a rest point and we first have to perform a change of the variables. Defining $x = G/K$ and $c = C/K$, and differentiating with respect to time gives $\dot{x}/x = \dot{G}/G - \dot{K}/K$ and $\dot{c}/c = \dot{C}/C - \dot{K}/K$. Thus, the new system is given by

$$\dot{x} = c\,\tau_C\left(\frac{1-\varphi}{1-\theta}\right) + \frac{\theta}{1-\theta}(c - x^{\alpha}) + c\left(\frac{1+\tau_C(1-\varphi)}{1-\theta}\right)x - \frac{1}{1-\theta}x^{\alpha+1}, \tag{12}$$

$$\dot{c} = \frac{c}{\sigma}\left(-r + \left(\frac{1-\alpha}{1-\theta}\right)x^{\alpha}\right) + c^2\left(\frac{1+\tau_C(1-\varphi)}{1-\theta}\right) - c\frac{x^{\alpha}}{1-\theta}. \tag{13}$$

Again, we analyze the effects of changes in the parameters brought about by fiscal policy, and we exclude the economically meaningless steady state $x = c = 0$.

To begin with, we start with a variation in the tax on consumption, τ_C. In contrast to a change in the income tax rate, variations of the consumption tax do not have a direct effect on economic growth. This can be seen from the condition resulting from the maximum principle, $\gamma_1 = C^{-\sigma}(1+\tau_C)/(1-\theta)$, stating that increases in the consumption tax rate reduce the marginal utility of a given level of the consumption good. This leads to a decline in the level of (net) consumption but the lower spending for net consumption, is then used to pay the higher price for gross consumption, brought about by the increase in τ_C. The fact that variations in τ_C do not have direct effects on the level of private investment can also be seen from the equation giving the evolution of the shadow price of capital, $\dot{\gamma}_1$, which is independent of τ_C. Therefore, a higher tax on consumption does not affect the allocation of private resources and influences economic and Futagami et.al. (1993). Only if the government subsidizes private investment τ^* is larger than the elasticity of aggregate output with respect to public capital α.

It should also be mentioned that propositions 3 and 4 do not say anything about the exact value of the growth maximizing investment subsidy rate and income tax rate. So, boundary solutions cannot be excluded. However, in Greiner (1996) ch. 4.1 numerical examples are presented which illustrate propositions 3 and 4 and show that for realistic parameter values interior solutions exist for θ and τ which maximize economic growth.

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with $\tau_C \in (0,1)$ tax on consumption. Assuming that growth is bounded by $(1-\sigma)g < r$, it can again be shown that a solution to problem (1) subject to (8) exists. The proof proceeds in analogy to the proof of proposition (1). The current-value Hamilltonian is now written as $H(\cdot) = C^{1-\sigma}/(1-\sigma) + \gamma_1(-C(1+\tau_C) + K(t)^{1-\alpha}G(t)^{\alpha} + T_P)/(1-\theta)$, and the necessary optimality conditions are given by

$$\begin{aligned} \gamma_1 &= C^{-\sigma}\left(\frac{1-\theta}{1+\tau_C}\right), \\ \dot{\gamma}_1 &= \gamma_1 r - \gamma_1\left(\frac{1}{1-\theta}\right)(1-\alpha)K^{-\alpha}G^{\alpha}, \\ \dot{K} &= \frac{-C(1+\tau_C) + K(t)^{1-\alpha}G(t)^{\alpha} + T_P}{1-\theta}. \end{aligned}$$

The budget constraint of the government is again given by $T = \dot{G} + \varphi T + \theta\dot{K}$. Using $T = \tau_C C$ it can be rewritten as $\dot{G} = (\tau_C C(1-\varphi) + \theta(C - K^{1-\alpha}G^{\alpha}))/(1-\theta)$.

