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A NOTE ON POLICY, THE COMPOSITION OF PUBLIC EXPENDITURES AND ECONOMIC GROWTH

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Abstract

In this article we study the growth and welfare effects of fiscal and monetary policies in economies where public investment is part of the productive process. We present four different models that share the same technology with public infrastructure as a separate argument of the production function. We show that growth is maximized at positive levels of income tax and inflation. However, unless there are no transfers or public goods in the economy, maximization of growth does not imply welfare maximization. We show that the optimal tax rate is greater than the rate that maximizes growth and the optimal rate of money creation is below the growth maximizing rate. With public infrastructure in the production function we no longer obtain superneutrality in the Sidrausky model.

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1. Introduction

This note investigates the effect of changes in the composition and level of government expenditures and financing on economic growth. We basically present some main results of the literature at the same time that we add different forms of public outlays and emphasize the effect of alternative kinds of government financing on growth and welfare when the investment of the public sector can affect private returns and productivity.

We start working in a "AK" technology due to Rebelo (1991) expanded by the presence of public investments, following Barro (1990), among others. We will subsequently introduce more structure to this basic model. We first add a public good that directly affects the utility of individuals. The next model divides agents in two classes, capitalists who own the capital and save, and workers that do not save and live out of wage income. Here we synthesized results of Alesina and Rodrik (1992). In the last model money is introduced.

We assume in all those models that government expenditures are divided in two parts: one "productive" (R&D, education, capital formation, infrastructure, etc.), affects the productivity of the private sector technologies and the other, "consumption," do not and will be modeled either as consumption transfers to the private sector, public good or simply as "waste". In these economies government expenditures are financed through distortionary taxation and/or seignorage.

We aim to use these different structures to answer two basic questions:

What is the impact on economic growth of shifts of public expenditures from investment to consumption? Or more generally, what are the macroeconomics effects of changes in fiscal and monetary policy when the productive role of government is taken into account?

The second question is: what is the optimal level of taxes and other policy instruments in economies where public investment is part of the production function? How
does the optimal tax rate or public investment ratio compare with the tax rate and investment ratio that maximize growth?

The four different frameworks we use give diverse answers to these questions. The answer depends both on the way the public sector finances its expenditures and the particular form that these expenditures assume.

In general growth is maximized when public consumption or transfers are zero and at positive levels of tax. Moreover, there is an interval where growth rates increases with the tax rates. Zero taxation is not an equilibrium as tax revenues are needed for the financing of public infrastructure.

But maximum growth do not imply optimal growth. Unless public transfers are wasted and do not affect people's behavior in any way, the optimal tax rate is always above the maximum growth rate and the optimal ratio of investment to total public expenditures is below one, the ratio that maximizes growth. This result is also true for the models with public good and conflict between classes. On the other hand, the optimal rate of money supply is positive in all economies, but always below the rate that maximizes growth.

Although these models are all highly abstract, we think that we can gain some insights about the role of government in certain recent growth experiences.

For instance: public expenditures in capital, for a given level of total expenditures and taxes, positively affect growth rates because it increases the productivity of physical capital. On the other hand, growth rates would fall with taxes for a given level of public investment as it reduces the return on private investment. However, the effect of an increase in the total government expenditures over growth is ambiguous: increasing total expenditures would push public investment up boosting the rate of growth. But, at the same time, in order to finance the increased expenditures government would have to raise taxes and this old reduce the growth rate.

The conclusion of the argument above is straightforward: there is no direct relationship between government size, productivity and economic growth. A large government sector with relatively large unproductive expenses would give rise to the usual
intuition of the effects of big government over the economy (lower productivity and lower growth) but this may not be true if the proportion of productive expenditures on total expenditures is high. Therefore, the usual IMF recipe for troubled countries may well misfire if the cuts in government size are done in the wrong sectors or in the wrong proportions.

When money is introduced in this economy the expenditure size of government remains the same but now we have one extra source of distortion. It is still true that increases in the public investment ratio would probably increase growth so that two countries with the same rate of inflation but different proportions of public capital could have different rates of growth. In other words, there is no one to one relationship between inflation and growth. Nevertheless, if the level of investments remains constant while inflation rises, the increase in the total government expenditure financed by the extra inflation tax revenue will be accompanied by lower rates of growth. It may be true, however, that for some combination of parameters an increase in seignorage can lead to faster growth. In this case, the distortionary effect of higher inflation is counteracted by the effect of public investment over the marginal productivity of capital.

We think that the model with money could help the understanding of the recent experience of some Latin America nations. During the fifties and the sixties countries in this region experienced fast economic growth (averages rates sometimes higher than 4%) while government investment increased sharply. At the same time inflation rates were well above the acceptable level for developed countries (in Brazil it was seldom below 15%). So we can think of this set up as a large public sector with high investment ratio and high money creation with a combination of parameters that allows the effect of public investment over growth to exceed the negative one from higher taxes and seignorage. However, specially after 1982 we observe an acceleration of inflation and a reduction of expenditures in infrastructure. At the same time due to political pressures expenditures in consumption rises. Here we have not only reduction in the investment rates but also in the absolute level of public investment, while distortionary taxation increased. The two factors could help to explain the sharp reduction in the growth rates during the eighties experienced by these countries.
The paper is organized as follows. In the next section the basic framework is presented. In the next one we introduce public good and in section four we study an economy with two classes and distribution conflict. In section five money is introduced to basic model while in section six we make some concluding remarks.

