Nonlinearities and Price Puzzle in Brazil.

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Abstract:
This paper uses a VAR to analyse the response of monetary policy to inflation in Brazil, focusing mainly on the problem of the price puzzle effect. When nonlinearities in the data were considered, most of this effect vanishes. This is done firstly by checking if the series are unit root processes or (non)linear trend stationary. After that a nonparametric co-trending analysis was applied. The test result was in favor of a common nonlinear trend between inflation and the interest rate, which seems to affect the system innovation analysis, inducing in a large amount the price puzzle effect.
Key Words: Monetary Policy, Nonlinearities, Nonlinear Trend, Co-Trending, Common Treds, Price Puzzle.

Resumo:
Este trabalho usa um VAR para analisar a resposta da política monetária à taxa de inflação no Brasil, com o objetivo primário de dar um tratamento alternativo ao que é conhecido como ”price-puzzle”. Quando as não linearidades dos dados são consideradas, a maior parte desse efeito é resolvido. Isto é feito, primeiramente, verificando se as séries são estacionárias em torno de uma tendência linear ou não linear, ou se há uma raíz unitária nelas. Depois, foi aplicada uma análise não paramétrica de co-tendência. O resultado do teste foi em favor de uma tendência não linear comum entre a taxa de inflação e a taxa de juros, o que parece afetar a análise das inovações do sistema, provocando em grande parte o efeito ”price puzzle”.
Palavras-Chaves: Política Monetária, Não Linearidades, Tendência Não Linear, Co-Tendência, Tendências Comuns, Price Puzzle.

1. INTRODUCTION

It is now well documented that structural changes affect unit root tests. Perron (1989, 1990) shows that if there is a break in the deterministic trend, the unit root hypothesis is hardly rejected. Bierens (1997) expanded this discussion, suggesting an ADF type test against a nonlinear deterministic time trend alternative, approximated by Chebishev polynomials.

Macroeconomic time series may move together over time even thought they are not integrated. In other words, it is possible that some variables that are not unit root processes to act like cointegrated series. Bierens (2000) shows that this might happen when the series have a common nonlinear deterministic time trend. He applied his nonlinear co-trending analysis to U.S. inflation and interest rate; and found that what is called price puzzle is largerly due to a common nonlinear trend between these two variables.

Price puzzle effect has been reported in the vector autoregression (VAR) literature by Eichenbaum (1992), Sims (1992), Bernanke and Blinder (1992), Christiano, Eichenbaum and Evans (1994), for instance; and it means a positive and persistent response of the inflation rate to a unit shock in the interest rate's innovation.

This effect was also previously reported in some studies using Brazilian data. Minella (2001) estimated an unrestricted VAR with four monthly variables in the following order: output, inflation rate, interest rate and M1. To allow for differences in the dynamics of the inflation rate his VAR was estimated in three subsamples. He found an inflation-puzzle in the second (1985-1994) and third (1994-2000) subsamples. In the second subsample this effect disappeared when centered inflation was used, and on the third subsample this problem was solved through the missing variable approach. Cysne (2004), used the bias-corrected bootstrap bands, proposed by Pope (1990) and Kilian (1998), to deal with the price-puzzle in a VAR applied to quarterly brazilian data from 1980:Q1 to 2004:Q2.

The main objective of this work is to verify if there is a common nonlinear trend in Brazilian inflation and interest rate, and to check if this phenomenon may be the cause of a price puzzle in Brazil. In other words, it tries to answer the question if Brazilian output, M1, inflation and interest rates are really unit root processes. Brazilian inflation and interest rate seems to move together. What if they are not integrated series? If this is the case, a nonlinear co-trending analysis can be used, instead of cointegration tests, to investigate the long run comovement between these variables. Then, this information can be included into the previously mentioned VAR to see if it is capable to produce better impulse response functions. The result could be an alternative model capable of furnishing a better explanation of short and long run dynamics of the economy.

Besides this introduction this study has three more sections. The first one, as usual, contains a review of the most important theoretical background for the work. Subjects such as unit root tests, the co-trending test and the VAR are discussed. The second one, contains the main results of these tests and the estimation of the VAR model. The conclusions and main remarks are presented in the last section.

2. THEORETICAL BACKGROUND

This work will use the same series used in Minella (2001), but with an expanded number of observations. The first step in this study is to verify if these variables are really unit root processes. For this purpose, Dickey-Fuller (1979) tests, Phillips and Perron (1988) and Bierens (1997) unit root tests will be used. Then, Bierens' co-trending analysis will be performed to check if there is a common nonlinear trend between interest and inflation rates. Next, the price puzzle problem may be solved including these nonlinearities into the VAR. Thus, the next subsections contains a brief presentation of these concepts.

2.1 UNIT ROOT TESTS

2.1.1 Dickey-Fuller tests

Consider the Gaussian AR(1) process:

$$y_t = \alpha + \rho y_{t-1} + \varepsilon_t, \text{ or} \tag{1}$$

$$\varepsilon_t \sim i.i.d.\ N(0, \sigma^2) \tag{2}$$

The Dickey-Fuller (DF) ρ test for the for the null hypothesis of a unit root ($\rho = 1$) against the stationarity alternative hypothesis is given by the statistic $T(\hat{\rho} - 1)$ which has a nonstandard distribution. When there is serial correlation in the data Dickey and Fuller (1979) suggested to add higher-order autoregressive terms in the auxiliary regression. Now, consider an AR(p) process:

$$y_t = \alpha + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \rho y_{t-1} + \varepsilon_t \tag{3}$$

The Dickey-Fuller ρ test in this case is $\frac{T(\hat{\rho}-1)}{1-\sum_{j=1}^{p-1}\hat{\alpha}_j}$. This test is know as the Augmented Dickey-Fuller test (ADF). A linear time trend may be included in the regression. Thus, the null hypothesis of a unit root is tested against a linear trend stationarity hypothesis[1].

