Growth and Fiscal Effects of Infrastructure Investment in Brazil*

Pedro Cavalcanti Ferreira
Graduate School of Economics - EPGE
Fundação Getulio Vargas

Carlos Hamilton Vasconcelos Araújo
Fundação Getulio Vargas and Banco Central do Brasil

Abstract

This paper studies the productive impact of infrastructure investment in Brazil. Public capital expenditure have declined steadily over the last two decades, and this paper shows the significant impact this has had on infrastructure stocks. The long-run association between output and infrastructure is investigated, and the results are then used to study the short-run dynamic of these variables. Whether in the short or long run, the productive impact of infrastructure is substantial. Simulations explore the impact of debt-financed increases in public investment on debt to GDP ratio as well as public cash flow and net worth.

*The authors would like to thank the comments of Luis Serven, Leandro Nascimento and seminar participants at Lacea 2005, PUC-RJ, IPEA and EPGE-FGV.

1 Introduction

Public investment in Brazil, as a share of gross domestic product (GDP), has been falling for the last twenty five years. While in the 1969-1984 period, gross capital formation of the central government alone averaged 4.03%, in the following sixteen years it was only 1.85%. In the last few years it has remained at around 0.9% of the GDP, while the gross investment of total government is only 2.2% of output. Moreover, although timing varies, the cuts 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 0.5% of GDP[1] (Afonso, Araújo and Biasoto Jr.,2005), a small figure when compared to almost 1.8% in the peak year of 1979. Similar figures, if somewhat less dramatic, apply to the energy sector, ports, etc.

As a consequence, there has been a general decrease in the quality of infrastructure services and a relative scarcity of quantities supplied. With respect to the former, although not much data is available, casual evidence is abundant. The blackouts and rationing of energy of 2001/02 are believed to have been caused by the reduction in investment in the energy sector. Power-generating capacity, which grew at an average rate of 10% from 1960 to 1980, increased on average only 3% per year in the following twenty years. World Bank figures show that the total length of paved roads in the country has stagnated, if not decreased, during the last decade. At the same time, Velloso (2004) shows that in 2003 only 17% of roads in the country were considered in good or very good condition, while 42% were in poor or extremely poor condition.

The reduction of capital expenditures is a general phenomenon in Latin America (Calderon, Easterly and Serven (2002)) and is associated with the numerous economic crises the region experienced since Mexico's default in 1982. These were particularly acute in Brazil, as reflected, for instance, by hyperinflation, fiscal crisis, the suspension of external debt payments, insolvent regional governments, increasing poverty, etc. As stated by many (e.g., Roubini and Sachs(1989), Calderon, Easterly and Serven (2002) and Mintz and Smart(2004)), in times of fiscal restrictions, public investments tend to be overly reduced and the burden of fiscal adjustment is felt first and with more intensity in infrastructure sectors.

[1] Note also that at least one third of public investiment in the transport sector is due to municipalities, and so does not include roads and ports.

This is somehow an expected, if myopic, outcome of the political process. If current and capital expenditures are weighted the same in the government budget decisions, policy makers with short-term tenures (e.g., four or six years) have little incentive to consider the future gains of infrastructure expenditures. This is so because, while most of the expenses are incurred under their own term, most of the benefits will be enjoyed after they leave office. Even if the net present value of the project is positive, its initial cash flow is always negative and this is critical for any political decision. In an environment with high political instability such as Latin America, this problem tends to be amplified.

In the Brazilian case, aside from fiscal problems and widespread economic crisis, the public budget has become increasingly rigid in the recent past, with mandatory expenditures in education and health, for instance, and mounting expenses in payroll, social security, various social programs and interest[2]. Moreover, fiscal targets - such as the target of 4.25% primary surplus in the current year - as usual, make no differentiation between current and capital expenditures. When adding up these factors, one should not be surprised by the reduction of public investment in general, and infrastructure-capital expenditures in particular, observed in Brazil.

This chapter analyzes the economic impact of the recent evolution of infrastructure investment in Brazil. It is divided in four sections in addition to this introduction. The next section presents the relevant stylized facts and comments on the relationship between investment flows and the observed variation of infrastructure stocks. In the third section we estimate the growth impact of public capital and of different measures of infrastructure stock. This has found to be significant by a large number of studies ((e.g. Aschauer (1989), Ai and Cassou (1995), Canning and Bennathan (2002), Easterly and Rebelo (1993), Creel, Monperrus-Veroni and Saraceno(2006)) using different data and econometric methodology. We initially employ cointegration analysis to investigate the long-run association between output and infrastructure, extending in several directions the analysis presented in Ferreira and Maliagros (1998). These results are then used to study the short-run dynamic of GDP and per capita GDP after shocks to public capital and infrastructure. The productive impact of the different measures of infrastructure were found to be relevant both in the short and long run.

Section Four presents a very simple simulation of tax collection, debt

[2] See Afonso, Araújo and Biasoto Jr. (2005) for a detailed exposition of the recent evolution of Brazilian public finances.

service and public solvency after an increase in public capital stock entirely financed by debt issue. We show that, under reasonable assumptions, infrastructure does pay for itself in Brazil, as a given investment generates revenues more than sufficient to cover the debt service and additional investment. This result contrasts with those in Perotti(2004), who rejects the hypothesis, for 6 OECD countries, that shocks to public investment are self-amortizing. Similarly, Pereira and Pinho (2006) estimate that in only two - Italy and Germany - out of the twelve Euro countries they study public investment pays for itself. In the remaining ten countries the hypothesis of productive impact of public investment was rejected or this impact was not strong enough to generate the necessary tax revenue. Both papers use methodologies close to ours. Finally, Section Five presents some concluding remarks.

2 Some Basic Stylized Facts

After reaching a peak of 5.3% of GDP in 1969, public investment today is only 2.2% of Brazil´s GDP. It experienced a timid recovery from 1987 to 1994, when the average ratio rose to around 3%, but after that it has remained quite small. Out of the total investment today, a large fraction is due to municipalities (40%), which means parks, schools, street pavement, sidewalks and similar expenditures with little productive impact.

