Tax- versus Debt-Financing of Public Investment: A Dynamic Simulation Analysis*

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I. Introduction

In the restructuring of the economies in Eastern Europe, in order to give more freedom to private enterprise and the market mechanisms, full employment, long-run growth and structural balance can only be ensured by complementary investment in the basic public infrastructure capital. In some western economies, a decline in investment expenditures and newly-adopted performance standards have produced a considerable capital "needs gap".[1] Therefore, in both types of economies a substantial fraction of national savings will be needed for public capital accumulation. The question then arises as to whether or not the present burden of reduced private consumption might be shifted, at least in part, to future generations by public debt finance.

Since the publication of Buchanan's book on "Public Principles of Public Debt" (1958), there has been much controversy concerning the difference between tax and debt finance of government expenditures. Buchanan rejected the orthodox notion that the burden of government expenditures is borne in the present by society as a whole because resources are withdrawn from private production. He placed emphasis on individual decisions, and on the gain or benefit side of individual exchanges. In his view debt finance of government expenditures does not involve a sacrifice in any direct sense because the purchaser of government securities do not sacrifice any real economic resources but make a presumably favorable exchange by achieving an optimal intertemporal distribution of lifetime consumption. Instead, the real burden of the debt is imposed compulsorily on future generations of taxpayers who are forced to reduce their real income in order to transfer funds to bondholders who earn interest on public debt. As a result the burden of public debt in terms of reductions of individual utility is shifted into the future.

* I have benefitted from helpful comments of an anonymous referee.

1 For the USA see, for example, *Hulten/Petersen* (1984).

Many economists disagreed with Buchanan's concept of burden in one important respect. They argued that neither society nor individuals suffer a burden in the long run as long as the increase in government debt is accompanied by productive government expenditure.[2] If public investment contributes to the real income of future generations, future taxes levied to finance the interest on the debt do not reduce individual utility levels, but may be regarded as a "bona fide division of the cost between generations".[3] Thus efficient and equitable pay-as-you-go financing of present expenditures to provide for future benefits is ensured.

In the theoretical literature public investment has been discussed in the framework of optimal taxation (see *Sandmo/Drèze* (1971); *Pestieau* (1974, 1975); *Yoshida* (1986)). This approach starts from a government which maximizes intertemporal social welfare and is focused on the determination of the appropriate rate of discount for public investment. The present paper, in contrast, does not study optimal policy but is concerned with the effects of public investment policy on the economy. The macroeconomic effects of productive public expenditures have been studied in a paper by *Grossman/Lucas* (1974). However, their analysis concentrates exclusively on steady states. No private capital stock is incorporated in the model and only the global effects of fiscal policy on output and employment are examined.

As the paper has to deal with short- and long-run effects of fiscal policy and with redistribution across generations we use the framework of a general-equilibrium, overlapping-generations model which originated by *Samuelson* (1958) and has since been developed further by *Diamond* (1965) and others. The Samuelson-Diamond model is extended by including investment outlays and the return on public capital in the government's budget constraint. Moreover, it is assumed that public capital enters into the production function of the private sector and enhances its productive potential. Dynamic simulations of public investment policy

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2 See the contributions of *Elliot, Lerner, Miller, Mishan, Modigliani, Scitovsky* and Wiseman, in: *Ferguson* (1964). Buchanan does not agree with this view of the public debt. In his opinion even if the debt is created for productive public expenditure the two sides of the government budget should be separated. "The productivity or unproductivity of the project is unimportant in itself. In either case, the taxpayer is the one who *pays,* who *sacrifies* real resources." *Buchanan* (1958), p. 42. In a more recent paper, *Buchanan* (1986) cautions against a simplistic definition of "public capital investment" and, once more, stresses his point that debt-financed government spending amounts to a destruction of the capital stock.

3 *Musgrave* (1959), p. 563: See also *Musgrave* (1988).

will show the equilibrium transition path of the economy as well as the global effects on steady-state values under different assumptions concerning tax policy and the appropriability of public capital.[4] This will also allow us to deepen our understanding of the way in which economy-wide changes in real output and interest rates caused by an alternative choice between tax and debt financing of public investment affect the government's budget constraint, a subject that has not yet been studied in detail in the prevailing literature.

The paper is organized as follows. In section 2 the analytical framework of the model is presented. The short- and long-run effects of debt versus tax finance of public investment on capital formation, on the government budget, and on individual savings behavior will be analyzed in detail in sections 3 and 4 of the paper. A dynamic simulation of the model will show how the welfare of current and future generations is affected during transition from one equilibrium to another. This clarifies as to which generation has to bear a burden in the sense of Buchanan's concept of burden and why and to what extent a burden is shifted to the future. The sensitivity of the simulation results to the choice of alternative tax regimes, to assumptions concerning the appropriability of the return to public capital and to alternative parameters of utility and production functions will be examined in sections 5, 6, and 7. Finally, pareto-superior transition paths are discussed in section 8.

II. Public Investment and Intertemporal Decision Making

1. Household Behavior

We consider a two-period life cycle model in which one young and one old generation exist at any point in time. Each member of generation t is assumed to have preferences that can be represented by a utility function of the Cobb-Douglas type:

$$u_t = (c_t^1)^\mu \left(c_{t+1}^2\right)^\varphi (c^g)^\Theta \tag{1}$$

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[4] Recently *Ihori* (1988) has investigated the issue of debt burden and intergeneration equity in a similar framework. However, in his paper public capital is not dealt with explicitely except in a short comment (see *Ihori* (1988), pp. 172 173). A lump-sum tax is only levied upon the young generation. No general-equilibrium effects of public investment policy are considered. Transitional effects are only scheduled by phase diagrams. This paper, therefore, extends Ihori's contribution in a number of ways.