2.1.2 Phillips-Perron Test

Based on eq(1), Phillips and Perron (1988) suggested a unit root test when ε_t is serially correlated and heteroskedastic. Their approach consists of adding a correction factor to the DF test statistic. The Phillips-Perron (PP) ρ test is[2]

$$T(\hat{\rho} - 1) - 0.5(T^2 \hat{\sigma}^2_{\hat{\rho}}/s^2)(\hat{\lambda}^2 - \hat{\gamma}_0), \text{ where} \tag{4}$$

$$\hat{\lambda}^2 = \hat{\gamma}_0 + 2\sum_{j=1}^{q}[1 - j/(q+1)]\hat{\gamma}_j \tag{5}$$

$$\hat{\gamma}_j = T^{-1}\sum_{t=j+1}^{T}\hat{u}_t\hat{u}_{t-j} \tag{6}$$

$$T^2\hat{\sigma}^2_{\hat{\rho}}/s^2 = \frac{1}{T^{-1}[T^{-1}\sum y^2_{t-1} - (T^{-1}\sum y_{t-1})^2]} \tag{7}$$

2.1.3 Bierens Test

Bierens (1997) shows how to test the unit root with drift hypothesis against a linear or nonlinear trend alternative hypothesis. For this purpose he used Chebischev time polynomials, defined as: $P_{0,n}(t) = 1; P_{k,n}(t) = \sqrt{2}\cos[k\pi(t - 0.5)/n]$; for t=1,...n, and k=1,...,n-1. These polynomials are orthogonal, have a closed form, and can approximate linear and highly nonlinear time trends quite well. Another important step in this procedure is to transform these polynomials, for k=1,2,...,(n/2), such that they become orthogonal to the time trend, in order to distinguish linear and nonlinear trends as follows: $P^*_{0,n}(t) = 1$;

[1] The distributions of these tests and further details may be found in Hamilton (1994).
[2] The distribution of this test is nonstandard and may be found in Hamilton (1994).

$P^*_{1,n}(t) = \frac{t-(n+1)/2}{\sqrt{(n^2-1)/12}}$; $P^*_{2k,n}(t) = \frac{P_{2k-1,n}(t) - \alpha_{k,n} - \sum_{j=1}^{k-1}\beta_{k,j,n}P_{2j-1,n}(t) - \gamma_{k,n}(t/n)}{c_{k,n}}$; $P^*_{2k+1,n}(t) = P_{2k,n}(t)$; and the $c_{k,n}$ are such that $n^{-1}\sum_{t=1}^{n}[P^*_{2k,n}(t)]^2 = 1$. Suppose now that,

$$\Delta y_t = -\rho y_{t-1} + \lambda_0 + \rho\lambda_1 t + f(t) + \varepsilon_t \tag{8}$$

The unit root with drift hypothesis corresponds to $H_0: \rho = 0; f(t) = 0$, and the alternatives hypothesis of linear and nonlinear trend stationarity are respectively $H_1^L: \rho = 1; f(t) = 0$ and $H_1^{NL}: \rho = 1$. The χ^2 test statistic type suggested is

$$\hat{T}(m) = \frac{\left(\sum_{t=1}^{n}\Delta y_t P_{t,n}^{(1,m)} - \hat{\xi}_1 P_{n+1,n}^{(1,m)} - \hat{\xi}_1 P_{1,n}^{(1,m)}\right)'\left(\sum_{t=1}^{n}\Delta y_t P_{t,n}^{(1,m)} - \hat{\xi}_1 P_{n+1,n}^{(1,m)} - \hat{\xi}_1 P_{1,n}^{(1,m)}\right)}{n^{-1}\sum_{t=1}^{n}\left(y_t - \hat{\theta}^{(m)\prime}P_{t,n}^{(m)}\right)^2} \tag{9}$$

Where, $P_{t,n}^{(i,m)} = (P^*_{i,n}(t), \ldots, P^*_{m,n}(t))'$, $i = 1, \ldots, m$; and

$$\hat{\theta}^{(m)} = n^{-1}\sum_{t=1} y_t P_{t,n}^{(m)}, \text{ where } P_{t,n}^{(m)} = (P^*_{0,n}(t), \ldots, P^*_{m,n}(t)) \tag{10}$$

This test has a nonstandard distribution, and must be conducted in a two-sided way. Left rejection means linear trend stationary, while right rejection means nonlinear trend stationarity.

2.2 THE NONPARAMETRIC NONLINEAR CO-TRENDING ANALYSIS

Bierens (2000) also shows how to test if two or more variables have a long run comovement, like a cointegrated process, for the case in which these series are not integrated processes; i.e., they are not unit root processes. If $y_t = g(t) + u_t$, where y_t is a k-variate time series vector, u_t is a k-variate zero-mean stationary process, $g(t) = \beta_0 + \beta_1 t + f(t)$, and $f(t)$ is a deterministic k-variate nonlinear trend function, then nonlinear co-trending exists when there is a vector θ such that $\theta' f(t) = 0$. Now, define two matrices, $\hat{M}1$ and $\hat{M}2$, such as,

$$\hat{M}1 = \frac{1}{n}\left[\hat{F}(1/n)\hat{F}(1/n)' + \ldots + \hat{F}(1)\hat{F}(1)'\right] \tag{11}$$

$$\hat{M}2 = \frac{1}{n}\left[\hat{F}'(m/n)\hat{F}'(m/n)' + \ldots + \hat{F}'(1)\hat{F}'(1)'\right] \tag{12}$$