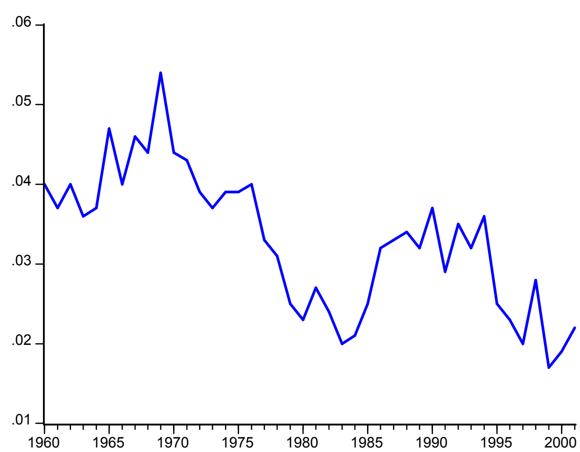

Figure 2.1 Public Investiment do GDP Ratio

In fact, most of the (recent) observed fall in the public investment ratio is due to the Central Government, whose current investment, as percent of GDP, amounts today to half the 1994 value (it stands at 0.7% to 0.9% of GDP). Fiscal adjustment is the main explanation for this fall. After 1994, as part of the Real Plan, tighter controls over public finance were introduced in the country, perhaps for the first time. Although initially the adjustment was achieved mainly through tax increases, the numbers show clearly that investment, and particularly infrastructure investment, was badly affected. Public expenditure in Brazil is extremely rigid, with mandatory outlays in education, health, personnel, social security, etc. On the other hand, there are few restrictions - legal or political - on investment, which gives the government a relatively low-cost option to reduce public expenditure, or at least to compensate for spending increases in other dimensions[3].

The figure below shows gross investment as percentage of GDP by infrastructure sectors. It is apparent that the drop in infrastructure expenditure in Brazil affects all sectors. In almost all cases it started at least twenty years ago, when the first fiscal crisis (in 1982 after Mexico‘s default) exploded. Given that almost all telecommunication businesses were privatized before 1999, the recent fall in (public) investment in this sector comes as no surprise. As for investments in energy, they reached a peak in 1976 and remained relatively high until the early-mid eighties. After this date there is a pronounced downward trend that has continued until today. The fall in transportation investment is even more pronounced[4]. Numbers in Velloso (2003) show that in 2003 the investments of the Ministry of Transportation were only 0.1% of GDP, and according to Afonso, Araújo and Biasoto Jr. (2005) the investment of the three levels of government in 2003 in the sector was only 0.5% of GDP.

[3] Note that only a small part of the reduction in investment by the central government is related to privatization of services (e.g., telecommunications) and industrial enterprises (e.g., steel and chemistry).

[4] Investments in tranportation in Figure 1.2. do not include those due to the municipalities.

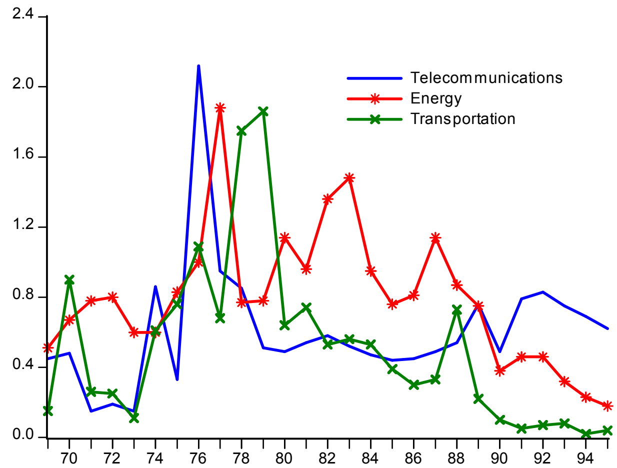

Figure 2.2 Public Investiment as Proportion of GDP

Investment in electricity suffered a steep decrease from the eighties on. In fact, investment in power generating in 1995 was less than 30% of corresponding investment achieved in the peak year of 1982, which is more or less the same picture observed for total investment. Figure 2.3 shows that investment fall had a strong effect on the expansion of generating capacity, whose growth rate decreases after 1981. The slowdown of capacity of generating growth continued after 1995, as shown in Figure 2.3. This figure also displays the mean growth before and after 1980: 10.3% and 3.6%, respectively.[5]

[5] Not by accident, in 2001/2002 the country experienced energy rationing, most likely for lack of investment.

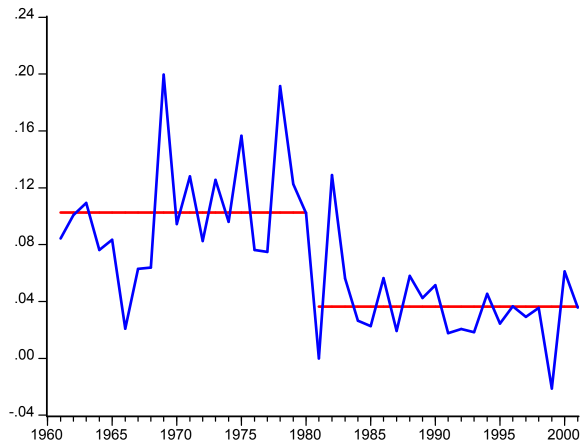

Figure 2.3 Growth Rate of Generating Capacity

It is relevant to understand the relationship between infrastructure investment and variations in infrastructure stocks. In other words, there are good theoretical reasons (see Prichett (2000)), and anecdotal evidence in Brazil, to show that money invested or accounted as investment does not necessarily end up as actual variation in infrastructure stock[6]. Figure 2.4 presents total investment in roads (all investment figures are from Ferreira and Maliagros(1999)) and *new* paved roads, constructed from World Bank data. One can see that until 1978 both new construction and investment grew more or less together, but correlations are less pronounced after 1980. But, if anything, except for a steep fall in 1978 that looks like a data problem, the extension of new paved roads has fallen less than investments in the last two decades. When a trend line is adjusted to investment and new roads, we could note that the downward slope of investment starts at 1976/77 and is never reverted, but in the case of new roads the trend was never negative after the break in the same period. The correlation figures also point to some change of patterns. While between 1961 and 1980 the investment and new roads correlation is 0.54, it is only 0.07 from 1980 to1995, and for the entire period it is 0.36.[7]

[6] There may be losses in the process, inefficiencies or even corruption. In the first two cases one could think of the billions spent on the Brazilian Nuclear Program, the Transamazônica highway and the Ferrovia do Aço railroad, huge projects that were either never finished (sometimes finished but never implemented) or ended up costing much more than initially planned.

