Welfare and Growth Effects of Alternative Fiscal Rules for Infrastructure Investment in Brazil

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Abstract

This article studies the interplay between fiscal rules, public investment and growth in Brazil. It is investigated if it would make sense to raise public investment and, if so, under which fiscal rule it is best to do it – whether through tax financing, debt financing, or a reduction of public consumption. We construct and simulate a competitive general equilibrium model, calibrated to Brazilian economy, in which public capital is a component of the production function and public consumption directly affects individuals' well-being. After assessing the impacts of alternative fiscal rules, the paper concludes that the most desirable financing scheme is the reduction of public consumption, which dominates the others in terms of output and welfare gains. The model replicates the observed growth slowdown of the Brazilian economy when we increase taxes and reduce public capital formation to the levels observed after 1980 and shows that the growth impact of the expansion of tax collection in Brazil was much larger than that of public investment compression.

Key Words: infrastructure; public goods; welfare and growth; public debt.
JEL Classification Numbers: E62, E65, H54, H30, O47.

1 Introduction

The productive impact of infrastructure has been investigated in the last years by an increasing number of studies, starting with Aschauer's (1989) pioneering article. These studies use different econometric techniques and data samples to estimate the output and productivity elasticity to public capital. Although the magnitudes found vary considerably, the overall estimates (e.g. Aschauer (1989), Ai and Cassou (1995), Easterly and Rebelo (1993) and Calderón and Servén (2003)) tend to confirm the hypothesis that infrastructure capital positively affects productivity and output.

At the same time, public investment in Brazil, as a share of gross domestic product (GDP), has been falling for the last twenty-five years. From 1960 to 1980 public investment ratio averaged 4.0% of GDP, but it was only 2.2% in 2002. Moreover, the decrease in infrastructure expenditure affected virtually all sectors. For instance, direct investment in roads from 1990 to 1995 was only, in real terms, one fifth of those made in the 1970-1975 period (Ferreira and Maliagros (1998)), while total public investment in the transportation sector today is less than 0.1% of GDP. The reduction in relative public capital formation coincides with the slowdown of GDP growth rates. While GDP per capita grew at around 3% from 1950 to 1980, in the following period this rate fell to less than 1%.

In this article we study the welfare and macroeconomic impact of government actions when its productive role is taken into account. In this sense, we construct and simulate a competitive general equilibrium model in which public investment can be financed through a variety of sources. Our model basically starts from the neoclassical growth models of Ferreira (1993) and Rioja and Glomm (2003), although the latter use an overlapping-generations framework, and add a budgetary regime analogous to the general case presented in Greiner and Semmler (2000). The model economy was solved by simulation techniques and parameters and functional forms were calibrated to match features of the actual Brazilian economy.

Hence, the main motivation for this article is the interplay between fiscal rules, investment and growth. The paper's core is whether (1) it would make sense to raise public investment and (2) if so, under which fiscal rule it is best to do it – whether through tax financing, debt financing, or a cut in public consumption.

With respect to the first question, we find that even using very conservative calibration for the elasticity of output to public capital, results show that, if the public investment ratio returned to its before-1980 level, output growth would be sizeable. Such result is robust to functional forms, reasonable combinations of parameters and fiscal rules. The welfare gains were in general smaller than output expansion, because, as public investment rises, work effort increases, public consumption temporarily decreases and, moreover, convergence is very slow. The welfare gains, in any case, were relevant and, although values vary considerably depending on the fiscal rule considered, may surpass 3% when using a measure based on compensated variations in consumption.

Most of the paper is dedicated to the second question above, comparisons of the impact of alternative fiscal rules to finance public capital expenditures. We investigate variations of three basic schemes. In the first one we mantain government size constant and reduce public consumption proportionally to the increase of public investment. Debt in this regime is used chiefly for interest payment. The second variation is a "looser" regime with respect to debt, as we allow the government to borrow to finance capital expenditures and not only interest payment. Finally, in the last fiscal regime we use tax expansion to pay for the extra investment.

We also perform a number of counterfactual exercises asking what would the GDP path be if public investment and taxes had not changed after 1980. This is indeed an important question since, after fluctuating around 25% for many years, tax collection in Brazil is today more then 35% of GDP. So, any simulation that does not consider this variation in tax structure will overestimate the impact of the fall of infrastructure investment on output.

When we increase taxes and reduce capital formation to the levels observed after 1980, the model is able to replicate the observed growth slowdown of the Brazilian economy. We then isolate the impact of each of these factors and show that the growth impact of the expansion of tax collection in Brazil was much larger than that of public investment reduction. At the same time, the welfare loss caused by the latter is one fifth of the one caused by the former. Although magnitudes vary, this result is robust to changes in parameters and functional forms.

The discussion of enlarging fiscal space for infrastructure investment in Brazil has to take this fact into account. This result suggest that the most promising direction in terms of output, consumption and welfare gains would be to reduce overall government size by cutting taxes. At present, this is surely not politically realistic. The best alternative, when we take into account the overall results of the different fiscal regimes simulations (apart from privatization or public-private partnership not dealt in this paper[1]), is the reduction of public consumption in favor of investments, keeping government size constant. Although the growth impact are similar in some other fiscal rules, welfare improves considerably more under this regime.

There is plenty of room for increasing fiscal space for investments only by rearranging expenditures. Tax collection has expanded significantly in the recent past, and in the last year, due to economic growth and new taxes, central government alone had some extra R$ 12 billion (close to US$ 4.1 billion) of unforeseen revenues that could have been used partly on capital expenditures. Moreover, current expenditures increased significantly in the past, so that some compression here is feasible[2]. However, after some obvious cuts, this may imply tough political battles on issues such as social security reform. Moroever, in this article public consumption includes everything that is not investment, and so health and education spending, which is not exactly what one want to cut. Finally, as in most of the literature cited above, we are taking as given the fact that the private sector is not able to do the same as the public sector in the infrastructure sectors, otherwise we would not care about the public investment trajectory.

We proceed as follows. In the next section the model is presented, while section 3 discusses the simulation and calibration procedures. Results are presented in section 4 and some model variations in section 5. Finally, Section 6 concludes.

[1] See Ferreira (2001) for the welfare and output gains of privatization.

[2] The first and still tentative estimations of central government expenditures in 2004 indicate an increase of 10% in real terms. Which is extreme, even if we take into account that in 2003 there was some expenditure compression and that GDP should have grown in 2004 by 4 to 5 percent.

2 Model

2.1 Consumer

Consider an economy in which individuals are infinitely-lived and derive utility from private consumption (cp_t), leisure (l_t) and government consumption (Cg_t), which is basically a public good that does not suffer from congestion. Momentary utility is

$$U(cp_t, Cg_t, l_t) = \log(cp_t + \mu Cg_t) + A \log l_t,$$

where the parameter μ measures how a typical individual values public consumption relatively to private consumption. The specification for the relationship between private and public consumption follows Aschauer (1985), Barro (1981) and Christiano and Eichenbaum (1992).

Given an intertemporal discount factor $\beta \in (0,1)$, agents have preferences over streams of consumption and leisure according to the expression

$$\sum_{t=0}^{\infty} \beta^t U(cp_t, Cg_t, l_t). \tag{1}$$

In each period, there is a budget constraint limiting current spending on private consumption, private capital (k_{t+1}) and government bonds (b_{t+1}):

$$cp_t + k_{t+1} + b_{t+1} = (1-\tau_h) w_t h_t + (1 + (1-\tau_k) r_t - \delta) k_t + (1 + (1-\tau_k)\rho_t) b_t, \tag{2}$$

where w stands for wages, r for capital rents, δ is the constant geometric depreciation rate of private capital, τ_k (τ_h) is the tax rate on capital (labor) income, $h_t = 1 - l_t$ represents total hours worked when we normalize time endowment to unity, and ρ represents interests paid on public debt.

2.2 Production

Productive activities are undertaken by a single firm. It uses private capital, labor and also public capital (Kg_t) to produce:

$$Y_t = F(Kg_t, K_t, H_t) = Z_t Kg_t^{\phi} K_t^{\theta} H_t^{1-\theta}, \tag{3}$$

where Z_t is an exogenous technological factor. The assumption on Kg_t follows Barro (1990), Barro and Sala-i-Martin (1993), and Aschauer (1989). It implies that public and private capital are not perfect substitutes and that public capital (e.g., infrastructure) is essential to private production. Capital letters are used to represent aggregate variables (taken as given by the consumer), while small letters represent individual specific variables which are chosen by the household. Notice that, even though the production function F has constant returns to scale to private inputs, it also includes public capital as an externality whose intensity is regulated by $\phi > 0$.

As usual we assume that the firm maximizes its profits by solving

$$\max_{H_t,K_t}\left\{Z_tKg_t^{\phi}K_t^{\theta}H_t^{1-\theta}-w_tH_t-r_tK_t\right\} \tag{4}$$

each period.

In this economy we assume, to simplify matters, that $Z_t = Z$ for all periods. However, we could, making small adaptations in the production function, impose exogenous growth to the model. For instance, we could assume that $Y = K_t^{\theta}\left(Z_tH_t\right)^{1-\theta}\widetilde{Kg}_t^{\phi}$, with $Z_t > 1$ and $\widetilde{Kg}$ representing public capital in effective units (i.e., divided by Z_t). With this formulation the steady-state of the model would be a balanced growth path where variables grow every period by $Z_t - 1$. Results would not change at all, only their interpretations. Another alternative would be $Y = Kg_t^{\phi}K_t^{\theta}\left(Z_tH_t\right)^{1-\theta-\phi}$. Results with the latter are very close to those that used (3) and are presented in the appendix.

2.3 Government

Public sector levies linear taxes on private capital returns, government bonds returns and labor income. In addition, government finances its expenditures either by current tax revenue or by issuing public debt:

$$Cg_t + Ig_t + \rho_tB_t = G_t + B_{t+1} - B_t, \tag{5}$$

where $G_t = \tau_kr_tK_t + \tau_k\rho_tB_t + \tau_hw_tH_t$ represents total taxes revenue and $Ig_t = Kg_{t+1} - (1 - \delta_g)Kg_t$ stands for public investment in infrastrucuture (δ_g is the public capital depreciation rate).

We consider a budgetary regime analogous to the general case presented in Greiner and Semmler (2000). Government allocates a fixed fraction γ_0 of current tax revenue to finance public consumption and a fraction γ_1 of interest payments:

$$Cg_t + \gamma_1\rho_tB_t = \gamma_0G_t. \tag{6}$$

Public investment is financed by a fraction γ_2 of the remaining proceedings, that is:

$$Ig_t = \gamma_2(1-\gamma_0)G_t. \tag{7}$$

Notice that, substituting (6) and (7) into (5), we get $\Delta B_{t+1} = \left(\gamma_0 + \gamma_2(1-\gamma_0) - 1\right)G_t + (1-\gamma_1)\rho_tB_t$. Then, government tends to accumulate more debt the lower is the fraction of current revenue allocated to interest payments (γ_1) and the higher is the residual fraction of tax revenue to finance public investment in infrastructure, $\gamma_2(1-\gamma_0)$.

Other authors such as Turnovsky (1997, 2000) have also considered the case of running public deficit to finance public investment. However, the budgetary structure set forth in Greiner and Semmler (2000) is more general and also analytically very tractable. Note also that if we rule out public debt (that is, $B_t = 0$ for all t), it clearly encompasses a non-debt model as a particular case by setting $\gamma_0 = 1-\alpha$ and $\gamma_2 = 1$, where $\alpha = \frac{Ig_t}{G_t}$ in such restricted model. Later on we also report some results on this non-debt model.

3 Calibration and Simulation Procedures

In this section we propose a benchmark calibration for the structure of the Brazilian economy as of 2004. The parameters are chosen based on existing empirical works for Brazil whenever they are available and also based on the restrictions derived from the equilibrium solution of the model.