Where, $\hat{F}(t/n) = (1/n)[x(1) + \ldots + x(t)]$; $\hat{F}'(t/n) = (m/n)[\hat{F}(t/n) - \hat{F}(t/n - m/n)]$; $m = n\alpha$; $0 < \alpha < 1$ and $x(t)$ is the detrended or demeaned y_t. Bierens suggested to use $\alpha = 0.5$, because this value is optimal to the convergence of the $\hat{M}2$ matrix. The test of the null hypothesis that there are g co-trending vectors, against the alternative, that there are less than g co-trending vectors, is based on the statistics $n^{1-\alpha}\hat{\lambda}_g$; where $\hat{\lambda}_g$ are the g's increasingly ordered smallest solutions of the generalized eigenvalue problem $\det(\hat{M}1 - \lambda\hat{M}2) = 0$. Two alternative estimators for the co-trending vector $\hat{\theta} = (\hat{\theta}_1, \ldots, \hat{\theta}_g)$ are the $k - g$ columns of the orthonormal eigenvectors associated with the g smallest eigenvalues of $\det(\hat{M}1 - \lambda\hat{M}2) = 0$; and the eigenvectors of the minimum $k - g$ eingenvalues of $\hat{M}1$ matrix alone.

2.3 THE VECTOR AUTOREGRESSION

Following Hamilton (1994), the reduced form of a pth-order Gaussian vector autoregression can be expressed as,

$$y_t = c + \sum_{i=1} \Phi_i y_{t-i} + \varepsilon_t; \text{ or simply} \tag{13}$$

$$y_t = \Pi' x_t + \varepsilon_t \tag{14}$$

Where, y_t is an $(n \times 1)$ vector with the values at date t of n variables, $\varepsilon_t \sim i.i.d.\ N(0; \Omega)$, $\Pi' = [c\ \Phi_1 ... \Phi_p]$, and $x_t = [1\ y_{t-1} ... y_{t-p}]'$. In this unrestricted case, the maximum likelihood estimate (MLE) of Π and Ω, are the same as the one calculated by ordinary least squares (OLS).

It is worth to remember that a VAR is related to a dynamic system such as $B_0 y_t = k + \sum_{i=1}^{p} B_i y_{t-i} + u_t$. This means that $\varepsilon_t = B_0^{-1} u_t$, and to compute the impact of a one-unit increase in the jth variable, at date t, on the ith variable, at t+s, an orthogonalized impulse-response function can be used. This is done based on a lower triangular Cholesky decomposition of ε_t into a set of uncorrelated u_t's, a useful characteristic to deal with cases where these innovations are contemporaneously correlated. On the other hand, an undesired effect of this decomposition is that changing the order of the variables in the vector y_t may produce different impulse-response functions. To be more specific, the first variable has an instantaneous effect on the others, but the contrary does not happen, and so on. The order adopted in this study is the same as the one used by Minella (2001) and Christiano, Eichenbaum and Evans (2000); that is, output, inflation, interest rate and M1.

3. EMPIRICAL RESULTS

The variables used in this work were the log of output (y), measured by the index of industrial production (seasonally adjusted); inflation rate (inf), measured by the IGP-DI; the Selic overnight interest rate (r), and the log of money aggregate (m1). All these series are at a monthly frequency, starting in january-1975 and ending up at january-2004. Figure 1, plots all these series[3].

3.1 Unit Root Tests Results

3.1.1 ADF tests

It is clear from Figure 1, that y and m1 have a time trend, but this is not so clear in the plot of inf and r which, by its turn, shows that inf and r have a similar time pattern. In the light of this figure, the null hypothesis of unit root with drift against the alternative of a linear trend, called here as type 3, was tested for y, m1, inf and r . For inf and r, it was also tested the null hypothesis of unit root against stationarity, called type 2. The results of both tests are presented in Table 1, where R=rejected and NR=not rejected. These two tests did not reject the null hypotesis of unit root.

TABLE 1 - ADF TESTS RESULTS

	Type 3				Type 2			
	Critical Region		Test Statistic	Conclusion	Critical Region		Test Statistic	Conclusion
	5%	10%			5%	10%		
Series					-	-	-	-
y	-3.4	-3.1	-2.72	NR	-	-	-	-
inf	-3.4	-3.1	-1.96	NR	-2.9	-2.6	-1.9	NR
r	-3.4	-3.1	-1.85	NR	-2.9	-2.6	-1.88	NR
m1	-3.4	-3.1	-1.59	NR	-	-	-	-

[3] All the figures of this work are in the Appendix 1.

3.1.2 Phillips-Perron Tests

When correlation and heteroskedasticity in the residuals are considered, the results about stationarity of the series under analysis are quite different - y, inf and r are now (linear trend) stationary processes. Table 2 shows the results of the PP tests.

TABLE 2 - PP TESTS RESULTS

	Type 3				Type 2			
	Critical Region		Test Statistic	Conclusion	Critical Region		Test Statistic	Conclusion
	5%	10%			5%	10%		
Series					-	-	-	-
y	-21.8	-18.4	-80.8	R	-	-	-	-
inf	-21.8	-18.4	-29.5	R	-14.5	-11.7	-29.6	R
r	-21.8	-18.4	-21.5	NR;R	-14.5	-11.7	-21.7	R
m1	-21.8	-18.4	-3.23	NR	-	-	-	-

3.1.3 Bierens' Test

Looking at the plot of m1 (Figure 1), it is clear that it would be very difficult to reject the null hypothesis of unit root in favor of a linear trend, because this series seems to have a nonlinear or a linear trend with breaks in the mean. A similar argument can be used for inf and r. Testing unit root hypothesis, against nonlinear trend, produces new results presented in Table 3 (LR means left rejection and RR means right rejection).