[7] In most of the exercises in this section, we used 1995 as the end year of our sample,

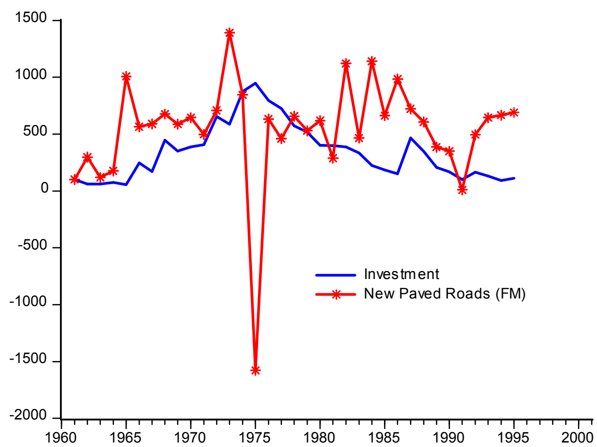

Figure 2.4 New Paved Roads and Investment

To further explore the relationship between investment flow and stock variation, we performed in a previous version of this paper some simple econometric analysis in which the annual change of three physical measures of infrastructure - paved roads (PAV), main telephone lines (TEL) and power-generating capacity (CAP)- is regressed on the respective investment series. Table 2.1 below presents a sample of these regressions[8]:

---

because investment data in the aggregation level used have this limitation, although World Bank data goes up to 2001 in most cases. This is less problematic in the case of roads because data in the final years of the sample looks suspect in any case: from 1997 to 2001, total paved roads fell by 45% and in 3 years before that they did not change at all.

[8] Variables are in logs and stock data are from the World Bank. There were no cointegration vectors between any pair of variables we tested, and so we chose to run regressions in OLS, since there is no error-correction term omitted in these regressions.

Table 2.1: Regressions of stock change on investment flows

Equation	1	2	3
	ΔPAV	ΔCAP	ΔTEL
C	4.23	0.61	1.12
	(6.32)	(0.26)	(2.15)
investment in roads	0.37		
	(2.24)		
investment in energy		0.80	
		(2.98)	
investment in telecom.			0.75
			(7.50)
obs.	31	29	28
R^2	0.09	0.40	0.46

note: White Heteroskedasticity correction used in all regressions

In the models above (and many others we ran), the estimated coefficients are significant and have the right sign. Moreover, the magnitude of the estimated elasticities is considerably large. For instance, a 10% increase in investments in the energy sector imply an 8% expansion in generating capacity. Similar results were obtained for the transportation and telecommunication sectors. In general, the explanatory power of the regressions, as given by the R^2, is high. This suggests that once infrastructure investment is allowed to increase, the corresponding expansion of power generating capacity and paved roads, for instance, will be vigorous, even if there is a small amount of waste in the process.

3 The Growth Impact of Infrastructure

Having established a firm relationship between investment flows and infrastructure capital variation, the next step is to assess relationships between public capital and GDP (and per capita GDP). After that, we verify the short- and long-run impact of public capital shocks on output.

The figure below presents the evolution of GDP and Public Administration Net Stock of Capital (Ipeadata series) from 1960 to the present[9]. The latter is divided between structures and machinery and equipment capital.

[9] The public capital stock series in the IPEADATA were constructed from past public investment series (displayed in Figure 2.1.) using the perpetual inventory method.

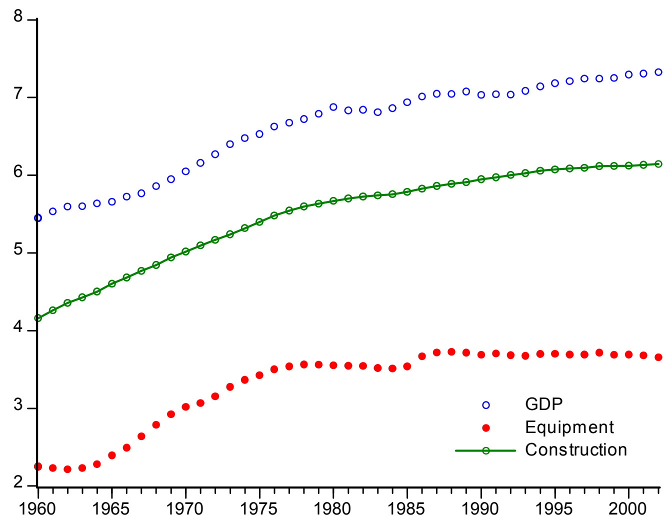

Figure 3.1 GDP, public structures and public equipment

As one could expect, given the likelihood that public capital measures and GDP contain a common trend, these series move very closely. The same can be said of physical measures of infrastructure capital and GDP. Another exploratory analysis of this relationship is presented in the correlation table below, where variables are expressed in level below the main diagonal and in first differences above it. Y stands for GDP, y for per capita GDP, KGs for public structures and KGe for public stock of machinery and equipment:

Table 3.1 Correlation Matrix

	Y	y	KGs	KGe
Y		0.994	0.493	0.543
y	0.973		0.409	0.506
KGs	0.970	0.971		0.598
KGe	0.927	0.965	0.979	

* Variables are in level under main diagonal and in first difference above it.

Not surprisingly, the correlations in levels are all very large and close to one. However, the correlations in first differences are all positive and not small either. A similar pattern can be found in the correlations between physical measures of infrastructure and GDP, as shown in Table 3.2.

Table 3.2 Correlation Matrix

	Y	y	CAP	PAV	TEL
Y		0.994	0.485	0.255	0.303
y	0.991		0.421	0.216	0.301
CAP	0.995	0.977		0.090	0.284
PAV	0.972	0.950	0.972		-0.201
TEL	0.974	0.942	0.985	0.938	

* Variables are in level under main diagonal and in first difference above it

Again, correlations between GDP (and also per capita GDP, y) and infrastructure stocks are close to one. The first difference correlations are, as expected, smaller, and the largest magnitude corresponds to the case of power-generating capacity (CAP). The correlations with the variation of paved roads (PAV) were the weakest among all pairs, while that of main telephone lines (TEL) displays intermediate values. As a first indication, there seems to exist a positive link between output and public capital and infrastructure[10].