In equation (1) lifetime utility is expressed as a function of private consumption when young, c_t^1, private consumption when old, c_{t+1}^2, and public consumption, c^g, the latter being given exogenously. The lifetime budget constraint of an individual born in period t is given by equation (2):

$$(2) \qquad (1+\tau_{ct})\,c_t^1 + \frac{(1+\tau_{ct+1})\,c_{t+1}^2}{1+r_{t+1}} = (1-\tau_{wt})\,w_t - \left[\tau_t^1 + \frac{\tau_{t+1}^2}{1+r_{t+1}}\right],$$

where w_t is the gross wage earned in period t, τ_{ct} and τ_{wt} are proportional tax rates on consumption and labor, and τ_t^1, τ_{t+1}^2 are lump-sum taxes which are levied in period t and $t+1$. The right-hand side of equation (2) represents the lifetime resources the individual has at his disposal to spend on current and future consumption.

Maximization of the utility function (1) subject to the budget constraint (2) yields the consumption demands in equation (3) and (4):

$$(3) \qquad c_t^1 = \frac{\mu}{\mu+\varphi}\,\frac{1}{1+\tau_{ct}}\left\{(1-\tau_{wt})\,w_t - \left[\tau_t^1 + \frac{\tau_{t+1}^2}{1+r_{t+1}}\right]\right\}$$

$$(4) \qquad c_{t+1}^2 = \frac{\varphi}{\mu+\varphi}\,\frac{1}{1+\tau_{ct+1}}\left\{\left[(1-\tau_{wt})\,w_t - \tau_t^1\right](1+r_{t+1}) - \tau_{t+1}^2\right\}.$$

Savings carried out by generation t when they are young are defined as the difference between after-tax earnings from labor, $(1-\tau_{wt})\,w_t - \tau_t^1$, and gross consumption, $(1+\tau_{ct})\,c_t^1$. Thus, optimal savings can be expressed as

$$(5) \qquad s_t^1 = \frac{\varphi}{\mu+\varphi}\left[(1-\tau_{wt})\,w_t - \tau_t^1\right] + \frac{\mu}{\mu+\varphi}\,\frac{\tau_{t+1}^2}{1+r_{t+1}}$$

2. *Firm Behavior*

The model has a single production sector using private capital K_t^p, public capital K_t^g and labor L_t subject to a constant-returns-to-scale production function $Y_t = F(K_t^p, K_t^g, L_t) = (K_t^p)^\alpha (K_t^g)^\beta (L_t)^\gamma$ with $\alpha+\beta+\gamma = 1$. This can also be written in the per-capita form.[5]

$$(6) \qquad y_t = f(k_t^p, k_t^g) = (k_t^p)^\alpha\,(k_t^g)^\beta$$

[5] Capital letters indicate absolute values, small letters per capita units.

where $y_t = Y_t/L_t$ is the output per capita of the young generation, $k_t^p = K_t^p/L_t$ and $k_t^g = K_t^g/L_t$ are the capital intensities of the private and the public capital stock. As output Y_t is a function homogeneous of degree one in all the variables, output per capita, y_t, can be decomposed into the imputed shares of private capital, $f_{pt}k_t^p$; government capital, $f_{gt}k_t^g$; and labor, F_L; where f_{pt}, f_{gt}, and F_L are the marginal productivities of private capital, public capital and labor, respectively. Assuming that the production sector behaves competitively the share of private capital equals interest income. The share of labor income is also received by private individuals. Thus we have

(7) $$r_t k_t^p = \alpha\, y_t$$

(8) $$w_t = \gamma\, y_t$$

With regard to the services of government capital we first assume that the government recovers its full share:

(9) $$f_{gt}\, k_t^g = \beta\, y_t .$$

The sensitivity of the simulation results to different appropriation assumptions will be examinded subsequently.

3. *Government Behavior*

The government needs to finance consumption expenditures C_t^g, public investment $\Delta K_t^g = K_{t+1}^g - K_t^g$, and spending on debt service $r_t B_t$. Its revenue consists of total tax collections T_t, credit financing $\Delta B_t = B_{t+1} - B_t$, and the rental payments on public capital, $f_{gt} K_t^g$, appropriated by the government. Therefore, the government's budget constraint is $T_t + \Delta B_t + f_{gt} K_t^g = C_t^g + \Delta K_t^g + r_t B_t$. Assuming that labor is growing at rate n such that $L_t = (1 + n) L_{t-1}$ and that public debt as well as the government's capital stock are growing at the same rate n in order to keep the public capital intensity k^g and per capita debt b constant the government's budget constraint can be written in the following form:

(10) $$\tau_t = (r_t - n)\, b - (f_{gt} - n)\, k^g + c^g$$

Total tax revenue is composed of wage taxes, $\tau_{wt} w_t$, and consumption taxes, $\tau_{ct} c_t^p$, where c_t^p is total private consumption in period t. The government also levies a lump-sum tax $\bar{\tau}_t$ which is divided up between the two generations such that $\tau_t^1 = T_t^1/L_t = (1-a)\bar{\tau}_t$ and $\tau_t^2 = T_t^2/L_{t-1} = (1+n)\,a\bar{\tau}_t$.

4. *Capital Market Equilibrium*

As is shown in equation (5) the supply of assets solely depends on the consumption-saving decision of the young generation because the elderly consume all available resources during their second period. The capital stock as well as outstanding government debt in period $t+1$ is financed by the savings of the young generations in period t, so that the equation $S_t^1 = K_{t+1} + B_{t+1}$ holds. Savings per capita of the young generation are then given by equation (11):

$$s_t^1 = (1+n)(k_t^p + b)\,. \tag{11}$$

III. Base Case Simulation[6]

The model presented in equations (1) to (11) can be solved in different ways. Frequently the effects of fiscal policy are studied in a comparative-static analysis of steady states. Though this approach is not excluded here the following focusses on a dynamic simulation analysis of transition paths. Thus we are able to examine in what way the short run effects of debt versus tax financing of public investment differ from their long-run effects, what kind of financing generates a burden to present generations and how this burden may be shifted into the future.