2. The Basic Model

The simplest model that generates endogenous growth is the so called AK model. We will use it as a first step toward a more comprehensive model. Note, however, that our technology includes government expenditures.

Let the technology be given by

\[ y_t = A(g_t)^(\lambda k_t) \]

In the above expression \( g \) is the ratio of government expenses (G) to output, \( g_i \) the ratio of public investment to output, \( \phi \) is a positive parameter smaller than one that gives the productivity of government capital and \( \lambda \) is the proportion of investments out of total public expenditures. As it is usual in this type of model, \( K_t \) should be interpreted in a broad sense and including, for instance, human capital. Government expenditures are financed by a proportional tax over income.

We also make the usual assumption that the instantaneous utility function is CES and we rule population growth out. The consumer problem is
In the above expression $\delta$ is the depreciation rate of capital, $V$ government transfers ($= (1-\lambda)G$), $\rho$ is the discount rate and $\sigma$ is the inverse of the elasticity of substitution. The expression simply says that the net investment is equal to the difference between income ($=(1-\tau)y+V$) and consumption. Alternatively we could suppose that government consumption is always "wasted" so that $V(t)$ would not be present in the above expression. This would not change the results. The Hamiltonian for the consumer problem is:

\[
H = \frac{c_{t}^{1-\sigma} - 1}{-\sigma} + \varphi \left( (1-\tau)y_{t} - c_{t} - \delta k_{t} + V_{t} \right)
\]

The solution for this problem is given by the following first order conditions (from this point on we drop the time subscript for simplicity sake):

\[
c^{-\sigma} = \varphi
\]

\[
\dot{\varphi} = \varphi \left( \rho - r + \delta \right)
\]

and the transversality condition:
\[ \lim_{t \to -} e^{-rt} \varphi k_i = 0 \]

In the above expressions \( r \), the interest rate, is given in equilibrium after the solution of the problem of the firms, by \((1-\tau)A(\lambda g)\phi\).

From equations three and four we obtain the growth rate of consumption, \( \gamma \):

\begin{equation}
\gamma = (r - \delta - \rho)/\sigma
\end{equation}

From the above result and the transversality condition it can be shown that capital grows at the same rate of consumption\(^1\). Given that by expression one output grows at the same rate as capital, and consequently also \( G \) (which is equal to \( \tau y \)), all the variables of this economy are in a balanced growth path at the same rate \( \gamma \). Note from the definition of \( r \) that the growth rate is given by

\[ \gamma = ((1-\tau)A(g_i)\phi - \delta - \rho)/\sigma = ((1-\tau)A(\lambda g)\phi - \delta - \rho)/\sigma \]

so that for a given tax rate \( \tau \) an increase in the parameter \( \lambda \) (a raise in the government investment ratio) with \( g \) constant will boost the rate of growth of this economy by

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\(^1\) In section 5 we prove this result in a more general framework.
which is always positive for any $\lambda$ between zero and one. Consequently, $\lambda$ equal one maximizes growth. But note also that if a change in the composition of public expenditures in favor of investment helps economic growth, the impact decreases with the size of $\lambda$. The diminish returns of $\lambda$ results of course from our hypothesis that $\phi$ is less than one. We will see soon that there is robust empirical evidence that this is in fact the case.

On the other hand, it is not clear that growth rates will fall with an increase in taxation as in standard endogenous growth models (see Rebelo (1991), among others). In those models the interest rate would be given by $(1 - \tau)A/\sigma$ and the marginal productivity of capital is not affected by public investment. But in the present case, as in Barro (1991) and Barro and Sala-i-Martin (1991), this is no longer true. The interest rate is given by $(1-\tau)A(\lambda g)^{\phi} g^{-1}$ so that the negative impact of higher tax rates may be compensated by the positive effect brought about by the increase in public investments. Note that:

\[
\frac{dy}{d\tau} = \frac{1}{\sigma} \left[ -A(\lambda g)^{\phi} d\tau + \phi(1 - \tau)A(\lambda g)^{\phi} g^{-1} dg \right]
\]

After some manipulations we obtain:

\[
\frac{dy}{d\tau} = \frac{A(\lambda g)^{\phi}}{\sigma} \left[ \frac{(1 - \tau)}{\tau} \phi \eta_{t,r} - 1 \right]
\]
where $\eta_{gt}$ is the elasticity of government expenditures with respect to taxes. From the above expression $dt/dg$ is positive only if $\eta_{gt} \phi > \nu(1 - \tau)$, and negative otherwise.