We set $\mu = 0.5$ as a benchmark, implying there is imperfect substitution between private and public consumption. Some sensitivity analysis is also performed in a non-debt model for the extreme cases of $\mu = 1$ (consumers weight public and private consumption equally) and $\mu = 0$ (public consumption is pure waste). Empirically, such calibration is supported by Evans and Karras (1996), who estimate $\mu = 1.14$ with a standard deviation of 0.63 via GMM. Since the GMM estimator is asymptotically normally distributted (Hansen (1982)), the three alternatives $\mu = 0$, 0.5 or 1 would not be rejected by standard hypotheses tests.

The parameter ϕ is a technology parameter and as such should be similar to all market economies. However, there is little consensus in the literature about the acceptable values of ϕ. For example, Ratner (1983), using U.S. annual data from 1949 and 1973, estimates output elasticity with respect to public capital around 0.06. Duffy-Deno and Eberts (1991) estimate similar and slightly higher values using data for 5 metropolitan areas of the U.S. The same is true in Canning and Fay (1993), who used a variety of cross-country data bases, and in Baffes and Shah (1993), who worked with OECD and developing country data. Aschauer (1989) estimated much larger values, with ϕ ranging from 0.35 to 0.45.[3] Ferreira and Issler (1998) estimate a similar model using American quarterly data but they take in account non-stationarity of variables. Using co-integration methods they estimate long-run elasticity of output to public capital around 0.19. Ai and Cassou (1995) use the GMM method to estimate Euler equations of a dynamic model and also found values close to 0.2. On the other hand, Holtz-Eakin (1992) and Hulten and Schwab (1992) found no evidence of public capital affecting productivity.[4]

For the Latin America, Calderón and Servén (2004) estimated, using panel data methods, a Cobb-Douglas production function expanded by physical measures of infrastructure. They found output elasticities from 0.156, in the case of telephone lines, to 0.178 in the case of roads. The only (published) evidence for Brazil that we know is Ferreira and Maliagros (1999), that use co-integration methods and find long-run elasticities of output to infrastructure capital above 0.4. Note, however, that one has to be cautious to use these parameters estimates for ϕ, as there is not a one-to-one correspondence between then and the present model.[5]

Given this picture, we decided to be very conservative and pick a value in the lower range of these estimates so that our analysis should be understood as a "lower bound" to the effects

[3]He used, however, the OLS method, which may have biased his results because of endogeneity of variables. The method used, as pointed out by Gramlich (1994), also has a problem of common trends between the infrastructure series and the output series employed. Furthermore, the rate of return on public capital implied by these estimates lies above that of private capital, a very implausible result.

[4]This list is by no means complete, since the empirical literature on the subject is quite large. See Gramlich (1994) and Glomm and Ravikumar (1997) for surveys.

[5]For instance, in our model here the production function says that output is a Cobb-Douglas function of capital, labor and public infrastructure. The co-integration estimates in Ferreira and Maliagros (1999) assume no causality and estimates basically a long-run relationship assuming no functional form. It is also not clear how precise it is to use long-run elasticities to investigate short-run fluctuations of output.

of public infrastructure on economic variables. In contrast, using higher values such as those in Ferreira and Maliagros (1999) we could be driving results, as any small increase in public investment, almost by construction, would have a huge impact on the economy. We pick $\phi = 0.09$ as estimated by Ferreira (1993) for the U.S. economy and also normalize, without any loss, $Z = 1$.

Depreciation rate is $\delta = \delta_g = 0.0656$, following in the first case Araújo and Ferreira (1999), and setting δ_g for symmetry.

In the model, interest rate is determined by the marginal productivity of capital: $r = \theta K g^{\phi} \left(\frac{H}{K}\right)^{(1-\theta)}$. This equation can be rewritten as:

$$\theta = \frac{rK}{Y}.$$

From the National Accounting data we have that $\frac{K}{Y} = 2.98$. We set ρ, steady-state real interest paid on public debt, to 5%. There is evidence that taxes levied on capital correspond to 8.01% of GDP when we include investment taxes.[6] Since our model also allows for public debt, we equally divide capital taxes to GDP ratio into taxes on physical capital accumulation and taxes on government bonds. In this sense we have $\frac{\tau_k r K}{Y} = \frac{\tau_k \rho B}{Y} = \frac{0.0801}{2}$. In equilibrium, the return of public debt net of taxes must be equal to the return on capital also net of taxes, because only one financial asset is required to accomplish all intertemporal trades in a model without uncertainty. Mathematically:

$$\rho_t = r_t - \frac{\delta}{1-\tau_k}. \tag{8}$$

Therefore, given depreciation rate δ, the participation of capital taxes on GDP, (private) capital to GDP ratio, and ρ, the following non-linear equation (derived from $\tau_k r K = \frac{0.0801}{2} Y$ and (8)) is solved to find τ_k:

$$\tau_k \left(\rho + \frac{\delta}{1-\tau_k}\right) = \frac{0.0801}{2}\frac{Y}{K}.$$

Given $\tau_k = 11\%$, which is the unique solution to the above equation subject to $\tau_k \in [0, 1]$, we finally set private capital share on product, θ, such that, using its own definition and the fact that, in steady-state, $r = \rho + \frac{\delta}{1-\tau_k} = 12.37\%$:

$$\theta = \frac{rK}{Y} = 0.3686.$$

Using the fact that labor income taxes represent 26.98% of GDP[7], we also obtain the labor

[6] This calculation is performed by using the decomposition of total taxes into its components as presented in Araújo and Ferreira (1999).

[7] Note that our model only allows for capital and labor taxes. In this sense it was proportionally transferred to labor taxes the consumption taxes and to capital taxes the taxes on investment, in order to obtain the observed tax ratio of the Brazilian economy, 35%. As our experiments relate to the overall level of tax collection and not to its distribuition, this procedure does not affect the results significantly.

tax rate:

$$\tau_h = 0.2698\frac{Y}{wH} = 0.4273.$$

Intertemporal discount factor, β, is found by using the long-run equation derived from first-order conditions of the model (see below):

$$\beta = \frac{1}{1 + (1-\tau_k)r - \delta},$$

yielding $\beta = 0.9574$. Lastly, $A = 2$ as in Cooley and Hansen (1992). This value implies that individuals spend about $\frac{2}{3}$ of their free time not working.

In order to calibrate the fiscal policy parameters γ_0, γ_1 and γ_2, we find analytical expressions for the known (as of 2004) ratios: $\frac{G}{Y}$, $\frac{Ig}{Y}$ and $\frac{B}{Y}$. In particular, we assume $\frac{G}{Y} = 0.35$ and $\frac{Ig}{Y} = 0.022$ (Ferreira (2004)), and set $\frac{B}{Y} = 0.56$ based on Afonso (2004). This last step in calibrating relevant parameters requires solving a non-linear system of equations subject to $(\gamma_0, \gamma_1, \gamma_2) \in [0,1]^3$. After using numerical methods so as to solve such system, we get the fiscal policy vector $\gamma = (\gamma_0, \gamma_1, \gamma_2) = (0.85, 0.11, 0.47)$.

The parameterized model is solved using numerical simulations. Steady-state values are easily found by means of the first-order conditions of the consumer problem (maximizing utility subject to budget constraints and taking aggregate variables and theis laws of motion as given) when $x_{t+1} = x_t$ and $X_t = x_t$ for each variable. Indeed, the first-order conditions are given by the following set of equations:

$$C_{t+1} = \beta(1 + (1-\tau_k)r_{t+1} - \delta)C_t, \tag{9}$$

$$C_{t+1} = \beta(1 + (1-\tau_k)\rho_{t+1})C_t, \tag{10}$$

$$(1-\tau_h)w_t(1-h_t) = AC_t. \tag{11}$$

The first two equations imply the arbitrage condition (8) between the price of government bonds and private capital. The steady-state of the model is computed using (9)-(11) and the constraints (2) and (5).The dynamics between steady-states is given by the system of equations consisting of (9), (11), and:

$$Ig_t = Kg_{t+1} - (1-\delta_g)Kg_t = \gamma_2(1-\gamma_0)G_t,$$

where

$$G_t = \left(\tau_h(1-\theta) + \tau_k\theta\right)Y_t + \tau_k\rho_t B_t. \tag{12}$$

The expression of total consumption that goes into (9) is given by

$$C_t = cp_t + \mu Cg_t = \Upsilon_1 Y_t - K_{t+1} + (1-\delta)K_t - B_{t+1} + \left(1 + \Upsilon_2\rho_t\right)B_t, \tag{13}$$

where Υ_1 and Υ_2, both greater than zero, are constants that depend upon parameters of the model.

A law of motion describing public debt evolving over time has the following expression:

$$B_{t+1} = \left(1 + \tilde{\rho}_t\right)B_t - \Upsilon_3 Y_t, \tag{14}$$

with $\tilde{\rho}_t = \Upsilon_4 \rho_t$, $0 \leq \Upsilon_3 \leq 1$ and Υ_4 being constants. Such equation is derived by substituting (6) and (7) into (5), and letting G_t and Cg_t be given, respectively, as in (12) and (13).

In order to rule out explosive paths of public debt, we impose a transversality condition (see (15) below) after solving forward the equation (14). After some algebra and letting

$$\lim_{T \to \infty} \frac{B_{T+t+1}}{\Pi_{j=0}^{T}(1+\tilde{\rho}_{t+j})} = 0, \tag{15}$$

which is true if we want to reach a new steady-state after T^* periods of transition, we get the following expression for public debt along the transition path $t = 1, ..., T^*$:

$$B_t = \quad \Upsilon_3 \underbrace{\left(\sum_{i=t}^{T^*} \frac{Y_i}{\Pi_{j=t}^{i}(1+\tilde{\rho}_j)} \right)}_{\text{present value of GDP path along transition}} \quad + \quad \Upsilon_3 \underbrace{\left(\frac{1}{\Pi_{j=t}^{T^*}(1+\tilde{\rho}_j)} \frac{Y_{new}}{\tilde{\rho}_{new}} \right)}_{\text{present value of GDP path after new steady-state}}, \tag{16}$$

where Y_{new} and $\tilde{\rho}_{new}$ correspond to the new steady-state values of GDP and $\Upsilon_4 \rho_t$, respectively. A necessary condition for convergence of the second term in (16) is that $\tilde{\rho}_{new} > 0$, which is true whenever $\Upsilon_4 > 0$, which requires $\gamma_1 < (1-\tau_k) + \tau_k\,(\gamma_0 + \gamma_2(1-\gamma_0))$.

3.1 Transition paths and welfare criterion

In our experiments we are not interested in merely finding steady-states and competitive recursive equilibria, but mostly in deriving the transition path from a given steady-state to a new one after some policy change. This is particularly important when attempting to assess the effects on variables such as welfare and production, because the transition path can have a long convergence period, implying that the full effect of a new fiscal policy would be felt many years or even decades later. It can also happen that variables can move for a large number of periods in the opposite direction of the final steady-state. In the last case, a policy that, for instance, increases the income level in the long run may be undesirable in the end because of the costs along the path to achieve the higher output level: given that we discount the future, a reduction of output in the initial periods may outweigh the long-run gains.

If the old steady-state is disturbed, for example, in period $t = 1$, the transition path is straightforwardly computed by taking decision variables indexed by $t = 0$ and state variables indexed by $t = 1$ as given, and solving the non-linear system given by (9)-(11), the laws of motion of K and Kg, and government budgetary regime. This system is solved until $t = T^*$ large enough so that the new steady-state is reached in $T^* + 1$. In the computations we set T^* to 150 years.

The first welfare measure is based on the change in total consumption (private plus public) required to keep the consumer as well-off under the new policy as under the original one. The measure of welfare loss (or gain) associated with the new policy is obtained computing compensating variations in consumption, x, that solves the following equation:

$$\log\left(C^B\right) + A\log(1-H^B) = \log\left((1+x)C^D\right) + A\log(1-H^D),$$

where C^i stands for long-run consumption under policy i and H^i has a similar interpretation.

