An econometric analysis *of private-sector* investment in Brazil

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This article analyses the main determinants of private-sector investment in Brazil during the period 1956-1996, using an empirical model employed in the most recent studies on developing countries. The econometric procedures followed not only take into account the non-stationarity of the data series examined, but allow for the possible difficulties involved in treating the conditioning variables as exogenous ones or as policy instruments. The findings –both the long-term equations and the short-term models– reveal the positive impact of the output, public investment and financial credit variables and the negative effect of the exchange rate. The results of the weak exogeneity and superexogeneity tests show the importance of credit and public investment as economic policy instruments, while obviating Lucas' critique.

I

Introduction

Capital goods investment decisions are of the greatest importance for a country's economic growth, and are generally taken in the private sector, which is expected to play a fundamental role in productive investment.

In developing countries, the decline in investment rates that began in the 1980s inspired empirical research into the main determinants of private-sector investment. This research was also motivated by the institutional and structural characteristics of capital formation in those countries, such as financial repression in the credit market, a strong government presence, foreign currency dependency and different forms of economic instability. More recent studies on private-sector investment in developing countries (among others, Greene and Villanueva, 1995; Servén and Solimano, 1993 and Agosin, 1994) have also extended empirical analysis to variables representing uncertainties in the investment decision-making process and external constraints. These last were included because of the external debt crisis and the deterioration in the terms of trade that affected developing economies in the 1980s.

In the specific case of Brazil, empirical studies have mainly sought to analyse the relationships between private- and public-sector investment. The most recent study along this line of research was that of Cruz and Teixeira (1999), which used the stationarity and cointegration tests to arrive at estimates that took account of the non-stationarity of time series. The results obtained showed that public- and private-sector investments were complementary in the long term and substitutive in the short term.

What has inspired the present paper, however, is the fact that empirical analysis of private investment cannot yet be considered wholly satisfactory from the point of view of modern econometrics. Not even the most recent empirical studies, of Brazil or of groups of developing countries, have investigated the exogenous character of the explanatory variables, which means that private investment has been treated, a priori, as a typically endogenous variable. Since the parameters of an econometric model are estimated on the basis of its explanatory variables, the direct assumption must be that the marginal process of each of these variables offers no information of relevance to the calculation. These hypotheses need to be verified empirically, however. Should the marginal process of some explanatory variable prove to be relevant, this variable could not be regarded as exogenous, as that would mean neglecting important information and would result in inefficient estimation of the parameters.

Another use of empirical exogeneity tests for the subject on hand is the identification of macroeconomic variables that can be used as policy instruments, i.e., of variables whose structure can change without affecting the model parameters. This would obviate Lucas' critique (1976), which holds that, assuming rational expectations, the parameters estimated from an econometric model would become inapplicable as policy changes led agents to modify their behaviour in order to adapt to the new situation. Consequently, econometric models could not be used for economic policy-making purposes. Lucas' critique was a powerful challenge to the way econometric modelling had traditionally been used as an instrument for economic policy evaluation. Although the empirical importance of this critique is still debated, it was instrumental in the introduction of new standards for the modelling of interactions between policy rules and the responses of private agents.

The objective of this paper is to analyse the main determinants of private investment in Brazil during the period 1956-1996, using modern instruments such as stationarity, cointegration and exogeneity tests that allow the Lucas critique to be obviated. The econometric model used is based on the most recent studies of developing countries and takes account not only of the more common variables, but of the influence of external constraints on private investment as well. Consequently, it has a more generic character than the models used in previous studies on Brazil. The main goal is to obtain a private investment model that is well specified and consistent with theory.

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The stationarity and cointegration analyses allow the short-term and long-term effects of the explanatory variables to be distinguished from one another. The exogeneity tests, meanwhile, demonstrate the efficiency of the model as an estimation tool and provide data for policies to promote private-sector investment. The results obtained indicate that, during the period under study, private investment was positively influenced by output level, public investment and financial credits, and negatively influenced by the exchange rate and conditions of uncertainty. The exogeneity tests reveal the importance of public investment and financial credits as policy instruments for encouraging private investment.

This article consists of five sections, of which this introduction is the first. The second section contains some considerations regarding the variables used in this analysis and the sources of statistical data. The third briefly describes the methodology that is to be employed. The fourth analyses the empirical results obtained, and the fifth sets out the conclusions.

II

Statistical data and variables

According to Servén and Solimano (1992), there are theoretical and empirical considerations which suggest that the variables of most importance in determining private investment levels in emerging countries are: domestic output, the real interest rate, public investment, credit available for investment, the size of the external debt, the exchange rate and macroeconomic stability. As a starting point for empirical analysis, we believe that this is a satisfactory description of the problem.

The private investment data used were taken from the private-sector gross fixed capital formation figures published in the system of national accounts of the Brazilian Institute of National Statistics and Geography (IBGE). They include private investment in construction, machinery and equipment.[1]

According to the neoclassical theory of investment, which originated in the work of Jogerson (1963), the value of the capital stock desired by a competitive enterprise is a positive function of its output level, which may be treated as a proxy for the level of demand. If this result is extended to more aggregate levels, a country's output can be considered as a measure of demand in the private sector as a whole. In this paper we have used gross domestic product (GDP) figures from the IBGE system of national accounts.