We next use time-series econometric techniques, particularly VAR models, to study the relationship between output and public capital and infrastructure. We want to estimate long-run relationships in order to build a dynamic model to be used in impulse-response exercises. In essence, we estimate the output impact of changes in infrastructure capital.

The first step is to test variables for unit roots. We used Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski-Phillips-Schmidt-Shin tests, and in all three cases and for all variables we could not reject the hypothesis of the variables being integrated of order one.

Table 3.3 below presents, in rows, the result of the cointegration estimation of output per worker on public and private capital per capital and human capital. We used the KGs series for public infrastructure, the IPEA-DATA series of private stock of machines and equipment, KPe, for private

[10] The physical measures include private and public infrastructure, as opposed to the monetary measures in which private and public stocks are separated. However, for most of the period private infrastructure stocks are very small.

capital and secondary attainment, from the Barro-Lee (2000) database, for human capital, KH.

Ferreira, Issler and Pessôa(2004) test different production functions used in growth studies and their results favor the Mincerian specification of human capital against more traditional specifications such as that used by Mankiw, Romer and Weil (1992). In practical terms, once we apply logarithms, the only difference between functional forms is whether human capital enters in logs or levels. In Tables 3.3 we included both. Although we are not estimating production functions, results are sensible to the way we introduce human capital in the regression. We found one cointegration vector and the constant term is omitted.

Table 3.3 Cointegration Equations

sample	y	KGs	KPe	KH^*	KH
60-00	1.00	-0.04	-0.59		-0.94
		(0.08)	(0.06)		(0.11)
60-96	1.00	-0.16	-0.53		-0.75
		(0.11)	(0.07)		(0.17)
60-00	1.00	-0.06	-0.59	-0.25	
		(0.09)	(0.06)	(0.03)	
60-96	1.00	-0.22	-0.51	-0.19	
		(0.12)	(0.08)	(0.04)	

ADF/PP/KPSS tests support the hypothesis of first-order integration of all variables. Variables in logs, except KH^*.

In all estimations shown the coefficient of public capital was estimated with the right sign but in most cases it was not statistically significant at the usual confidence levels. When we use a different time period, 1960-1996 instead of 1996-2000, estimations are more precise with respect to the coefficient of KGs. In the case of the fourth regression, when capital enters in levels the fit is much better confirming a long-run relationship between output and public capital. The estimated coefficients might be interpreted as long-run elasticities; hence, from a steady state to another, the estimates of this last equation show that a 10% change in public infrastructure stock is associated with a change of 2.2% in output per worker. This shall be our benchmark model. Note that it is important to control for human capital and private capital, as the omission of any of these variables would boost the estimated impact of public infrastructure on output. As a matter of fact, bivariate cointegration regressions between y or Y and KGs or KGe found long-run elasticities above one, as the latter most probably were capturing the effect of omitted variables.

Estimations are more precise when we normalize variables by population instead of labor force. Of course, the latter makes more sense from an economic perspective. However, while the population series is an official statistic from the IBGE, the Brazilian statistic bureau, the former is constructed interpolating census data, and therefore it is somewhat arbitrary. As a double check, the results are presented below:

Table 3.4 Cointegration Equations, variables per capita

sample	y	KGs	KPe	KH^*	KH
60-00	1.00	-0.21	-0.38		-0.79
		(0.20)	(0.13)		(0.32)
60-96	1.00	-0.25	-0.50		-0.84
		(0.14)	(0.08)		(0.25)
60-00	1.00	-0.09	-0.59	-0.30	
		(0.10)	(0.06)	(0.04)	
60-96	1.00	-0.33	-0.46	-0.19	
		(0.15)	(0.09)	(0.07)	

ADF/PP/KPSS tests support the hypothesis of first-order integration of all variables. Variables in logs, except KH^*

Similarly to the per-worker estimations, regression results with the full sample are less precise although in all cases the coefficient of KGs has the right sign and its magnitude is in line with the literature. Once again, the best fit was obtained when using human capital in levels and the shorter sample. In this case the estimated coefficient was larger than before, implying that a 10% increase of the stock of public infrastructure would raise long-run output per capita by 3.3%.

As it is well known, for a set of integrated variables, the Granger Theorem of Representation establishes the equivalence between cointegration and Vector Error Correction Model (VECM). Hence, we estimated the corresponding VECM for the fourth model of Table 3.3 (that uses the smaller sample), from which we obtained a dynamic system of equations for y, KGs, KPe and KH, with the latter variable expressed in levels. We used this VAR system to simulate the response of economic variables to infrastructure shocks[11]. The figure below presents the response of per capita output and private capital to a shock to KGs corresponding to 1% of GDP .

[11] Alternative ordering of the impulse-response exercises did not change significantly the results.

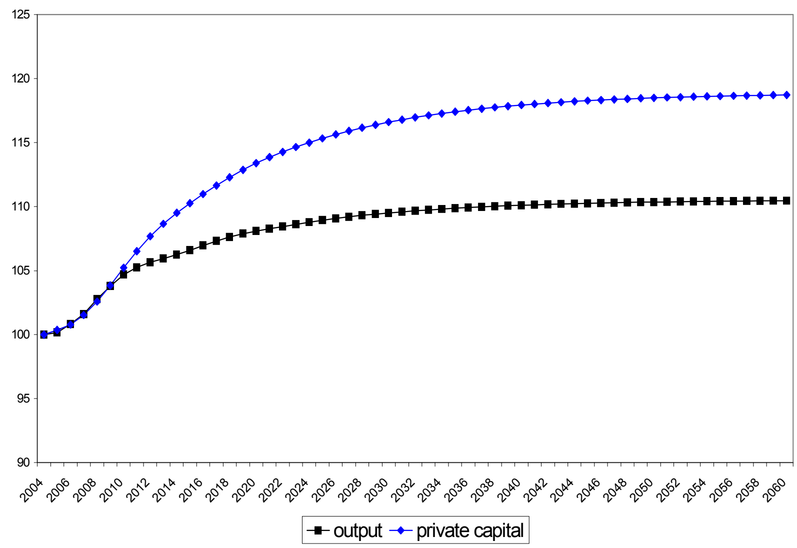

Figure 3.2 Response of per capita GDP and KPe to one unit shock to KGs

The cumulative impact of changes in public capital on private capital and output per capita is relatively sizeable, especially if we consider the long-run response. Per capita output increase by 10% in the long run and KPe by almost 20%[12]. It is important to stress the auto-regressive character of the growth rate of output, with significant feedback impact in all equations and in the propagation of the initial shock. In this sense, after its initial shock of 1%, public infrastructure increases in the long run by almost 8%, and its convergence rate is faster than those of other variables. In any case, the cumulative responses are large and well above similar exercises that use U.S. and other OECD countries data (see for instance Perotti(2004)). These results are robust; they do not change significantly when we use the full sample or change the form in which human capital enters in the regression[13]: the productive impact of infrastructure in Brazil is significant and large.