If $x > 0$, we are better off in a world with the original policy, B, rather than with D. Both B and D are fairly general and represent any policy one may consider. Welfare changes will be expressed as either in terms of compensated consumption, x, or as a percentage of steady-state output ($\frac{\Delta C}{Y}$) where ΔC ($= xC^D$) is the total change in consumption required to restore an individual to the previous utility level.

Besides this long-run welfare analysis, we also perform the computation of the compensating variation in consumption by taking into account the transition path. As said before, this will be the main focus of our analysis. In this case, our task consists in assessing the welfare gains by considering not only the steady-state utilities but also the momentary utility along the transition path. If $\bar{U}^B$ represents momentary utility under the old long-run equilibrium with policy B, we want to find x such that:

$$\sum_{t=0}^{T} \beta^t \left(\bar{U}^B - \left(\log \left((1+x) C_t^D \right) + A \log(1 - H_t^D) \right) \right) = 0, \tag{17}$$

where $T = \infty$ or T^* depending on whether we are interested in computing the welfare costs for the entire path or just for the first T^* periods. Our welfare measure in this case is x or the present value of ΔC ($= xC^D$) over all periods of simulation as a percentage of the present value of income:

$$wc = \frac{\sum_{t=0}^{T} \beta^t \Delta C}{\sum_{t=0}^{T} \beta^t Y_t^D}. \tag{18}$$

The scaling of the present value of consumption in (18) by $\sum_{t=0}^{T} \beta^t Y_t^D$ is the transition path equivalent of measuring an economic variable in terms of GDP.

Finally, we also calculate the momentary utility derived from a given level of consumption and leisure, that is, $U_t = \log C_t + A \log(1 - H_t)$. Given an initial level U_0, we will be concerned on the percentage deviation from it: $100 \left(\frac{U_t - U_0}{U_0} \right)$.

4 Results

4.1 Effects of increasing current public infrastructure expenditure

4.1.1 Public consumption-financed expansion of public investment

Public investment in Brazil as a fraction of GDP is currently around 2.2%. However, two decades ago it was close to 4%. In this subsection we ask the following question: what are the economic effects of doubling the current public investment to GDP ratio, returning to its before-1980 level, at the same time that we reduce public consumption proportionally?

To this end, the new fiscal policy is expressed by $\gamma = (0.79, 0.06, 0.60)$, which gives exactly the targeted change in public investment. At the same time, we keep $\frac{B}{Y}$ and $\frac{G}{Y}$ fixed at their 2004 levels. Everything else remains the same, so that we are basically comparing a stylized picture of Brazil today with one of Brazil today with proportionally more public investment. This scenario corresponds to a *"public consumption-financed expansion of public investment"*. The outcome of the model simulation along the transition path is displayed in figures 1 to

4. They show the percentage change of several variables with respect to the their original steady-state values.

The model predicts (see Figure 1) that in the long run output and capital expand by almost 11%. One possible interpretation of this results is that if the Brazilian economy returned to the public investment ratios of the sixties and seventies, we would observe growth acceleration in the short to medium run, and a slow convergence so that, after 60 years, the country would be growing at its steady-state growth rate but with output levels 11% higher. If, for instance, Brazilian long-run growth rate is that observed from 1950 to 1980, 3%, for the first ten years after this policy change, GDP per capita would grow at 3.5% on average and in the following ten at 3.4%.

The model predicts also that private consumption would increase (Figure 2) in the long run by 10% above its previous path, with half this gain in the first twenty years. At the same time, public consumption (i.e., the supply of public goods) would decrease by more than 6% in the first period after the policy change. This is so because the increase in public investment implies a reduction of public consumption in the short run. After a while, the impact on GDP, and so on taxation and public expenditures, of higher public investments sets in and dominates the reduction on the Cg/GDP ratio, so that in the long run Cg increases by 4%. Adding up these variations, utility increases by almost 4% in the long run, considerably less than the gains in consumption, among other reasons because agents are working more now, which represents disutility.

Welfare gains, in terms of compensated consumption (i.e., x in expression (17)), when the transition path is taken into account are 3.6%. This means that consumption would have to decrease by almost 4% in the new regime to leave individuals as well off as in the old one. If we compare only steady-state utilities, the gains are even larger: 8.5%. The difference between the two welfare measures is due to the fact that the latter ignores the decrease in public consumption at the beginning of the transition path. As a proportion of the present value of income (i.e., wc) the gains are considerably smaller, 0.83%.

The dynamics of public debt is worth mentioning (see Figure 3). At the initial years of transition, the debt-to-GDP ratio increases by nearly 0.5 percent points because of the reduction of the fraction of current tax revenue allotted to interest payments (i.e., a lower γ_1). However, as the productivity effects of increasing public investment take place, the debt-to-GDP tends to its stable long-run level, 56%, after some years of undeshooting. In any case, debt to GDP ratio varies in a very thin interval. The behavior of interest rate is similar, as one can see in Figure 4. In this case, note that the long-run variation of K and GDP are very close to each other. Hence, given that $r = \theta Y/K$,after an initial increase (because during the transition Y grows faster in the initial periods) the interest rate in the long run returns to the same level as in the original steady-state.

4.1.2 Public consumption-financed expansion of public investment with higher debt ratio

The second scenario is an augmented version of the previous in which we also allow for an ad-hoc increase of public debt from 56% of GDP to 60%. Thus, public investment expansion here is partially financed by an increase of public debt. We assume that the economy is initially in the steady-equilibrium characterized by the benchmark calibration. Then, fiscal policy changes to $\gamma = (0.79, 0.10, 0.59)$, which implies a new steady-state where $\frac{Ig}{Y} = 0.04$ and $\frac{B}{Y} = 0.60$.

Steady-state comparisons suggest that changes in relevant variables are very close to those observed when debt-to-GDP ratio is kept constant and we increase public investment share by reducing proportionally government consumption. Output increases a bit less (11%), but private consumption a bit more (11.4%)

The growth gains are lower but very near to 0.4% point as in the first experiment. The transitional dynamics is qualitatively identical to previous cases so that we do not display the figures. Welfare gains in terms of consumption (i.e., x) are slightly lower: 3.36%. Finally, transition path of $\frac{B}{Y}$ is displayed in Figure 5 and shows that convergence is somewhat fast to it is new steady-state, even though there is a small overshooting at the very beginning of the path.

4.1.3 looser regimes

The "looser regime experiment" consists in changing the calibration of the budgetary regime parameters γ_0, γ_1 and γ_2 so that government is explicitly allowed to run public debt so as to finance public investment (i.e., $\gamma_2 > 1$). In this case the calibration of relevant parameters required solving a non-linear system of equations subject to $(\gamma_0, \gamma_1, \gamma_2) \in [0, 5]^3$,instead of $[0, 1]^3$ as in the benchmark calibration. After using the same numerical methods as before, we get now a fiscal policy vector $\gamma = (\gamma_0, \gamma_1, \gamma_2) = (0.95, 1.23, 1.41)$.

The experiment, as the previous two exercises, simulates the transition path from the benchmark economy to an economy with this new fiscal regime. The economic impacts of this policy are negligible. (See figures 6-7). No variable increases by more than 0.03% in the long-run, while public debt falls by only 0.33%. The long-run welfare gain is almost zero, 0.004%.

One variation of this scenario, say "looser 2", would be to force the public investment ratio to increase, in addition to $\gamma_2 > 1$ as above. So, in this experiment we fixed $\frac{Ig}{Y}$ to 4% as in the first two and, following the same procedure, solve the model to obtain a new fiscal policy vector γ, in this case $\gamma = (\gamma_0, \gamma_1, \gamma_2) = (0.95, 1.89, 2.59)$. By examining expression (7) it is clear that these parameters imply a significant boost in the share of investment in total public expenses. However, as we commented before, the higher is the residual fraction of tax revenue to finance public investment in infrastructure, $\gamma_2(1 - \gamma_0)$,the higher the growth in debt.

The effect on the economy of this new policy is now relevant. Long-run output increases by 12%, while private and public consumption by 34% and 4%, repectively. Growth rate, for the next twenty years, is 0.5% above the long run trend. Although utility increases by 4% in the long run, welfare gains (x) when taking into account the transition path is much smaller, only 0.8%. This is so because imediatialy after the policy switch, Cp falls by 10% and Cg by 80% (to compensante for the increase in Ig), so that in the short-run utility falls. As the converge is slow, the welfare variation is small. Finally, as expected, the long run level of public debt is now higher, 12% above the previous level.

Table 1 compares the main results of the four different fiscal regimes. We present long-run variation of output, private consumption , public capital and public debt and the two welfare measures that take into account the transition path. In all cases the benchmark economy is the "before" scenario (Brazil in 2004) and so the entries represent percentual variation with respect to it.

<<< Insert Table 1 >>>

With the exception of the "looser" regime in columm three, long-run output gains are very close to each other in the 3 remaining fiscal rules. Same is true for infrastructure and public debt (although, as expected, in the "public-financed investment with higher debt regime", in columm 2, debt variation is higher). However, welfare gains in the "public consumption-financed regime" clearly dominates both "looser" regimes. It seems that the use of debt to finance public investment does not add much in terms of output gains, but there are a clear disadvantage in terms of welfare. As we will see in the next section, there is also indications that a tax-financed investment expansion is inferior to a proportional reduction in public consumption, keeping government size constant.

4.2 Counterfactual exercises

From 1960 to 1980, public investment as a proportion of GDP averaged more or less 4% of GDP, with a maximum of 5.3% in 1969. In 2002 and 2003 it was only 2.2%. At the same time, after fluctuating for many years around 25% of GDP, tax collection in Brazil is above 35% of GDP today. Any evaluation of the impact of the compression of public capital expenditures in the recent past has to take into account this last fact. Otherwise the output and welfare losses due to investment cuts will certainly by overestimated. Moreover, although the direction of the impact is not clear, debt to GDP ratio in the same period went from 33% to 56% in the period.

In this section we perform a group of counterfactual exercises in order to investigate the impact on product and welfare of the increase in total taxes to 35% of GDP jointly with a reduction of public investment to 2.2% and an expension of B/Y to 56%. We assume that tax revenues are distributed as before between capital and labor, and that θ, δ, δ_g, ϕ and β remained constant over the last two decades. This is Policy 1 in Table 2 A second issue is to separate the impact of investment reduction from tax increases. Policy 2 keeps $\frac{Ig}{Y}$ constant and varies tax collection to 35%, while Policy 3 keeps tax rates constant and decreases $\frac{Ig}{Y}$ to 2.2%. In both cases the vector γ changed accordingly. Results for the 3 experiments are sumarized in Table 2.

<<< Insert Table 2 >>>

Transition paths for private and public consumption (Policy 1), hours and welfare (utility) are displayed in Figure 8 . Immediately after the policy switch, public consumption jumps up by more than 40% while hours and private consumption falls by more than 10% and utility increases slightly. However, the reduction of public investment (not displayed) has a direct impact on output. As public capital reduces over time, the marginal productivity of private capital also falls and hence private investment and capital too, hurting even more GDP (see figure 9). Consequently, both types of consumption fall over time and also utility.

Output loss in the long run is huge, 23.2%, and also steady-state welfare, almost 16%. Note that, when taking into account the transition path, welfare loss in terms of the compensated consumption measure, x, is also extremely high, 14.2%. It is much smaller, 3.17% ($= wc$), although still very large, when measuring it as a propotion of the present value of income. This is due to the fact that utility convergence very slowly to its long-run level, and future is discounted[8].

Growth loss is also sizeable. Instead of growing at 3% on average, as observed before 1980, the simulated economy grows by only 1.33% ,on average, until 1990 and 1.95% until 2000. How these numbers compares to the actual performance of the Brazilian economy? From 1980 to 1990 per capita GDP in Brazil grew at 0.3% per year, and in the next decade by 1.2%. Hence, the model under-predicts the slowdown of Brazilian GDP in the last decades, but explains in any case most of it. This result is not robust to changes in the calibration of relevant parameters, as we will see later. In the case of $\mu = 0$ (no weight to public consumption in welfare) the match is almost perfect. We find this hypothesis extreme, however, given the supply of security, justice, and other services by the government.

