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An approach to testing the exogeneity of the money supply in Brazil by mixing Kalman filter and cointegration procedures: 1964.02 to 1986.02

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Uma abordagem para testar a exogeneidade da oferta monetária no Brasil empregando o filtro de Kalman e a cointegração: 1964.02 a 1986.02

ABSTRACT

We examine the extent of the exogeneity of the money supply using monthly data spanning from 1964.04 to 1986.02. The tests applied investigated the plausibility of classical hypotheses. We employed Kalman Filter procedures, Johansen cointegration procedures, and the bootstrap approach. We argued that the real rate of interest did cause, in the Granger sense, the bond stock supporting the claim that the monetary authority was able to perform indirect monetary control through open market transactions. The results show that seigniorage collection was a white noise and econometrically independent from the inflation rate. Money creation and the inflation rate were cointegrated. We found that money growth was weakly exogenous for the parameter of interest in the conditional model of inflation, but the reverse is not true for inflation. Moreover, Granger's causal relation between them was unidirectional from money to inflation. Therefore, money growth was strongly exogenous concerning the inflation rate. These empirical findings differ greatly from many previous results. Our main contribution is having demonstrated that the monetary supply was exogenous with respect to the inflation rate and that the monetary authority had enough independence to execute an active monetary policy.

Key words: Kalman filtering, cointegration procedures, bootstrap, econometric modeling, inflation, money supply, monetary policy.

RESUMO

Usando dados mensais de 1964.4 a 1986.2, examinamos o grau da exogeneidade da oferta de moeda. Os testes implementados investigaram a plausibilidade das hipóteses clássicas. Empregamos filtros de Kalman, o procedimento de cointegração de Johansen e a abordagem de

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bootstrap. Argumentamos que a taxa real de juros causava a dívida pública no sentido de Granger, o que suporta a tese de que a autoridade monetária era capaz de realizar indiretamente o controle monetário através das operações de mercado aberto. Os resultados mostraram que a coleta de senhoriagem se comportava como um ruído branco e era econometricamente independente da taxa de inflação. A expansão monetária e a taxa de inflação eram cointegradas. Os testes indicaram que a expansão monetária era fracamente exógena para os parâmetros de interesse no modelo condicional da inflação, mas o inverso não é válido para a taxa de inflação. Ademais, a relação de causalidade de Granger entre essas variáveis era unidirecional, da expansão monetária para a inflação. Portanto, o crescimento monetário era fortemente exógeno no que concerne à taxa de inflação. Esses resultados são inteiramente divergentes de estudos anteriores. Nossa principal contribuição é ter demonstrado que a oferta monetária era exógena com respeito à taxa de inflação e que a autoridade monetária tinha independência suficiente para executar uma política monetária ativa.

Palavras-chave: filtros de Kalman, cointegração, *bootstrap*, modelagem econométrica, inflação, oferta de moeda, política monetária.

JEL Classification: C32, C52, E31, E51, E52.

1 Introduction

From 1964 to 1985, the policy of inflation stabilization was centered on aggregate demand management and wages, exchange rate, public prices and concentrated sector price controls. The fact that during these years the economic policy was conducted in a seemingly "orthodox way" could induce us to conjecture about the behavior of the monetary policy. Are there reasons to support the claim that the money supply was exogenously determined concerning the inflation rate, that is, did the monetary authority follow a rule of money creation that did not accommodate the movements in the inflation rate? The motivation that guides the present paper addresses these issues.

The purpose of this paper is to prove that the monetary supply was exogenously determined from 1964.04 to 1986.02. That is, we claim that the monetary policy was active, and within Cagan's (1956) and Sargent and Wallace's (1973) models, show that the formation rule of the inflation expectation followed an adaptive scheme. We thus postulate that the monetary rule was executed independently and the rule that guided the monetary execution was exogenous with respect to both the ‘model in question’ and the inflation rate (for a detailed description of the monetary policy of the period, see Simonsen, 1985 and Cerqueira, 2007a).

We intend to support this assumption with three arguments. First, the monetary authority conducted the open market policy increasing the real interest rate in order to stimulate the demand for bonds. Second, even if during part of this period the seigniorage collection remained constant as a share of GDP, the government succeeded in keeping its fraction of revenues by reducing the monetary base multiplier[1]. Moreover, the seigniorage-GDP ratio followed a white noise process and was therefore independent of the inflation rate. Third, the existing causality between money growth and inflation was unidirectional from the former to the latter.

Many Brazilian economists thought the money supply was passive during most of the period from 1964.04-1986.02. One likely rationale supporting this belief is the hypothesis of rational expectations. If the demand function for real balances follows Cagan’s form, the solution for the current inflation is a function of the expected money creation rate, excluding the possibility of rational explosive bubbles. In this case, money supply is endogenous.

An alternative argument is based on Sargent and Wallace’s (1973) scheme derived from Cagan’s model under the hypotheses of adaptive expectations and a monetary rule, which depend on past inflation rates. This is a model in which the adaptive mechanism is rational. In Sargent & Wallace’s model, the best way to forecast the subsequent rates of money creation is by extrapolating lagged rates of inflation. This in turn implies that inflation itself is best forecast by extrapolating past inflation rates. So both money creation and inflation are best forecast by extrapolating current and lagged rates of inflation. Lagged rates of money creation add nothing to forecasts made in this way. In this model, past values of inflation influence money creation but the opposite is not true; thus, money supply is passive.

An essential element in this argument is the hypothesized feedback that occurs from expected inflation to money creation. This feedback emerges due to the government’s attempt to finance a roughly constant rate of operational deficit by money creation. In this sense, this is also a description of Bruno and Fischer’s (1990) version of Cagan’s model, in which monetary expansion is endogenously determined by expected inflation, given a constant level of seigniorage.