[12] A possible reason for these large responses is the fact that infrastructure in Brazil is relative scarce when comparing to Europe and the U.S., for instance. Hence, the gains for a given variation is higher in the former than in the latter countries, as the marginal return is much bigger. Most likely, in a future in which public investiment increase markedly, the impact of KGs on y and KPe will be much smaller.

[13] In contrast, when we employ per capita variables the cumulative impact on (per capita) output and private capital was found to be much smaller, 3% and 6% respectively.

4 An Experiment on Cash Flow and Solvency

In this section we perform a (partial equilibrium) simulation of the impact of increasing public investment, using debt finance, on tax collection, debt and public solvency. The experiment is rather simple, but it can be useful as a first approximation, and can give us an idea of the magnitudes of the impact and the limitations of this type of policy. We investigate the impact of one single "project" - public investment increases by 1% of GDP in one year - in the government future cash flow and net worth. We basically want to study whether public investment in infrastructure pays for itself, especially in the form of increased tax collection.

We use the impulse-response system of Section 3 to simulate in the first place the paths of GDP and KGs after a shock to the latter at time zero (2004), and the initial increase in KGs is financed entirely by debt. From the simulated path of output we then calculate the variation of tax revenues, assuming that the tax ratio remains forever in the current level, 35%. This is trivially given by $dTax_t = 0.35 * dY_t$,and the trajectory of taxes follows that of GDP.

Moreover, from the path of KGs we have to calculate the increase in gross public investment, which is a cost. This is done by the following formula[14]:

$$I_t = KGs_{t+1} - KGs_t + (KGs_t - KGs_0)\,\delta$$

Some additional assumptions were necessary to run this experiment. First, we set real interest rate constant at 8% for the entire period. This is not far from its current value: at the moment interest rates on central government bonds are close to 8.5% to 9% in real terms, although this is clearly not an equilibrium value. When considering longer periods (say, the last 20 to 30 years) this rate may be below 8%, but discount rates used in the privatization of public infrastructure in general were above this rate, which is also close to the rate that the federal government finances its investment projects.

Note, however, that the assumption of a constant interest rate, although necessary for the simulations in this sub-section, may be problematic. First of all, in the long-run public capital accumulation and the increase in government net worth will decrease the interest rate. In contrast, given current levels of debt to GDP ratio, short run growth in debt and reduction in net revenues will pressure this rate up. Given the simple partial equilibrium

[14] Note that we subtracted $KGs_0 * \delta$ in order to eliminate from the formula the investment necessary to make up for the depreciation of the existing capital stock.

methodology we use, it is impossible to verify which effect dominates. We relax, albeit arbitrarily, this assumption in one simulation presented in Figure 4.1[15]. Second, we abstract of any general equilibrium consequence of public capital on private capital, which can be positive or negative, depending on many factors, and certainly impacts tax collection.

Finally, results are somewhat influenced by depreciation rate, as it affects gross investment and costs. We used as a benchmark 5%, but also 3.5% and 10%, as a robustness check. The chosen value may seem low, but we consider it adequate for public capital structures. Moreover, it is close to most estimates in the literature. For instance, Morandi and Reis (2004) estimated that the depreciation rate in Brazil is, on average, 3.7%, while Pereira and Ferreira (2006), using standard calibration techniques, found that the depreciation rate of the public capital stock is around 5.4%.

A common way of analyzing the impact of a given project on fiscal sustainability is to study its influence in the government net worth:

$$NW = \sum_{t=0}^{T} \frac{(Tax_t - I_t - C_t)}{(1+r)^t} - D_0 \qquad (1)$$

As it is standard, the net worth is the present value of government primary surplus, $(Tax_t - I_t - C_t)$ minus the initial value of debt. This is a straightforward calculation, given the simulated values of tax collection and investment above and the hypothesis that public consumption, C, does not change with new capital projects. Note that in the formula above we are not considering user fees nor are we taking into account the increase in the value of public assets, i.e., the variation of KGs.

We performed this exercise for different models (i.e., human capital in level or in logs) and time periods (full sample or the 1960-96 sample). Results are somewhat influenced whether we use per capita or per labor values, so we report both. Following Perotti (2004) we report in Table 4.1 below results assuming the final date T to be 5, 10 or 20 years, and the order of the models follows data of Table 3.3:

[15] One option we tried to pursue without success was to endogeneize the interest rate so that its value would be determined, for instance, by the debt to GDP ratio. The problem in this case is the absence, to our knowledge, of any study of the determinants of real interest rate in Brazil, much less any stable relationship with D(t)/Y(t). Absent such studies there was no safe way to calibrate the behavior of r.

Table 4.1: Net Worth as proportion of GDP

sample	5 years	10 years	20 years
60-00 (KH)	-0.3	-1.6	3.1
60-96 (KH)	-2.3	0.4	7.0
60-00 (KH^*)	-2.6	-0.6	3.9
60-96 (KH^*)	-2.1	0.9	7.1

obs: models in each line correspond to those in Table 3.3

Net worth values are presented as a proportion of 2004 GDP and correspond to the models in per worker terms. Given the large response of GDP to public capital shocks observed in the exercises of the previous section, the net worth of an investment project which is equivalent to an increase by 1% of GDP public capital stock is positive in the very long run (after 20 years), as one could expect. Hence, public investment does pay for itself, in the sense that the increase in tax collection is more than enough to offset the debt increase and the necessary investment implied by the increase in public capital after the initial shock. This contrast to the results in Perotti(2004), who rejects the hypothesis, for 6 OECD countries, that shocks to public investment are self-amortazing.