Another variable that neoclassical theory considers relevant in investment decision-making is the real interest rate, which in this case would represent the usage cost of capital or the cost of credit for the company. Given that increases in the interest payable are a disincentive to investment, it might be expected that the relationship between the two variables would be negative. However, some recent studies (Agosin, 1994, on a group of developing countries, and Cruz and Teixeira, 1994, on Brazil) have found that the relationship is not statistically significant, apparently because of the short-term nature of interest rates and the shortcomings of credit markets in developing countries. For this analysis, use has been made of the Over/Selic interest rate data for the period 1973-1996, which represent the average interest rate for federal bonds and are published by the Central Bank of Brazil. For the period 1956-1973, the series has been supplemented with Ronci's data (1987).

Developing country governments generally play a large part in economic activity, the justification being the private sector's lack of involvement in large investment projects. The presence of public-sector capital affects private-sector investment in two different ways. On the one hand, the public sector competes with the private sector to appropriate scarce resources, both physical and financial, and may even produce marketable goods that compete with those of the private sector. This is known in economic literature as "crowding out". As against this, public-sector capital can increase productivity by generating a positive externality, as happens in the case of investments in infrastructure and the provision of public goods, and may act countercyclically, increasing the demand for private-sector inputs and services. This positive effect

[1] Some empirical studies on Brazil have counted investment by State-owned companies as part of public-sector investment. Since the important thing is the nature of the investment and not its ownership, we have chosen not to follow this approach.

is known as "crowding in". The public investment data used were taken from the public-sector gross fixed capital formation statistics published in the IBGE system of national accounts.

In emerging countries, many companies encounter restrictions in the credit market, apparently as a result of information asymmetries between lenders and borrowers and a degree of precariousness in the workings of capital markets and financial intermediation systems. As a rule, it can be said that certain sectors of emerging capital markets, such as long-term financing and the futures market, are underdeveloped, and this means that bank loans and external borrowing may be the only sources of credit available for private-sector investment financing. When resources of this type are available, it becomes viable to invest even when investors' own funds are insufficient to finance their projects. This analysis uses BNDES disbursement data for long-term lending at low interest rates to finance spending on capital goods.

The size of the external debt is one of the variables that exemplify the influence of external credit constraints on the financing of production activities in emerging countries. According to Servén and Solimano (1992), low investment rates in the 1980s reflected the decline in external resources being transferred to heavily indebted countries. In addition, high debt levels meant that resources previously used to finance local companies had to be transferred abroad as service payments and charges. The data used here are those for the external debt/GDP ratio published by the Central Bank of Brazil.

The exchange rate can influence the level of private-sector investment, as it is one of the components that determine the real cost of imports. A currency devaluation increases the real costs of purchasing imported capital goods, thereby reducing the profitability of the private sector and possibly causing investment to decline. Furthermore, a real devaluation can mean a fall in the real income of the economy as a whole, thus reducing production capacity and activity to levels that businesses find uncomfortably low.

As against this, a real currency devaluation can have a positive impact on investment in sectors producing internationally traded goods, as it increases competitiveness and export volumes. The data used are those for the nominal exchange rate against the dollar (average selling rate for the period) as reported by the Central Bank of Brazil.[2]

According to the theory of investment irreversibility (Pindyck, 1988), spending on fixed capital cannot be recovered in full if the company concerned should decide to sell this capital at a later date. The fact that many capital goods are company-specific and have a resale value lower than their purchase price means that investment is an irrecoverable cost. As a result, installed capital cannot be used for other purposes without the company incurring costs.

Caballero (1993) holds that it is mainly in developing countries that investment is irreversible, as secondary markets for capital goods are imperfect and adjustment costs of various kinds have to be met. If this view is accepted, the existence of uncertainties may have a large influence on investment decisions, since if the future is unpredictable any increase in current production capacity may leave the company with an excess of capital that cannot be eliminated without costs. This would explain why companies prove reluctant to carry out major investments, even during periods of prosperity. Thus, it would appear that economic stability and the credibility of public policies play an important role in stimulating investment. For the purposes of this paper, changes in the inflation rate will be used as a proxy for uncertainty in the economy. These data are calculated from the general price index for domestic supply (IGP-DI) provided by the Getúlio Vargas Foundation.

Most of the data used for the explanatory variables are only available annually. This is the case, for example, with the data on public- and private-sector investment, credit and external debt. As we are going to analyse a reasonable number of explanatory variables, as well as models including lags for each variable, we tried to obtain a sample with the largest possible number of observations. Also, during the period 1956-1996 the Brazilian economy operated under a variety of different circumstances, which means that investigating Lucas' critique is an interesting subject for this empirical study.