For the general case where $g$ is not proportional to income and in the hypothesis that there is a "nice" Laffer curve in this economy (as it is the case for this simple model), the effect of taxes over growth would depend on the level of the tax rate, the productivity parameter of public capital $\phi$ and the position of $g$ in the Laffer curve. If the economy is in the left side of the Laffer curve and not close to the peak, $\eta_{gt}$ is not only positive but relatively large so that it is possible that the first term in the brackets of the above expression is larger than one. In this case higher rates will increase, and not decrease, growth. The intuition is obvious: the negative distortionary effect of higher tax rates is smaller than the positive effect of the increased public capital over the marginal productivity of private capital. A "big government", however, which means $g$ close or to the right of the maximum of the Laffer curve, can only harm growth with higher taxes.

In the unrefined framework of our model, as we did not allow public debt and/or money, this general discussion can be simplified considerably. Here the variable $g$, which is $G/y$ by definition, is given by $ty/y$ which reduces, of course, to $\tau$. In this case, the elasticity of $g$ with respect to $\tau$ is constant and equal to one. Now the condition for the growth rate to increase with the tax rate is no longer $\eta_{gt} \phi > \nu(1 - \tau)$ but just:

$$\phi > \frac{\tau}{(1 - \tau)}$$

With the estimates of $\phi$ available in the literature we can estimate the interval of tax rate for which the derivative of $\gamma$ with respect to $\tau$ is positive. These estimates, for American aggregate data, vary considerable. For instance, Aschauer (1989) found values around 0.35 while in Ferreira (1993) they are 0.09 on average and in Nadiri and Manuneas (1992) the estimates are all between these two values. In the first case $dy/d\tau$ is positive while the tax rate (which is equivalent to the tax burden in the model) remains below 0.25.
a value close to the Brazilian and American tax burden. However, for \( \phi \) close 0.1 this derivative becomes negative for \( \tau \) above 1/11. For \( \phi \) close to zero we obtain the usual neoclassical result that tax increases can never boost economic growth. But the main conclusion of this section remains that once we recognize the productive role of the government, \( dy/dt \) negative is no longer a general result.

The Government Problem

We can now investigate what would be the optimal tax rate and \( \lambda \) that a government that wants to maximize the welfare of the agents would choose. We will start with the simplifying assumption that the transfers \( V \) are zero in every period (they are simply wasted). Notice that from the equilibrium growth rate we have:

\[
\frac{\dot{k}}{k} = \frac{(1 - \tau) A (\lambda \tau)^\sigma - \delta - \rho}{\sigma} = \frac{(r(\lambda, \tau) - \delta - \rho)}{\sigma}
\]

From the consumer's problem we have:

\[
\dot{k} = (r - \delta) k - c
\]

Manipulating these two equations above we obtain an expression for consumption:

\[
c = \left( (r(\lambda, \tau) - \delta)(1 - \gamma_\delta) + \frac{\rho}{\sigma} \right) k
\]
Expression eight says that consumption in equilibrium is a fixed proportion of capital once we recognize that the interest rate for given $\tau$ and $\lambda$ is a constant. Moreover if, instead of the more general CES we had a logarithm utility function, so that $\sigma$ is equal to one, expression eight would be simply $C = \rho K$. This gives us the usual "Calvinist" vision of growth: a more thrift nation, which gives a high weight to the future (low $\rho$) would consume less today but grow faster and consume more in the future.

Using expression eight above, the government problem is:

$$\max_{\{\lambda, \tau\}} \int_0^\tau \left( \left( \frac{\left( r(\lambda, \tau) - \delta \right) (1 - \gamma) + \rho / \sigma}{k^{1-\sigma}} \right)^{1-\sigma} \right) e^{-\rho t} dt$$

s.t. $\dot{k} = \gamma(\lambda, \tau) k$

The Hamiltonian of this problem is given by:

$$H(\lambda, \tau) = \left( \left( \frac{\left( r(\lambda, \tau) - \delta \right) (1 - \gamma) + \rho / \sigma}{k^{1-\sigma}} \right)^{1-\sigma} \right) - 1 + \theta \gamma(\lambda, \tau) k$$

Taking derivatives with respect to $\tau$ and $\lambda$, we obtain:
Taking into account (from 5) that the derivative of the interest rate with respect to \( \tau \) and \( \lambda \) is equal to \( \sigma \) times the derivative of the growth rate with respect to the same variables, expressions nine and ten reduces to:

\[
(11) \quad (c^{-\sigma} (1-\gamma) \sigma + \theta) \frac{\partial \gamma}{\partial i} = 0, \quad i = \lambda, \tau
\]

The left hand side of expression 11 is only zero when \( dy/d\tau \) and \( dy/d\lambda \) are zero, as the term in brackets is positive for the vast majority of estimates of the parameter \( \sigma \): consequently for this particular economy the optimal tax rate and \( \lambda \) are the ones that maximize growth. A government that aims to maximize the welfare of its citizens should pick a policy that maximizes the growth of the economy: choose \( \tau^* \) equal to \( \phi / (1+\phi) \) and \( \lambda \) equal to one. Both these results are somehow expected but they are by no means general. If the transfers are not zero or, as we will see next, there are public goods that affect people's utility, the optimal policy will no longer be to maximize growth.
3. A Model With Public Goods