TABLE 3 - BIERENS' TEST RESULTS

		Fractiles of the asymptotic null distribution						
Series	Ᵽ ¡ test statistic	0.025	0.05	0.10	0.90	0.95	0.975	Conclusion
y	192.5	223.5	280.6	359.5	1408.7	1660.1	1930.5	LR
inf	104.4	223.5	280.6	359.5	1408.7	1660.1	1930.5	LR
r	115.8	223.5	280.6	359.5	1408.7	1660.1	1930.5	LR
m1	3229	223.5	280.6	359.5	1408.7	1660.1	1930.5	RR

These results corroborate the PP tests for y, inf and r. Now, m1 is nonstationary around a nonlinear trend. Back to Figure 1, one can see that inf and r have a similar time plot, thus the next step is to test if they have a common trend. Other studies have found that there is no unit root in output (Minella, 2001). Cati, Garcia and Perron (1999) have found mixed results about Brazilian inflation, but they concluded in favor of a unit root process. In this study, not only the possible structural breaks are included in the unit root test, but it was also allowed for the possibility of other nonlinear trend types. Thus, at least inf, r and m1 series may be considered as mixed processes, instead of pure unit root processes.

3.2 Nonlinear Co-Trending Test

As mentioned before, inf and r have a very similar plot, a cointegrated like process, and at the same time they are possibly stationary processes or nonstationary around a linear trend. Thus, it seems to be important to test if these series have a common linear or nonlinear deterministic time trend. Bierens' nonlinear co-trending analysis was applied on demeaned data, because the series do not have a clear trend. The next table presents the results of this test.

TABLE 4 - CO-TRENDING TEST RESULTS

Demeaned Data

g	test statistic	10% Critical Region	5% Critical Region	Conclusion
1	0.22	0.32	0.47	g=2 at 5%
2	0.61	0.55	0.67	g=1 at 10%

This work sticks to the conclusion that g=1 at 10%; i.e, there is one co-trending vector. Figure 2A and 2B shows the components of $\hat{F}(x)$ and $\hat{F}^0(x)$, respectively, where a common pattern among them is easily perceived, leaving ground for the possibility of a nonlinear co-trending between inf and r.

3.3 VAR Results

Based on the previous results, three types of VAR were estimated: a) without any trend; b) with a linear trend and c) with Chebishev time polynomials. The Akaike, Hanan-Quinn and Schawarz information criteria were used to select lags. In case a) and b), 3 lags seems to be the better specification. Their impulse response analysis are very similar; that is, there is a inflation-puzzle that lasts more than 20 months; and, as expected, there are some shocks with permanent effects, because the variables are not pure I(0) process. Figure 3 contains some of the plots of the impulse analysis of the VAR without a trend.

When this analysis is conducted on the basis of a VAR, called VAR(c1), with 3 lags and 3 Chebishev time polynomials, added next to the intercept to capture data nonlinearities, all shocks become transitory; i.e., the effect of an impulse vanishes over time. Moreover, the inflation puzzle lasts only 7 months. Figure 4 presents these results.

Figure 4, also shows that output reacts negatively to a unit shock in the interest rate. The reduction reaches its maximum in the fourth month, something around 1.5%. Interest rate, by its turn, has been used to accommodate shocks in output, and reacts negatively to shocks in M1. The impulse response of inflation rate to its own shock shows that its persistence has a 5 or 10 months duration.

There is a initial negative response of m1 to interest rate shocks that becomes positive, differently from Rabanal and Schwartz (2001), which found a negative response. The initial negative response of m1 to output, inflation and interest rate was expected, after that m1 is raised to keep the liquidity balance on the economy.

A shock on output causes a positive response of the inflation rate, and the interest rate seems to be used to stabilize output and inflation, while m1 seems to be used only to maintain the economy liquidity. Most of these results are in tune with Minella (2001).

Using 4 lags and 20 Chebishev time polynomials for the innovation analysis, called as VAR(c.2), the effect of the interest rate on output lasts less than in the VAR(c.1), and its biggest impact happens in the second month. Again, there is an initial negative response of m1 to interest rate shocks that becomes positive, but it lasts only 8 months, when it then vanishes. M1 really seems to be used to maintain the liquidity in the economy. The inflation puzzle was severely reduced to only 3 months, and much of the above results was preserved under this new VAR, as presented in figure 5.

4. CONCLUDING REMARKS

In this work a VAR was used to analyse the effects of monetary policy in Brazil. The fact that nonlinearities may cause some undesired effects on time series analysis was taken into account. Bierens (1997) shows that many series firstly looking as unit root processes could be, indeed, nonstationary with a nonlinear deterministic trend. Thus, using a VAR which takes into consideration these nonlinearities, all the sample could be used, instead of breaking it in small subsamples in order to avoid the undesirable effects of strucutural breaks to this kind of procedure.

Therefore, all the monthly data (1975:01 to 2004:01) used in this work, such as the log of output (y); the inflation rate (inf); the Selic overnight interest rate (r), and the log of money aggregate (m1) were submitted to both traditional and Bierens (1997) unit root tests. It seems that all the series are neither pure unit root processes nor stationary or nonstationary with a deterministic trend. To be precise, the plots of inf, r and m1 indicate that they have a nonlinear trend, and for m1, Bierens' test corroborates this feeling.