[2] Although Brazil has quite a diversified pattern of foreign trade involving a number of countries of origin and destination, we believe that changes in the exchange rate against the dollar reflect, on average, changes in the effective exchange rate.

III

Methodology

The econometric procedures will be carried out in four stages. In the first, the order of integration of each of the series used in the analysis will be determined by applying the stationarity or unit root tests. To start with, the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) will be applied. Decisions as to the stationarity of time series will also be based on visual inspection of their correlograms, as the unit root tests are a formalization of this inspection.

Given that the existence of structural breaks can result in the adf test wrongly indicating non-stationarity in what is actually a stationary series, the unit root test suggested by Perron will be carried out.[3] This test seeks to establish the order of integration of a time series by considering the likelihood of structural changes occurring in its behaviour.

In the second stage, the variables that are significant in the private investment equation will be identified, with their respective lags. Working "from the general to the particular", a general model known as the autoregressive distributed lags (ADL) model, will first be estimated.[4] Using the restriction tests, the model will be gradually reduced by eliminating variables and lags that prove to be statistically insignificant.

In the third stage, Engle and Granger's method (1987) will be used to verify the cointegration hypothesis in what prove to be integrated series of order one, followed by estimation of the differences model with the error correction mechanism. Johansen's method (1988) will also be used to analyse the cointegration vectors by means of a vector autoregressive (VAR) model, to determine more accurately the number of cointegration ratios and the coefficient vector estimates for these ratios. This stage is called for because the trend of a time series can be of two types, deterministic or stochastic. In the first case, the series may become stationary when the time variable is included in a regression model. With a stochastic trend, on the other hand, cointegration tests need to be carried out to check whether a linear combination of two or more time series may generate a stationary residual, even if individually they are not stationary. Cointegration of two or more time series suggests a long-term relationship between them, while the error correction mechanism only indicates the inclusion of the lagged stationary residual in the short-term model, to reconcile the short-term behaviour with the long-term equilibrium.

In the fourth stage, the weak exogeneity and superexogeneity tests will be carried out. According to Engle, Hendry and Richard (1983), the weak exogeneity hypothesis ensures that efficient inferences can be drawn from the parameters when the analysis is restricted to the conditional model. In the present paper, this model uses private investment as an endogenous variable. The weak exogeneity tests will be carried out on the parameters of the short- and long-term equations.

The combination of weak exogeneity and structural invariance in the parameters estimated leads to the concept of superexogeneity. If an explanatory variable were superexogenous, changes in its distribution would have no effect on the parameters of the conditional model. This being the case, its effects on the endogenous variable can be analysed in terms of policy simulations, with inferences being drawn in environments where intervention can take place. In this way, confirmation of superexogeneity obviates Lucas' critique, the thrust of which is to question the use of the estimated parameters of an econometric model to produce policy simulations, as agents are constantly revising their expectations in the light of changes in the economic environment.

[3] The test to be used is called the additive outlier test. For further details, see Perron (1989).

[4] For further information on the basis of this methodology, see Charemza and Deadman (1997).

IV

Analysis of econometric results

In all the econometric analysis carried out, use was made of the natural logarithm of the time series of each variable. This is because series expressed in logarithms present roughly constant variances, while the variance of a level series tends to increase with the size of the sample. As in Greene and Villanueva (1995) and Rocha and Teixeira (1996), the real interest rate variable was defined as: $\frac{(1 + i / 100)}{(1 + \pi / 100)}$, where *i* is the nominal percentage interest rate and π is percentage inflation.[5]

1. Stationarity tests

Visual analysis of the diagrams and correlograms of the level and first difference series indicates the possibility that the inflation rate variation and real interest rate series are stationary, while the other series seem to be integrated series of order one.[6]

a) *Results of the augmented Dickey-Fuller test*

The results of the augmented Dickey-Fuller (ADF) test for the level and first difference series are given in table 1. The second column shows the deterministic parameters (constant and linear trend) which presented a significant value t at the 10% level, and were therefore included in the regression of each of the variables. The third column shows the number of lags introduced into each regression to eliminate possible autocorrelation of the residuals, which were determined by minimizing the criteria of Akaike and Schwartz. The last column shows the value of the τ-ADF statistic or, where no lag has proved significant, the τ-DF statistic.

The results obtained show that the interest rate and inflation rate variation series are integrated ones of order zero or stationary, while the first differences of the private investment, public investment, external debt, exchange-rate and credit series refute the null hypothesis of non-stationarity and are therefore integrated series of order one. In the graphic analysis carried out previously, the GDP series was the only one whose result differed from what was expected. To obtain a more reliable result from this series, the Perron test had to be used.

b) *Results of the Perron test*

The Perron test was conducted for all the series that the ADF test showed to be non-stationary, to see whether they were really non-stationary or were affected by a structural break giving rise to a permanent change in their averages.[7] Table 2 shows the results of the Perron test for the level and first difference series. The second and fourth columns give the values obtained for the t-statistic. The upper critical values of t, supplied by Charemza and Deadman (1997, pp. 301-303), are –3.48 and –4.15 at the 5% and 10% significance levels, respectively.