Using the equation giving the evolution of public capital, the economy is completely characterized by the following set of differential equations

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$$\frac{\dot{G}}{G} = \tau_C \frac{C}{G}\left(\frac{1-\varphi}{1-\theta}\right) + \frac{\theta}{1-\theta}\left(\frac{C}{G} - \left(\frac{K}{G}\right)^{1-\alpha}\right), \tag{11}$$

In the following, we shall assume that the growth of public capital is high enough to compensate for the decline of the marginal product of private capital brought about by a rising capital stock so that sustained per capita growth is feasible. In this case, system (9)-(11) does not have a rest point and we first have to perform a change of the variables. Defining $x = G/K$ and $c = C/K$, and differentiating with respect to time gives $\dot{x}/x = \dot{G}/G - \dot{K}/K$ and $\dot{c}/c = \dot{C}/C - \dot{K}/K$. Thus, the new system is given by

$$\dot{x} = c\,\tau_C\left(\frac{1-\varphi}{1-\theta}\right) + \frac{\theta}{1-\theta}\left(c - x^{\alpha}\right) + c\left(\frac{1+\tau_C(1-\varphi)}{1-\theta}\right) x - \frac{1}{1-\theta} x^{\alpha+1}, \tag{12}$$

$$\dot{c} = \frac{c}{\sigma}\left(-r + \left(\frac{1-\alpha}{1-\theta}\right) x^{\alpha}\right) + c^2\left(\frac{1+\tau_C(1-\varphi)}{1-\theta}\right) - c\frac{x^{\alpha}}{1-\theta}. \tag{13}$$

Again, we analyze the effects of changes in the parameters brought about by fiscal policy, and we exclude the economically meaningless steady state $x = c = 0$.

To begin with, we start with a variation in the tax on consumption, τ_C. In contrast to a change in the income tax rate, variations of the consumption tax do not have a direct effect on economic growth. This can be seen from the condition resulting from the maximum principle, $\gamma_1 = C^{-\sigma}(1+\tau_C)/(1-\theta)$, stating that increases in the consumption tax rate reduce the marginal utility of a given level of the consumption good. This leads to a decline in the level of (net) consumption but the lower spending for net consumption, is then used to pay the higher price for gross consumption, brought about by the increase in τ_C. The fact that variations in τ_C do not have direct effects on the level of private investment can also be seen from the equation giving the evolution of the shadow price of capital, $\dot{\gamma}_1$, which is independent of τ_C. Therefore, a higher tax on consumption does not affect the allocation of private resources and influences economic growth only by changing the ratio G/K. If the additional tax income is used for public investment then this ratio will rise and lead to an increase in economic growth.

As to changes in the investment subsidy and in transfer payments, we see that they have the same effects as in the model with income taxation. Proposition 5 gives the exact results.

Proposition 5 *Increasing the consumption tax rate raises balanced growth if the additional tax income is used for public investment. Moreover, proposition 3 remains valid for the model with the income tax replaced by a tax on consumption.*

The proof of that proposition proceeds in analogy to the proof of proposition 3 and is included in the appendix available on request[7].

The condition that the additional income raised through increases in τ_C must be spent for public investment is automatically fulfilled for our model if the parameters φ and θ are constant. Moreover, this proposition demonstrates that productive government spending should be financed with non-distortionary taxes to promote economic growth. But we must be aware that up to now we have only considered the effects of fiscal policy on economic growth but not on welfare. Therefore, in the next section we will study welfare effects of fiscal policy.

4 Welfare Effects of Fiscal Policy

Let us next analyze welfare effects of fiscal policy. Barro (1990) has demonstrated that maximizing economic growth is equivalent to maximizing welfare in his model. Futagami et.al. (1993) have shown that Barro's result crucially depends on the absence of transitional dynamics and they proved that maximizing economic growth is no longer equivalent to maximizing welfare if transitional dynamics are taken into account. We will see that in our model maximizing economic growth is not equivalent to maximizing welfare even if we confine our analysis to the BGP only.