In the above simulation we showed that the model calibrated to the observed changes in tax collection and public investment reduction displayed large welfare and output losses. We now investigate which one of these factors were more relevant, tax expansion or investment fall. Suppose first that from 1980 to 2004 taxes increased (so that G/Y raises from 25% to 35%) whereas $\frac{Ig}{Y}$ remained constant. This is Policy 2 in Table 2, and the impact over economic variables are displayed in figures 10 and 11. The welfare cost of this policy change was estimated to be 2.44%,as proportion of present value of output, or 11.1% when measured by x.

The increase in τ_k and τ_h causes an immediate reduction on hours worked and private investment (not displayed), given that the net return of both factors were reduced. GDP drops down with hours and later with private capital. As we fixed public investment ratio, Kg also falls because tax collection was reduced. In the long run, output would be 14.4% smaller than it would be in the previous regime. The impact on private consumption is also significant (close to 20%) and it offsets, when considering utility, the expansion of Cg and the reduction in hours worked. The estimated reduction in growth of this policy was 1.46% in the first ten years and 0.76% in the nineties.

Finally, suppose that tax rates remained at the levels of 1980 so that G/Y is kept constant, but γ adjusted so that $\frac{Ig}{Y}$ in equilibrium falls from 4% to 2.2%. The variation of GDP and private capital is smaller than in the previous experiment, 11% in this case. At the same time, while in the previous case private consumption in the long-run would be 25% smaller after the policy change, it now falls less than 7%. As Cg initially increases and hours worked falls, the decrease in utility is now considerably smaller. As a matter of fact, the estimated welfare loss in present value terms is only 0.82% ($= wc$). This is one third of the loss estimated in the previous case. Likewise, we found $x = 3.69\%$.

In summary, the simulations indicate that the welfare and growth costs of the increase of tax collection in Brazil were far greater than those caused by the reduction of public

[8]Debt/GDP converge is instantaneous, immediatly after the policy change it jumps to the new ratio.

investment. In the last case, average growth rate in the ten years after the policy change falls by only 0.4 points, while the expansion of taxation alone would have induced a drop of 1.5 points, more than half the observed growth slowdown in the eighties. Although the sum of the welfare loss implied by Policies 2 and 3 overpredicted slightly that of Policy 1, due to non-linearities of the model, the observed increase in taxes explains almost 75% of the welfare loss and, at the same time, 56% of the output loss[9].

5 Alternative Scenarios: the model without debt

One problem of the above simulations is that, given the number of variables included and especially the procedures involved with public debt, it takes from five to six hours to run one single experiment. This of course limits sensitivity analisys and robustness checks. Given that we are running several of these experiments, the computational time implied render these sensitivity tests unfeseable in the present set up[10].

One possible (partial) solution is to run experiments without debt. By simplifiying considerably the model and, consequently, computer programs, simulations in this case last a very small fraction of the time of the complete program with public debt(at most five minutes). Of course, this would be a problem if results were too different from each other. However, this is not the case. For instance, in the very first model simulation, labeled "*public consumption-financed expansion of public investment*", instead of increasing by 11.5%, GDP now raises by 10.5%,while in both cases Kg doubles and Cg increases by 4%. Moreover, from Figure 12 it is clear that transition paths are also very similar (compares to Figure 1). This is also the case for Policy 1 and the other experiments.

In very few cases there are any significant differences and they all refer to welfare variations. In this sense, we opt to present a number of sensitivity exercises using the model without debt as we believe the result are very close to those of the model with public debt. Moreover, in one case (the "tax-financed investment") the simulations did not converge in the full model, so that we present below the results of this fiscal regime when using the model without public debt. In this case we compare results with those of the "consumption-financed" regime without public debt. This is done before the sensitivity analisys.

We propose an artifitial economy where the utility function, technology and firm´s problem is the same as the above, but with some relevant differences. The households' budget constraint is now given by:

$$cp_t + i_t = (1 - \tau_h)w_t h_t + (1 - \tau_k) r_t k_t,$$

By ruling out debt financing, government budget constraint reads:

$$Cg_t + Ig_t = G_t = \tau_k r_t K_t + \tau_h w_t H_t. \tag{19}$$

[9] As we will see in the next section, the impact of debt variation is very small. Replicating Policy 1 with no variation in debt found almost the same output loss and slightly higher welfare loss.

[10] For instance, suppose we want to check the effect of μ and ϕ on the simulation results. Suppose we want to use 3 alternative values for both parameters. So for every policy experiment above we would have 9 simulations. Only for the 3 counterfactual experiments this would add to 162 hours, if no mistake is commited.

For the sake of simplicity, we assume that government follows a simple and known rule to split its expenditures between consumption and investment:

$$Cg_t = (1-\alpha)G_t, \tag{20}$$

$$Ig_t = \alpha G_t, \tag{21}$$

where $0 \leq \alpha \leq 1$. Therefore, in our set-up fiscal policy is represented by the triple (τ_k, τ_h, α). Simulations, transition paths and welfare calculations follow closely those discussed in Section 3, and the calibration procedures are presented in an appendix.

5.1 Long-run relationships

The relativity simplicity of this model also allows us to better understand the economic effects of public investment. Steady-state is significantly influenced by the proportion of public investment in total public expenditures. If we increase α, government consumption decreases, while public capital rises (see figure 13). Note that public consumption increases with lower values of α. In this case the productive impact of public investment offsets the negative impact of lower consumption share, so that the level of Cg goes up.

This fact clearly presents a trade-off when α is raised. In the one hand, welfare tends to go down, because public consumption is lower after a certain level of α. On the other hand, welfare increases with Kg, as it has a positive effect on output and consumption. This fact is rarely taken into account in the analysis of the welfare and productive impact of infrastructure. Depending on the weight of public consumption on the government budget and how much agents value Cg, it may be the case that, although output always increase with α (see figure 14), welfare may improve with reductions of public investment.

In figure 16 below we can see clearly that the positive effects of Kg on GDP dominates up to a certain level of α, increasing income and private consumption sufficiently to raise steady-state welfare. After some threshold α^*, that depends of parameters such as ϕ and μ, welfare tends to decrease with expansions of public investment.

5.2 A new experiment: tax financed investment

The simplicity of the model without debt allowed us to to perform one extra experiment that we could not do in the original model due to the limitations of the simulation procedures. We want to investigate the economic impact of using an expansion of tax collection to finance the increase of public investment from 2.2% to 4% of GDP. In this sense, we keep consumption as a share of GDP constant but increase government size. In other words, while in the "public consumption-financed expansion of public investment" experiment we keep G/Y constant and decrease Cg/Y to finance Ig/Y, now Cg/Y is kept constant and G/Y rises accordingly (to 37% from 35%).

The gains now are smaller than those of simple switching Cg for Ig, although they are still sizeable. There is a long-run output gain of 7.34%(using the benchmark no-debt calibration) which is 3 points below that of the consumption-financed experiment. Likewise, the welfare gain in terms of consumption compensation is 4.04%, 2 points smaller. For the following 20 years the economy would grow at a rate 0.2% above its long-run trend, althouth there is an absolute reduction of GDP immediately the implementation of the new policy, because of the rising taxes, as one can see from Figure 16. The trajectory of most variables, in any case, are very close to those of the consumption-financed investement expansion rule.

Table 3 compares the main results of the 2 different fiscal regimes, the "public consumption-financed expansion of public investment" and the "tax-financed expansion of public investment".

<<< Insert Table 3 >>>

It is not surprising that the latter dominates the former in terms of long-run output growth and also in terms of welfare gains. Both experiments expand public investement by the same amount, but when using taxes the government increases alocative distortions in the economy, while in the "consumption-financed" fiscal rule taxes remain the same.

5.3 Sensitivity Analysis (μ and ϕ)

We adopted in the above experiments a conservative calibration for the parameter ϕ, picking a medium to lower value among the many estimates in the literature. We think this was the most reasonable choice, otherwise we could be blamed for artificially boosting the gains of infrastructure investment. However, it is interesting to check if results change too much when a larger value of this parameter is employed. In the case of the counterfactual exercises we would get a better assessment of the importance of taxation vis-à-vis infrastructure expenditures for the growth slowdown of the last two decades. In this sense we redo all the previous experiments with $\phi = 0.15$ and 0.20. These values are close to the estimations in Calderón and Servén (2003), for instance, and, in particular, $\phi = 0.15$ is the value used by Rioja and Glomm (2003).

At same time, previous experiments have assumed that private and public consumption are imperfect substitutes, i.e., $\mu < 0.5$. This is rather unfortunate assumption for some authors, who claim that public consumption is pure waste, with zero utility impact. In order to assess how the results would change we consider the extreme cases of $\mu = 0$ and 1. The former value implies that public consumption does not enter the utility function, while the latter means private and public consumption are now perfect substitutes.

First we consider the experiment of increasing public investment to GDP ratio from 2.2% to 4%, labelled "public consumption-financed expansion of public investment" (Table 4). As with all sensitivity analysis simulations, no qualitatively distinct dynamic behavior with respect to the variables along the transition path were observed, so that we opted not to present pictures. Focusing on the steady-state, main results are the following. If we hold ϕ constant at 0.09, when $\mu = 0$ output increases by 9.2% in the long-run, instead of 10.5% as in the benchmark case, a rather small change (see Table 4). At the same time, long run welfare (wc) falls marginally from 1.51% of GDP to 1.27%. On the other hand, growth gains are smaller, falling to 0.31% during the first 10 years (as opposed to 0.42%). Note that the growth costs for the case $\mu = 1$ almost match the actual growth slowdown of the Brazilian economy.

Similarly, results with respect to couterfactual "Policy 3" - keeping taxes constant at their 1980 level and reducing infrastructure investment from 4.4% to 2.2% - do no change much, as one can see from Table 7. This is expected given that both groups of simulations are close to each other. Note also that, if agents value public consumption as much as private consumption ($\mu = 1$), the welfare and growth gains of expanding government capital expenditures would increase with respect to those observed in the benchmark economy.

There are sizable differences with respect to the "Policy 1" and "Policy 2" counterfactual experiments. In both cases taxes decreases, but in the former infrastructure also falls while in the latter it remains constant at the 1980 level. In Policy 1, as one can see from Table 5, the fall of output when $\mu = 0$ is much smaller than when $\mu = 0.5$ (13% in the first case and 22% in the second, respectively). In contrast, welfare loss are larger in the first case. There is no puzzle here because the increase in public consumption observed in both experiments does not affect utility by construction when $\mu = 0$. Hence, although C_g raises by only 12% in the long run when $\mu = 1$, as opposed to 36% when $\mu = 0$, consumers do not benefit from the latter. In the former the increase in government current expenses partially compensates the loss in private consumption, and so welfare loss is smaller. The same reasoning works for Policy 2 displayed in Table 6 .

The big picture with respect to different utility function parametrizations is that output cost of tax variations are higher when agents value public consumption, but welfare losses smaller. In contrast, there are no relevant differences with respect to changes in the proportion of capital expenditures in the government budget.

If μ is held constant, higher values of ϕ are associated with greater levels of output, consumption and utility, whereas hours worked remain barely constant. Looking at the transition paths, the higher is ϕ, the greater is the growth in the short-run (although not by much). The transitional dynamics of simulations respecting policies 1, 2 and 3 do not display any surprising change, as already stressed. A complete understanding of how the model has performed under the sensitivity analysis exercises follows from the inspection of Tables 4-7. In the case where taxes are held constant, but Ig/Y falls to 2.2% (Policy 3) the output loss when $\phi = 0.2$ is more than twice as large as in the benchmark economy - as the impact of the decreased Kg is now applied - while welfare loss is three to four times larger, depending on the measure used.