Note, however, that in all cases the transition involves negative values during a long period. In all models net worth is negative after five years and in two of them it is still negative after ten years. This is so because the response of public capital is initially faster than that of GDP and taxes, which is a fixed proportion of the former. Estimations using the full sample reached more modest outcomes in the long run (around half the values obtained with the smaller sample). In the benchmark model (line four, human capital in levels and shorter sample) net worth is positive but close to zero ten years later. This could mean that, if the government decides to implement annually a sequence of projects using debt finance, the costs along the transition could be too high and not sustainable, even if in the long run solvency is guaranteed[16].

Results, of course, depend on the value of the interest rate and on the depreciation rate used in the investment equation. Larger depreciation rates imply higher investment in the future, and consequently net worth falls. However, there is no significant change when parameters are kept within

[16] Estimations using per capita variables in two cases reached very different outcomes. When using the 1960-2000 sample, even after 20 years net worth is negative, no matter how human capital is specified. In this case, net worth reaches zero only about 100 years later.

realistic bounds. For instance, with $\delta = 10\%$ net worth as proportion of GDP after 20 years decreases to 6.1% in the benchmark model.

Similarly, net worth falls with interest rate, as we discount heavier the future. However, the benchmark model delivers positive net worth of this type of investment project for any reasonable combination of parameters, and interest rate has to be well above 15% - everything else constant - to change qualitatively results. In the full sample model, results are somewhat more sensitive to parameters values, but even in this case only with $r = 12\%$ and $\delta = 10\%$ the net worth as a proportion of current GDP falls to zero.

Same can be said about the assumption that tax collection will stay forever at 35% of GDP. If this value falls in the future, it may be the case that investment will not pay for itself. However, if anything taxation will most probably grow in Brazil, as in the previous 15 years it went from 25% of GDP to 35%, so that a decline does not seem likely. Moreover, even with tax collection at 25% of output net worth is still positive when considering the 20 years period. All in all, we do not think that results are driven by our assumptions and they look quite robust to reasonable changes in the parameters values.

There is one variation of equation (1) that is worth studying, which is to take into account the increase in the value of public assets, i.e., to add the variation of KGs to the government net worth. In doing so we have to decide what fraction of new public structures are liquid or what is the relationship between the estimated variation in real terms of KGs and its market value. A one-to-one hypothesis is for sure extreme, as a large part of infrastructure in this country (e.g. most roads and sewage system in poor regions) cannot be sold to private agents at positive price as demand is low or at least low enough not to pay for the investment. Just as a benchmark, for lack of a better number, let's say that half the increase in public capital could be sold at its estimated value.

Another required decision concerns the date these assets would be "sold". If we set it at a date too far in the future, the variation of Kgs in present value tend to zero, of course. We will estimate this modified net worth (equation (1) plus the present value of the variation of public capital) following the dates of Table 4.1. As one could expect, solvency improves. In the benchmark case, the net worth of a project corresponding to an initial increase of KGs of 1% of GDP, is now only -1.2% after 5 years and 2.1% when considering 10 years, as opposed to -2.1% and 0.9%, respectively, observed in Table 4.1 above. In the case of the full-sample model (human capital in levels) net worth after 10 years is now positive.

Although results in general are very favorable to the argument that investment pays for itself and that one should not impose too many restrictions on debt finance of capital expenditures, some caution is necessary. First, as said before, not all types of public structures are liquid or can be sold without at a premium. Most probably, the majority is not, and the recent PPP law is an indication of that. Moreover, in the impulse-response exercise there is no loss or inefficiency: there are no "white elephants" and every Real invested turns into public capital that generates enough tax revenue or is potentially interesting to the private sector. It is highly unlikely that all new public assets could be classified as such.

This does not imply that our results are invalid. It only qualifies them in the sense that, if in the one hand there are clear and robust indications that debt finance is worth pursuing as a mechanism to fund public infrastructure, on the other hand our methodology assumed that all public investment projects are (equally) "good projects", which is not the case. Moreover, as noted before, estimated elasticities and the response of GDP to KGs shocks are bit large and well above those obtained in similar studies for other countries.

Figure 4.1 presents the paths of public debt ratio corresponding to two simulation exercises. In both cases debt and GDP series were obtained separately: the former is the old debt plus the initial shock, compounded in each subsequent period by the interest rate while GDP path is obtained from the impulse-response exercise.

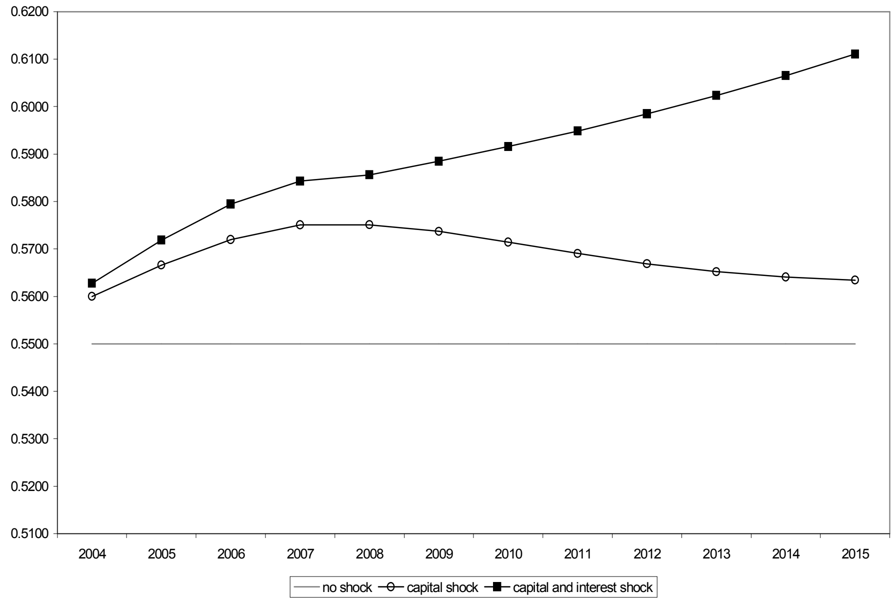

Figure 4.1 Simulated Paths of the Debt to GDP Ratio

The horizontal line assumes that primary surplus would stay at a level high enough to hold constant the debt ratio in the absence of shocks. The line in the middle corresponds to the previous simulation (a temporary shock to KGs of 1% of GDP financed by debt issue), and shows that new public investment expenses may lead to short run problems for public finances (as the debt ratio overshoots), although in the medium to long run the debt ratio falls. However, after ten years the debt ratio is still marginally above its pre-shock level, and it will take some years to fall bellow such level[17].