[7]The model with the consumption tax also has at most one BGP which is a saddle path. A sketch of the proof can be found in the appendix.

To calculate growth effects of fiscal policy on the BGP we first compute (1) on the BGP as

$$J[C(t)] \equiv \arg\max_{C(t)} \int_0^\infty e^{-rt} C(t)^{1-\sigma}/(1-\sigma)dt = \frac{C(0)^{1-\sigma}}{(1-\sigma)(r-g(1-\sigma))}. \tag{14}$$

In (14) we have used $r > g(1-\sigma)$ which also guaranteed that (1) remains bounded. Since $K(0)$ and $G(0)$ are fixed at $t = 0$ only $C(0)$ may react to changes in the fiscal parameters. To find how $C(0)$ reacts to an exogenous rise in the income tax rate we proceed as in Barro (1990) and express that variable as a function of the balanced growth rate g. From (4) we have

$$\frac{C(0)}{K(0)} = -g(1-\theta) + (1-\tau(1-\varphi))K(0)^{-\alpha}G(0)^{\alpha}.$$

Further, from (3) we know that on the BGP

$$g = \frac{1}{\sigma}\left(-r + (1-\alpha)\left(\frac{1-\tau}{1-\theta}\right)K(0)^{-\alpha}G(0)^{\alpha}\right).$$

Combining those two expressions gives

$$C(0) = K(0)\left[-g(1-\theta) + (1-\tau(1-\varphi))(\sigma g + r)\frac{1-\theta}{(1-\tau)(1-\alpha)}\right]$$

and leads to

$$\begin{aligned} J &= \frac{K(0)^{1-\sigma}}{(1-\sigma)(r-g(1-\sigma))}\left(\frac{1-\theta}{1-\alpha}\right)^{1-\sigma} \cdot \\ &\left(g\left(-1+\alpha+\frac{\sigma(1-\tau(1-\varphi))}{1-\tau}\right) + \frac{r(1-\tau(1-\varphi))}{1-\tau}\right)^{1-\sigma}. \end{aligned}$$

Before we analyze how variations in fiscal parameters influence the utility functional (14) we will study the effects of an increase in g on $J(\cdot)$. Differentiating (14) with respect to g gives

$$\begin{aligned} \frac{\partial J}{\partial g} &= \frac{K(0)^{1-\sigma}}{1-\sigma}\left(\frac{1-\theta}{1-\alpha}\right)^{1-\sigma} \cdot \\ &\frac{(1-\sigma)Z^{-\sigma}\left(-1+\alpha+\frac{\sigma(1-\tau(1-\varphi))}{1-\tau}\right)(r-g(1-\sigma)) + (1-\sigma)Z^{1-\sigma}}{(r-g(1-\sigma))^2}, \end{aligned}$$

with

$$Z = \left(g\left(-1+\alpha+\frac{\sigma(1-\tau(1-\varphi))}{1-\tau}\right)+\frac{r(1-\tau(1-\varphi))}{1-\tau}\right).$$

After some calculations we get

$$\frac{\partial J}{\partial g} = \left(\frac{K(0)(1-\theta)}{1-\alpha}\right)^{1-\sigma} Z^{-\sigma} \cdot \frac{(r-g(1-\sigma))\left(\alpha+\frac{\sigma(1-\tau(1-\varphi))}{1-\tau}\right)+r\left(\frac{1-\tau(1-\varphi)}{1-\tau}-1\right)+\left(\alpha+\sigma\frac{\varphi\tau}{1-\tau}\right)g}{(r-g(1-\sigma))^2},$$

demonstrating that $\partial J/\partial g > 0$ for $r > (1-\sigma)g$.

With that result we are in the position to analyze welfare effects of changes in the fiscal parameters. First we will study the model with income taxation. As to a change in the income tax rate proposition 6 shows that the welfare maximizing income tax rate does not coincide with the growth maximizing rate.