However, if monetary expansion follows a purely autoregressive process or a white noise process, then under adaptive expectations monetary expansion and money supply are exogenous regarding the inflation rate. In this system, money creation influences current and subsequent inflation rates; but given lagged rates of money creation, past inflation rates exert no influence on money creation. The system is one in which money creation causes inflation, in Granger's sense, whereas inflation does not cause money creation. In this model adaptive expectations are not rational, feedback occurs from the expected inflation to the current inflation rate, emerging from an autonomous increase in monetary expansion. Therefore, under adaptive expectations the money supply passivity is a consequence of the monetary rule followed by the monetary authority.

Brazil's long experience with high inflation rates gave rise to an efficient indexation system that protected agents from the effects of inflation. Even if the indexation rules did not fairly contemplate the agents, one cannot deny that such rules prevented the ever-rising inflation from degenerating into public panic, speculative run and an open hyperinflation process. Furthermore, the indexation rules were developed slowly throughout the seventies and eighties simultaneously with an increasing inflation rate. Price system inflexibility was then introduced gradually, which augmented inflation inertia but did not destroy the inflationary memory. Thus, as the economy's degree of indexation rose, the inflation rate became inertial, i.e., its present values began to depend on its past ones. These arguments supposedly explain why the agents had adaptive expectations about the inflation in the period. Therefore, Brazil's experience over the period did not provide evidence of expectations being formed rationally. One can therefore argue that the monetary policy followed a rule independent of the inflation rate. This assertion is tested in section 3.

The assumption of endogenous money growth cannot be supported by empirical evidence. Surprisingly, some Brazilian authors found a unidirectional relation between inflation and money creation; see the empirical studies of Marques (1983), Triches (1992), Pastore (1994/1995, 1997). We can suppose that their results were obtained by using lower frequency data (quarterly). The resulting information loss may have distorted the causality test results. They relied on the Ljung-Box test and the related correlogram for detecting serial correlation and setting the lag length in autoregressive models. It is well known that the portmanteau test may have very low power in the detection of specific important departures from the assumed model. It is therefore unwise to rely exclusively on this test to check model adequacy. However, it can be valuable when used with other tests. The Breusch-Godfrey Lagrange multiplier test is a common complement to the Q-test (Granger and Newbold, 1986). By carrying out both tests and using monthly data from 1964.04 to 1986.02[2], we achieved results that contrast sharply with earlier findings by other Brazilian authors. This might explain why different conclusions emerged when the same causality tests were applied.

Why in that period monetary expansion increased uninterruptedly with a behavior close to that of an I(1) process remains an unanswered question. We conjecture that the answer may be found in the chronic public deficit that was partly financed by issuing bonds. This produced an ever-increasing financial component[3]. If the rule governing the monetary authority was to achieve debt sustainability, then it was urgent to support the deficit financing by increasing money creation. This led to a pegging of the inflation rate. Thus the monetary authority chose, or was compelled to choose, the inflationary deficit finance in order to sustain the debt. There was, then, a choice of economic policy.

This paper is organized as follows: In section 2 we describe in general lines the results presented in Cerqueira (2006) on the Brazilian monetary regime and the relation between real interest rate and the public debt. In section 3 we present the paper's theoretical framework, and provide a statistical procedure for determining the stochastic process of seigniorage collection. Section 4 offers an econometric study about the long-run relationship between money creation and inflation rate. And in section 5 we present our conclusions. In appendix A we provide an analysis of the integration order of the two series. In appendix B we report the results of the cointegration tests. To save space we do not report all relevant tests and diagnoses but one can access them in Cerqueira (2007b), working paper 217, in the site www.uff.br/econ/publicações/textosdiscussão.

2 The Brazilian monetary regime

In Brazil, monetary control did not take place through open market transactions, discount loans or reserve requirements. Over here the monetary policy was conducted indirectly, through a particular form of open market transactions. Moreover, there was an economy with a consistently increasing inflation.

In the Brazilian monetary regime, firstly the Treasury financed itself directly through the Central Bank. Secondly, public bonds were not sold to the final takers, but to financial institutions instead, which financed themselves through overnight deposits from the private sector. At the same time, the Central Bank informally gave liquidity to excess bonds over these deposits by means of repurchase agreements. If in a primary auction the financial intermediaries did not succeed in getting a permanent and equal increase in their funding, they could then resell their holdings of excess bonds to the Central Bank. The repurchase agreements were needed because free reserves were costly to the banks. If the banks had to wait for government securities to mature and the Central Bank did not provide (inexpensive) liquidity to the system, banks would either have had to hold a much larger volume of free reserves (within an inflationary environment), or have resorted more often to the discount loans, which would have been unbearably costly to them.

The main consequence of this procedure was the elimination of open market operations as an instrument of monetary policy. Money supply was controlled indirectly by increasing the interest rate to expand the demand for bonds. This procedure was efficient from 1966 to 1985, as demonstrated in Cerqueira (2006). The author’s results show that the causality in Granger’s sense was unidirectional from the real interest rates to the public debt/GDP ratio from 1974 to 1985. Thus, one could assume that the real interest rates were strictly exogenous as to the demand for bonds; see Sargent (1987). It can thus be concluded that the monetary authority altered the real interest rates to cause changes in the demand for bonds. Besides, since the public debt is a non-monetary liability, this mechanism operated as an instrument to control the money supply. Finally, the demand for bonds was elastic to the real interest rates, and the overnight interest rates were high enough to encourage bond sales. These empirical facts suggest an active behavior of the monetary authority instead of a passive monetary policy and an endogenous money supply.