6 Concluding Remarks

Results in this paper indicate that the compression of capital expenditures observed in the recent past may have played a significant role in the growth slowdown of the Brazilian economy after the eighties. Moreover, if public investment ratio return to its level of two decades ago, the country would converge to a balanced growth path in which GDP would be 11% greater than today's path. Growth rate would be 0.5 points above its after war average for at least 20 years. Welfare, in present value, would also improve, but in a smaller scale. This outcome could be achieved either by increasing permanently public debt from 56% of GDP to 60% or by reducing proportionally government consumption in favor of investment, keeping everything else constant.

The model was also used to investigate how much the deterioration of infrastructure conditions can explain the recent trajectory of the Brazilian economy. We concluded that it can replicate part of this path, but it seems that the aggressive increase of taxation after the eighties was considerably more detrimental to growth than public investment compression.

This should not surprise us. Tax base in Brazil was for many years 25% of GDP, but it is now more than 35%. Our calibration found that the corresponding increase in the capital tax rate was 39.8%, so that the negative impact on its return was strong, reducing the incentives to invest. The same is true with respect to the labor income taxation.

The lagging of infrastructure expenditure also affects returns, but our simulations showed that the growth and welfare impact were smaller. The main reasons are, in the one hand, that the impact is mostly felt in the long run, given that public capital is a stock. In the other hand, Kg enters in the production function to the power of ϕ, so that the impact of its variation on returns is drastically reduced (to the power of 0.09, in the present calibration).

The question of enlarging fiscal space to infrastructure investment has to take into account these observations. The simulations in the article, summarized in Tables 1 and 3, allow one to conclude that the reduction of public consumption to finance the necessary expansion of public capital investment is the most desirable fiscal scheme among those we examined. The use of debt to finance investment reached mixed results and tax financed investment was dominated in all dimensions by the consumption-financed investment rule. As we stressed in the introduction, there is certainly room for this type of policy in Brazil, especially when we take into account the recent increase of government size. Moreover, in all simulations the expansion in investment is relatively modest (although not the benefits) and can easily be financed by a small adjustment in public expenses.

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7 Figures and Tables

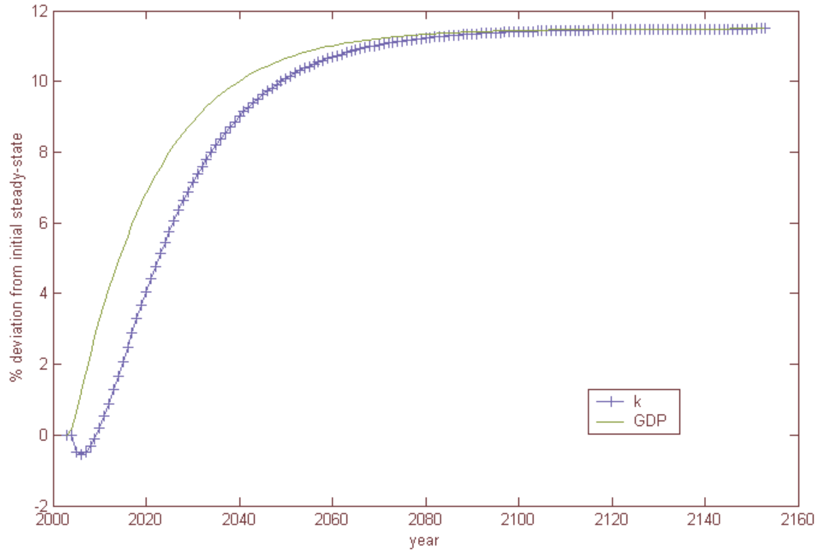

Figure 1: Transition path of capital and GDP ("consumption-financed" policy)

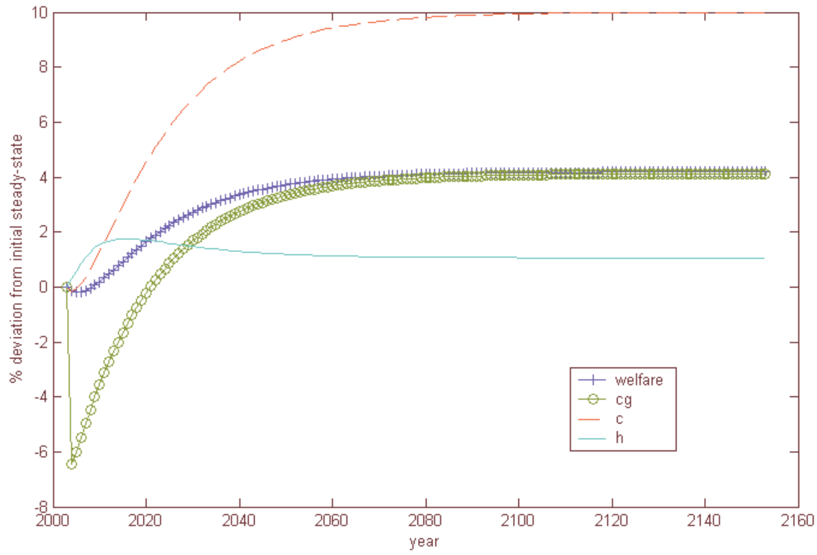

Figure 2: Transition path of consumption, hours and utility ("consumption-financed" policy)

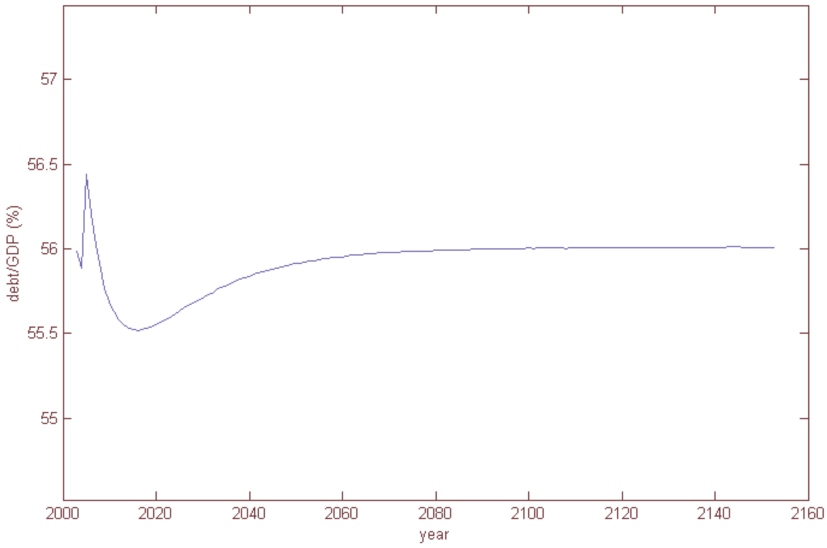

Figure 3: Debt/GDP ratio after permanent increase in Ig/GDP ("consumption-financed" policy)

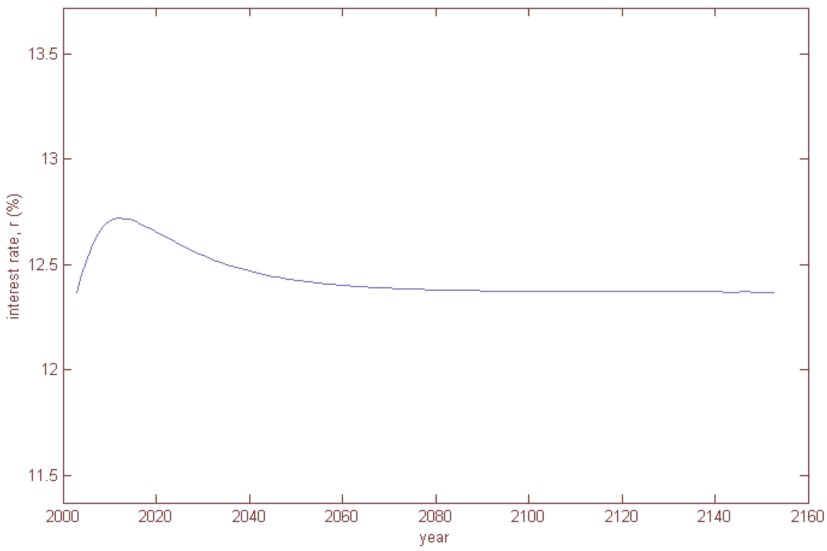

Figure 4: Interest rate transition path ("consumption-financed" policy).

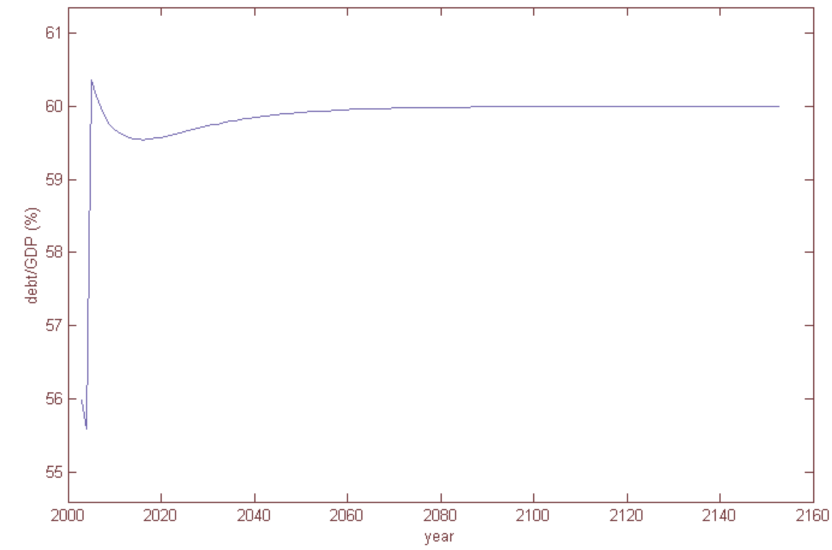

Figure 5: Transition path of Debt/GDP ("consumption-financed" policy with debt increase)