The first-differenced GDP series was shown to be stationary, confirming the result obtained from analysis of its diagram and correlogram. Thus, the result of the ADF test for this series seems to be skewed by the presence of a structural break. For the other series, the results confirm those obtained from the ADF test and the correlogram analysis.

Following the unit root tests, it can be affirmed that in the period under consideration:

i) the private investment, output, public investment, external debt, exchange-rate and credit series are integrated series of order one I(1), being non-stationary in level while their first differences are stationary.
ii) the interest rate and inflation rate variation series are stationary in level or I(0).

[5] The values of the private investment, output, public investment, exchange-rate and credit series are expressed in millions of 1995 reais. For the investment series, we used the IBGE gross fixed capital formation deflator. For the other series, we used the general price index for domestic supply (IGP-DI). All the econometric results were obtained using the computer programs PC-GIVE and PC-FIML, version 9.10.

[6] For reasons of space, we have not included diagrams and correlograms.

[7] To determine accurately the period of occurrence of the structural break in each series (or the main break, if there was more than one), the recursion diagrams of the estimates of each series were analysed in a model with only a constant and a linear trend. With the exception of private investment and the exchange rate, the series presented large structural changes in the early 1980s, a period marked by low economic growth, high inflation and the debt crisis.

TABLE 1

Results of the ADF test: level and first difference series

Variable	Deterministic parameters	Lags	τ-ADF or τ-DF
Log private inv.	Constant	1	–1.756
Log output	Constant and trend	4	–2.406
Log interest rate	Constant and trend		–4.29[a]
Log public inv.	Constant	1	–1.864
Log external debt		3	–0.619
Log exchange rate	Constant and trend	4	–2.955
Log credit		4	–0.547
ΔLog inflation		6	–2.23[b]
ΔLog private inv.	Constant	1	–4.742[b]
ΔLog output		1	–1.603
ΔLog public inv.		0	–5.765[a]
ΔLog external debt		2	–3.959[a]
ΔLog exchange rate	Constant	4	–3.183[b]
ΔLog credit		3	–2.039[b]

[a] Denotes significance at 1% level.
[b] Denotes significance at 5% level.

TABLE 2

Perron's test for level and first difference series

Variable	t	Variable	t
Log private inv.	–0.839	ΔLog private inv.	–5.396[a]
Log output	–1.202	ΔLog output	–3.835[b]
Log public inv.	–2.528	ΔLog public inv.	–6.484[a]
Log external debt	–1.639	ΔLog external debt	–8.608[a]
Log exchange rate	–0.236	ΔLog exchange rate	–7.037[a]
Log credit	–2.080	ΔLog credit	–7.486[a]

[a] Indicates refutation of null hypothesis at 1% significance level.
[b] Indicates refutation of null hypothesis at 5% significance level.

2. Restriction tests on variables and lags

The method used was to begin by estimating a general model and then, with the application of restriction tests, gradually to reduce its size by eliminating lags and variables that proved to be insignificant.

The general case will be described as an autoregressive distributed lags (ADL) model. This model uses private investment as a dependent variable, this being expressed as a function of its own lags and of the current and lagged values of the other variables whose series were given as I(1): output, public investment, external debt, exchange rate and credit.

Owing to the large number of explanatory variables and the relatively small number of observations, the analysis began with estimation of an ADL(3) model, with three lags for each variable. Nonetheless, there proved to be a strong correlation between the public investment series and the GDP, credit and exchange-rate series. To avoid the problem of multicolinearity, we decided to estimate two adl models separately for private investment. The dependent variables used for the first are GDP, debt, the exchange rate and credit, while the second only has public investment as an explanatory variable.[8]

TABLE 3

Values of the sum of squared residuals (SSR), estimated standard deviation of residuals (σ) and Schwarz criterion for ADL(3) models

Model	SSR	σ	Schwarz
ADL(3)	0.1008	0.0728	–4.1134
ADL(3) without debt var.	0.1341	0.0764	–4.2109

Model ADL(3) → ADL(3) without ext. debt var.: F(4,19) = 1.5691 [0.2231]

The results of the Lagrange multiplier (LM) tests of joint significance for the first model indicate that the contribution of the three lags is significant at the 10% level. In addition, the LM tests for each variable show that external debt was not significant as a determinant of private investment in the period considered. The first step in reducing the model is to eliminate the variables that proved not to be significant. Table 3 presents the values of the sum of squared residuals (SSR), the estimated standard deviation of the

[8] The Ramsey specification test was applied to each ADL model and no specification errors were detected.

residuals (σ) and the Schwarz criterion for the ADL models with and without the presence of the external debt variable.

The values referred to did not differ greatly between the two models. The result of the F test does not rule out the hypothesis that all the coefficients of the external debt variable are equal to zero, confirming the possibility that these could be excluded. Analysis of the recursion diagrams of the model also confirmed that there was a structural break in 1995. A dummy impulse variable for that year was included in the model.