3 Seigniorage and inflation

Let us consider the following continuous time version of Cagan's model:

$$m \equiv \frac{M}{PY} = ce^{-\alpha\pi_e}\text{, } c > 0 \text{ and } \alpha > 0 \text{ (money demand equation),} \tag{1}$$

$$\overset{\circ}{\pi}_e = \beta(\pi - \pi_e)\text{, } \beta > 0 \text{ (expectation rule equation),} \tag{2}$$

where M is nominal money demand, P is index price, Y the GDP, c is a constant which captures nominal shocks and financial innovation changes, π_e is the expected inflation rate, α is the semi-elasticity of money demand with regard to the expected inflation, and β is the opposite of inflationary memory (the bigger β is, the smaller the effect of past inflation on present inflation expectations). We assume a constant growth rate and a constant real interest rate. For a given level of exogenous money growth μ, the seigniorage flow is given by:

$$S = \frac{\overset{\circ}{M}}{PY} = \frac{\overset{\circ}{M}}{M}\frac{M}{PY} = \mu ce^{-\alpha\pi_e}. \tag{3}$$

By making some operations we get to the expected inflation rate dynamics equation:

$$\dot{\pi}^e = \frac{b}{1-\alpha b}(\mu - \pi^e) \tag{4}$$

In a steady state $\dot{\pi}^e=0$ and $\mu = \pi^e = \pi$ and the inflation tax equals the seigniorage. The seigniorage is maximized ($S^*=c/\alpha e$) when $\pi = 1/\alpha$. With a constant operational deficit at the $S = \overline{S}$ level, the monetary authority would react according to:

$$\mu = \frac{\overline{S}}{ce^{-\alpha\pi_e}} \tag{5}$$

The monetary expansion rate increases with the expected level of inflation and thus is passive. So a reduction in the constant term c caused by a financial innovation shifts down the reaction curve that increases the monetary expansion and the inflation rate – in the (π^e,μ) mapping –, which implies increases in monetary expansion and inflation expectations.

The postulation of a reaction curve as (5) and the existence of empirical evidence that the monetary authority had been following it are two different things. Such behavior implies a passive a money supply caused, in Granger's sense, by lagged inflation rates, a popular hypothesis among Brazilian economists. This claim tends to be accepted due to the empirical evidence in Pastore (1994/1995, 1997), whose results show that money growth is caused by inflation, but the opposite is not true. Therefore the author concludes that the money supply was predominantly passive.

Intuition suggests that the Central Bank's repurchase agreements tended to make money supply endogenous. However, some reflection shows that the former facilitates the latter, though does not determine it. If the inflation rates grow due to a negative supply shock and the Central Bank's goal was to keep the real interest rate constant, the Bank would automatically buy bonds through repurchase agreements, sanctioning the price increase with a larger monetary base stock. The money supply was made endogenous or caused by the Central Bank's rule to fix the real interest rate, and was but was facilitated – or accelerated – by the repurchase agreements, not due to the latter *per se*. Money endogeneity runs independently of the monetary regime provided that the Central Bank keeps the real interest rate constant[4].

Notwithstanding, if the Central Bank allows the real interest rate's floating to sell bonds, such causality will be eliminated or reduced. In the Brazilian monetary regime, selling bonds would cause a simultaneous increase in the nominal and real interest rates, whereas in a conventional monetary regime the increase of interest rates would cause a growth of bond demand, implying a more instantaneous and precise control of monetary stock than in our case.

Cerqueira (2006) showed that the real interest rates floating not only appeared to be significant in the public bonds demand, but also caused the public debt. These empirical results contradict Pastore's evidence, making us review his empirical analysis on the causality between the inflation rate and money growth. We shall start by analyzing the behavior of the seigniorage/GDP ratio series. In 1976, the monthly inflation rate went above 3% and from 1976.1 to 1988.4 the monetary base growth as GDP fraction did no present any significant change. We thus admit that from this level the inflation acceleration would not have any impact over government revenue with issuance base. Then the primary money growth can be taken as relatively constant and independent from the inflation rate. This leads us to presume that seigniorage can be described as an erratic process similar to a white noise; see figure 1. This hypothesis is based on the increasing cost of holding money and on the process of fiat money replacement by other financial assets, which took place after 1976.

The seigniorage/GDP series has a quarterly frequency, as does the GDP. The real GDP is the one estimated in Cerqueira (2007c), by Kalman filter with benchmarking adjustment; see Durbin and Koopman (2004). Since the seigniorage/GDP shows seasonality and some outliers, we decided to extract these components first. We estimated a stationary structural model using Kalman filter procedures with an AR(1) component, fixed seasonal dummies, intervention variables such as impulse dummies – 1986.2, 1986.3 and 1987.1 – and an irregular term. As required, the smoothed disturbances model are approximately $N(0,\sigma^2)$[5].

The statistical approach thus proceeds using independence tests on the adjusted series. We first performed unit root tests. The Augmented Dickey-Fuller, Phillips-Perron, without break dummies, and their modifications for the series level largely reject (with p-values near zero) the null hypothesis of a unit root; see Cerqueira (2007b) for further details. In the next step we study the autocorrelation functions, spectrum, cumulative periodogram, CUSUMSQ, histogram and QQ of the Seigniorage/GDP series. Ljung-Box test statistics accept the hypothesis that there is no autocorrelation up to order 12 and 24 with p-values 0.9883 and 0.2698, respectively. Spectral density is close to that of a stationary series similar to a white noise like the frequency response function computed with bandpass filtered series with Christiano-Fitzgerald’s method. The cumulative periodogram behaves likewise, and the associated Kolmogorov-Smirnov statistics accept the null hypothesis that the series is close to a white noise at 5%. Evidence shows that the money growth series over GDP is an ergodic process close to a strong white noise[6].

The normality tests statistics of Bera-Jarque and Hansen-Doornik have p-values equal to 0.766 and 0.776, respectively, which suggests that the series is a Gaussian white noise. Assuming that the above results are correct, Seigniorage/GDP (SY) regression against a constant and the inflation rate (PI) must reach the following results: (i) constant significant at the level of the sample mean (0.017); (ii) non-significant inflation rate coefficient; (iii) R^2 close to zero; (iv) residuals approximately NIID. These results are evidenced in table 1. With p-value 0.9879, we cannot reject the hypothesis that the equation's constant term approximately equals the series' sample mean. Nor can we reject the hypothesis that the inflation rate coefficient is non-significant; and that both R^2 and residuals behave according to expectations.