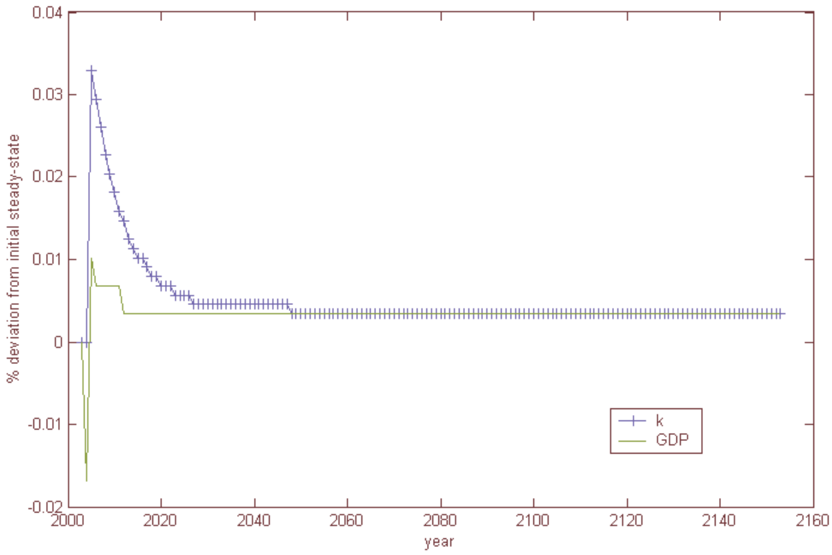

Figure 6: looser regime

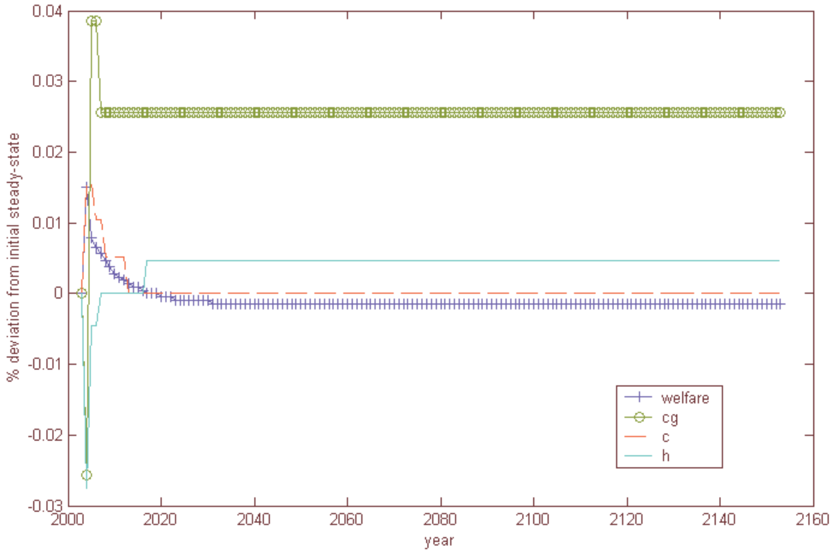

Figure 7: looser regime

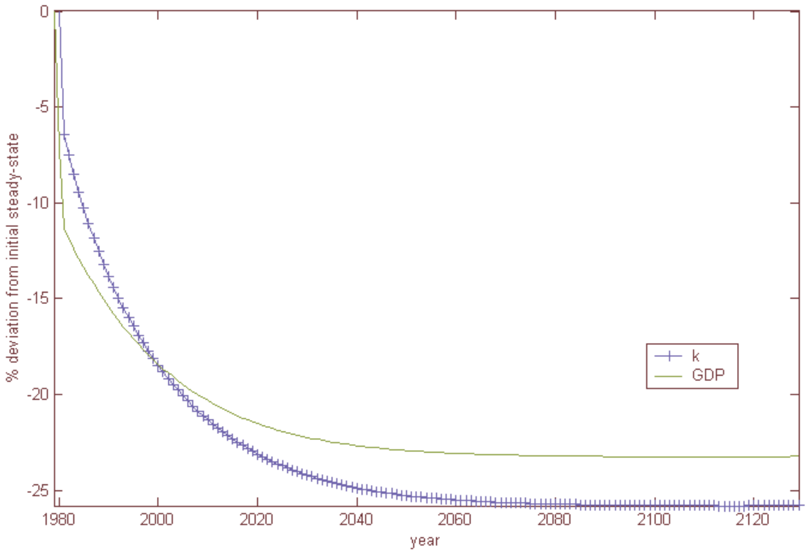

Figure 8: Policy 1

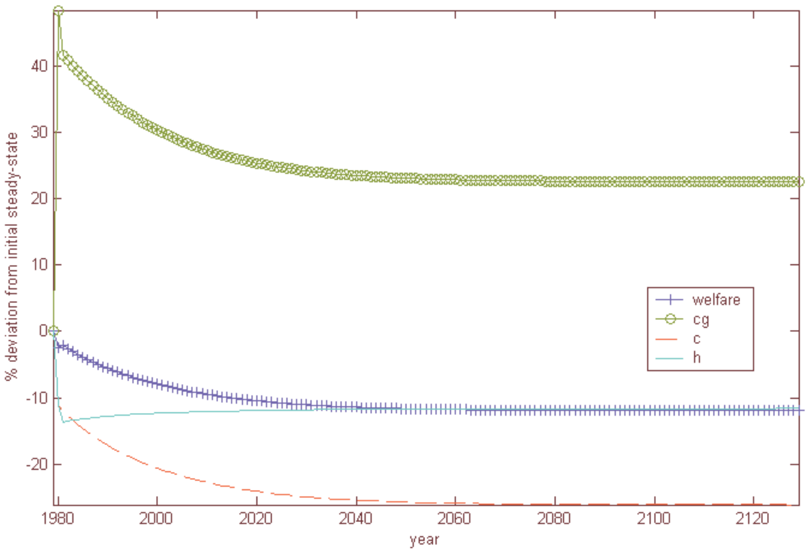

Figure 9: Policy 1

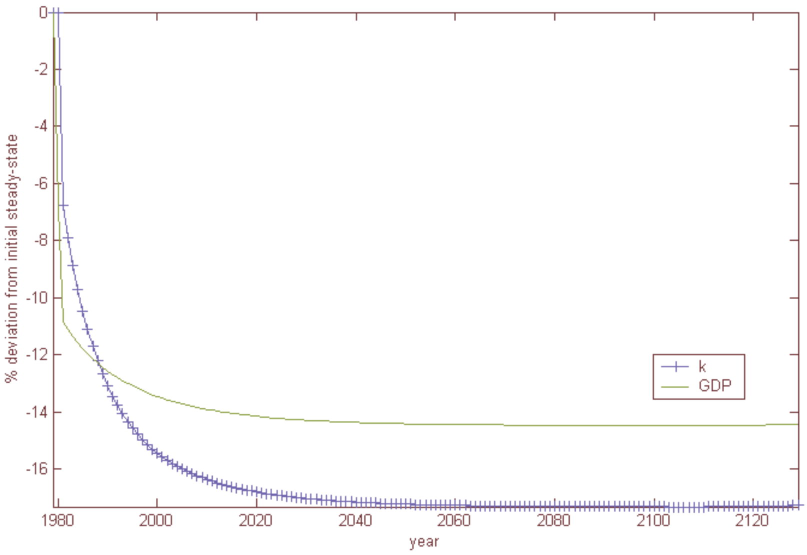

Figure 10: policy 2

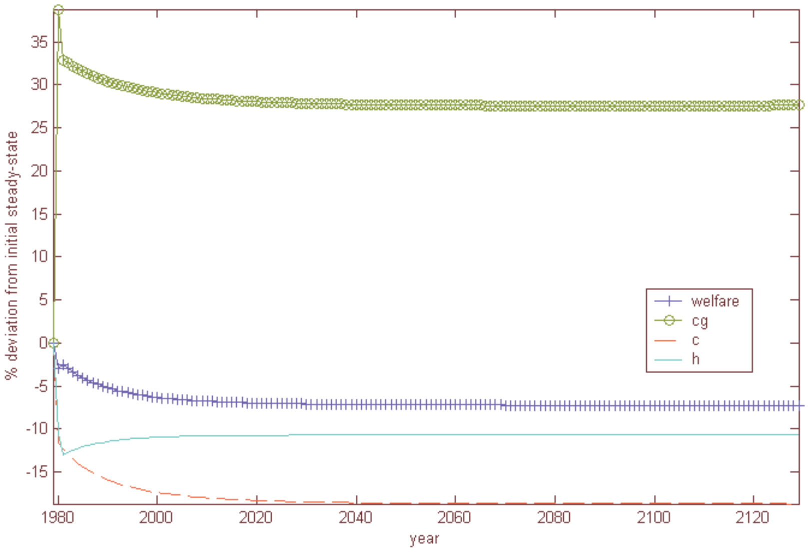

Figure 11: Policy 2

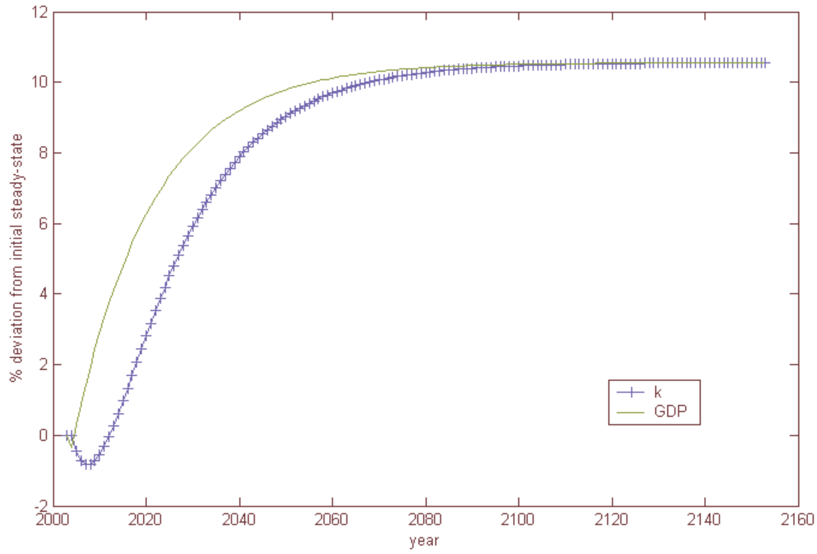

Figure 12: Transition paths of GDP and capital (no-debt model, consumption-financed investment)