In the second model, the joint significance tests for each lag show that the second and third lags for private and public investment are not significant in the analysis. Table 4 gives the values for the sum of squared residuals (SSR), the estimated standard deviation of the residuals (σ), the Schwarz criterion for the ADL(3) and ADL(1) models and the F test for parameter reduction.

The values did not differ greatly between the two models. The outcome of the F test does not rule out the hypothesis that the coefficients of the second and third lags are jointly equal to zero, confirming the possibility that they can be excluded. Analysis of the recursion diagrams of the model also showed a structural break in 1990.

TABLE 4

Values of the sums of squared residuals (SSR), estimated standard deviation (σ) and Schwarz criterion for ADL(3) and ADL(1) models

Model	SSR	σ	Schwarz
ADL(3)	0.4372	0.1188	–3.7948
ADL(1)	0.5068	0.1203	–4.0300

Model ADL(3) → ADL(1): F(4,31) = 1.233 [0.3172]

3. Cointegration tests

For the cointegration analyses, use was made only of the integrated variables of order one that proved statistically significant in determining private investment: output, exchange rate and credit for the first model, and public investment for the second model.

a) *Results obtained using the Engle-Granger method*

The coefficients for the long-term relationship between private investment and the significant variables were obtained from the specific models of the previous section. The long-term equations estimated showed the following results (see models 1 and 2).

The ADF for the residuals of equations [4.1] and [4.2] indicate stationarity of level. As the private investment, output, public investment, exchange-rate and credit series are all I(1), we have two long-term equilibrium ratios given by [4.1] and [4.2].

In the first equation estimated, the output and credit coefficients are positive in the period 1959-1996, while the exchange-rate and dummy variable coefficients are negative. The positive coefficients for output and credit show that private investment was stimulated both by the level of activity in the economy and by the availability of long-term financing, which agrees with most of the empirical findings reported in the literature. The negative coefficient for the exchange rate shows that, over the long term, currency devaluation/depreciation led to a fall in investment. This was probably due to the decline in the economy's real income and the increase in the cost of imported capital goods, resulting in a lower level of activity overall.

The second equation estimated, for the period 1957-1996, shows the predominance of the crowding in effect, with investment in public goods having a positive impact on private-sector investment. In accordance with the negative values of the coefficients for the dummy impulse variables in [4.1] and [4.2], it also shows a decline in private investment levels in the 1990s.

Once the long-term dynamic of private investment has been analysed, the next step is to determine the short-term relationships among the variables. These relationships are represented in the models with the first differences of the I(1) variables, incorporating the error correction mechanism (ECM) and the real interest rate and inflation rate variation variables, whose series proved to be stationary in level.

Tables 5 and 6 give the results of the estimates, along with the residual diagnostic tests. In the two models estimated, the ECM term showed a significant negative coefficient, which confirms, according to Granger's representation theorem, that the series cointegrate. The results of the residual tests indicate an absence of autocorrelation (LM test) and of heteroscedasticity (ARCH1 and White's tests). The residuals proved normal, in accordance with the statistical value X^2. Ramsey's tests show that the two regressions are well specified.

In the first model, estimated for the period 1959-1996, the first differences of the output and credit series presented positive coefficients, showing themselves to be important factors in private investment in the short term as well. The negative coefficients for the exchange rate (first-difference, no lag and two lags) indicate that

Model 1 [4.1]

Log private inv. = 0.7509 Log output – 0.2312 Log exchange rate + 0.1702 Log credit – 0.2424 i1995
(t-statistic) (70.2432) (–9.8593) (10.6842) (–2.3398)

Wald's test for joint significance: $Chi^2(4) = 2.3624e+005$ [0.0000]**
ADF residual test: τ-ADF = –2.67**

Model 2 [4.2]

Log private inv. = 1.2120 Log public inv. – 1.9550 i1990
(t-statistic) (64.0931) (–1.9492)

Wald's test for joint significance: $Chi^2(4) = 6967.7$ [0.0000]**
ADF residual test: τ-ADF = –2.126*

* Indicates refutation of null hypothesis at 5% significance level.
** Indicates refutation of null hypothesis at 1% significance level.

TABLE 5

Estimated short-term model and respective tests, 1959-1996

(Dependent variable: ΔLog private investment)

Variable	Coefficient	Standard deviation	t	t prob.
ΔLog private inv. –1	0.4918	0.1224	4.018	0.0004
ΔLog output	1.4152	0.2679	5.283	0.0000
ΔLog exchange rate	–0.4274	0.0881	–4.851	0.0000
ΔLog exchange rate –2	–0.1085	0.0613	–1.772	0.0865
ΔLog credit	0.1619	0.0357	4.542	0.0001
ΔLog inflation	–0.0598	0.0314	–1.906	0.0602
ECM 1	–0.7756	0.1389	–5.585	0.0000
i1995	–0.3314	0.1471	–2.253	0.0317
$R^2 = 0.7649$	σ = 0.0775	D.W. = 2.24		
		Residual tests		
Test	Statistics		t prob.	
LM (autocorrelation)	F(2,28) = 1.0856		0.3515	
ARCH 1	F(1,28) = 1.0029		0.3252	
Normality	$X^{2(2)} = 3.3579$		0.1866	
White (heteroscedasticity)	F(15,14) = 0.2636		0.9925	
		Regression specification test		
Ramsey	F(1,29) = 0.1927		0.6639	