We now introduce a public good in this economy. The present model is similar in everything to the previous one but for the presence of a public good, financed by a proportion \((1 - \lambda)\) of tax revenues, in the instantaneous utility function:

\[
\begin{align*}
u (c_t, v_t) &= \frac{c_{t-\lambda}^{1-\sigma} - 1}{1-\sigma} \cdot v_t^{\sigma} \\
\end{align*}
\]

In the expression above, \(v_t\) is given by \((1 - \lambda) g = (1 - \lambda) \tau\), as \(g\) is given by \(G/Y\) and \(G\) is simply \(\tau\) times the income. We are implicitly assuming that the consumption of public goods is subject to some form of congestion, so that it is its proportion to income and not its absolute supply that affects the consumer's utility. Moreover, with this hypothesis, \(v_t\) is constant for given \(\lambda\) and \(\tau\).

The consumer solves the same problem as in the last section, using the now amplified utility function and noting that there are no transfers. The technology is the same with a proportion \(\lambda\) of government expenditures going to investment which is an argument of the production function. Government finances its expenses by taxing income with a tax rate of \(\tau\).

The first order condition of the representative consumer's problem with respect to consumption and capital are given by, respectively.

\[
\begin{align*}
(11) \quad c_t^{\sigma} v^{\alpha} &= \phi \\
(12) \quad \dot{\phi} &= \phi \left( \rho - r + \delta \right)
\end{align*}
\]
Notice that $v$ is constant, so that the growth rate of consumption is still given by

$$\gamma = (((1-t)A(\lambda \tau)^\phi - \delta \cdot p)/\sigma$$

and it is straightforward to show that capital, income and public expenses all grow at this same rate. Given the way public goods were introduced in the utility function - and this is one of the only two ways compatible with a balanced growth path (the other one is the logarithm utility function) in "AK" models - the growth rate has exactly the same form as in the previous model without public goods. Consequently, it is still the case that the growth rate grows with $\tau$ for rates below $\phi/(1+\phi)$ and always grow with $\lambda$, so that growth is maximized at

$$\tau = \tau^* = \frac{\phi}{1+\phi}, \text{ and } \lambda = \lambda^* = 1$$

The government problem, however, is no longer the same. Now he must weight the growth effect of extra investments against the utility gain of additional public goods. It is still the case that the consumption decision rule is given by

$$c = \left( (r(\lambda, \tau) - \delta)(1-\gamma) + \frac{\rho}{\sigma} \right) k$$

so that the problem is now
The only difference with respect to the previous case is the presence of the term \((1 - \lambda \tau)\alpha\) in the utility function. The first order conditions with respect to \(\tau\) and \(\lambda\) are now, respectively,

\[
\begin{align*}
\frac{\partial}{\partial \tau} U(c_t, v) &+ \theta k \frac{\partial}{\partial \tau} + \frac{\alpha U(c_t, v)}{v} \frac{\partial v}{\partial \tau} = 0, \\
\frac{\partial}{\partial \lambda} U(c_t, v) &+ \theta k \frac{\partial}{\partial \lambda} + \frac{\alpha U(c_t, v)}{v} \frac{\partial v}{\partial \lambda} = 0
\end{align*}
\]

Expression 12, after some simplifications reduces to

\[
\begin{align*}
( -\sigma (1 - \gamma) k((1 - \lambda \tau)^\alpha + \theta k \frac{\partial}{\partial \tau} + \frac{\alpha U(c_t, v)}{v} \frac{\partial v}{\partial \tau} = 0
\end{align*}
\]

The first thing that calls our attention is that \(\tau = \tau^*\), the tax rate that maximizes growth, is no longer the optimal policy. This would only be the case if the last term in the left hand case was zero, which corresponds to the previous case without public good. In
this case the only solution would still be $\frac{\partial y}{\partial \tau} = 0$. Now, in order for the whole expression to be zero, $\frac{\partial y}{\partial \tau}$ cannot be zero any longer. Moreover, given that the term in brackets in the first expression in the left hand side is positive as well as the second expression, it turns out that $\frac{\partial y}{\partial \tau}$ has to be negative in order for the whole expression to be zero. But we know that this derivative is only negative for tax rates greater than $\tau^*$, so that in this case the optimal policy is to use a tax rate greater than the one that maximizes growth.

This result is similar, as we will see in the next section, to results obtained by Alesina and Rodrik (1992). The intuition for it is the following: at $\tau$ equal to $\tau^*$, the first order effect of an increase in the tax rate over growth is zero as this is the rate that maximizes growth, so there is only a second order effect. However, there is a first order effect over public goods: as the tax rate deviates from $\tau^*$ the government can increase welfare by financing extra public goods. Hence, there is an incentive for the government to deviate from $\tau^*$, and to operate at tax rates higher than that.