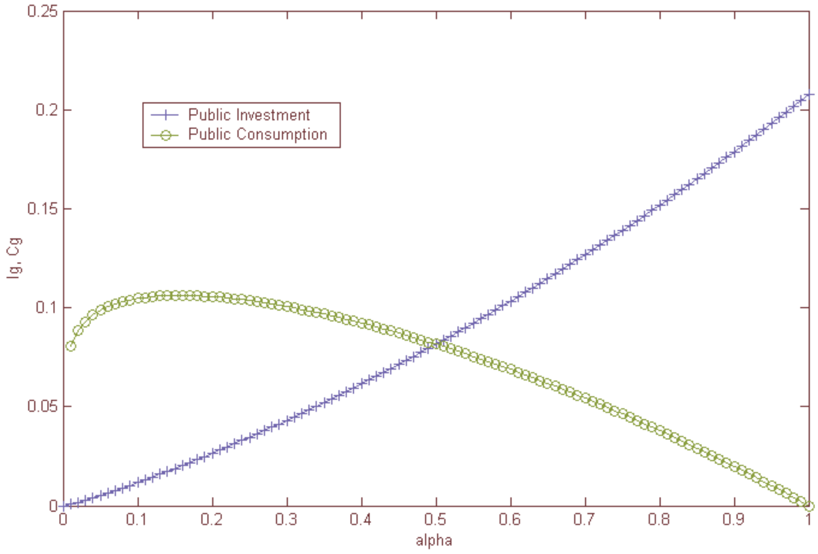

Figure 13: Steady-state levels of public consumption and public investment

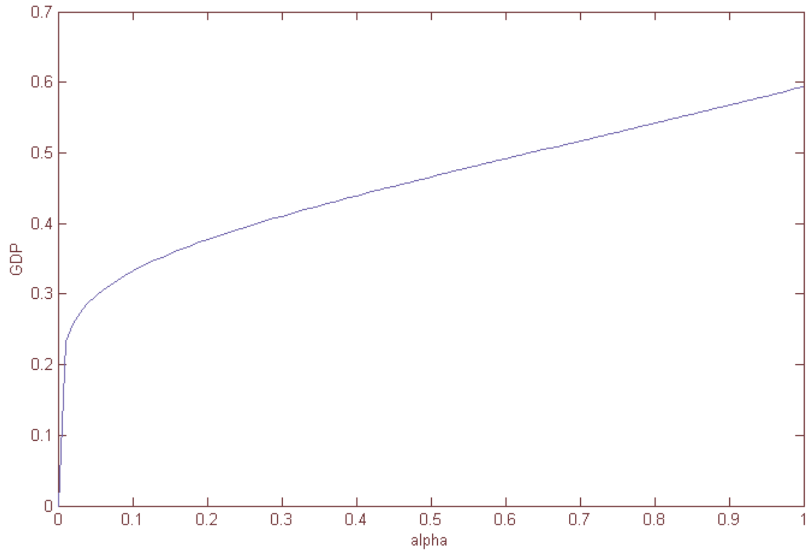

Figure 14: Steady-state output level

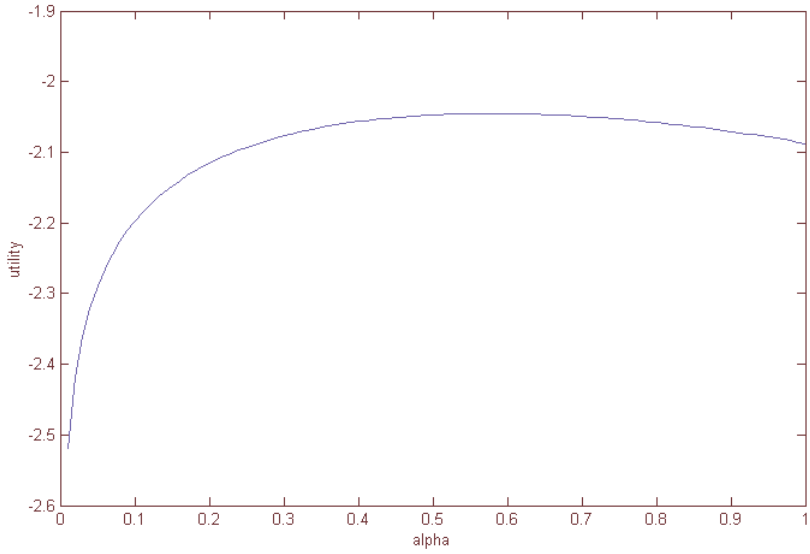

Figure 15: Steady state utility levels

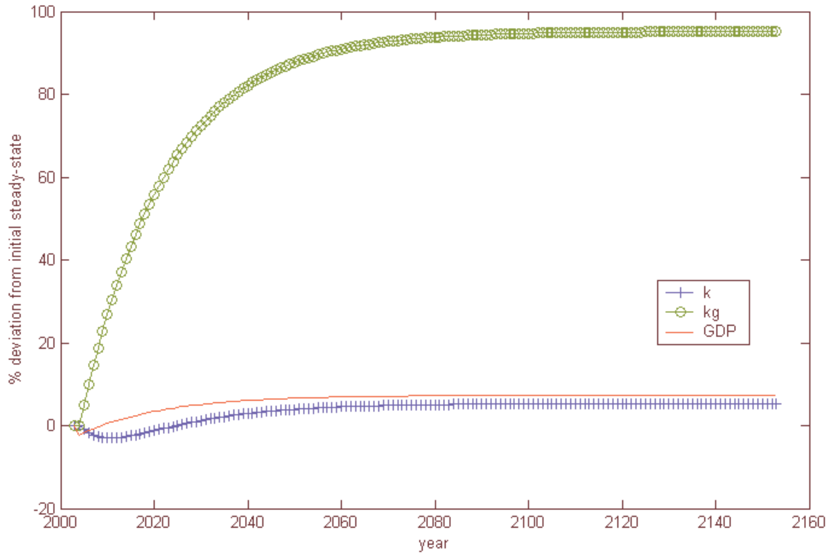

Figure 16: Transition path of GDP, K and Kg (tax-financed investment)

Table 1 - Fiscal Rules for Investement Financing

	consumption-financed	consumption-financed + Change Debt	Looser Regime	Looser Regime 2
output variation (%)$^{(*)}$	11.49	11.00	0.003	12.09
private consumption var. (%)	11.14	11.56	12.82	34.95
public capital var. (%)	99.23	95.19	0.00	105.85
public debt var. (%)	11.53	18.96	-0.22	12.08
growth costs (10 yrs, %)	-0.46	-0.43	0.000	-0.36
growth costs (20 yrs, %)	-0.38	-0.36	0.000	-0.50
$x^{(**)}$	-3.57	-3.36	-0.004	-0.77
$wc^{(**)}$	-0.83	-0.83	-0.001	-0.31

(*) Steady-State.

(**) Takes into account transition and is expressed in percentual terms.

Table 2 - Counterfactual Policies

	Policy 1 (tax and Ig change)	Policy 2 (only tax changes)	Policy 3 (only Ig changes)
output variation (%)$^{(*)}$	-23.23	-14.40	-11.11
private consumption var. (%)(*)	-32.73	-25.37	-6.31
public capital var. (%)(*)	-57.38	-15.10	-51.10
public debt var. (%)(*)	26.93	41.58	50.94
growth costs (10 yrs, %)	1.77	1.54	0.43
growth costs (20 yrs, %)	1.05	2.24	0.34
$x^{(**)}$	14.24	11.11	3.69
$wc^{(**)}$	3.17	2.44	0.82

(*) Steady-State.

(**) Takes into account transition and is expressed in percentual terms.

Table 3 - Fiscal Rules for Investement Financing (no Debt)

	consumption-financed	tax-financed
output variation (%)$^{(*)}$	10.55	7.33
private consumption var. (%)(*)	10.55	3.96
public capital var. (%)(*)	101.00	95.13
growth costs (10 yrs, %)	-0.42	-0.140
growth costs (20 yrs, %)	-0.35	-0.210
$x^{(**)}$	-6.30	-4.04%
$wc^{(**)}$	-1.51	-0.98%

(*) Steady-State.

(**) Takes into account transition and is expressed in percentual terms.

Table 4 - Consumption-Financed - Sensitivity Analysis

			ϕ		
			0.09	0.15	0.2
μ	0	*output variation (%)*$^{(*)}$	9.19	17.64	26.89
		growth costs (10 yrs, %)	-0.31	-0.51	-0.68
		growth costs (20 yrs, %)	-0.29	-0.51	-0.69
		$x^{(**)}$	-7.25	-12.82	-17.99
		$wc^{(**)}$	-1.27	-2.50	-3.93
	0.5	*output variation (%)*$^{(*)}$	10.55	19.28	28.84
		growth costs (10 yrs, %)	-0.42	-0.62	-0.78
		growth costs (20 yrs, %)	-0.35	-0.56	-0.75
		$x^{(**)}$	-6.30	-12.04	-17.35
		$wc^{(**)}$	-1.51	-3.28	-5.39
	1	*output variation (%)*$^{(*)}$	11.49	20.39	30.16
		growth costs (10 yrs, %)	-0.49	-0.69	-0.84
		growth costs (20 yrs, %)	-0.39	-0.60	-0.79
		$x^{(**)}$	-6.03	-11.85	-17.23
		$wc^{(**)}$	-1.84	-4.18	-7.05

(*) Steady-State.

(**) Takes into account transition and is expressed in percentual terms.

Table 5 - Couterfactual Policy 1 - Sensitivity Analysis

			ϕ		
			0.09	0.15	0.2
μ	0	*output variation (%)*$^{(*)}$	-12.97	-19.67	-25.95
		growth costs (10 yrs, %)	0.62	0.74	0.83
		growth costs (20 yrs, %)	0.47	0.63	0.76
		$x^{(**)}$	31.61	40.23	49.23
		$wc^{(**)}$	5.70	8.33	11.67
	0.5	*output variation (%)*$^{(*)}$	-21.85	-28.70	-35.05
		growth costs (10 yrs, %)	1.59	1.72	1.82
		growth costs (20 yrs, %)	0.97	1.14	1.29
		$x^{(**)}$	19.65	28.64	38.10
		$wc^{(**)}$	4.91	8.33	12.87
	1	*output variation (%)*$^{(*)}$	-27.74	-34.64	-40.97
		growth costs (10 yrs, %)	2.25	2.38	2.49
		growth costs (20 yrs, %)	1.31	1.50	1.65
		$x^{(**)}$	15.29	24.76	34.78
		$wc^{(**)}$	4.90	9.35	15.43

$^{(*)}$ Steady-State.

$^{(**)}$ Takes into account transition and is expressed in percentual terms.

Figure 1:

Table 6 - Counterfactual Policy 2 - Sensitivity Analysis

			ϕ		
			0.09	0.15	0.2
μ	0	*output variation (%)*$^{(*)}$	-4.97	-5.50	-6.03
		growth costs (10 yrs, %)	0.44	0.45	0.45
		growth costs (20 yrs, %)	0.24	0.25	0.26
		$x^{(**)}$	22.42	22.95	23.49
		$wc^{(**)}$	3.86	4.37	4.95
	0.5	*output variation (%)*$^{(*)}$	-13.60	-14.96	-16.32
		growth costs (10 yrs, %)	1.32	1.34	1.36
		growth costs (20 yrs, %)	0.70	0.73	0.76
		$x^{(**)}$	12.49	13.92	15.35
		$wc^{(**)}$	2.93	3.68	4.56
	1	*output variation (%)*$^{(*)}$	-19.43	-21.31	-23.16
		growth costs (10 yrs, %)	1.92	1.96	1.98
		growth costs (20 yrs, %)	1.01	1.06	1.10
		$x^{(**)}$	8.75	10.81	12.87
		$wc^{(**)}$	2.62	3.68	5.00

$^{(*)}$ Steady-State.

$^{(**)}$ Takes into account transition and is expressed in percentual terms.

Table 7 - Counterfactual Policy 3 - Sensitivity Analysis

			ϕ		
			0.09	0.15	0.2
μ	0	*output variation (%)*(*)	-8.42	-15.00	-21.20
		growth costs (10 yrs, %)	0.18	0.30	0.39
		growth costs (20 yrs, %)	0.23	0.38	0.51
		$x^{(**)}$	7.54	14.11	20.94
		$wc^{(**)}$	1.45	3.10	5.26
	0.5	*output variation (%)*(*)	-9.46	-16.07	-22.29
		growth costs (10 yrs, %)	0.29	0.40	0.49
		growth costs (20 yrs, %)	0.28	0.43	0.56
		$x^{(**)}$	6.37	12.98	19.86
		$wc^{(**)}$	1.50	3.55	6.28
	1	*output variation (%)*(*)	-10.27	-16.90	-23.14
		growth costs (10 yrs, %)	0.37	0.48	0.56
		growth costs (20 yrs, %)	0.32	0.47	0.60
		$x^{(**)}$	5.79	12.46	19.39
		$wc^{(**)}$	1.63	4.09	7.44

(*) Steady-State.
(**) Takes into account transition and is expressed in percentual terms.

A Calibration and Simulation Procedures of the Model Without Public Debt

We follow the model with public debt and use as benchmark values $\mu = 0.5$ (imperfect substitution between private and public consumption) and $\phi = 0.09$. We will use in the sensitivity analysis μ equal one and zero and ϕ equal 0.15 and 0.2.

In the model, interest rate is also determined by the marginal productivity of capital: $r = \theta K g^{\phi} \left(\frac{H}{K}\right)^{(1-\theta)}$. This equation can be rewritten as:

$$\theta = \frac{rK}{Y}.$$

From the National Accounting data we have that $\frac{K}{Y} = 2.98$ and current real interest rate is $r = 0.1$, so that we set capital share to 0.298.[11]

Depreciation rate is $\delta = \delta_g = 0.0656$, following in the first case Araújo and Ferreira (1999), and setting δ_g for symmetry.

With respect to the fiscal policies parameters, there is evidence that taxes levied on capital correspond to 8.01% of GDP when we include investment taxes[12]. In this sense we have:

$$\tau_k = 0.0801 \frac{Y}{rK} = 0.2688.$$

Similarly, using the fact that labor income taxes represent 26.98% of GDP[13], we obtain:

$$\tau_h = 0.2698 \frac{Y}{wH} = 0.3844.$$

The share of public investment expenditure, α, is ideally set by taking into account that total taxes over GDP are nearly equal to 35% and that the public investment rate $(\frac{Ig}{Y})$ is 2.2% (Ferreira (2004)). Thus:

$$0.022 = \frac{Ig_t}{Y_t} = \alpha \frac{G_t}{Y_t} = \alpha 0.35$$
$$\Rightarrow \alpha = 0.0628.$$

Intertemporal discount factor, β, is found by using the long-run equation derived from the first order condition of the model, as before:

$$\beta = \frac{1}{1 + (1 - \tau_k)r - \delta},$$

which gives $\beta = 0.9925$. Finally, $A = 2$ as in Cooley and Hansen (1992). This value implies that individuals spend about $\frac{2}{3}$ of their free time not working.

The parameterized model is solved using numerical simulations. Steady-state values are easily found by means of the first-order conditions when $x_{t+1} = x_t$ and $X_t = x_t$ for each variable.

[11] This value is a bit below the international evidence (see Gollin (2003)) and well below Brazilian National Accounting data. In the case of the latter, however, we should not be too worried as they do not take into account a number of imputations that ends up overestimating capital share.