The graph of inf and r produces another impression - that they are cointegrated. However, these series are not integrated processes. In this case it was applied the nonlinear co-trending analysis suggested by Bierens (2000). The test confirmed that inf and r have a comovement and, as expected, this may cause a price-puzzle on VAR's innovation analysis. Adding Chebischev time polynomials next to the intercept, most of the inflation puzzle was removed - it lasts only 3 months. Cysne (2004), applying a VAR with bias-corrected confidence bands to Brazilian data, obtained a price-puzzle that lasts one quarter, also.

Why a co-trending does exists to inf and r ? There are some possible reasons to explain this phenomenon. Brazil has experienced a long period of high inflation, and at this time all the prices in the economy were indexed. The past inflation was automatically transmitted to current prices, including the price of money - the interest rate. In July 1999, the Central Bank of Brazil adopted a inflation target regime, using the interest rate, instead of m1, as the monetary instrument to control inflation, or expected inflation. This affirmative is corroborated by the impulse response analysis of VAR(c.1) and VAR(c.2), where the interest rate was used to stabilize output and inflation, while m1 reacts only to maintain the monetary balance.

It seems, therefore, that much of the positive response of inflation to a unit shock in the interest rate is due to the co-trending phenomenon between these two variables, and when the possibility of these nonlinearities in the data are considered, not only does the impulse response functions of the system become stationary, but also that the problem of inflation puzzle was diminished.