It is interesting to notice that, as we saw in the last section, governments in general operate at tax rates (in the models of section two and three: at government sizes) that are well above the ones that maximize growth. One possible explanation advanced by the present model is the fact that they operate with multiple tasks and objectives and that at least part of their actions affect the utility of agents. This imply that the optimal tax rates are above $\tau^*$, as we just saw. Of course, the environment that government choose their policies is much richer than ours, but the lesson from this section remains true: it is not necessarily bad that governments policies do not maximize economic growth, this can be an answer for the demands of its citizens.

Expression 13, after some manipulations becomes

$$
(15) \quad \left( c^{-\sigma} (\sigma - 1) \nu^\sigma + \theta \right) k \frac{\partial \gamma}{\partial \lambda} - \frac{\alpha U(c, \nu)}{(1 - \lambda)} = 0
$$
From 14 and 15 we obtain:

\[
\frac{\gamma_t}{\gamma_{\lambda}} = -\frac{(1 - \lambda)}{\tau}
\]

Which after some manipulations becomes:

\[
(16) \quad -\frac{(1 - \lambda)(1 - \tau)}{\tau}\frac{1}{\lambda} = \left(\frac{(1 - \tau)}{\tau}\phi - 1\right)
\]

Lambda equal to one in expression 16 is only a solution when the right hand side is zero, which corresponds to the case when \(\tau\) is equal to \(\tau^* = \phi / (1 + \phi)\), the tax rate that maximizes growth. But the optimal rate \(\tau\) is greater than \(\tau^*\) so that \(\lambda\) is always less than one. This makes economic sense, as lambda equal to one implies zero public goods in this model. Consequently, any increase in \(\lambda\) would increase the consumers welfare, because the utility level is zero with zero public goods.

4 A Model With Two Classes

In this section we present a synthesis of the main results of Alesina and Rodrik (1991 and 1992) and compare them with some of our previous findings. In this model the technology is given by
\[ Y_t = AK^{a}G_t^{1-a}L_t^{1-a} \]

where \( L \) is labor and \( G \) is public investment in infrastructure. Government finances its expenses only with a tax over capital stock, and a proportion \( \lambda \) of the revenues goes to public investment, so that \( G \) is given by \( \lambda \tau K \), and \((1-\lambda)\) of the revenues are transferred to workers.

There are two classes in this economy. Capitalists live from capital income and are the only ones who save. Workers do not save and live from wage income and government transfers \( v_t \) which are equal to \((1-\lambda)\tau K^2\). The utility function of both classes is assumed to be logarithm. The problem of a representative capitalist is:

\[
\max_{\{c_t\}} \int_0^\infty \ln c_t e^{-\rho t} \, dt \\
\text{s.t.} \quad K = (r - \tau)K - C_k
\]

It is straightforward to show from the first order conditions that the rate of growth of \( C_k \), \( \gamma \), is given by \((r - \tau - \rho)\).

The problem of the representative worker is:

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2 The model could be written such that people would have income from both capital and wages, but with different proportions of income from each one of these sources, so that there is a distribution of capital and saving among the population. This would not change the basic conclusions we want to stress here, and this path is investigate by the authors in a section of the original paper.
\[
\max_{\{C_t\}} \int_0^T \ln C_t e^{-r_t} dt \\
\text{s.t. } C_L = wL + v
\]

Notice, as we have already stressed, that the representative worker do not save, he consumes the equivalent of his income in every period, which is equal to his wage income plus government transfers. Notice also that workers and capitalist are assumed to have the same discount rate. This is not necessary for the results, it only simplifies the algebra.

It can be shown, solving the consumer's problem and using the transversality condition of the capitalist's problem, that income, capital and the consumption of the representative worker all grow at the same rate \( \gamma \) as the consumption of the capitalist.

From the firms' problem we obtain the equilibrium wage and interest rate:

\[
r = \frac{\partial y}{\partial K} = \alpha A (\lambda \tau )^{1-\alpha} \equiv r(\lambda, \tau) \\
w = \frac{\partial y}{\partial L} = (1-\alpha) A (\lambda \tau )^{1-\alpha} K \equiv \omega(\lambda, \tau) K
\]

Using the expression for the interest rate the growth rate can be written as:

\[
\gamma = \alpha A (\lambda \tau )^{1-\alpha} - \tau - \rho = \gamma(\lambda, \tau)
\]

The derivative of the growth rate with respect to lambda is always positive, so that as in the previous models, growth is maximized when the government expends all its
money in investments and none in transfers, which in the present case goes entirely to the workers. On the other hand from the derivative of $\gamma$ with respect to $\tau$ we obtain that growth is maximized when

$$\tau = \tau^* = [\alpha(1 - \alpha)A \lambda^{1-a}]^\gamma = [\alpha(1 - \alpha)A]^\gamma$$

In the last expression in the right hand side we used the fact that $\lambda$ equal to one maximizes growth and we also normalized $L$ to one without any loss of generality. From 17 it is possible to show that $\partial \gamma / \partial \tau$ is positive or negative either $\tau$ is greater or smaller than $[\alpha(1 - \alpha)A]^\gamma$. Hence, either tax increases will hurt or help economic growth depends on either the tax rate is already too high (above $\tau^*$) or still too low (below $\tau^*$). As in the two previous models the relationship between economic growth and taxation is not linear or monotone, and the productive role of (part of) public expenditures may counteract the distortionary effect of tax increases so that more taxes may be followed by an acceleration of growth if $\tau$ is less than $\tau^*$.