TABLE 6

Estimated short-term model and respective tests, 1958-1996

(Dependent variable: ΔLog private investment)

Variable	Coefficient	Standard deviation	t	t prob.
ΔLog public inv. –1	0.2177	0.1164	1.871	0.0695
ECM 2	–0.1323	0.0329	–4.011	0.0003
i1990	–0.3104	0.1020	–3.043	0.0044
$R^2 = 0.5422$	σ = 0.1018	D.W. = 1.85		
		Residual tests		
Test	Statistics		t prob.	
LM (autocorrelation)	F(2,34) = 2.0811		0.1404	
ARCH 1	F(1,34) = 2.3777		0.1323	
Normality	$X^2(2) = 4.246$		0.1197	
White (heteroscedasticity)	F(5,30) = 0.6392		0.6716	
		Regression specification test		
Ramsey	F(1,35) = 1.6402		0.2087	

the fall in investment resulting from currency devaluation/depreciation occurred in both the long and short terms. Variations in the inflation rate also proved to be significant as a determinant of private investment, indicating that uncertainty in the economy was instrumental in reducing the investment level. The interest rate coefficients did not prove statistically significant, which indicates that short-term variations in this rate did not affect investment significantly. The coefficient estimated for the dummy impulse variable again points to a fall in 1995.

The second model estimated shows the positive impact of lagged public investment in one period, and the fall in private investment in 1990. The result obtained confirms the crowding in effect: as public investments came to fruition, they had a positive effect on the productivity of private capital, which agrees with Cruz and Teixeira's results (1999) for the long term.

b) *Results obtained using Johansen's method*

As use is being made of the VAR model, which does not specify the endogenous and exogenous variables *a priori*, and considering the possibility that there may be more than one cointegration vector, Johansen's method of cointegration analysis is more general in character than the Engle-Granger method.

Considering the results obtained in section IV.2, a three lag VAR was estimated for the private investment, output, exchange-rate and credit variables, and another VAR model with one lag was estimated for the private investment and public investment variables. Tables 7 and 8 show the results of applying Johansen's procedure

TABLE 7

Cointegration analysis using Johansen's method: VAR(3)

Hypothesis	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
$\mu_{minimum}$	39.29[a]	14.01	4.215	0.599
Critical value at 5%	27.1	21.0	14.1	3.8
Hypothesis	$r = 0$	$r = 1$	$r = 2$	$r = 3$
$\mu_{maximum}$	58.11[a]	18.82	4.814	0.599
Critical value at 5%	47.2	29.7	15.4	3.8
		Autovectors β'		
	Log private inv.	Log output	Log exchange rate	Log credit
	1.0000	–7108	0.2501	–0.1829
	0.0121	1.0000	0.4045	–0.2917
	–4.1359	–11.0740	1.0000	10.3610
	–1.0034	–2.1547	–0.4419	1.0000
		Coefficients α		
Log private inv.	–0.6334	0.8003	0.0011	0.0119
Log output	0.0733	0.0825	–0.0003	0.0079
Log exchange rate	–0.0254	–0.5612	–0.0114	–0.0033
Log credit	2.0316	2.1885	–0.0115	0.0002

[a] Indicates refutation of null hypothesis at 1% significance level.

TABLE 8

Cointegration analysis using Johansen's method: VAR(1)

Hypothesis	$r = 0$	$r \leq 1$
$\mu_{minimum}$	19.28[a]	3.112
Critical value at 5%	14.1	3.8
Hypothesis	r = 0	r = 1
$\mu_{maximum}$	22.39[a]	3.112
Critical value at 5%	15.4	3.8
	Autovectors β'	
	Log private inv.	Log public inv.
	1.0000	–1.9316
	–1.4506	1.0000
	Coefficients α	
Log private inv.	–0.1034	0.0461
Log public inv.	0.1797	0.0471

[a] Indicates refutation of null hypothesis at 1% significance level.

on the basis of the VAR(3) and VAR(1) models, respectively.[9]

In both models, the results for the lower and upper statistical values would seem to refute the null hypothesis of no cointegration while not refuting the hypothesis, at the upper level, of one cointegration vector. Consequently, the statistics suggest that there is just one cointegration vector in the two models estimated. The first line of matrix β' gives the coefficients estimated for the long-term equations that have private investment as an endogenous variable:

Log priv. inv. = 0.7108 Log output – 0.2501 Log exchange rate + 0.1829 Log credit [4.3]

Log priv. inv. = 1.9316 Log public inv. [4.4]

The results are similar to those obtained using the Engle-Granger method. The coefficient values of equation [4.3] are roughly equal to those obtained in equation [4.1]. The coefficient obtained in equation [4.4] is higher than the coefficient estimated in equation [4.2].