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APPENDIX I

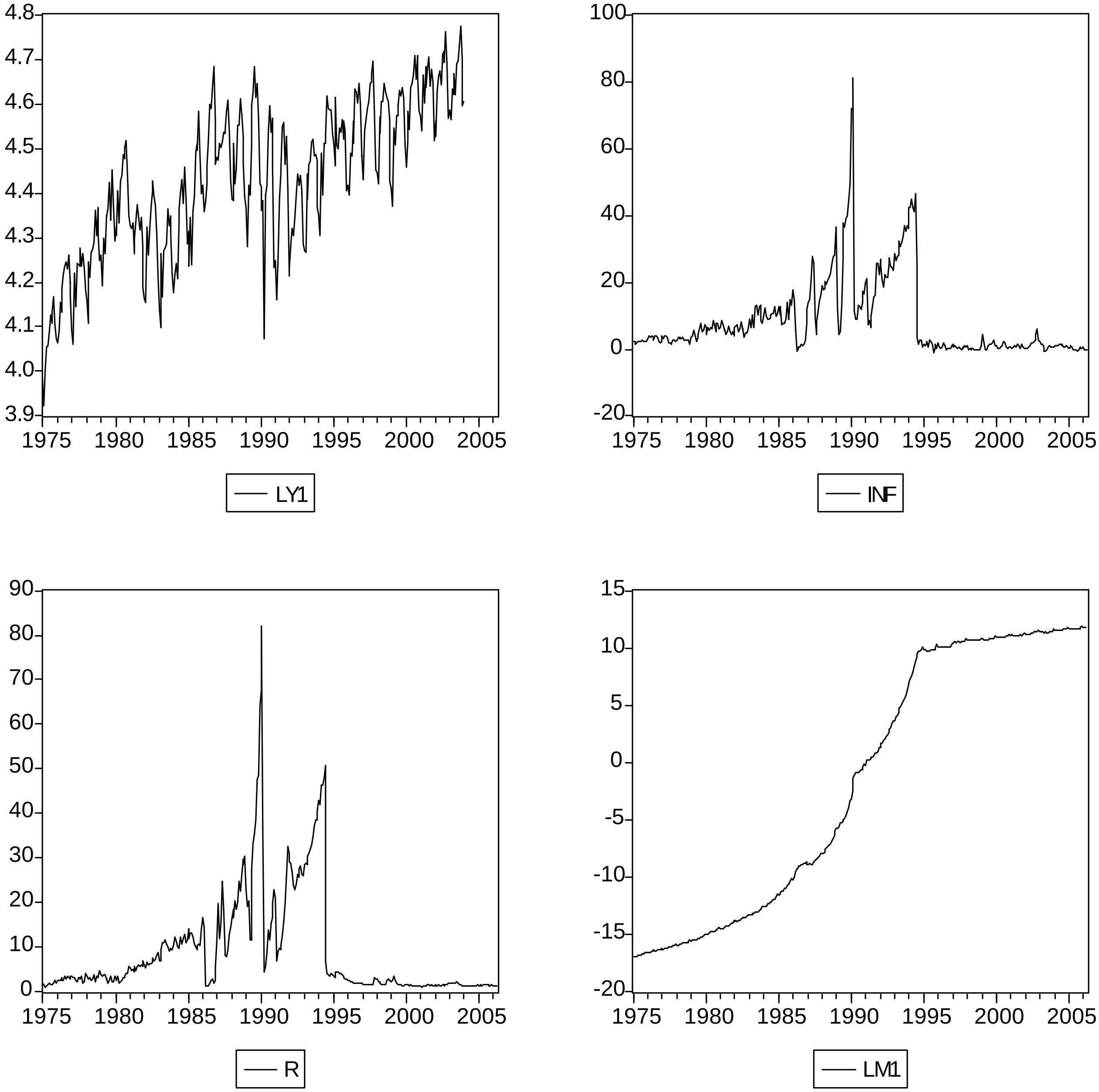

FIGURE 1 - PLOTS OF THE SERIES

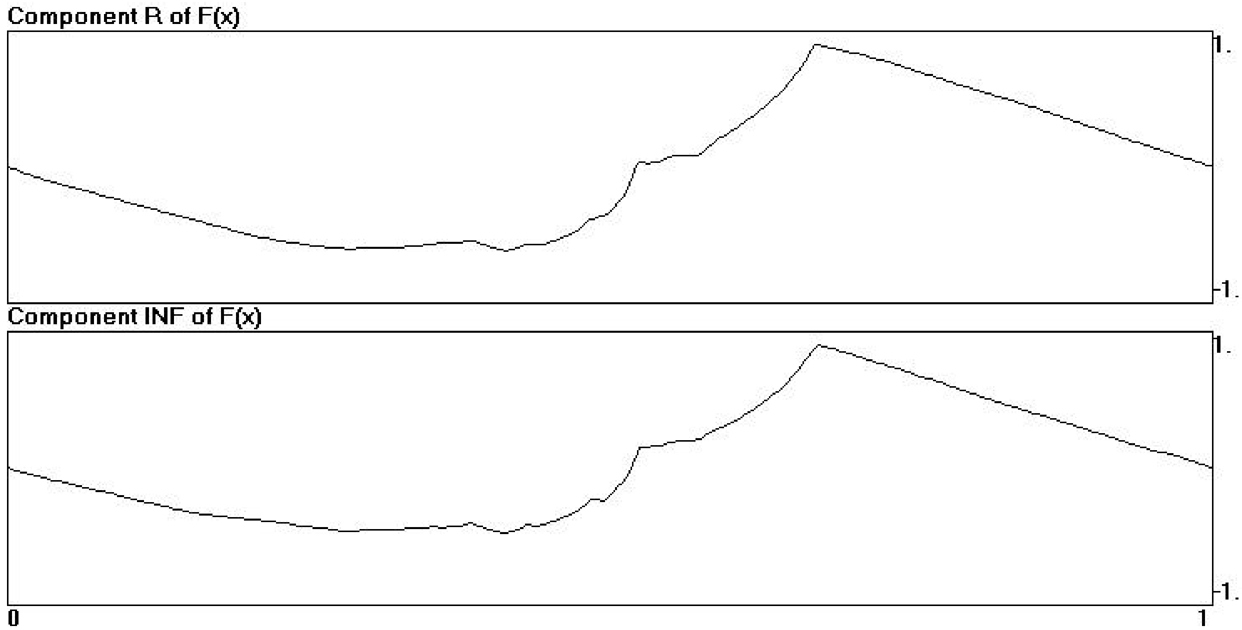

FIGURE 2A - COMPONENT INTEREST AND INFLATION OF F(X)

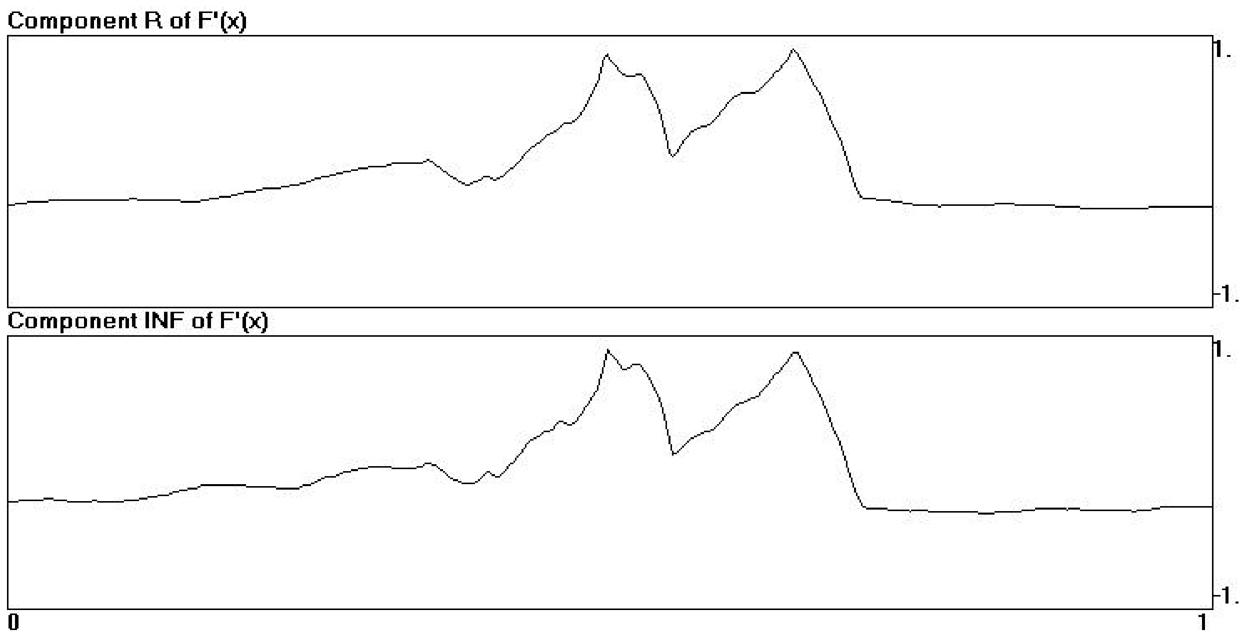

FIGURE 2B - COMPONENT INTEREST AND INFLATION OF F’(X)