If investors respond to the negative fiscal shock by demanding higher interest rate to refinance old public debt and to finance the new project, the short run problems become more acute - see upper line. In this simulation interest rate increased by 0.5% in 2005 and decreased subsequently by 0.1% a year, until it returned to 8%, its original level. In this case, ten years after the shock debt ratio is still six points above 55% and it exceeds this value for decades. This adds another caveat to the results in Table 4.1.

[17] This result is sensitive to sample period and specification. In general, debt ratio falls faster when we use the per-worker specification and the 1960-1996 sample.

5 Conclusion

In this paper we have shown, using different data sets and methodologies, that the productive impact of infrastructure in Brazil is relevant. Impulse-response exercises indicated that the observed decrease in capital expenditures in the recent past might have hurt growth and brought about high output and social costs. In most exercises we showed that shocks to infrastructure stock can generate sizeable variations in output.

There is now consensus in Brazil on the need to expand capital and maintenance expenditures in the infrastructure sector. However, fiscal irresponsibility in the past led the public sector to record-high indebtedness levels ever, which demanded tight fiscal policies from the central and state governments in the recent years. Such policies are often perceived as the cause of the reduction of infrastructure expenditures, so that under current rules, it is not realistic to expect a considerable expansion of public investment. Moreover, simulations reported in this chapter showed that if entirely financed by debt, the expansion of public capital expenditures might lead in the short and medium run to debt to GDP ratios above the current level. Given that this ratio in Brazil is already extremely high, solvency of the public sector is an issue. Small increases in this ratio, even a short-run variation backed by future tax collection or user fees, may lead to increases in the interest rate of public bonds that could offset future revenue gains. For this not to be the case, Brazil will first have to increase creditworthiness, achieving debt tolerance, by mostly reducing debt ratios well below the current level.

A deep discussion of new rules and regimes for financing public investment is beyond the scope of this article. However, given that the gap in infrastructure investment has significant productive impacts, this is an important question that should be immediately addressed by policy makers and academics. We showed in the net worth simulations that, most probably, public investment does "pay for itself": the present value of tax revenues and the capital gain associated to new investment projects is in the long-run above the costs involved. Although we made somewhat strong assumptions about the market value of public assets and efficiency of public investment, we believe that this result is robust. This is an indication that debt finance could be used, but that it should be restrictive and selective, and associated to projects that clearly generates enough revenue or are potentially interesting to the private sector.

References

[1] Afonso, J.R., E. Araújo e G. Biasoto Jr; ,2005, "Fiscal Space and Public Sector Investments in Infrastructure: A Brazilian Case-Study," Textos para Discussão 1141, IPEA

[2] Ai, C. and S. Cassou (1995) "A Normative Analysis of Public Capital," Applied Economics, 27, pp. 1201-1209.

[3] Aschauer, D. (1989) "Is Public Expenditure Productive?" Journal of Monetary Economics, 23, pp. 177-200.

[4] Calderón, C. and L. Servén (2003) "The Output Cost of Latin America's Infrastructure Gap," In W. Easterly and L. Servén (eds.) The Limits of Stabilization: Infrastructure, Public Deficits, and Growth in Latin America, Stanford University Press and the World Bank.

[5] Calderón, C., W. Easterly and L. Servén (2003) "Infrastructure Compression and Public Sector Solvency in Latin America," in W. Easterly, W. and L. Servén (eds.): The Limits of Stabilization. Infrastructure, Public Deficits, and Growth in Latin America, Stanford University Press.

[6] Canning D. and E. Bennathan (2002), "The Social Rate of Return on Infrastructure Investment", World Bank Policy Research Discussion Paper 2390.

[7] Creel, J., Monperrus-Veroni, P and F. Saraceno(2006) "Estimating the Impact of Public Investment for the United Kingdom: has the Golden Rule of Public Finance Made a Difference?", manuscript, OFCE.

[8] Easterly, W and S. Rebelo (1993) "Fiscal Policy and Economic Growth: an Empirical Investigation", Journal of Monetary Economics, 32, pp. 417-458.

[9] Ferreira, P.C. and T. Maliagros (1998) "Impactos Produtivos da Infra-Estrutura no Brasil – 1950/95", Pesquisa e Planejamento Econômico, v.28, n.2, pp.315-338.

[10] Ferreira, P. C., Issler, J. V. and Pessôa, S. A. (2003) "Testing Production Functions Used in Empirical Growth Studies," Economic Letters, Vol. 83(1), April 2004.

[11] Ferreira, P. C. and L. Nascimento, (2006) ”Welfare and Growth Effects of Alternative Fiscal Rules for Infrastructure Investment in Brazil”, Ensaios Econômicos # 604, EPGE-Getulio Vargas Foundation.

[12] Mankiw, G., Romer, D. and D. Weil, (1992) "A Contribution to the Empirics of Economic Growth," Quarterly Journal of Economics, 107, 2, pp. 407-437

[13] Mintz, J. and M. Smart(2004) “Incentives for Public Investment under Fiscal Rules” Mimeo, University of Toronto.

[14] Morandi, L. and E. J. Reis (2004) "Estoque de capital fixo no Brasil - 1950-2002", XXXII Encontro Nacional de Economia - ANPEC.

[15] Pereira, R. and P.C. Ferreira(2007) "Efeitos de Crescimento e Bem-estar da Lei de Parceria Público-Privada no Brasil", manuscript, EPGE-Getulio Vargas Foundation.

[16] Pereira, A. and M. Pinho (2006) "Public Investment, Economic Performance and Budgetary Consolidation: VAR Evidence for the 12 Euro Countries", The College of William and Mary, Dept. of Economics WP 40.