4. Exogeneity tests

The first exogeneity test was carried out on the parameters of the long-term equations obtained in section IV.3.b. On the basis of the works of Hendry and Mizon (1993) and Johansen (1994), the exogeneity hypothesis is formulated as a parametric restriction in matrix of adjustment α. Table 9 shows the results obtained in each of the models. The likelihood ratio (LR) statistical test was calculated for each of the variables included in the VAR models of the section indicated. The critical value, at a 5% significance level, is 3.84.

Going by the results, we can reject the hypothesis that the coefficients of adjustment α of the private

[9] Here we are using a procedure similar to that of section IV.2 to analyse the statistical significance of each variable and each lag in the VAR models.

TABLE 9

Weak exogeneity tests on long-term parameters

VAR(3) model				
Variable	Log private inv.	Log output	Log exchange rate	Log credit
LR statistic	4.3106[a]	0.7258	0.0028	5.0299[a]
VAR(1) model				
Variable	Log private inv.	Log public inv.		
LR statistic	4.7946[a]	8.8767[b]		

[a] Indicates refutation of null hypothesis at 5% significance level.
[b] Indicates refutation of null hypothesis at 1% significance level.

investment and credit variables in the VAR(3) model are null. The same is true of the private investment and public investment variables of the VAR(1) model. Consequently, the marginal processes generating these variables contain information that is relevant for the cointegration ratios. It therefore does not seem appropriate to include credit and public investment as exogenous variables in the long-term equations, as the estimates became inefficient.

a) *Weak exogeneity tests for the long-term model parameters*

The first step, before carrying out these tests, was to formulate the marginal models for the explanatory variables present in the short-term models. The attempt to specify the marginal processes began with estimation of an ADL(3) model. Working "from the general to the particular", the model was purged of insignificant terms. Table 10 shows the results of the marginal models obtained empirically.

For a variable to be deemed a weak exogenous one in the short-term model, it must meet the following conditions: i) its marginal model must not contain the ECM error correction term; ii) the residuals of its original model must not be correlated with the residuals of the short-term model.

Table 11 gives the results obtained for the estimates of the marginal models with the inclusion of the ECM term. The results of Wald's test are also given, so that we can analyse the significance of the residuals of each of the marginal models in the respective short-term models.

According to the results of the t-statistics for each ECM term, and of the F statistics of Wald's test, all the variables meet both weak exogeneity conditions. Consequently, we can conclude that inferences relating to the parameters of the two short-term private investment models can be drawn without any relevant information being lost.

b) *Results of the superexogeneity tests*

The most usual way of checking the structural invariance of the parameters of a conditional model is to verify the significance of the squares of the residuals estimated in the marginal models within the model itself. This type of test was proposed by Engle and Hendry (1993). For superexogeneity to be accepted, the squares of the residuals do not have to enhance estimation of the conditional model, but must be statistically significant. Table 12 gives the results of the LM tests that verify the significance of these residuals as variables left out of the two conditional models.

In all the marginal models, it has been found that their estimated residuals are not correlated with the respective conditional models. On the basis of these results, we can say that the parameters of the short-term models are invariant, as they are unaffected by structural changes in the marginal models. Consequently, all the conditioning variables can be admitted as superexogenous, as changes in their structure do not affect the parameters estimated, so that Lucas' critique is obviated.[10]

[10] We also carried out analysis of the recursion diagrams of the marginal and conditional models, which also showed that the structural breaks in the short-term models did not coincide with the breaks in the marginal models. These diagrams have been omitted for reasons of space.

TABLE 10

Marginal models estimated for explanatory variables

ΔLog output = 0.0279 + 0.4746 ΔLog output (–1)
t-statistic (2.784) (3.227)

R^2 = 0.2196 F(1,37) = 10.413 *D.W.* = 2.07

ΔLog exchange rate = –0.0842 –0.3780 ΔLog exchange rate (–3) + 0.6059 i94
t-statistic (–3.196) (–3.272) (4.212)

R^2 = 0.6530 F(2,34) = 11.667 *D.W.* = 2.16

ΔLog credit = –0.2345 –0.4836 ΔLog credit (–1) –0.4887 ΔLog credit (–2) –0.3873 ΔLog credit (–3) + 4.0646 ΔLog output (–3)
t-statistic (–2.055) (–2.862) (–3.004) (–2.164) (2.639)

R^2 = 0.3564 F(4,32) = 3.433 *D.W.* = 1.83

ΔLog inflation = –0.4476 ΔLog inflation (–3) –8.3259 ΔLog output (–2) + 9.0803 ΔLog output (–3)
t-statistic (–1.981) (–2.484) (2.648)

R^2 = 0.2115 *D.W.* = 1.86

ΔLog public inv. = 0.1042 ΔLog credit (–2) + 0.3565 i86
t-statistic (2.669) (3.054)