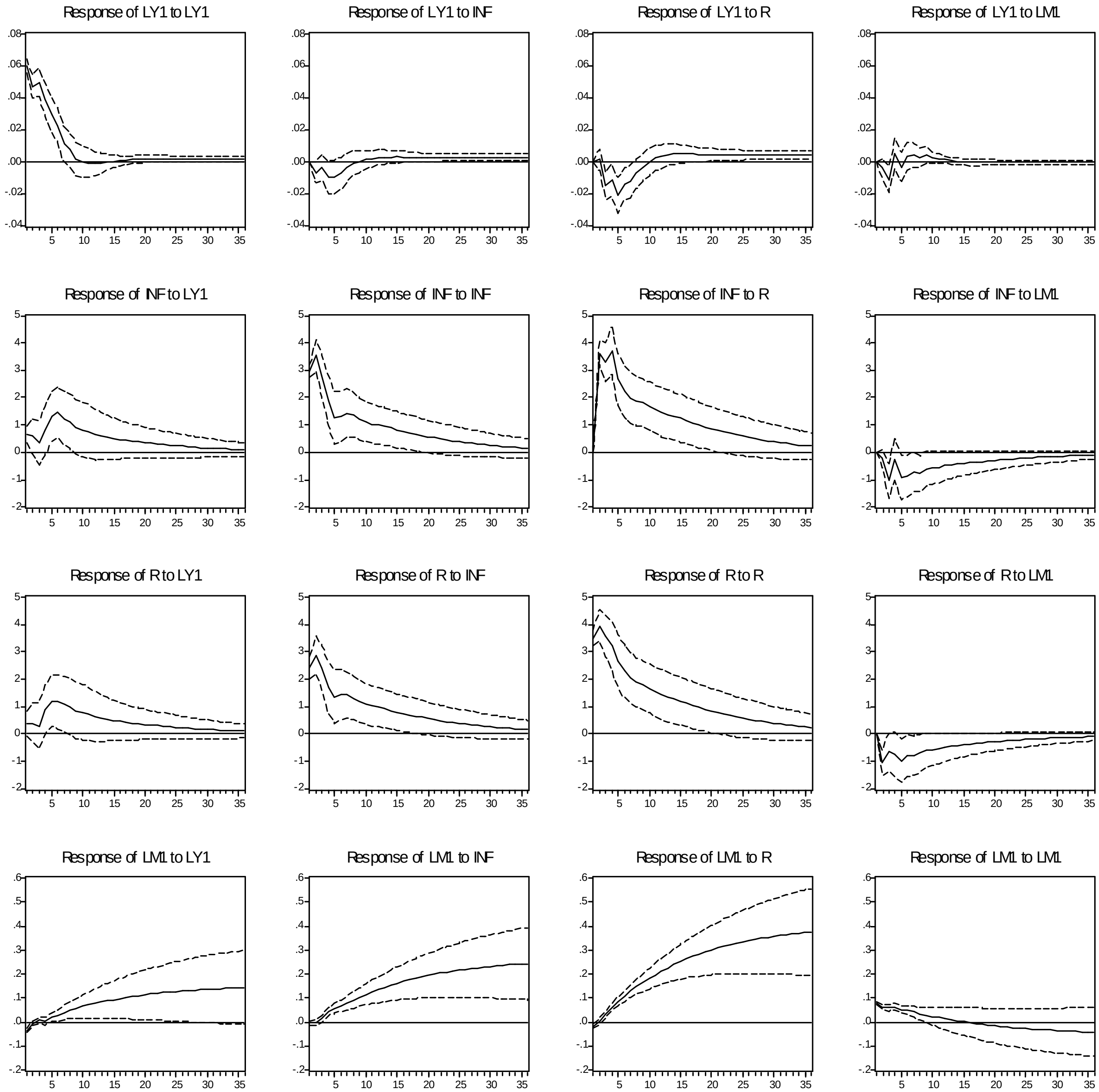

FIGURE 3 - IMPULSE RESPONSE:VAR(a)