We will solve now the government problem. We suppose that the government gives a weight $\beta$ to workers and $(1 - \beta)$ to capitalists. His problem is

$$\max_{[\lambda, \tau]} (1 - \beta) \int_0^T \ln C_t e^{-\rho t} \, dt + \beta \int_0^T \ln C_L e^{-\rho t} \, dt$$

s.t. $C_t = \rho K$, $C_L = (\omega(\lambda, \tau) + (1 - \lambda)\tau) K$, $K = \gamma(\lambda, \tau) K$

The Hamiltonian of this problem is
\[ H(K, \tau, \lambda) = (1 - \beta) \ln \rho K + \beta \ln \left( \omega(\lambda, \tau) + (1 - \lambda) \tau \right) K + \theta \gamma(\lambda, \tau) K \]

Taking derivatives with respect to \( \lambda \) and \( \tau \) we obtain the following first order conditions:

\[ \frac{\partial H}{\partial \tau} = \beta \left( \frac{\partial \omega(\lambda, \tau)}{\partial \tau} + (1 - \lambda) \right) \frac{K}{C_L} + \theta \frac{\partial \gamma(\lambda, \tau)}{\partial \tau} K = 0 \quad (18) \]

\[ \frac{\partial H}{\partial \lambda} = \beta \left( \frac{\partial \omega(\lambda, \tau)}{\partial \lambda} - \tau \right) \frac{K}{C_L} + \theta \frac{\partial \gamma(\lambda, \tau)}{\partial \lambda} K = 0 \quad (19) \]

From expression 18 it is clear that the optimal tax rate is equal to \( \tau^* \), the tax rate that maximizes growth, only when the government gives no weight to the welfare of the representative worker. As long as \( \beta \) is greater than zero, \( \partial \gamma / \partial \tau \) is never zero in expression 18 and the growth rate is below the maximum. In other words, maximization of growth is the best choice for the welfare of the representative capitalist but not for the representative worker, so that only a government of the capitalists would maximize growth: in a economy with distributive conflict, maximizing growth does not imply maximizing welfare.

Notice also that the term in brackets in the first expression in the right hand side of (18) is always positive. This will imply that \( \partial \gamma / \partial \tau \) is negative so that the optimal tax rate is to the right of \( \tau^* \), the growth maximizing level. We obtain here the same result as in the model with public goods: at \( \tau^* \) both growth and capitalist welfare is maximized. Consequently, a marginal increase in \( \tau \) from \( \tau^* \) will have only a second-order effect on capitalist welfare but a first-order effect on the consumption of workers, so that workers are made better of and capitalists would remain unhurt. So, as long as the government
gives some weight to the welfare of workers he will pick $\tau$ greater than $\tau^*$, so that the growth rate will be below the maximum.

As opposed to the model with public goods and representative consumer, in this model it can be the case that the optimal $\lambda$ is the same as growth maximizing level, which is one. This is true either $\beta$ is too small, so that the government do no care very much to the welfare of workers, or $\rho$ is very small. In this last case workers do not discount heavily the future, so that they would rather sacrifice their level of consumption today (receiving less direct transfers) in order to have a higher rate of growth for all subsequent periods. But remember that $\tau$ is always above the growth maximizing level, so that even if there is no direct transfer at all and only public investments, the growth rate will never be at the maximum attainable level.

5. Growth and Money

In this section we introduce money in the model of section two and we keep the same technology with government investment as a separate argument of the production function. Following Sidrausky (1967), among others, money is an argument of the instantaneous utility function which is given by

$$U(c_t, m_t) = \beta \ln m_t + (1-\beta) \ln c_t$$

The consumer problem is now:

$$\max_{c_t, m_t} \int \left( \beta \ln m_t + (1-\beta) \ln c_t \right) e^{-\rho t} dt$$
\[ s.t. \dot{a} = r a_{t+1} - c_{t+1} - (\pi + r) m_{t+1}, \]

where \( a = k + m \) is the consumers' wealth, \( \pi \) is the rate of inflation and the interest rate \( r \) is equal to \((1-\tau)A(\lambda g)^{\phi}\). We assume for simplicity sake that government consumption is wasted and not transferred to consumers.