Table 1: OLS Regression SY against PI.

Variable	Coefficients	P-value
C	0.0170	0.0000
PI	-0.0002	0.9852

N=52	R^2=0.000001	F=0.0004	SER=0.0052	DW=1.7914*	Q(12)=0.9883
Q(24)=0.2362	LM(4)=0.8284	WHITE=0.1230	ARCH(1)=0.7382		

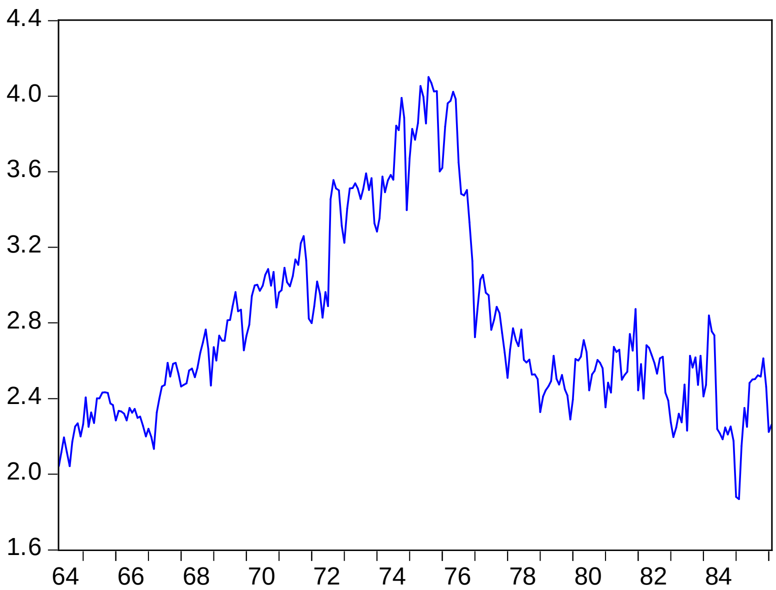
* The hypothesis test in which DW = 2 is taken with p-value = 0.4520.

The above results confirm the hypothesis that from 1976.1 to 1988.4 the ratio seigniorage/GDP followed a white noise statistic process ~ (0.0170; 0.0052). This means that, even having a finite average, its behavior could not be predicted due to the series' lack of memory. Thus, seigniorage collection behaved as a random shock. It did not show any relation with the contraction of money holdings or with the rise of the inflation rate. It can, therefore, be taken as independent from the inflation rate, which did not alter in any way this government-financing source. Such conclusion provides empirical support to the hypothesis that even if the monetary authority was attempting to finance a roughly constant rate of public deficit by money creation, the seigniorage collection did not follow a path consistent with the endogenous money supply.

We claim this is likely to be related to the policy of reducing the base multiplier. This policy contributed to maintain the effectiveness of inflationary tax collection, reinforcing the claim of an exogenous monetary policy. In such a case, money supply issuing influences current and future inflation rates, but past inflation values do not influence money supply[7]. The system is such that money creation causes inflation, though not the other way round. In this system, Cagan's adaptive scheme is not rational.

From 1976 to 1985 a host of financial innovations contracted the monetary demand that restricted seigniorage collection. However, the policy to reduce the monetary base multiplier counterbalanced this effect (Figure 1)[8]. Moreover, the observed inflation and monetary rates, while increasing, were very distant from the unstable levels, thus far from a hyperinflationary disequilibrium; see Cerqueira (2006). We thus assert that a fixed rate of public deficit permanently funded by money creation supported the sustainability of the public debt, as the exogeneity of money supply was preserved. This suggests the existence of a steady state public deficit financed by seigniorage, as in Cagan's adaptative model; see details in Cerqueira (2007b). To complete the exogeneity hypothesis' money supply proof, it must be shown that money growth in Granger's sense caused the inflation rate, but inflation did not cause money growth (see Sargent and Wallace, 1993).

Figure 1: Base Multiplier.