[17] Perotti, R. (2004) "Public Investment: Another (different) Look," Mimeo, Universitá Bocconi.

[18] Pritchett, Lant. (2000). “The tyranny of concepts: CUDIE (cumulated, depreciated, investment effort) is not capital.” Journal of Economic Growth, 5 (4), December, pp. 361-384.

[19] Roubini, Nouriel, and Jeffrey Sachs. 1989. “Government Spending and Budget Deficits in the Industrial Countries.” Economic Policy 8: 99–132.

[20] Velloso, R. (2004), “Cortar gastos correntes é a solução?”, Estudos e Pesquisas do Inae # 78.

A Dynamic system of Sections 3 and 4

We present below the procedure to obtain benchmark model that was used in the simulations in Sections 3 and 4. The estimation result of the Vector Error Correction Model corresponding to the fourth model of Table 3.3 is the following:

Error Correction:	D(y))	D(Kg)	D(kpe)	D(KH)
CointEq1	-1.143773	-0.021956	-0.321532	0.142539
	(0.20149)	(0.09208)	(0.10348)	(0.14144)
	[-5.67646]	[-0.23844]	[-3.10709]	[1.00777]
D(y(-1))	0.732974	0.026861	0.360950	-0.114994
	(0.20935)	(0.09567)	(0.10752)	(0.14696)
	[3.50114]	[0.28076]	[3.35706]	[-0.78251]
D(y(-2))	0.672063	-0.103378	0.304292	-0.138957
	(0.18899)	(0.08637)	(0.09706)	(0.13266)
	[3.55611]	[-1.19697]	[3.13507]	[-1.04746]
D(Kg(-1))	-0.060022	0.678424	0.307129	0.549147
	(0.40385)	(0.18456)	(0.20741)	(0.28348)
	[-0.14862]	[3.67592]	[1.48077]	[1.93713]
D(Kg(-2))	0.431614	0.238408	0.073549	-0.566349
	(0.42379)	(0.19367)	(0.21765)	(0.29748)
	[1.01846]	[1.23099]	[0.33792]	[-1.90382]
D(Kpe(-1))	-0.181992	0.215672	0.357704	0.111761
	(0.44023)	(0.20118)	(0.22609)	(0.30902)
	[-0.41341]	[1.07202]	[1.58211]	[0.36166]

(cont.)

D(Kpe(-2))	-0.051259	-0.179382	0.040111	0.038464
	(0.31007)	(0.14170)	(0.15925)	(0.21765)
	[-0.16532]	[-1.26593]	[0.25188]	[0.17672]
D(HK(-1))	-0.635105	-0.049177	-0.450141	0.996335
	(0.27908)	(0.12754)	(0.14333)	(0.19590)
	[-2.27573]	[-0.38559]	[-3.14062]	[5.08597]
D(Hk(-2))	-0.276756	0.019932	-0.029121	0.111368
	(0.31092)	(0.14209)	(0.15968)	(0.21825)
	[-0.89012]	[0.14028]	[-0.18237]	[0.51028]
R-squared	0.706920	0.830031	0.945755	0.732392
Adj. R-squared	0.613134	0.775641	0.928396	0.646758
Sum sq. resids	0.017926	0.003744	0.004728	0.008833
S.E. equation	0.026778	0.012237	0.013752	0.018797
F-statistic	7.537614	15.26069	54.48354	8.552541
Log likelihood	80.06987	106.6946	102.7257	92.10217
Akaike AIC	-4.180580	-5.746740	-5.513278	-4.888363
Schwarz SC	-3.776544	-5.342703	-5.109241	-4.484326
Mean dependent	0.017452	0.020904	0.018860	0.027494
S.D. dependent	0.043052	0.025835	0.051394	0.031626

We used these estimations to obtain the short-run dynamic equations used in the simulations in Section 3 and 4. These are simply the transformation to levels of the equations above, taking into account that some coefficient were not significant at the usual levels: .

$$Y_t = 0.82 + 0.57Y_{T-1} - 0.04\,Y_{T-2} - 0.67\,Y_{t-3} + 0.16\;KPU_{T-1} + 0.51\;KPU_{T-2} - 0{,}42KPU_{t-3}.$$

$$0.04KPR_{T-1} + 0.06\;KPR_{T-2} + 0.11\;KPR_{t-3} - 0.49\,KH_{T-1} + 0.36\;KH_{T-2} + 0.34KH_{t-3}$$

$$KG_{st} = 0.01 - 0.008\;Y_{T-1} - 0.11\;\;Y_{T-2} - 0.09\,Y_{t-3} + 1.65\;KPU_{T-1} - 0.41\;KPU_{T-2} - 0.23\;KPU_{t-}$$

$$0.22KPR_{T-1} - 0.45\;KPR_{T-2} + 0.24\;KPR_{t-3} - 0.11\;KH_{T-1} + 0.07\;KH_{T-2} + 0.04\;KH_{t-3}$$

$$Kpe = 0.23 + 0.04\;Y_{T-1} - 0.06\;Y_{T-2} - 0.30\;Y_{t-3} + 0.38\;KPU_{T-1} - 0.24\;KPU_{T-2} - 0.07\;KPU_{t-3}$$

$$1.52\,KPR_{T-1} - 0.29\;KPR_{T-2} - 0.05\;KPR_{t-3} - 0.36\,KH_{T-1} + 0.41KH_{T-2} + 0.01\;KH_{t-3}$$

$$KH_t = -0.10 - 0.01\,Y_{T-1} + 0.03\;Y_{T-2} + 0.12\;Y_{t-3} + 0.42\,KPU_{T-1} - 1.04\;KPU_{T-2} + 0.58\;KPU_{t-3}$$

$$0.04KPR_{T-1} - 0.28\;KPR_{T-2} + 0.16\;KPR_{t-3} + 1.73\;KH_{T-1} - 0.85\;KH_{T-2} + 0.09\;KH_{t-3}$$

In the simulations it was assumed that the economy in 2004 was in the steady-state, which implies that the relationship between output, public capital, private capital and human capital was given by the cointegration vector. We would then apply a shock in the economy (in 2005) and the path of these four variable would be given by the short run dynamic system.. The remaining procedures are explained in section 3 and 4.