The Hamiltonian for this problem follows closely the Hamiltonian of the previous sections and its solution is given by the following first order conditions:

\begin{align}
(21) & \quad (1 - \beta) c^{-1} = \phi \\
(22) & \quad \beta m^{-1} = \phi (\pi + r) \\
(23) & \quad \phi = \phi (\rho - \gamma)
\end{align}

and appropriate transversality conditions.

From equations 21 and 23 above we obtain the rate of growth of consumption which is given by \( \gamma = \pi - \rho \), and is equivalent to the growth rate in the second section as \( \sigma \), is now equal to one. Also from equation 22 and 23 we obtain the rate of growth of money holdings which is identical to the growth rate of consumption, so that we have:
\[
\gamma = \frac{\dot{c}}{c} = \frac{\dot{m}}{m} = (r - \rho)
\]

Using the transversality condition for capital accumulation and the law of motion of the wealth variable we can also show that capital grows at the same rate \( \gamma \). First substitute \( m \) in the law of motion of wealth to obtain

\[
\dot{k} + m = rk - c - \pi m
\]

Notice that by definition (as \( m = M/p \)) \( \dot{m} = (\mu - \pi)m_{(t)} \), where \( \mu \) is the rate of money creation. Substitute in the above expression to obtain:

\[
\dot{k} - rk_{(c)} = -c_{(c)} - \mu m_{(c)}.
\]

The solution for this differential equation is given by

\[
k_{c} = e^{rt}N - e^{rt} \int (c_{c} + \mu m_{c}) e^{-rt} \, dt = e^{rt}N - e^{rt} \int (c_{0} + \mu m_{0}) e^{-\rho t} \, dt
\]

\[
= e^{rt}N + \frac{c_{0} + \mu m_{0}}{\rho} e^{(r-\rho)t}
\]
where $N$ is an arbitrary constant.

Using the transversality condition is straightforward to show that $N$ is equal to zero, so that capital is given by the second expression in the right hand side. Simple differentiation of this expression gives the desired result that the growth rate of capital is also $(\tau - \rho)$, so that all the variables are growing at the same rate $\gamma$. We can, consequently, reproduce part of the analysis of the previous sections, specially the results concerning the effects of changes in $\lambda$ and $\tau$. The response of the growth rate to variations in the proportion of productive public capital ($\lambda$) follows exactly expression 6 in that $\gamma$ unambiguously increases with $\lambda$ (what comes with no surprise as $\lambda$ affects the interest rate by construction) so that $\lambda$ equal to one maximizes growth.

The derivative of $\gamma$ with respect to the tax rate is given by:

\[
\frac{d\gamma}{d\tau} = A(\lambda \sigma)^\phi \left[ \frac{(1 - \tau)}{\tau} \phi \eta_{\gamma,\tau} - 1 \right]
\]

Equation twenty four corresponds exactly to equation seven of section two. Hence, the response of $\gamma$ to changes in the tax rates still depends on the relative size of $\phi$, $\tau$ and the elasticity of $g$ with respect to tax. Note, however, that the elasticity is no longer constant and equal to one as $G$ is given now by $G = ty + \mu m$, and the total seignorage, $\mu m$, changes when the tax rate changes. The derivative of the growth rate with respect to $\mu$ is given by:

\[
\frac{d\gamma}{d\mu} = A(\lambda g)^\phi \frac{(1 - \tau)}{\mu} \phi \eta_{\gamma,\mu}
\]

The sign of expression 25 depends only on the elasticity of $g$ with respect of $\mu$ being positive or negative, given that all the other terms are positive. Everything else being
constant, as long as the receipt from money creation grows with μ the common rate of
growth of the economy rises with μ. This result contrast with the superneutrality result
from the Sidrausky model. With the introduction of public expenditures in the production
function financed partly by seignorage this is no longer true. Once some functionality is
given to public expenditures we can see from expression 25 above the growth rate of
money supply affects the common growth rate of all real variables of the economy.

Note however that the maximization of growth does not necessary implies
maximization of seignorage. Expression 25 is zero only when \( \eta_{g\mu} \) is zero. But \( \eta_{g\mu} \) is
given by

\[
\eta_{g\mu} = \frac{\mu m}{g y} \left( 1 + \eta_{m\mu} - \eta_{s\mu} \right)
\]

where \( \eta_{m\mu} \) is the elasticity of money balances with respect to μ and \( \eta_{s\mu} \) is the
income elasticity to μ. Seignorage is maximized when \( \eta_{m\mu} \) equals minus one, which is the
usual Cagan condition. But growth is maximized when \( \eta_{m\mu} \) equals minus one plus \( \eta_{s\mu} \),
or when the difference of these two elasticities equals minus one.