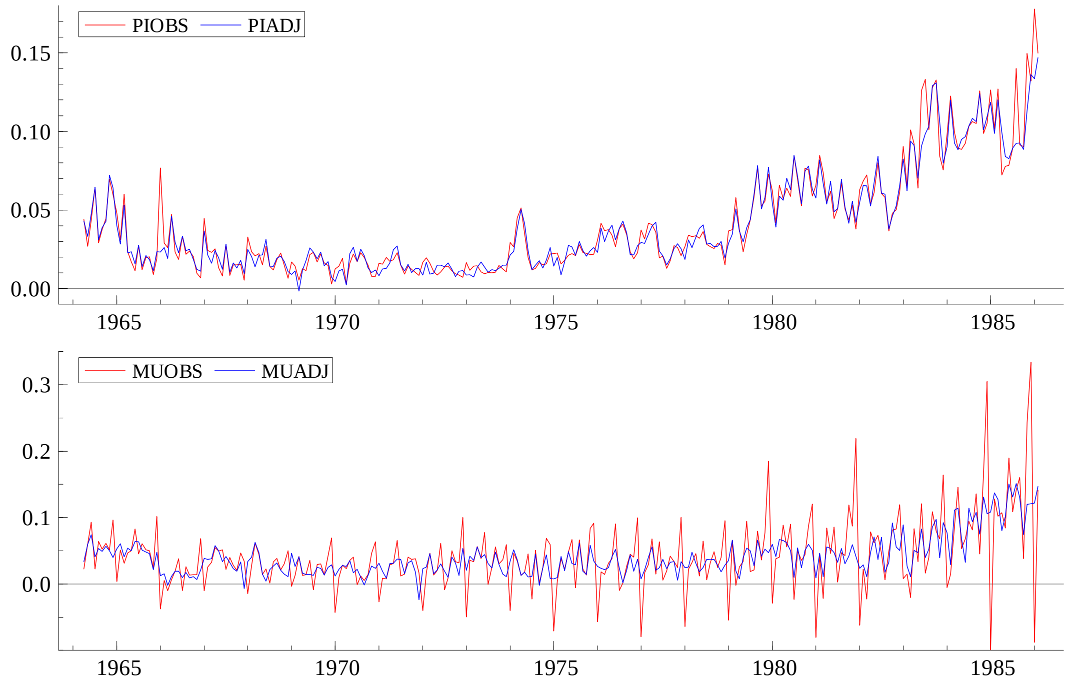
4 Money supply exogeneity

The study comprises the 1964.04-1986.02 period. The former marks the end of a period of monetary imbalance and the beginning of a vigorous and successful plan to stabilize inflation, based on harsh fiscal and monetary policies. The period truncation is for 1986.02 due to a radical change in the inflation stabilization policy – which took place in 1986.03 – which brought about wage and price freezing and an accommodative monetary policy. The implication was acceleration and permanent change in inflation dynamics, which supposedly changed the rules of inflation expectation formation. Thus, we underline that the results in this paper refer only to the period between 1964.04 and 1986.02.

When looking for a causal relation, the first step is determining the series series' integration order, and then testing the existence of a cointegration relation between them. If so, it is tested whether any of the variables can be regarded as weakly exogenous with a given interest parameter. Ultimately, causality tests in Granger's sense are carried out. As the series present many outliers and their presence makes it difficult to implement cointegration tests (see Cerqueira, 2006), we chose to have the series go through the previous treatment by using univariate structural models with Kalman filtering procedures. We also decided to seasonally adjust the series by putting aside the respective stochastic seasonal component identified by the same approach. Both procedures imply causing the VAR to be parsimonious, especially when working with monthly data. The adjusted (ADJ) and observed (OBS) series are shown in Figure 2 in monthly frequency. Unit root tests are reported in Appendix A. Inflation series show no ambiguities I(1), the money supply series is also taken as I(1).

The next step is finding a cointegration relation between the variables. We chose Johansen's (1991) co-integration procedure test. Choosing the VAR lag length and the deterministic components is crucial for the test results. We decided to specify the VAR according to the recommendation by Gonzalo (1994), Dolado and Lütkepohl (1996), Giles & Mirza (1998) and Lütkepohl and Saikkonen (1999). Thus we searched for a stable VAR – which led to the introduction of a linear trend term – whose residuals assessed by multivariate portmanteau (with minimal lag adjusted by the degrees of freedom and T/4) and Breusch-Godfrey type tests (1 to 12 lags) did not carry any serial correlation. This made us reach 10 as the minimal lag number. On the other hand, an overfitting model has little efficiency loss, whereas consistency is lost if the lag length is too small. Wald test's power loss is small when extra lags are added, in case the true VAR order is large and the system dimension small. Moreover, when unidirectional causality is suspected, overfitting methods cause less distortion with often little or no power loss if compared to the pre-testing procedures; see Giles and Mirza (1998). For those reasons, we chose to work with an overfitted VAR(11).

Figure 2: Rate of Inflation (PI) and Money Growth (MU) Observed and Adjusted (with Kalman Filter).



Although the series are treated as outliers, analysis of the unrestricted VAR residuals – without imposition of cointegration relation – suggests the presence of ARCH elements and non-Gaussian residuals[9]. The causes for such violations derive fundamentally from the inflation rate. These are not a blow for the cointegration relation since asymptotic properties of Johansen's procedure exclusively depend on IID error hypothesis. So the normality hypothesis is thus not vital for conclusions – although the ARCH effect might be; see Johansen (1995).

We therefore rejected the null hypothesis that there is no cointegration at 1% significance level according to the trace statistics and at 1.8% with the maximum eigenvalue statistics[10]. The cointegration test results are displayed in table B1. Cointegration corroborates the hypothetical absence of no rational bubbles from 1964.04 to 1986.02. This implies excluding the hypothesis that inflation acceleration in the late-1985 to early-1986 period was causing speculative hyperinflation. Testing for the plausibility of the (1,-1,#,#) cointegrating vector confirmed a homogeneous long-run relation between money growth and inflation. This is the classical representation in which the long-run relationship between inflation and money growth has cointegrating vector β=(1,-1) and a moving stationary drift term. This could be represented by the real interest rate, which is an I(0) series.

Table B2 shows the results of two weak-exogeneity tests conditioned by the existence of one cointegrating vector: the first uses a theoretical vector (1,-1,#,#); the second the estimated vector shown in table B1. At usual significance levels, we found that money creation is weakly exogenous for the parameters of interest in the conditional model of inflation. However, the opposite is not true for inflation. Such results corroborate the idea implicit in equation (4). Monetary shock causes expected inflation to accelerate, which in turn increases inflation. The inflation rate drifts above its steady state. Once the adjustment coefficient is negative[11], expectation increase is reduced, thereby forcing the inflation rate down towards the long-run path.