Certainly, a dynamic simulation of fiscal policy necessitates a numerical specification of the parameters of the utility and production functions and of the exogenous variables as well. This implies a certain loss of generality of results. However, the model is rather complex and has no general solution. Even the comparative static results can only lead to a unique solution, if one is prepared to make some restrictive assumptions on the key variables of the model. Moreover the impact of alternative parameter values on the simulation results can be examined by sensitivity analysis.

Table 1 presents the parameterization and the initial steady state values of the base case economy. In the utility function the highest weight is given to current consumption ($\mu = 0.5$), whereas future con-

6 The computer simulations were carried out by Stephan Boll. I wish to thank him for able research assistance.

Table 1

Base case steady state

utility function	production function	
$\mu = 0.5$	$\alpha = 0.23$	
$\varphi = 0.3$	$\beta = 0.10$	
$\Theta = 0.2$	$\gamma = 0.67$	
population growth (n)		0.48 (1.3% p.a.);
tax distribution (a)		0.5
public capital stock (k^g)		0.0125
public debt (b)		0.007
output (y)		0.3195
private capital stock (k^p)		0.0471
interest rate		
– private (r)		3.1% p.a.
– public (f_g)		4.2% p.a.
credit financing ratio		
– in relation to output (nb/y)		1.1%
– in relation to public investment (nb/nk^g)		56.0%
public expenditure ratio $[(c^g + nk^g + rb)/y]$		22.5%
interest payments on public debt (rb)		0.0109
return on public capital ($f_g k^g$)		0.0320

sumption and government consumption have lower preference weights ($\varphi = 0.3$; $\Theta = 0.2$). The parameters of the production function imply that about two third (67 percent) of national income is earned by workers, and 23 percent by the owners of private capital. The government recovers 10 percent of national income in the form of returns on government capital. Population growth is assumed to be $n = 0.48$. As one period in the two-period life cycle model corresponds to a time span of about 30 years the population growth rate is 1.3% per annum.

In the base case simulation government collects only a lump-sum tax which is equally imposed upon both generations ($a = 0.5$). Public debt and public capital are chosen so as to give a credit financing ratio of 56 percent of public investment outlays. In the initial steady state this results in a public deficit of 1.1 percent in relation to national income. In total, public expenditures consisting of public consumption, c^g, investment outlays, nk^g, and interest payments on public debt, rb, constitute about 22.5 percent of total output. Though this seems to be a rather small fraction of national income one has to keep in mind that the model includes neither transfer payments nor social security benefits. In the base case steady state as well as throughout the dynamic policy simulations the return on public capital (f_g) is higher than or equal to the interest rate on private capital which in its turn is higher than the population growth rate ($r > n$). Thus, the economy always stays on a dynamically efficient growth path.

IV. Debt versus Tax Financing of Public Investment

The numerical simulations of public investment policy start from a 12 percent increase in the public capital stock. Two different policy simulations were carried out. In the first case additional investment expenditures are financed by a corresponding increase in public debt, whereas in the second case the increase in investment expenditures is purely tax financed. As in the baseline simulation the only tax levied by the government is a lump-sum tax which is payed in equal parts by both generations. One can easily see from the government's budget constraint in equation (10) that neither of these cases correspond to a really pure debt or tax finance of public investment. Rather, one has to analyse the effects of fiscal policy on interest payments and on the return on public capital. From equation (10) we have

$$\Delta\tau = \Delta(r_t b) - \Delta(f_{gt} k^g) + n(\Delta k^g - \Delta b) \tag{12}$$

Thus debt financing of public investment ($\Delta k^g = \Delta b$) may require additional tax collections if interest payments on public debt rise more than the return on public investment. On the other hand in the case of tax finance additional tax payments may only be small because of the possible rise in the return on public capital which is appropriated by the government. Finally, one must take into account that a rise in the tax burden does not necessarily imply negative welfare effects, and even less so if it is caused by a corresponding rise in public investment.

The global effects of public investment policy are measured by two indicators. For the first, $\Delta k^p / k^p$ shows the crowding-out of private capital by fiscal policy. Secondly, the welfare effects of a debt or tax financed rise in public investment expenditures are measured by a normalized wealth equivalent Ω. It represents the percentage increase in lifetime resources (see eq. 2), valued at original prices, needed to produce the same level of utility actually achieved with the change in investment policy.[7] As the utility function described in equation (1) is homothetic an increase in lifetime resources by a factor Ω_t, valued at original prices, generates a proportional increase in first and second period consumption of each generation, so that $c_t^1 = \Omega_t c_s^1$ and $c_{t+1}^2 = \Omega_t c_s^2$, where the suffix s indicates the initial steady-state values of consumption. Utility then increases to $u_t = \Omega_t^{\mu+\varphi} u_s$. Thus, the wealth equivalent is defined as

$$\Omega_t = \left[\frac{u_t}{u_s}\right]^{\frac{1}{\mu+\varphi}} \tag{13}$$

Table 2 presents the long-run effects of debt versus tax finance of public investment. It contains the indicators $\Delta k^p/k^p$ and $\Delta\Omega$ as well as the elements of equation (12).

Table 2

Policy simulation: Debt- versus Tax-financing of public investment (deviation from baseline)

	Debt financing		Tax financing	
public capital stock	+0.0015	+12.0%	+0.0015	+12%
public debt	+0.0015	+21.4%	–	–
$\Delta k^p/k^p$	−0.0014	− 2.9%	+0.0009	+1.8%
$\Delta\Omega$	+0.003	+ 0.3%	+0.017	+1.7%
tax revenue	+0.0027	+ 7.3%	+0.0002	+0.5%
return on public capital	+0.0002	+ 0.5%	+0.0005	+1.6%
interest payments on public debt	+0.0028	+25.6%	−0.0	−0.3%

As one can see from table 2 the welfare effects of additional public investment are positive in both cases. However, they are much lower in the case of debt finance (+0.3%) than in the case of tax finance (+1.7%).

[7] This is an indicator analogous to that which has been used by *Auerbach/Kotlikoff* (1987) in order to measure the welfare effects of dynamic fiscal policy.