[12] This calculation is performed by using the decomposition of total taxes into its components as presented in Araújo and Ferreira (1999).

[13] Note that our model only allows for capital and labor taxes. In this sense it was proportionally transferred to labor taxes the consumption taxes and to capital taxes the taxes on investment, in order to obtain the observed tax ratio of the Brazilian economy, 35%. As our experiments relate to the overall level of tax collection and not to its distribuition, this procedure does not affect the results significantly.

B Robustness: alternative production functions

In this section we consider modified versions of the previous environment. We now assume that, in addition to positive externality generated by (average) public capital, $\overline{Kg}_t$, there is also an internal effect symmetric to private capital. To this end, production function is now:

$$Y_t = F(Kg_t, K_t, H_t, \overline{Kg}_t) = K_t^{\theta} Kg_t^{\phi} H_t^{1-\theta-\phi} \overline{Kg}_t^{\chi}.$$

Government owns public capital Kg and levies taxes so as to finance its expenditure with both public investment and public consumption according to expressions (20)-(**??**).

Firms' maximization problem here is given by

$$\max_{H_t, K_t} \pi_t = \left\{ K_t^{\theta} Kg_t^{\phi} H_t^{1-\theta-\phi} \overline{Kg}_t^{\chi} - w_t H_t - r_t K_t \right\}.$$

It is easily checked that factor prices as a function of the aggregate variables read:

$$w_t = w(Kg_t, K_t, H_t, \overline{Kg}_t) = (1-\theta-\phi) K_t^{\theta} Kg_t^{\phi} H_t^{-\theta-\phi} \overline{Kg}_t^{\chi}, \tag{22}$$

$$r_t = r(Kg_t, K_t, H_t, \overline{Kg}_t) = \theta K_t^{\theta-1} Kg_t^{\phi} H_t^{1-\theta-\phi} \overline{Kg}_t^{\chi}. \tag{23}$$

Therefore, total profits, which are distributed to the household, represent

$$\pi_t = \phi Y_t.$$

Consumer's problem is to solve:

$$\begin{aligned} V(Kg_t, k_t, K_t, \overline{Kg}_t) = \max_{cp_t, i_t, h_t} & \left\{ U(cp_t, Cg_t, l_t) + \beta V(Kg_{t+1}, k_{t+1}, K_{t+1}, \overline{Kg}_{t+1}) \right\} \\ \text{s.t. } & cp_t + i_t = (1-\tau_h) w_t h_t + (1-\tau_k) r_t k_t + (1-\tau_\pi)\pi_t \\ & (\textbf{??}), (20), (21), (\textbf{??}), (22), (23) \\ & I_t = I(Kg_t, K_t, \overline{Kg}_t),\ H_t = H(Kg_t, K_t, \overline{Kg}_t), \end{aligned} \tag{CP'}$$

where τ_π is the tax rate on profits. Now, government's budget read:

$$Cg_t + Ig_t = G_t = \tau_k r_t K_t + \tau_h w_t H_t + \tau_\pi \pi_t. \tag{24}$$

A recursive competitive equilibrium is analogous to definition 1 when we take into account the new constraints and use the fact that, in equilibrium, $\overline{Kg}_t = Kg_t$.

Except for the tax structure, the calibration is basically the same as in section 3. We set in this case $\tau_\pi = \tau_k$ as dividends are taxed just like any other capital. We will simulate two economies. In the first we assume no external effect due to public capital and in the second both effects are present.

B.1 Results: $\phi = 0.09,\ \chi = 0$

The model in which there is no external effect due to public capital (i.e., $\chi = 0$) is interesting because we can interpret without any caveat its steady-state as a balanced growth path. In this case, instead of assuming $Z_t = Z = 1$ as we did in previous sections, we only need $Z_t = (1+z)^t$, $z > 0$ and then we could interpret the variables in level as variables in efficiency units, that is, divided by Z_t. This can be done by positing $Y_t = K_t^{\theta} K g_t^{\phi} \left(Z_t H_t\right)^{1-\theta-\phi}$.

It is reassuring to find that the simulations in this case are very close to the simulations with only external effect, so that all our interpretations carry on to an exogenous growth set up without any adaptation. When we reproduce the experiment in section 4.2, the variations in output, public and private capitals and hours are almost the same (11% in the case of output and private capital, for instance) with minor changes in public and private consumption. In that sense, if Brazil returned to its previous public investment ratio of 4%, output would converge to a new balanced growth path 11% above the current path. For the first 10 years, the growth rate would be 0.5 points larger and for the next ten, 0.4 points. Similarly to the case of no internal effect, convergence would be slow, as one can infer from figures A1 and A2. As for welfare, magnitudes are close but the gains using the present framework are smaller, only 1.14%.

The repetition of the counterfactual exercises of Section 4 with the new production function calibration generated almost the same results. The model is able to replicate very closely the growth slowdown of Brazil after 1980 when we change tax structure and investment ratio to their current levels. Moreover, the impact of the expansion of tax collection is still greater than that of public investment compression.

B.2 Results: $\phi = 0.05,\ \chi = 0.04$

Finally, figures A3 and A4 display the outcome of the simulations with both internal and external effect. In this case we followed Ferreira (2001) and set $\phi = 0.05$, $\chi = 0.04$. There is no relevant change with respect to any of the preceding models. The change in output of the four experiments are exactly the same as before and so is the variation in growth rate following the policy change. The model can still match very closely the observed GDP path after 1980. The only noteworthy difference is the welfare variation, smaller in absolute value in all cases, but not by much in any case.

The lesson we learn with the robustness check is that in the end functional form does not matter for growth and output simulations, and only marginally for welfare evaluation. In this sense, wether we assume only internal or external effect, or a combination of both, is not too relevant if we want to study the output loss caused, for instance, by cuts in public capital expenditure.

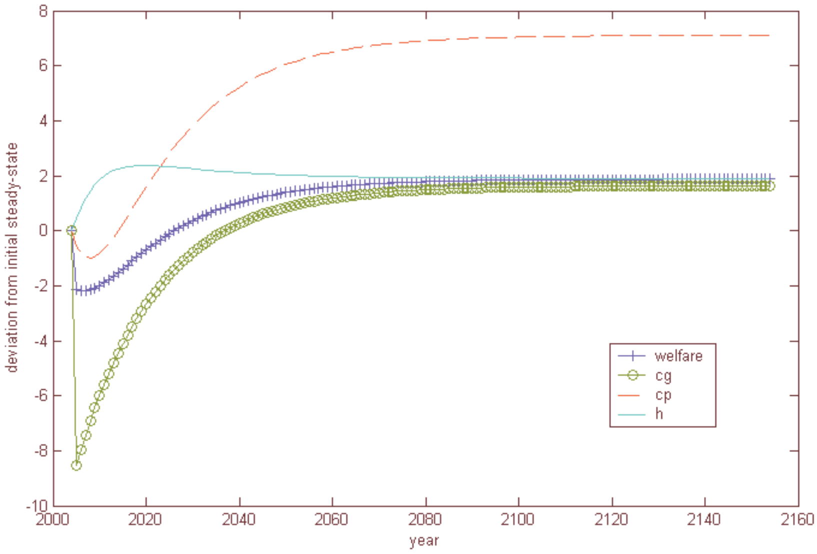

Figure A1: Transition paths when $\phi = 0.09$ and $\chi = 0$

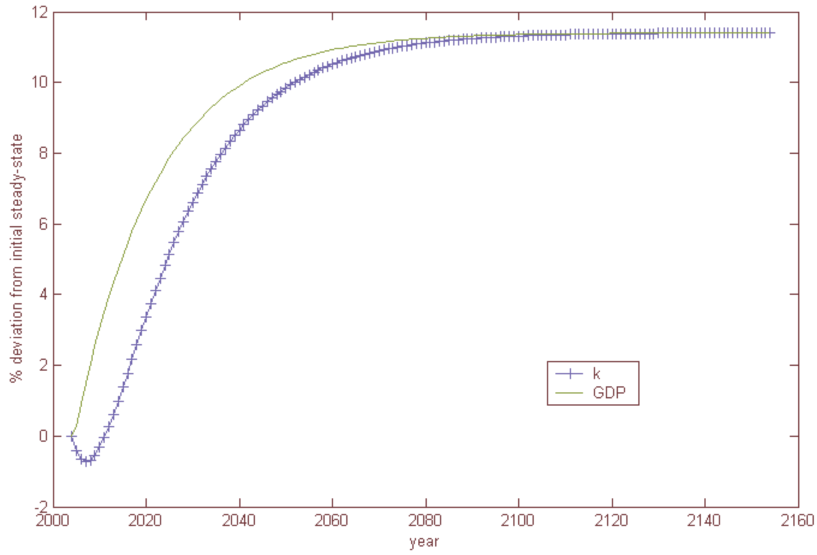

Figure A2: Transition paths when $\phi = 0.09$ and $\chi = 0$

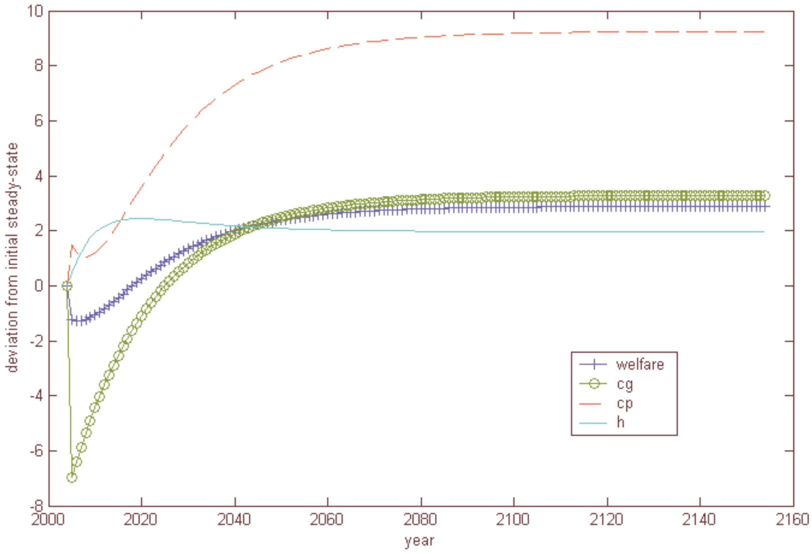

Figure A3: Transition paths when $\phi = 0.05$ and $\chi = 0.04$

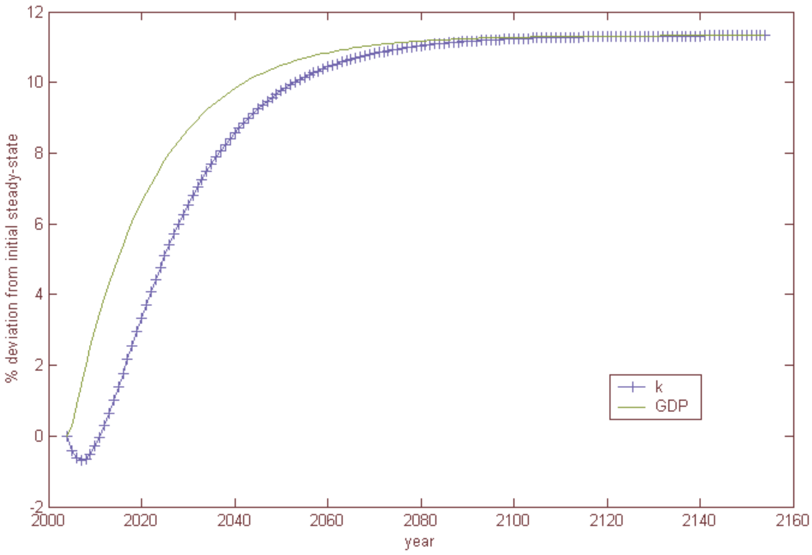

Figure A4: Transition paths when $\phi = 0.05$ and $\chi = 0.04$