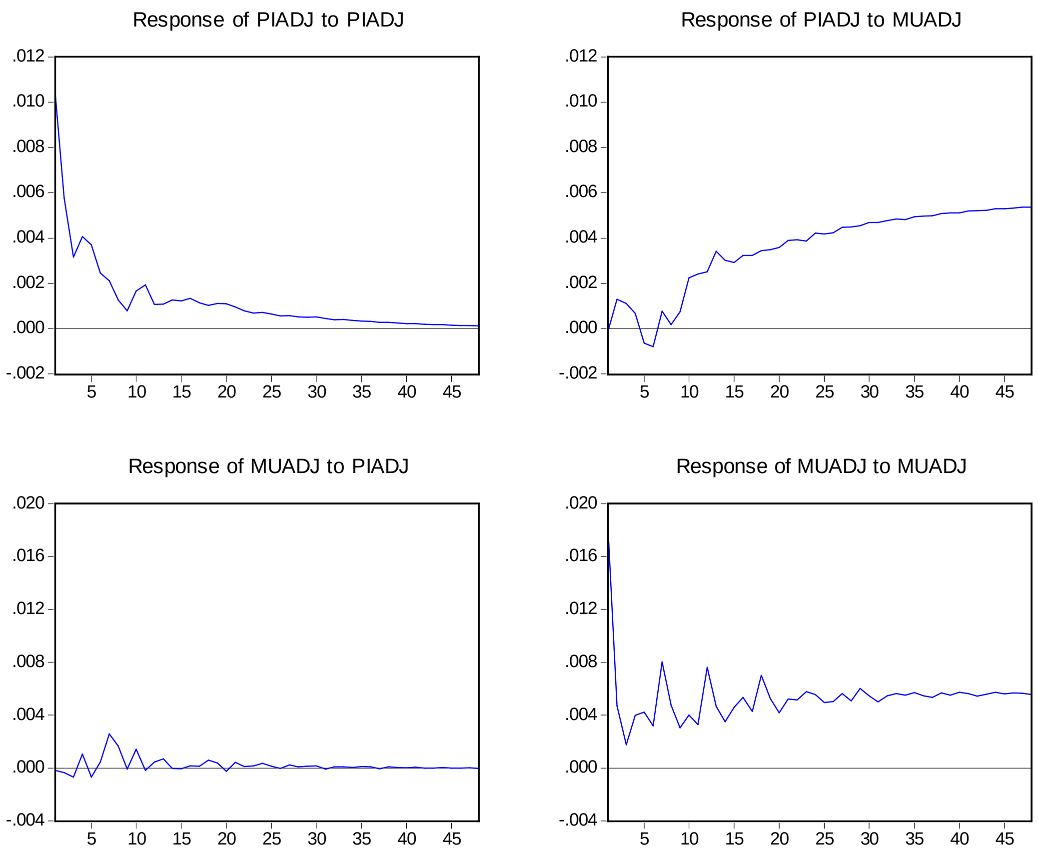
Table 2: Granger Causality Tests (P-Values)[a].

Null Hypothesis	Non-Gaussian Residuals [b]		Monte Carlo Tests [c]	
	MI	PI	MI	PI
PI $\nRightarrow$ MI				
F	0.5785		0.5749	
LR	0.5097		0.5749	
MI $\nRightarrow$ PI				
F		0.0014		0.0161
LR		0.0076		0.0161

(a) The symbol $\nRightarrow$ means "does not cause in Granger's sense". (b) Strong exogeneity: PI $\nRightarrow$ MI {F=0.6568; LR=0.5916}, MI $\nRightarrow$ PI {F=0.0003; LR=0.0001}. (c) Monte Carlo p-values for the strong exogeneity tests: PI $\nRightarrow$ MI {F=0.6510; LR=0.6510}, MI $\nRightarrow$ PI {F=0.0002; LR=0.0002}. MI represents money growth and PI inflation rate.

Inspection of residuals after imposing all the above restrictions enhances the residual stochastic properties, closer to being Gaussian. As in the non-restricted model (not reported), some hypothesis violations can be traced to the residuals of the inflation equation. There are also four roots in the companion matrix around 0.90. This shows that system stability is far from ideal, although it is not explosive. On the other hand, the multivariate diagnostic tests show that our choice of 11 lags for the VAR was appropriate. Firstly because the residuals have no serial correlation, and secondly because choosing a more parsimonious VAR would have led to the estimation of misspecified VECM model with autocorrelated residuals (these results are not reported in the paper, see Cerqueira, 2007b).

Figure 3: Response to Generalized one S.D. Innovations.



Two non-causality tests are shown in table 2 together with the strong exogeneity tests[12]. Granger's direct test specification is taken from the VECM estimates – with 11 lags – and the restriction given by (1,-1,#,#). Residuals of the money creation equation are approximately NIID, whereas residuals of the inflation equation are not. We thus used a parametrical bootstrap[13] to access the specific distribution of Wald (F) and likelihood ratio (LR) test statistics. As one can observe, the conclusions hold. Causality test results show that money growth causes inflation, whereas the inflation rate fails to cause money growth. There is no type of feedback from inflation to currency. This result contrasts with Cerqueira (2006). This is illustrated by the impulse-response functions[14] (Figure 3) estimated with generalized impulse. This procedure constructs an orthogonal set of innovations that does not depend on the VAR ordering[15]; see Pesaran and Shin (1998).

The one standard shock in money growth causes a period of fluctuations in this series until it achieves its new steady state level, around 0.56 percentage points (hypothesis accepted with p-value = 0.8379) above its initial level. Indeed, beyond period 27, the impulse functions are statistically different from zero, with p-value around 0%, which backs this claim. The impulse in monetary expansion leads to a permanent increase in the inflation rate, but an inflationary shock does not have any meaningful effect on money growth. The peak shown in the seventh period is not significant with p-value 0.8544, and the average impact is close to zero throughout the period.

On the other hand, a monetary shock has permanent impact on the inflation rate, close to 0.55 percentage points. When innovations are considered, either in inflation rate or in money growth, 84% of the final variation in inflation rate is caused by monetary shock. This result – attained with the inflation rate prediction error variance decomposition – shows a feedback effect (around 16%) on the inflation rate due to inflationary expectations. We can conclude that the existing persistence in inflation was mainly due to monetary causes, not disturbances on the real side of the economy or to the price indexation system. As for the inflation rate from 1964.04 to 1986.02, there is enough evidence to validate the hypothesis that money growth is strongly exogenous. Evidence supports the claim that causality is unidirectional and moves from money expansion to inflation[16]. This means that money supply was not passive and was strictly econometrically exogenous (Sims, 1972) with respect to determining prices[17]. Besides, this strongly indicates that the monetary authority did not, in the period, follow as a monetary rule a reaction curve as the one described in equation (5)[18]. Lastly, once the money supply was exogenous, Sargent and Wallace's (1973) model reveals that the inflation expectation from 1964.04 to 1986.02 followed Cagan's adaptive scheme.