Though the issuing of new public debt creates only a slight increase in the interest rate additional interest payments on public debt necessitate a rise in tax collections of about 7 percent because the rent on public capital remains nearly constant. This is due to the fact that the decline in the marginal productivity of public investment is not compensated for by the expansion of the public capital stock. Lump-sum taxes are equally paid over the whole life cycle but represent a higher burden in the present because future tax burdens are discounted. Therefore, the savings of the young generation are reduced by additional tax payments whereas the slightly increasing wages have opposite effects. In any case, even when savings are rising this is not sufficient to meet the growing capital needs for public investment, so that there is a crowding out of private capital (–2.9%). Thus, the positive welfare effect of debt financed public investment, though very small, is due to the compensating output effects of the additional public capital stock.

In the case of tax financing of public investment there is no crowding out of private capital. No additional tax payments are necessary for interest payments on public debt. Additional public investment is almost self financing because of a rise in the return on public capital. Thus the rise in private welfare is significantly higher than in the case of debt financing.

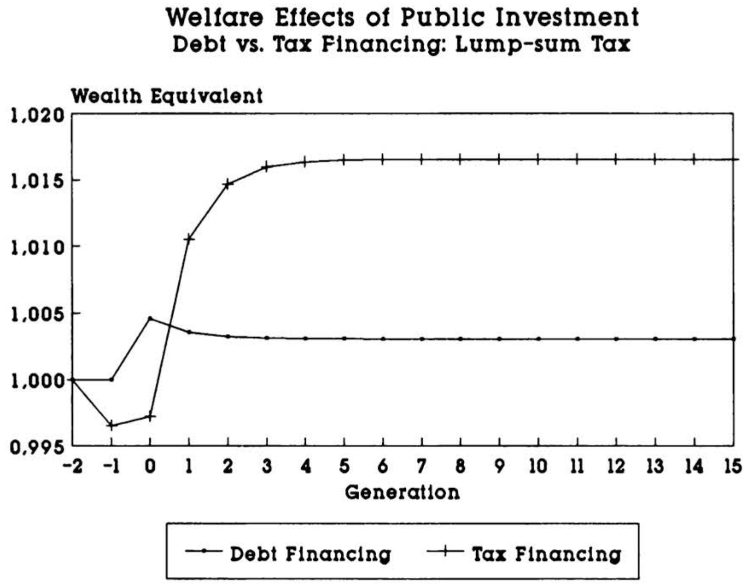

Figure 1

Fig. 1 shows the transition paths of the welfare effects that are generated by additional public investment expenditures. As one can easily see the policies of debt versus tax finance do not only differ in their long-run effects but also show opposite effects in the short run. Debt financing of public investment places no burden on the economy, neither on present nor on future generations. Individuals born in the period of the policy change ($t = 0$) don't have to bear any new taxes when young because higher interest payments on public debt only fall due in the next period. When they are old they have more income to consume. Their savings will yield a higher return because of rising interest reates, while the reduction in disposable income caused by the higher tax burden is much less important. So the generation born in period t gains from an expansion of its second period consumption. The following generations all have to pay additional taxes in both periods of their life cycle so that the positive welfare effect is dampened.

By contrast, in the case of tax financing of public investment welfare losses are produced during transition. The generation born in period $t = -1$, being old when the policy change occurs ($t = 0$), has to suffer a windfall loss because it cannot escape from paying higher taxes in order to finance additional investment expenditures. The generation born in the transition period $t = 0$ also has to bear part of the tax burden when young. When old the same individuals participate in the positive output effects of the additional public capital stock. However, they also have to bear the losses of a reduced interest rate on their savings. In total, there is still a welfare loss for this generation while the following generations fully participate in the benefits of additional public investment. Thus the higher long-run welfare gains from tax financing of public investment are obtained through welfare losses of some generations during transition.

V. Sensitivity to Alternative Tax Regimes

So far the base case and policy simulations were analyzed under the assumption that the government collects a lump-sum tax whose burden is equally distributed among both generations ($a = 0.5$). In this chapter, we briefly consider the sensitivity of these calculations to the choice of alternative tax regimes. The lump-sum tax is altered so as to place a heavier burden on the young generation. The old generation has only to pay 25 percent of the lump-sum tax ($a = 0.25$). We also look at both, the changes in the long-run capital stock and the welfare effects of debt-versus tax-financed public investment under a wage tax and a consumption tax, respectively.[8] As before, the government recovers the total return on its capital. In the base case economy it finances only part of its investment outlays by the issuing of public debt. In the policy simulation the additional public capital stock (+12 percent) is fully financed either by public debt or by taxes.

The patterns of the transition paths generated by the new lump-sum tax, the wage tax and the consumption tax do not differ much from those produced in section 4 (see fig. 1). In the case of debt financing the rise in welfare is most significant for generations alive during the first periods of the transition to the new steady state while the welfare effects are lowered in the following periods. In the case of tax financing generations alive during transition first suffer a welfare loss but are made better off in subsequent periods.

As can be seen from table 3 in comparison to table 2 even the long-run effects of additional tax-financed public investment are relatively unresponsive to the choice of alternative tax regimes. Welfare effects are positive and keep within a range of 1.6 to 2.0 percent. This should not be surprising. The global effects on interest payments for the public debt are rather small, and though speaking of tax finance the main part of additional receipts in the government's budget is provided for by the rise in the return on public capital.

When additional public investment expenditures are debt financed the qualitative and quantitative effects of public investment policy can be much more sensitive to the choice of alternative tax regimes. Table 3 shows that a positive welfare effect only occurs under a consumption tax. This tax does not alter the relative prices of current and future consumption and has no impact on the savings function. Moreover savings do not depend upon the interest rate so that there is no tendency towards supporting a stronger crowding out of private capital. Thus the global effects of additional public investment are very similar to those of an equally distributed lump-sum tax. When the lump-sum tax places a heavier burden on the young generation ($a = 0.25$) the welfare effects turn out to be negative. This can be explained by the impact of such a tax on life cycle behavior. The more the lump-sum tax falls on the first period of the life cycle the more evident the negative income effects on

[8] As the model does not incorporate variable labor supply none of these taxes is distortionary. The potential efficiency cost of taxation is disregarded in order to focus on tax incidence and redistribution across generations which may greatly affect the allocation of consumption and savings.