We can derive now the policy functions of the model, following Roubini and Sala­
i-Martin (1992). Just as a matter of simplification we will temporarily assume that \( \beta \) is
equal to one half. Note that from the first order condition for money and consumption we
obtain

\[
m = \frac{c}{\pi + r} = \frac{c}{\rho + \mu}
\]

Substituting in the expression for capital we obtain
From this expression we can derive easily the policy functions for consumption and money holdings:

\[
k = c \left[ 1 + \frac{\mu}{\rho + \mu} \right]
\]

\[
c = \rho \frac{\mu + \rho}{2\mu + \rho} k
\]

\[
m = \frac{\rho}{2\mu + \rho} k
\]

Note that, for a given \(k_t\), the level of both consumption and money holdings fall with the rate of money supply. The effect over consumption contrast again with the superneutrality of money in the original Sidrausky model. Note however that \(k_t = k_0 e^{\gamma t}\) and the growth rate depends indirectly of \(\mu\) because it affects government expenditures. So the final effect of a variation in of \(\mu\) over consumption and money holdings is not unambiguous negative.

We can use the two decisions rules above to study the problem of a government that wants to maximize the welfare of the agents picking \(\lambda, \tau\) and \(\mu\) optimally. Plugging them in the utility function and after some manipulations we get the following problem for the central planner:
\[
\max_{(\lambda, \mu, \tau, K)} \int_0^T \left\{ \ln pK + \beta \ln(\mu + \rho) - \ln(2\mu + \rho) \right\} e^{-\rho t} dt
\]

\text{s.t.} \quad \dot{k} = \gamma(\lambda, \mu, \tau) k \quad \text{for} \quad i = \lambda, \tau

The Hamiltonian now is given by:

\[
H(\lambda, \tau, \mu, K) = \ln pK + \beta \ln(\mu + \rho) - \ln(2\mu + \rho) + \theta \gamma(\lambda, \mu, \tau) k
\]

It is clear that the maximizing levels of \(\tau\) and \(\lambda\) of this problem are the same that maximizes the growth rate as

\[
\frac{\partial H}{\partial i} = \theta \frac{\partial \gamma}{\partial i} K, \quad \text{for} \quad i = \lambda, \tau
\]

In the above expression we obtain the same result than in section two. When transfers do not affect agents’ utility or budget constraint maximization of growth is always the optimal tax and investment policy. However, the same is not true for the rate of money growth, the optimal and the maximizing growth rate do not coincide. The first order condition with respect to \(\mu\) is

\[
\left( -\frac{2}{2\mu + \rho} + \frac{\beta}{\mu + \rho} \right) + \theta \frac{\partial \gamma}{\partial \mu} K = 0
\]

---

\text{3 We can go easily from} \quad \dot{k} + \dot{\tilde{m}} = e k_{t-c} - c_{t-1} - \pi m_{t-c} \text{ to} \quad \dot{k} = \gamma(\lambda, \mu, \tau) k, \text{ by plugging} \quad \tilde{m} = (\mu - \pi) m_{t-c} \text{ in the first expression and then substituting in the decision rule for} \quad m \text{ in terms of} \quad k.
The expression in brackets in the left hand side is unambiguous negative for any \( \beta \) (and not only one half, the value we derived the policy functions) so that \( \partial y / \partial \mu \) has to be positive for this expression to be zero. This implies that the optimal growth rate of money is below the growth maximizing rate. The level of consumption and money holdings, given by the policy functions above, falls with \( \mu \) for a given \( K \), so that the positive growth effect of more inflation taxes trades off with this negative level effect. In other words, a small decrease from the maximum growth level \( \mu \) has no first order effect over growth rates but increase consumption and money holdings, and consequently, consumer welfare.

As a last remark, it is possible to show that once public goods or direct transfer are introduced in this problem the \( \tau \) and \( \lambda \) picked by the central planner are no longer the same than the tax rates and public investment ratios that maximize growth. This result reproduces for this more general framework the results we obtained in the previous sections where maximization of growth rates is only optimal when the government sole action is to invest in infrastructure.

**Concluding Remarks**

In this article we studied the effect of fiscal and monetary policies in economies where public investment is part of the productive process. The four models presented have in common the same technology where public investment in infrastructure is a separate argument of the production function.

We used these set ups to answer some questions about the relationship between public policy, economic growth and welfare. We arrived to some general conclusions:

- Once the productive role of government is taken into account it is possible to have an interval of tax rates where growth rates increase with taxes. The reason is that the negative impact of extra taxes on the return of private investment is outweighed by the increase in returns due to the rise of public investment. Also, growth rates always increase
with the public investment ratio. These results are present in other articles in the literature, for some of the frameworks we studied.

- With money in the utility function and productive public expenditures the superneutrality result of the sidrausky model no longer hold. We showed that the money growth rate affects both the level and growth rate of real variables. We also showed that it is possible that growth rates increase with inflation for some interval of money creation rates. For this interval, the positive effect on returns caused by the new investments outweigh the distortionary effect of inflation taxes.

- Only when there is no transfers, no public goods or no conflict between agents or group of agents it is optimal for a central planner to maximize growth. In general the optimal tax rate is above the maximizing growth tax rate and the optimal investment ratio is below one.

Although the frameworks used in the article are highly simplified, our intuition is that most of the results we obtained could be achieved in more rich environments, with more general technologies and information structures.

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