5 Conclusions

This paper presents tests on the exogeneity of the Brazilian monetary supply for the military period spanning from 1964.01 to 1986.02 using monthly data. We chose this period because the macroeconomic policy was more homogenous regarding the inflation stabilization policy than that of more recent years. The results show that even if there was a nearly stable average seigniorage between 1976.1 and 1988.4, this did not lead to endogeneity of the money supply, since money growth was strongly exogenous with respect to the inflation rate. Results show that the monetary expansion caused the inflation rate in Granger's sense, and the former was weakly exogenous compared with the latter. This was possible because the monetary authority chose to reduce the base multiplier in order to keep its proportion of seigniorage collection. Therefore, even with (i) a permanent deficit with the seigniorage playing a crucial role in balancing the public accounts, and (ii) a host of financial innovations that led to the contraction of the money demand, the money supply remained exogenous with respect to the inflation rate. Therefore, Brazilian inflation followed an ever-increasing path without setting off a hyperinflationary process.

We may conclude that money creation influences current and future inflation rates, but, given lagged rates of money creation, past inflation rates exert no influence on money creation. This is an indication that Cagan's rational adaptive schemes are not adequate for the Brazilian economy and that the rule followed by economic agents to form expectations about inflation was adaptive. That is a normative conclusion from the Sargent-Wallace (1973) paper based on Cagan's. This contrasts sharply with an existing tradition among Brazilian economists, who assume that the monetary policy was completely passive during the 1970s and 1980s.

Indeed, our results reveal that the monetary policy was executed in an independent way, that is, the rule guiding monetary execution was taken exogenously with regard to the considered model and the inflation rate. Therefore, we postulate that the monetary authority chose to finance a roughly fixed rate of public deficit by issuing money. This explains the intermittent monetary expansion and the inflation rate. Such policy generated a vicious cycle: by exacerbating the inflation expectations, it introduced a feedback in the inflation growth. In addition, it caused the uninterrupted growth of the debt-service payments and, consequently, the continuous increase of the nominal public deficit.

Rejecting the causality from prices to money does not mean to propose there was a rigid monetary control. This depends on the monetary regime. In a regime whose monetary authority is independent, it is possible to fulfill almost any target of money stock. Compelled by public deficit, the monetary authority may refuse to buy public bonds in the open market and then impose upon the fiscal authority the cost of increasing the real interest rate through the primary auctions. In the Brazilian regime, this was a task for the Central Bank. It was enough that the real interest rate was restricted to float within a given range to determine the deficit monetization through repurchase agreements. In this regime, monetary control was indirect, and the instruments were less efficient but enough to manage an exogenous money supply from inflation variations. Perhaps these are somewhat old monetarist ideas, but we cannot deny they stamped their mark on the data. For further studies we suggest to apply the approach presented in the paper, that is it, the blend of Kalman Filter, Johansen's cointegration type-test, and the bootstrap approach.

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APPENDIX A

Integration order of the inflation rate (PI) and money growth (MI)

Table 1a reports the results of unit root tests to the series in levels and in first difference with monthly frequency. Besides the traditional ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) tests we also report their well-known modifications, namely: DF-GLS (Dickey-Fuller test with GLS Detrending), ERS-PO (Elliot *et al.*, 2004 point optimal test) and Ng-Perron (NG and Perron test); see Maddala and Kim (2002).

Table 1a: Unit Root Tests[19].

Test	ADF	DF-GLS	PP	ERS-PO	Ng-Perron			
Series					MZ^d_α	MZ^d_T	MSB^d	MP^d_T
PI	-0.3250 (0.9175)	-0.6547	-1.3833 (0.5905)	5.4947	-5.9332†	-1.2513	0.2109‡	5.4723
ΔPI	-17.3389* (0.0000)	-13.5691*	-20.7605* (0.0000)	1.1901*	-29.8104*	-3.7964*	0.1274*	1.0253*
MI	0.3954 (0.9825)	0.8579	-8.3199* (0.0000)	0.5988*	-117.137*	-7.4376*	0.0064*	0.5846*
ΔMI	-6.1662* (0.0000)	-0.3041	-58.8791* (0.0001)	7.0571	-4.0041	-1.2602	0.3147	6.2954

Note: (†) represents rejection of a unit root at the 10% significance level; (‡) at 5% significance; (*) rejection at 1%; no symbol means acceptation of the null hypothesis at 10%.

APPENDIX B

Cointegration test

Table 1b shows the cointegration tests with critical values at 1% level and the respective p-values; see Mackinnon *et al.* (1999).

Table 1b: Johansen cointegration test.

TEST STATISTICS (P-VALUES)				COINTEGRATING VECTOR
Trace		λ-Max		(MONEY, INFLATION, TREND, CONSTANT)
r=0	r≤1	r=0	r≤1	
35.8742	13.5674	22.3039	13.5673	(1.0000, -0.9645, -0.0002, 0.0903)
(31.1539)	(16.5539)	(23.9753)	(16.5539)	
(0.0020)	(0.0333)	(0.0183)	(0.0333)	

COINTEGRATION RESTRICTION TEST

RESTRICTION: (1,-1,#,#) $\chi^2(1) = 0.0459$; P-VALUE = 0.8309

Note: The symbol # means the parameter is unrestricted. The estimated eigenvalues are 0.0813 and 0.0503.