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Table 3

Welfare Effects of Public Investment: Alternative Tax Regimes

	Debt financing	Tax financing
lump-sum tax		
$\Delta k^p / k^p$	−5.3%	+2.1%
$\Omega_{\bar{\tau}}$	0.994	1.017
wage tax		
$\Delta k^p / k^p$	−12.8%	+2.7%
Ω_w	0.964	1.020
consumption tax		
$\Delta k^p / k^p$	−2.6%	+1.8%
Ω_c	1.004	1.016

the savings of the young generation will become. This effect is even accentuated under a wage tax which is only imposed on the young generation. Additionally, the crowding out of private capital formation via rising interest rates is reinforced by a reduction of savings through falling gross wages. Therefore, the wage tax creates a tremendous crowding out of private capital (−12.8 percent) and reduces welfare by nearly 4 percent. In total, the global effects of debt financing of additional public investment will become the more negative the higher the necessity for additional tax collections in order to finance growing interest payments on public debt and the more the tax system affects private savings behavior.

VI. Sensitivity to Private Appropriation of Public Returns

The foregoing analysis was confined to the case in which the government recovers the full share of its capital. This might be considered as an extreme and unrealistic assumption. Frequently, the services of government capital are completely inappropriable so that the government is restricted to finance its investment outlays through taxes or borrowing. In the framework of an optimal growth model *Arrow/Kurz* ((1970), chapter VI.9.) have demonstrated that the appropriability of return on government capitals serves no function in the intertemporal allocation of resources since user charges to recover some part or the total of the return to government capital can always be offset by appropriate changes in tax rates. However, in contrast to the model presented in this paper their approach does not include the effects of intergenerational redistribution. Moreover, the government may be restricted in the use of tax instruments so that the absence of user charges cannot be compensated by a corresponding modification of the tax system.

If the government is not in a position to appropriate the return to its capital, $f_g k^g$, this part of national income does no longer appear in the government's budget constraint but has to be imputed to the private sector in a specific form. Private individuals must have some way of appropriating the benefits from public investment and converting them into rents. Here, we assume that public capital is a public good in the sense that it improves the efficiency of both factors of production, of labor as well as of capital, and that the return on government capital is imputed to these factors according to its elasticity in production.[9]

Let public capital be embodied in private capital and in labor in the following form of a Cobb-Douglas technology: $Q_t = (K_t^p)^{\nu}(K_t^g)^{1-\nu}$; $N_t = (L_t)^{\phi}(K_t^g)^{1-\phi}$, where Q_t and N_t are private capital and labor, respectively, measured in efficiency units, and $0 < \nu < 1$; $0 < \phi < 1$. Assuming $Y_t = Q_t^{(\alpha/\nu)} N_t^{(\gamma/\phi)}$, where $(\alpha/\nu) + (\gamma/\phi) = 1$, is in accordance with the original production function $Y_t = (K_t^p)^{\alpha}(K_t^g)^{\beta}(L_t)^{\gamma}$ described in section 2. In a competitive economy where factor prices equal marginal products factor shares now are given by equation (14) and (15):

$$w = (\gamma/\phi)\,y = \left[\gamma + \frac{1-\phi}{\phi}\gamma\right] y \tag{14}$$

$$rk^p = (\alpha/\nu)\,y = \left[\alpha + \frac{1-\nu}{\nu}\alpha\right] y\,. \tag{15}$$

As before, the rental on public capital is

$$f_g k^g = \beta y = \left[\frac{1-\phi}{\phi}\gamma + \frac{1-\nu}{\nu}\alpha\right] y \tag{16}$$

(cf. equation 9). However, wage and interest payments now are higher than in the original version because workers and the owners of private capital each recover their parts of the return on government capital, $[(1-\phi)/\phi]\,\gamma y$, and $[(1-\nu)/\nu]\,\alpha y$, respectively.

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[9] This approach has also been used by *Carlberg* [(1988), chapter 2] in the framework of a neoclassical growth model.

In order to examine the impact of non-appropriability of the return on government capital on the simulation results the sensitivity of these results to alternative choices of parameter values ν and ϕ is analyzed. They are first chosen so as to give 90 percent of the imputed shares of return on government capital to workers and 10 percent to the owners of private capital. Then we examine what happens when the share of return appropriated by workers is declining to 75 percent and 25 percent respectively. All other parameters are those of the baseline case.[10]

When private appropriation of the returns on government capital is taken into consideration the results of investment policy simulation are not greatly affected in the case of tax finance. The transition paths to the new steady state as well as the long-run equilibrium values do not deviate significantly from the original policy simulation paths, irrespective of how the returns on government capital are imputed to the private sector. This can be explained by an effect similar to that already found in our sensitivity analysis of alternative tax regimes: Additional public investment is partly self-financing through higher income. Certainly, individuals now have to pay more additional taxes because government cannot recover the return on its investment. However, a relatively stronger increase in capital intensity and output makes individuals pay higher taxes without being restricted as to their consumption possibilities.

Again, policy simulations based on debt financing of public investment outlays are more responsive to alternative parameter values. Table 4 summarizes the long-run effects on capital formation and welfare of private appropriation of the return on government capital in comparison to a full appropriation by government when additional public investment outlays are fully debt financed. In general, table 4 reveals a tendency towards higher positive welfare effects when the return on government capital is appropriated by the private sector and when a lump-sum tax or a consumption tax is levied. The less of the return on government capital is imputed to labor income the higher the crowding out of private capital and the lower the welfare effects. Thereby, the results approach those of a full appropriation of the return on public capital by the government. In one case – when a lump-sum tax is levied and a 25 percent share of return on government capital is imputed to labor income – the positive welfare effect even vanishes almost completely ($\Omega_{\bar{\tau}}$ = 1.0004). These effects clearly reflect life cycle behavior since savings of private

10 Thus, α and γ are given. As α/ν and γ/ϕ must add to unity only one of the two parameter values ν and ϕ can be chosen independently.