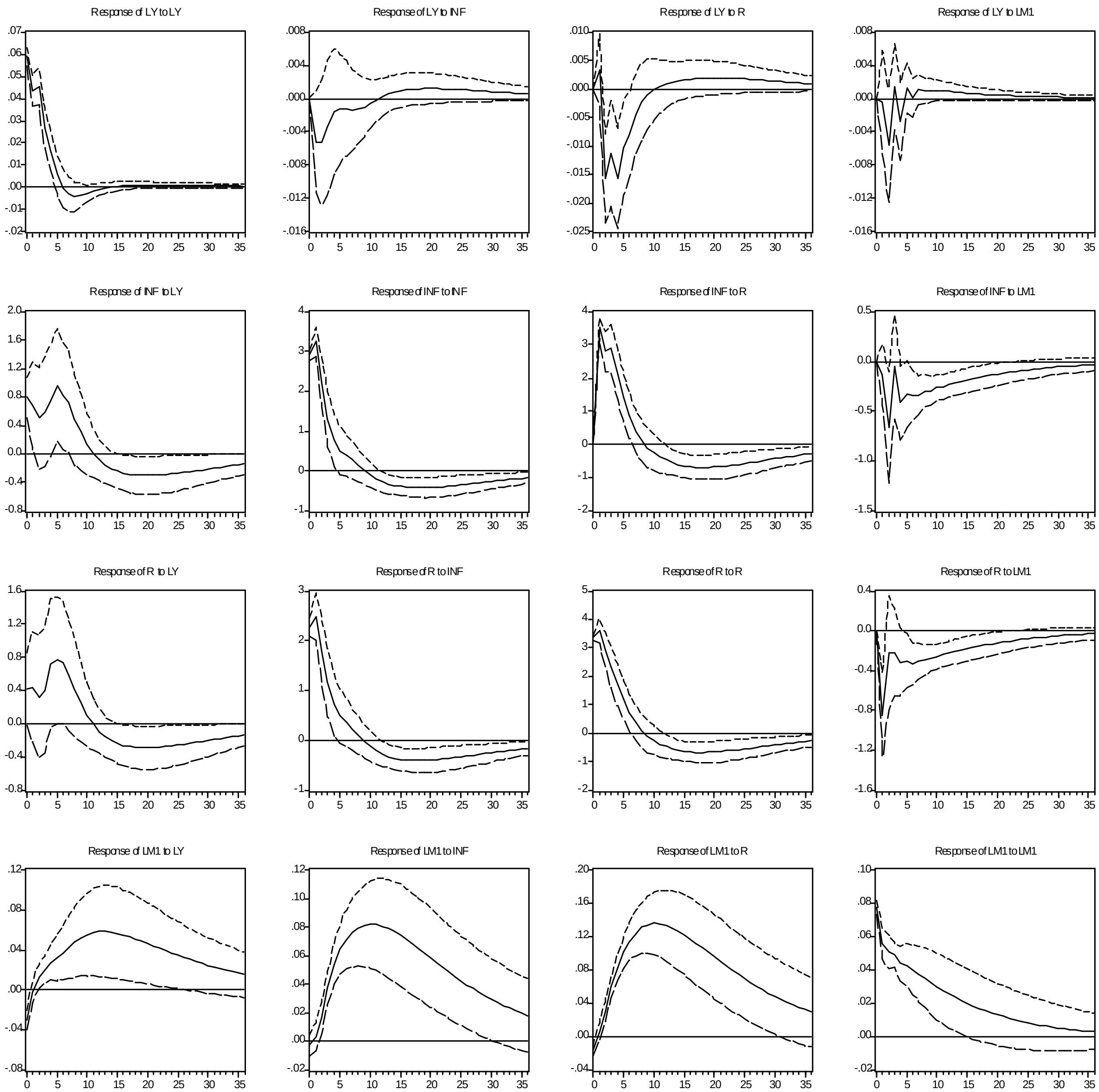

FIGURE 4 - IMPULSE RESPONSE: VAR(c1)

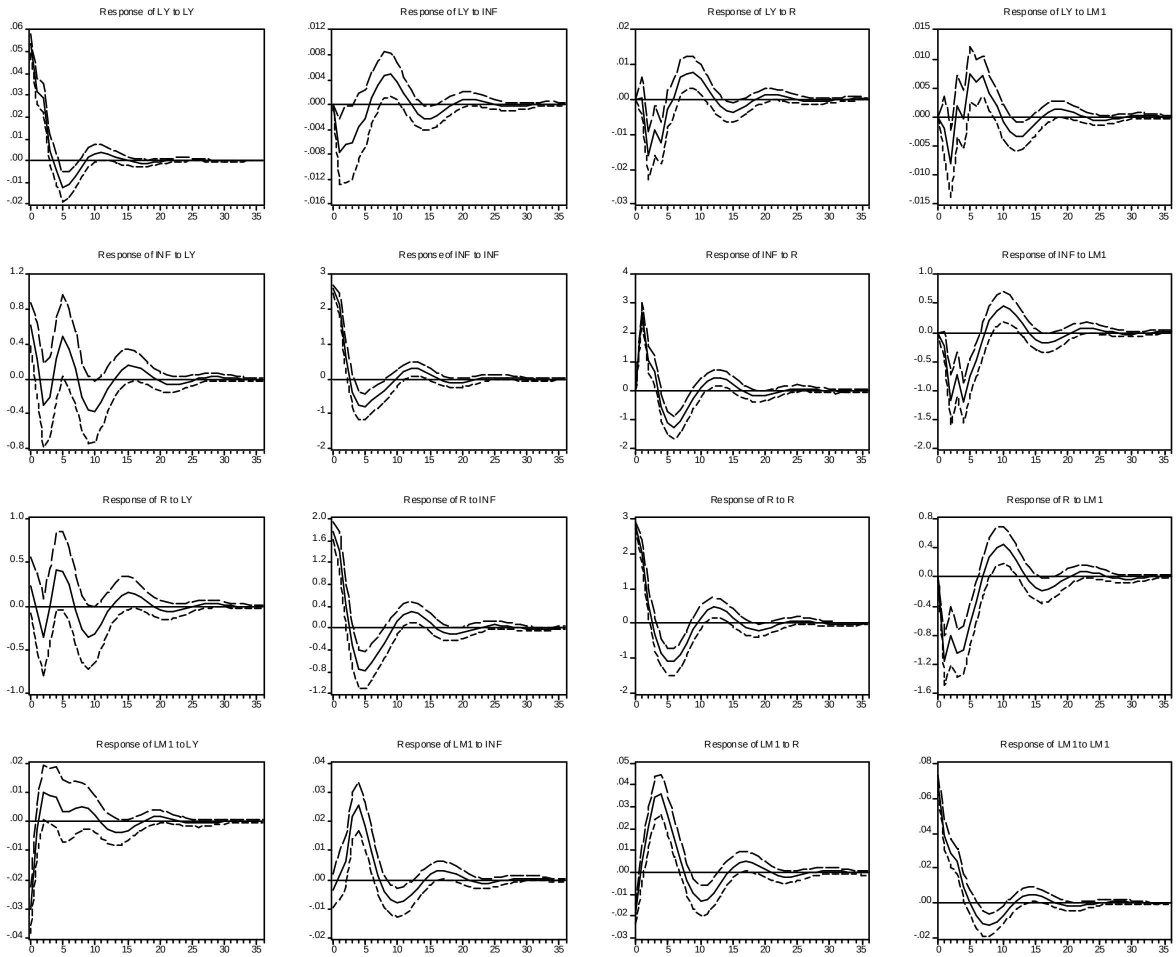

FIGURE 5 - IMPULSE RESPONSE: VAR (c2)