In Table 2b, we present the weak-exogeneity test using two different statistics. The first tests the joint hypothesis that the cointegrating vector is (1,-1,#,#) and the adjustment coefficients are respectively $(0,\alpha)$ and $(\alpha,0)$. The second, in brackets, uses the estimated cointegrated vector reported in Table B1 and these two adjustment coefficients.

Table 2b: Adjustment-coefficient weak exogeneity test.

NULL HYPOTHESIS	TEST STATISTIC	P-VALUE
MI is weakly exogenous for the parameter of interest of the PI conditional model	0.0823 (0.0265)	0.9597 (0. 8707)
PI is weakly exogenous for the parameter of interest of the MI conditional model	8.8580 (8.7229)	0.0119 (0.0031)

Note: Monte Carlo p-values H_0: MI is weakly exogenous to PI {F=0.9090; LR=0.9090} and H_0: PI is weakly exogenous to MI {F=0.0003; LR=0.0003}.

[1] Since M1=kB, where ***B*** is the monetary base and ***k*** the multiplier, the inflation tax-GDP ratio is given by IT= $\pi(B/PY) = \pi(M1/PY)(1/K)$, where ***P*** is the price index and π the inflation rate. This means that the government collects 1/k of the produced inflation tax by the real money balances. The difference (1-1/k) represents the inflationary transfer from the private sector to the bank system.

[2] Since the pioneer paper of Working (1960), it has been a well-known fact that temporal aggregation has statistical implications on the time series properties.

[3] We estimate that between 1966 and 1985 the proportion of the public deficit due to nominal debt-service increased from 19.7% to 77.1%, while the real service decreased from 3.5% to 3.1%. At the same time, the nominal deficit as a GDP fraction rose from 4.9% to 20.0%, and the operational deficit from 2.1% to 3.4%.

[4] It is worth mentioning that during this period Brazil was a closed economy with trade transactions of around US$20 billion per year. With great current account deficits that were covered by capital inflow – direct investments and/or long-run borrowings. In such a way, Brazilian foreign reserves throughout these years achieved small levels – they floated around US$5 billion – and, therefore, they never constituted an important source of monetary base expansion. And in the case of an extraordinary entrance of capital it was integrally sterilized.

[5] The estimates and tests were computed in OxStamp, if the procedure is Kalman filter, or in Eviews or Cats in Rats, if we are performing cointegration analysis.

[6] Indeed, considering Goldfeld-Quandt, LM ARCH and McLeod-Li tests one cannot reject the hypotheses that the series has constant non-conditional variance and does not have autoregressive conditional variance throughout the period; see Cerqueira (2007b) for details.

[7] By money growth rate we mean the percent variation of the M1 monetary aggregate; by inflation rate we mean the percent variation of IGP-DI of FGV, the Brazilian general price index.

[8] Whereas the reduction in the money demand's constant term implied the decrease of the required money stock by 43.9166%, from 1975 to 1984/85, the money multiplier dropped by 39.3997%, which represented an increase of 65.0160% in the rate of inflation tax collected on the M1 stock. This more than compensated for the first effect; see Cerqueira (2006).

[9] These results are not reported in the paper.

[10] These results must be taken cautiously, since one of the series – money growth – has a long memory and is not a pure I(1) process. As discussed in the appendix, it is hard to differentiate the series from a I(1) process with unit root tests. Another situation is when the I(1) variable VAR representation has a near singular covariance matrix, in which case Johansen's LR test tends to find spurious cointegration with probability asymptotically equaling 1. The Engle-Granger test is more robust to avoid deceitful results, it is recommended to use both tests; see Gonzalo and Lee (1995) and Maddala and Kim (2002). We carried out the Engle-Granger test with constant and trend – with residuals of the second step not showing serial correlation – and concluded that at 5% we reject the hypothesis of zero cointegration between inflation rate and money growth. Thus we can continue our analysis with certain relief.

[11] The value of α was found to be -0.2054.

[12] Strong exogeneity is the joint hypothesis of weak exogeneity and Granger's noncausality.

[13] Because VECM residuals are orthogonal, the error terms could be extracted from a normal distribution with diagonal covariance matrix.

[14] As in Lütkepohl and Reimers (1992), the impulse-response functions were calculated using (1,-1,#.#0) as the cointegrating vector and the adjustment factor in the form (-0.2054,0).

[15] Actually, the variable order is, in our context, irrelevant, since the correlation coefficient between restrict VECM residuals is -0.0106, which is approximately zero with p-value 0.6533 (Pearson's test), and the hypothesis that the inner product (0.0005) is zero is accepted with p-value = 0.8794 (by using conventional *t* test).

[16] By means of recursive estimation we investigate our model's parameter constancy. Reason shows that the estimated model has acceptable constancy properties which are evidence that money growth is super exogenous with respect to the parameter of interest. To save space, the tests carried out are not reported; see Cerqueira (2007b) for further details.

[17] Using the same series and extending the period to 1960.01 the results change, despite the presence of cointegration relation and the accepted homogeneity hypothesis. The hypothesis of weak exogeneity in any of the equations is not possible, and noncausality is rejected in both directions, which means that the inflation rate and money growth are both endogenous, which is a similar result to Pastore's (1997). However, such result is not a surprise, since the period prior to 1964.04 is marked by a complete lack of monetary control, with public deficits being financed basically by money issuing. In this period, inflation tax collection was essential for maintaining public expenditures. This imbalance turned out to modify the relation between money growth and inflation.

[18] This conclusion contradicts Marques (1983), Triches (1992), Pastore (1994/1995), and especially Pastore (1997). We conjecture that differences in methodologies and data frequency can explain the divergence between our results and the so-called "common wisdom" among Brazilian economists.

[19] Tests of inflation rate level were specified with 2 lags; for its first difference 1 lag; and of monetary growth, respectively, 11 and 10 lags. To estimate zero frequency spectra we chose quadratic spectral kernel. Computed p-values in brackets were also reported to ADF and PP tests statistics.