Table 4

Private Appropriation of Return on Debt Financed Public Investment

	Appropriation by Government	Private Appropriation		
		Imputed Share of Return on Government Capital		
		labor: 90 % priv. cap.: 10 %	labor: 75 % priv. cap.: 25 %	labor: 25 % priv. cap.: 75 %
lump-sum-tax				
$\Delta k^p / k^p$	−2.90 %	−2.1 %	−2.3 %	−3.3 %
$\Omega_{\bar{\tau}}$	1.003	1.006	1.005	1.0004
wage tax				
$\Delta k^p / k^p$	−12.8 %	−16.1 %	–[a)]	–[a)]
Ω_w	0.964	0.947	–[a)]	–[a)]
consumption tax				
$\Delta k^p / k^p$	−2.6 %	−1.8 %	−1.9 %	−2.3 %
Ω_c	1.004	1.007	1.006	1.004

[a)] No equilibrium could be achieved.

households are diminished when capital income which is fully spent for consumption is substituted for labor income.

In contrast to lump-sum and consumption taxation, under a wage tax non-appropriability of returns on government capital generates a clear strengthening of crowding-out effects and negative welfare effects. This is to be explained by the fact that rising interest payments caused by additional debt financing of public investment create a need for additional tax collections, thereby reducing net wages and savings. Moreover, rising interest rates are related to diminishing gross wages. This effect is larger in its absolute value in the case of private appropriation of public returns because we always have $(\gamma/\phi) > \gamma$. It is all the more important the smaller is the value of ϕ, i.e. the larger the share of return on government capital which is imputed to labor income. If a smaller share of the return on government capital is imputed to labor income, the negative gross wage effect decreases. Instead, interest income increases. Then we have a reinforcing of crowding-out effects: Savings are reduced because there is a lower level of gross wages. On the other hand, higher tax collections are needed to meet the rise in interest payments on public debt. Our simulations have shown that the latter effects are dominant to such a degree that no equilibrium could be obtained in two cases which are indicated in table 4.

VII. Further Sensitivity Analysis

The simulation results do not only depend upon the choice of alternative tax regimes and assumptions concerning the appropriation of the return on government capital. As can be seen from Table 1, parameters of the utility function and production function, population growth (n) as well as the size of public debt (b) and public capital (k^g) chosen in the initial steady state might affect the incidence of public investment policy. The calculations show that the welfare effects are rather unresponsive to the choice of alternative values of n, b and k^g. Therefore they are not considered here in more detail.[11]

Table 5 examines the sensitivity of the steady-state welfare effects of public investment policy to alternative parameter values of the utility and production functions. Two main results are coming forth from these calculations which confirm some of our findings from the previous sections. First, tax finance of public investment is less responsive to the choice of alternative parameter values than is debt finance. Secondly, tax finance never generates negative welfare effects in the long run. Table 5 even displays higher welfare effects in comparison with the base case simulation (1,7 %) at any of the alternative parameter values of the production function. By contrast, debt finance of public investment may create significant welfare losses.

The negative welfare effects of debt finance are the more important the more weight is given to present consumption. For example, raising μ from 0.5 to 0.7 generates a welfare loss of 3 percent. Similar and even stronger effects may be created when labor is given a lower share of total income as is the case in versions 8 to 10 of the sensitivity analysis. When labor income is reduced to 60 percent of national income and capital income amounts to 30 percent additional debt-financed public investment may produce welfare losses of about 10 percent (see table 5, version 11). The welfare loss may be less intense if the reduction in wage income is compensated for by a higher share of return on public capital

[11] For values of n = 0.36 to 0.60; b_0 = 0.003 to 0.010; k_0^g = 0.0115 to 0.0130 the long run welfare effects Ω do not differ more than 0.005 from each other.

because this lowers the tax burden such that savings are not so heavily affected (see table 5, version 9).

Table 5

Sensitivity analysis, alternative parameters of utility and production function

				$\Delta\Omega / \Omega$ (%)	
				debt finance	tax finance
	utility function				
	μ	φ	θ		
(1)	0.5	0.3	0.2	0.3	1.7
(2)	0.4	0.4	0.2	0.9	1.6
(3)	0.6	0.2	0.2	−1.7	1.8
(4)	0.6	0.3	0.1	−0.1	1.7
(5)	0.7	0.2	0.1	−3.0	1.9
	production function				
	α	β	γ		
(1)	0.23	0.10	0.67	0.3	1.7
(6)	0.20	0.13	0.67	1.1	2.1
(7)	0.15	0.18	0.67	2.2	2.9
(8)	0.23	0.13	0.64	0.2	2.4
(9)	0.23	0.18	0.59	−2.6	4.3
(10)	0.26	0.10	0.64	0.8	1.9
(11)	0.30	0.10	0.60	−10.4	2.6

VIII. Pareto-superior Transition Paths

In section 4 it was shown that debt finance of public investment creates no welfare losses neither in the short nor in the long run. In contrast, in the case of tax finance some generations alive when the new investment policy is implemented have to suffer welfare losses (see fig. 1). However, the long-run welfare gains from additional public investment are markedly higher than in the case of debt finance. Thus, the question could be raised, how fiscal policy could act in order to ensure that no generation be harmed.

One way to generate a pareto-superior transition path to a new steady-state equilibrium consists of an appropriate combination of debt and tax finance. If, for instance, the government would finance its additional investment outlays by collecting higher lump-sum taxes while simultaneously issuing new debt in order to pay lump-sum transfers to those alive during the implementation phase of the new investment policy, no generation would be made worse off. This reflects the fact, already known from the literature (cf. *Pestieau* (1974)) that government debt has the same effects as lump-sum transfers. However, there are pros and cons of debt policy. Certainly, government borrowing allows the burden to be equally spread over all future generations but, at the same time, reduces the steady state welfare gain of public investment policy. Moreover, there could be a ceiling on the government debt such that additional investment outlays can no longer be financed by borrowing. In the framework of the present model, it can be shown that the government is in a position to choose a pareto-superior tax-transfer policy that does not reduce the long-run steady state welfare level attained through tax financing of public investment.