Proposition 6 *The welfare maximizing income tax rate is higher than the growth maximizing rate.*

Proof: To prove that result we differentiate $J(\cdot)$ with respect to $\cdot$. That gives

$$\frac{\partial J}{\partial \tau} = \frac{K(0)C(0)^{-\sigma}}{r-g(1-\sigma)}\left((g\sigma+r)\frac{(1-\theta)\varphi}{(1-\alpha)(1-\tau)^2}\right)+\frac{\partial J}{\partial g}\frac{\partial g}{\partial \tau}.$$

The first part of that expression is always positive and the proposition is proved. □

That result demonstrates that maximizing economic growth is not equivalent to maximizing welfare. Instead, an income tax rate exceeding the growth maximizing tax rate yields higher welfare. If the government chooses an income tax rate which is larger than the growth maximizing rate, that measures reduces the growth rate which, on the one hand, tends to lower welfare. On the other hand, however, an increase in the income tax rate makes the household shift its resources from investment to consumption. Moreover, a part of the additional tax income is paid back to the household in form of lump-sum transfers which has a positive wealth effect. As a consequence, a higher income tax rate leads to an increase in the level of initial consumption. That effect dominates the negative welfare effect of a lower growth rate if the income tax rate is higher than the growth maximizing value of that parameter. It should be noted that in case of no transfer payments ($\varphi = 0$) the growth maximizing income tax rate also yields maximum welfare, which can immediately be seen from the proof of proposition 6. In that case, none of the additional tax income is redistributed to the household and an increase in the level of initial consumption can only be observed if the substitution effect (shift of resources from investment to consumption) dominates the negative wealth effect arising from a rise in the income tax rate. But note that even if $C(0)$ rises welfare declines if the income tax rate is higher than its growth maximizing value if $\varphi = 0$.

As to variations in the investment subsidy and transfer payments we see that the welfare maximizing values of those parameters take on values different from those maximizing the balanced growth rate. Proposition 7 gives the result in detail.

Proposition 7 *The welfare maximizing rate for the investment subsidy is lower than the growth mazizing rate. Further, there exists a welfare maximizing value for φ.*

Proof: To prove the first part we differentiate $J(\cdot)$ with respect to θ yielding

$$\frac{\partial J}{\partial \theta} = \frac{K(0)C(0)^{-\sigma}}{r - g(1-\sigma)} \left(-g \left(-1 + \frac{\sigma(1-\tau(1-\varphi))}{(1-\alpha)(1-\tau)} \right) - \frac{r(1-\tau(1-\varphi))}{(1-\alpha)(1-\tau)} \right) + \frac{\partial J}{\partial g}\frac{\partial g}{\partial \theta}.$$

The first part of that expression is always negative (for $r > (1-\sigma)g$ and $C(0) > 0$) and part one of the proposition is proved. To prove the second part we differentiate $J(\cdot)$ with respect to φ yielding

$$\frac{\partial J}{\partial \varphi} = \frac{K(0)C(0)^{-\sigma}}{r - g(1-\sigma)} \frac{\tau(1-\theta)}{(1-\alpha)(1-\tau)}(\sigma g + r) + \frac{\partial J}{\partial g}\frac{\partial g}{\partial \varphi}.$$

The first part of that expression is always positive whereas the second is always negative which proves the second part of the proposition. □

That proposition shows that an investment subsidy rate which is lower than the growth maximizing rate yields a higher social welfare than the latter. The economic mechanism behind that outcome is similar to the one of the income tax rate. If the government chooses an investment subsidy rate smaller than the growth maximizing rate a certain part of the additional tax income is redistributed as lump-sum transfers to the houshold. Further, the decrease in the investment subsidy by itself leads to a reallocation of private resources from investment to consumption which leads to a higher level of initial consumption tending to increase welfare. That latter effect alone has a positive welfare effect which dominates the negative one of a lower growth rate if θ is set lower than its growth maximizing value. That can be seen from the proof of propostion 7 which shows that the first part of that proposition remains valid even for $\varphi = 0$. This holds because the negative wealth effect of a decrease in the investment subsidy is smaller than the one associated with a rise in the income tax rate because the former makes consumption cheaper which can be seen from equation (4).