R^2 = 0.3054 *D.W.* = 2.11

TABLE 11

Results of the weak exogeneity tests: short-term parameters

ΔLog output = 0.0214 +0.3892 ΔLog output (–1) + 0.0943 ECM1
t-statistic (2.019) (2.537) (1.611)
Wald test for significance of residual: F(1,29) = 0.1189 (t prob. = 0.7328)

ΔLog exchange rate = –0.1043 –0.3661 ΔLog exchange rate (–3) + 0.6216 i94 + 0.1809 ECM1
t-statistic (–2.941) (–3.132) (4.268) (0.852)
Wald test for significance of residual: F(1,28) = 0.6297 (t prob. = 0.4341)

ΔLog credit = –0.2457 –0.4794 ΔLog credit (–1) –0.5076 ΔLog credit (–2) –0.3724 ΔLog credit (–3) +....+ 0.4091 ECM1
t-statistic (–2.107) (–2.807) (–3.038) (–2.043) (0.622)
Wald test for significance of residual: F(1,27) = 1.6518 (t prob. = 0.2096)

ΔLog inflation = –0.4535 ΔLog inflation (–3) –8.0688 ΔLog output (–2) + 9.6650 ΔLog output (–3) –0.4429 ECM1
t-statistic (–1.974) (–2.309) (2.449) (–0.313)
Wald test for significance of residual: F(1,28) = 0.4896 (t prob. = 0.4899)

ΔLog public inv. = 0.0875 ΔLog credit (–2) + 0.3440 i86 –0.0564 ECM2
t-statistic (2.213) (3.007) (–1.630)
Wald test for significance of residual: F(1,34) = 0.0468 (t prob. = 0.8300)

TABLE 12

Results of the LM tests to verify superexogeneity

Marginal model: ΔLog output		
LM test for significance of squared residual:	F(2,28) = 1.1731	(t prob. = 0.3241)
Marginal model: ΔLog exchange rate		
LM test for significance of squared residual:	F(2,26) = 0.0283	(t prob. = 0.9721)
Marginal model: ΔLog credit		
LM test for significance of squared residual:	F(2,26) = 0.8867	(t prob. = 0.4241)
Marginal model: ΔLog inflation		
LM test for significance of squared residual:	F(2,26) = 0.3661	(t prob. = 0.6970)
Marginal model: ΔLog public inv.		
LM test for significance of squared residual:	F(2,32) = 0.5460	(t prob. = 0.5846)

V
Conclusions

The objective of this paper is to reveal the main variables determining private investment in Brazil during the period 1956-1996. We started out from a set of explanatory variables based on the most recent empirical research for developing countries. By employing stationarity, cointegration and exogeneity tests, we sought to obtain a consistent, well specified model that was capable of furnishing information of relevance to the implementation of policies aimed at encouraging private investment.

Although the equations estimated for the long term showed deficiencies because some variables were regarded as exogenous, the two regression models for the short term presented weak exogenous regressors and structurally stable parameters. Consequently, it can be said that structural changes in the output, exchange-rate, credit, inflation variation and public investment models are not responsible for structural changes in the private investment models, and that Lucas' critique does not apply to these models.

Since the results obtained admit of each model's explanatory variables being used as policy instruments, at least three ways of bringing about a rise in private investment emerge: i) increasing economic activity, ii) increasing long-term credit and financing, and iii) increasing investment in public goods. It can also be said that, for the 1990s, analysis of indicators relating to the output, credit and public investment variables would be enough to explain the drop in private investment levels in Brazil.

Apart from the positive influence of output and the negative one of uncertainty, the following has been demonstrated in the case of Brazil: i) the importance of long-term credits from development banks, ii) the predominance of the crowding in effect that public investment has on private investment, and iii) the negative effects of currency devaluations on investment. Thus, measures involving large devaluations of the exchange rate or cuts in public investment are detrimental to capital formation in the country.

Consequently, we can conclude that the neoliberal policy recommendations of the Washington Consensus regarding reduction of the role of the State in the allocation and creation of resources (the doctrine that has prevailed among policy makers since the second half of the 1980s) are questionable. The revival of economic growth requires State participation, as this tends to stimulate the expansion of private investment, even in this era of globalization. Furthermore, the country needs to strengthen the fundamental balances of economic policy, something that involves: i) an appropriate real interest rate, ii) an inflation rate close to those of its trading partners, iii) a competitive and predictable exchange rate, and iv) long-term strategies for public investment projects. These goals need to be consistent with both internal and external equilibrium, so that a policy of self-sustaining growth, based essentially on productive investment, can become viable.

The models we have presented can be used to draw economic policy conclusions. It must be stressed, however, that they leave out certain crucial issues, such as non-linearity. It may be argued that the real process of capital accumulation and disaccumulation, and the effects of investment on income, involve considerations relating to the existence or otherwise of idle capacity and the occurrence of periodic crises. Consequently, interpreting econometric conclusions in terms of the historical accumulation and growth process is something that needs to be done with sensitivity and caution.

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