This can easily be demonstrated in the case of lump-sum tax finance which is diagrammed in fig. 2. If the initial elderly generation (born in period $t = -1$) is relieved of additional lump-sum taxation its utility level remains constant. Then, the generation born in period $t = 0$ has to bear a higher tax burden when young. The welfare of this generation can still be held constant by lowering second period lump-sum taxation such that its second period consumption can be raised accordingly. Again, the young generation, born in period $t = 1$, has to be hurt by higher lump-sum taxes in order to finance the government's additional investment outlays but is compensated by lower taxes when old. In total, during the first periods of transition the tax burden is shifted to the young generations in such manner that the negative impact on savings is stronger than in the case of an uncompensated transition. This explains why the generation born in period $t = 1$ does not benefit from the policy change and why, for some periods, the welfare gains remain lower than in the case in which there is no compensation for welfare losses. Hence, tax-transfer policy shifts the burden of financing additional public investment into the near future without reducing welfare gains in the long run.

Clearly, the shape of the pareto-superior transition path and the number of periods in which generations alive during transition cannot

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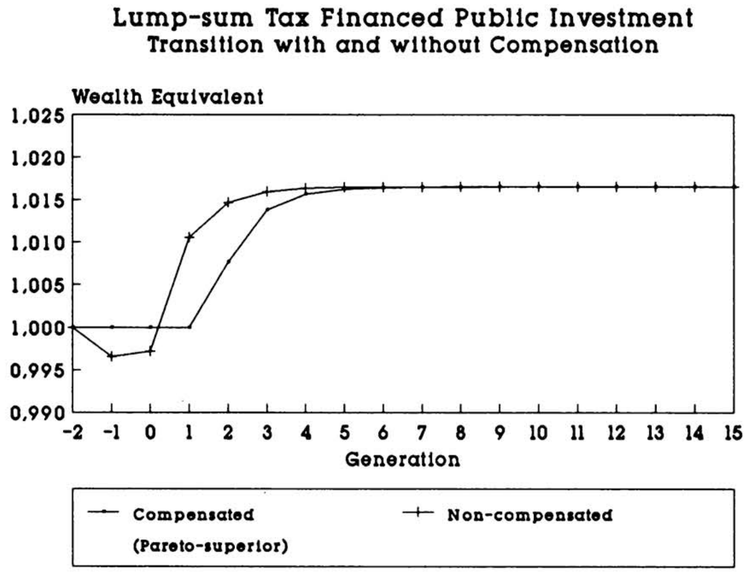

Figure 2

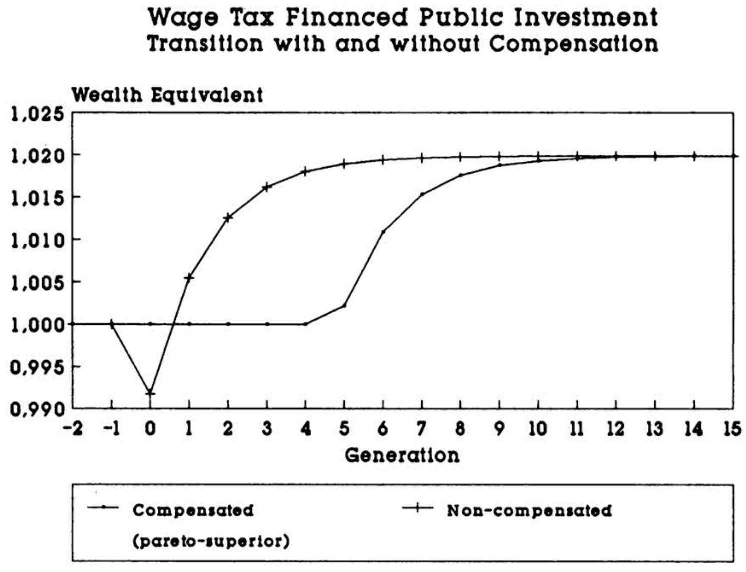

Figure 3

attain the uncompensated welfare level depends on both, the size of welfare losses to be compensated and the impact of tax-transfer policy on capital formation. In the case of a wage tax,[12] which is depicted in figure 3 the uncompensated transition path only indicates a welfare loss of the generation born in period $t = 0$, in which the policy change occurs. The pareto-superior transition path, however, shows that the new policy takes a relatively long time to generate a positive welfare effect. This is due to the fact that maintaining the wage tax necessitates high compensating transfers which have to be payed to the old generations in order to restore their utility levels. This creates a double burden to young generations and a stronger negative impact on savings than in the case of an uncompensated transition. Hence, capital formation is affected and a longer period is required in which the additional income created by public investment policy is used for the payment of transfers.

The welfare paths shown in figures 2 and 3 are only pareto improving in the sense that the welfare level of no generation will be lower than in the initial steady state. The impact on generations alive during the transition to the new steady state can be very different depending on which tax-transfer regime is used. Thus, there is no single choice between the infinite set of welfare improving paths. However, our results suggest that the long-run efficiency gains of public investment policy are large enough to allow for a tax-transfer policy which benefits all future generations.

IX. Conclusions

In eastern and western economies more public investment is required in order to ensure long-run growth and structural balance. Governments have to decide upon whether additional investment outlays should be financed by taxes or by government borrowing.