The second part of that proposition demonstrates that an increase in lump-sum transfers always has a positive direct effect on welfare. That outcome is obvious since an increase in transfer payments raises the individual's income and causes a higher level of initial consumption. However, there is also an indirect welfare effect resulting from the decrease in the growth rate brought about by the rise in transfer payments. It should be recalled that a rise in transfer payments lowers the balanced growth rate. Consequently, the optimum transfer payments are obtained when the positive direct welfare effect just equals the negative indirect one. However, it cannot be answered whether an interior solution exists and φ may take on boundary solutions, too.

Let us in a next step analyze welfare effects of varying the tax on consumption. From above we know that from the viewpoint of maximizing economic growth taxing consumption at the maximum rate is optimal. However, as we will see, that outcome does not hold if one considers welfare. To derive wefare implications of the consumption tax rate we again take the utility functional from (14). $C(0)$ is now obtained by combining (9) and (10) as

$$C(0) = K(0)\left(-g\frac{1-\theta}{1+\tau_C(1-\varphi)} + \frac{\sigma(1-\theta)}{(1+\tau_C(1-\varphi))(1-\alpha)}\left(g + r/\sigma\right)\right)$$

and leads to

$$J = \frac{K(0)^{1-\sigma}}{(1-\sigma)(r-g(1-\sigma))} \cdot \left(g\frac{1-\theta}{1+\tau_C(1-\varphi)}\left(-1+\frac{\sigma}{1-\alpha}\right) + \frac{r(1-\theta)}{(1-\alpha)(1+\tau_C(1-\varphi))} \right)^{1-\sigma}.$$

Differentiating that expression with respect to τ_C gives

$$\frac{\partial J}{\partial \tau_C} = -\frac{K(0)C(0)^{-\sigma}}{r-g(1-\sigma)} \frac{(1-\theta)(1-\varphi)(g(-1+\alpha+\sigma)+r)}{(1-\alpha)(1+\tau_C(1-\varphi))} + \frac{\partial J}{\partial g}\frac{\partial g}{\partial \tau_C}.$$

The first part of that expression is always negative and the second part is always positive[8]. Thus, we have proved the following proposition.

Proposition 8 *In our model, there exists a welfare maximizing tax on consumption.*

In contrast to the growth effects of a rise in the consumption tax rate, where an increase in that tax did not lead to a reallocation of resources and, therefore, always raised economic growth if the additional tax income was used for productive public spending, there exists a welfare maximizing value for that tax. The economic mechanism behind that result is obvious. Any increase in the consumption tax shows up as a negative welfare effect which reduces the level of initial consumption. On the other hand, a higher consumption tax rate raises economic growth and, thus, welfare. Consequently, the optimum value for that tax is obtained when the negative direct welfare effect just equals the positive indirect one.

5 Conclusion

The goal of this paper was to analyze the effects of fiscal policy on long-run economic growth and welfare within an endogenous growth model with productive public spending. Assuming that the stock of public capital positively influences the macroeconomic production function we could show that a reallocation of public resources from non-productive to productive uses or fiscal policies which lead to a reallocation of private resources from consumption to investment always raise the balanced growth rate.

[8] Note that $\partial J/\partial g > 0$ holds, too, if the income tax is replaced by a tax on consumption.

However, we could also demonstrate that such measures do not necessarily lead to higher welfare, even if one confines its investigations to the balanced growth path only. Instead, those measures always go along with a decrease in the level of private consumption which tends to lower social welfare. The advantage of the limitation to the balanced growth path was that it enabled us to give economic conditions why maximizing growth is not equivalent to maximizing welfare rather than to simply state that those two goals are not equivalent.

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