One of the main findings of our dynamic simulation analysis is that, in general, tax finance of additional public investment is superior to debt finance in the long run. As more private capital is crowded out by government borrowing the long-run welfare effects of public investment policy are lower than in the case of tax finance. Moreover, the long-run welfare effects are always positive when additional public investment outlays are tax financed while in the case of debt finance welfare effects are very sensitive to alternative tax regimes. This is to be explained by

12 As the transition paths generated by lump-sum taxation and consumption taxation are very similar the pareto-superior transition in the case of consumption taxation is not considered here.

the fact that a rise in interest payments on public debt requires additional tax collections. The more the tax burden caused by additional interest payments is placed on the young generations the more capital formation will be affected. Therefore, under a wage tax debt finance of public investment creates negative welfare effects in the long-run. Further sensitivity analysis has shown that the negative welfare effects of debt-financed public investment may even be strengthened when more weight is given to present consumption in the utility function or when labor receives a lower share of national income.

The dynamic simulations of the transition paths indicate that in the short run public investment policy reveals the reverse effects: Only tax finance produces welfare losses to the generations alive when the policy change is made. However, it was demonstrated that the government could achieve a tax-transfer policy that creates pareto-superior transition paths without lowering the long-run welfare effects. This can be accomplished by placing the burden of additional taxation on individuals when they are young and compensating them for welfare losses by paying transfers to them when they are old.

Throughout the paper it was assumed that the government is in a position to recover the full share of its capital. In section 6 we examined how the results are changed if the return on public capital is appropriated by the private sector. Again, tax finance of public investment outlays proved to be rather insensitive to different assumptions concerning the imputation of public factor return to the private sector. In contrast, policy simulations based on debt financing of public investment are more responsive to alternative imputations. In the case of lump-sum and consumption taxes there is a tendency towards higher positive welfare effects when the return on capital is appropriated by private individuals, although this is all the smaller the more it is imputed to labor income. Under a wage tax the appropriation of returns on government capital by the private sector entails a strengthening of crowding-out effects such that no equilibrium could be obtained when a large part of the return is imputed to the owner of private capital.

In summary, dynamic simulation analysis of tax- versus debt-financing of public investment suggests that there is no justification for debt financing of public investment. In the long-run, debt-financing creates substantially higher crowding-out effects than does tax-financing of public investment. Negative short-run effects of tax-financing can be avoided by an efficient tax-transfer policy during transition periods, without lowering the long-run welfare gains of public investment policy.

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Zusammenfassung

Finanzierung von öffentlichen Investitionen durch höhere Steuern oder durch höhere Verschuldung: Eine dynamische Simulationsanalyse[13]

Dieser Beitrag enthält ein sich über zwei Perioden erstreckendes Wachstumsmodell, mit dem die globalen Wirkungen von durch höhere Steuern im Gegensatz zu durch höhere Verschuldung finanzierte öffentliche Investitionen aufgezeigt werden sollen. Es werden dynamische Simulationen verwendet, um zu zeigen, wie

13 Ich verdanke einem anonym gebliebenen Referenten nützliche Hinweise.

Kapitalbildung und Wohlfahrt dieser sowie künftiger Generationen durch den Übergang zu einem neuartigen Gleichgewicht beeinflußt werden. Es wird aufgezeigt, wie Veränderungen der realen Produktionsmenge und der realen Zinsen in der Volkswirtschaft insgesamt, die durch die Wahlmöglichkeit zwischen steuer- und schuldenfinanzierten öffentlichen Investitionen bewirkt werden, die Haushaltszwänge der Regierung beeinflussen; dies ist ein Thema, das in der Literatur bisher noch nicht im einzelnen untersucht worden ist. Die Ergebnisse deuten darauf hin, daß eine Steuerfinanzierung einer Schuldenfinanzierung von öffentlichen Investitionen vermutlich überlegen ist. Langfristig bewirkt eine Schuldenfinanzierung einen wesentlich stärkeren Verdrängungswettbewerb als die Steuerfinanzierung von öffentlichen Investitionen. Negative kurzfristige Effekte einer Steuerfinanzierung öffentlicher Investitionen können durch eine effiziente Steuertransferpolitik während der Übergangszeiträume vermieden werden, ohne daß die langfristig durch die öffentlichen Investitionen erzielten Wohlfahrtsgewinne dadurch geschmälert werden.

Summary

Tax- versus Dept-Financing of Public Investment: A Dynamic Simulation Analysis.

In this paper a two-period life cycle growth model is presented in order to illustrate the global effects of debt versus tax finance of public investment. Dynamic simulations are used to show how capital formation and the welfare of current and future generations are affected during the transition to a new equilibrium. It is demonstrated how economywide changes in real output and interest rates caused by an alternative choice between tax and debt financing of public investment affect the government's budget constraint, a subject that has not yet been studied in detail in the prevailing literature. The results suggest that tax finance is superior to debt finance of public investment. In the long run, debt-financing creates substantially higher crowding-out effects than does tax-financing of public investment. Negative short-run effects of tax-financing can be avoided by an efficient tax-transfer policy during transition periods, without lowering the long-run welfare gains of public investment policy.

Résumé

Financement fiscal vs. financement par la dette des investissements publics: une analyse de simulation dynamique

L'auteur présente dans ce travail un modèle de croissance du cycle de vie de deux periodes afin d'illustrer les effets globaux du financement fiscal vs par la dette des investissements publics. Des simulations dynamiques sont utilisées pour montrer comment sont affectés la formation de capital et le bien-être des générations actuelles et futures pendant la période de transition vers un nouvel équilibre. Il est démontré comment l'économie change en terme d'output réel et comment les taux d'intérêt, causés par un choix alternatif entre le financement fiscal

et par la dette des investissements publics, affectent la contrainte budgétaire du gouvernement, un sujet qui n'a pas encore été approfondi dans la littérature actuelle. Les résultats suggèrent que le financement fiscal est supérieur au financement par la dette des investissements publics. A long terme, le financement par la dette crée des effets de détournement considérablement plus élevés que le financement fiscal des investissements publics. On peut éviter des effets négatifs à court terme du financement fiscal en appliquant une politique de transfert fiscal efficace pendant les périodes de transition, sans abaisser les bénéfices de bien-être à long terme de la politique des investissements publics.