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An Algorithm for Analysis Time Series Data

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ABSTRACT

The objective of this article is to develop an algorithm for the identification of structural changes in time series data. The algorithm consists of five stages: an exploratory analysis of the data, test for homogeneity, test for stationarity, test for the direction of causality and, finally, modeling. This algorithm was utilized in the analysis of Brazilian macroeconomic variables in the period from January of 1971 to December of 1991. The objective of this article is to develop an algorithm for the identification of structural changes in time series data. The algorithm consists of five stages: an exploratory analysis of the data, test for homogeneity, test for stationarity, test for the direction of causality and, finally, modeling. This algorithm was utilized in the analysis of Brazilian macroeconomic variables in the period from January of 1971 to December of 1991. Several structural changes were encountered. With the proposed monitoration of data algorithm we can detect the separation of two interest sub-periods to the brasilian economic, that is, the priori and posteriori period of the 70 decad. The period in what the algorithm detected changes in the variables , that is, 1979, was the year is, what occured significant structural changes in the contry, because as yet mentioned, was from 1979, that the brasilian economy go in the more turbulent phase, with sequentialy accelerator shocks, making that the annual rate of inflation change from 77,2% in 1979 and 110,2% in 1980. The separation in two sub-periods provide the analysis of the changes of directions of causality in the economic studied of variables. For the nine analyzed variables only three presented no change in for the two sub-periods, before and after 1980, in the monetary base, interest rates and governament debit, this show the importance of these variables in the determination of a plan to reduct the inflation.

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INTRODUCTION

There are multiple theories of inflation which can be explained in part by recognizing that inflations differ through space and time. The causes of inflation may be different from one country to another, depending upon level of development, openness to international trade, competition within the country and with other countries, the form of government, among other factors (Cardoso, 1977; Marques, 1983; Brandão, 1985). An approach which tends to be more statistical than theoretical for studying the Brazilian inflation of the last two decades has been proposed.

The objective of this article is to develop an algorithm for the identification of structural changes in time series data. The algorithm consists of five stages: an exploratory analysis of the data, test for homogeneity, test for stationarity, test for the direction of causality (Pierce; Haugh, 1977) and, finally, modeling. This algorithm was utilized in the analysis of Brazilian macroeconomic variables in the period from January of 1971 to December of 1991.

Several structural changes were encountered. With the proposed monitoration of data algorithm we can detect the separation of two interest sub-periods to the brasilian economic, that is, the priori and posteriori period of the 70 decad. The period in what the algorithm detected changes in the variables, that is, 1979, was the year is, what occured significant structural changes in the contry, because as yet mentioned, was from 1979, that the brasilian economy go in the more turbulent phase, with sequentialy accelerator shocks, making that the annual rate of inflation change from 77,2% in 1979 and 110,2% in 1980. The separation in two sub-periods provide the analysis of the changes of directions of causality in the economic studied of variables. For the nine

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The basic theory related to this paper is presented in section 2. The results and final considerations of are presented in section 3.

Basic Theory:

This algorithm was developed with the objective for the identifying of structural change in time series (Box and Jenkins, 1976; Camargo, 1992), as description follows.

Step 1 - Exploratory analysis of the data:

a) Make the histogram with statisties sumary of the global serie, apply the Chi-Square (X^2) test to verify the normality of the data, as well as the presence of the components and of the outliers. If the data are not normal we use the general linear transformation of Box-Cox.

b) Subdivide the serie into k subseries. The size (n) of each sub-serie may be in accord with the periodicity of data. Find out the basic statistics (mean and variance) and make the graphs.

Step 2 - Test for homogeneity of Time Serie:

A test for homogeneity will indicate the existence of outliers in the time series. If in the homogeneity test H_o is accepted, the method ends rejecting the existence of any outliers, and therefore the time series show no structural changes, on the other hand, if the null hypotheses is rejected, we go to the next step of the method where the observation that, in accordance with an objective criterion, will is selected that, in accordance with an objective criterion, will be considered as an outlier (Chang and Tiao, 1983; Chang; Tiao and Chen, 1988; Chow, 1960).

So, we consider a time serie $Y_1, Y_2, \ldots, Y_n$, of size n of a stochastic process with probability density function f(Y,δ). The likelihood of the time series can be generally represented by:

$$L(Y_1, Y_2, \ldots, Y_n; \delta) = \prod_{i=1}^{n} f(Y_i, \delta) \tag{1}$$

In the proposed method we consider the follow model of discordance:

1. Null hypothesis (H_o), of homogeneity.

We admit that all the observations $Y_1, Y_2, \ldots, Y_n$ have the same probability density function $f(Y_i, \delta)$, (i = 1,...,n). Let $L_0(Y_1, Y_2, \ldots, Y_n; \delta)$ the likelihood of the time serie at the H_o hypothesis.

2. Alternative hyphothesis (H_a), natural alternative

Admit the presence of one more outlier values in the sample and that, they could any of the n observations. In this since to be H_{aj} the hypothesis that admit Y_j as discordant observation, that is, so that: Y_j have probability density $f(Y_t, \delta)$ to some j ∈ {1, 2, ..., n} and $Y_1, Y_2, \ldots, Y_{j-1}, Y_{j+1}, \ldots, Y_n$ following one distribution with density $f(Y_i, \delta)$ to $i \neq j$.

Accepting the natural alternative hypothesis (H_a), existing therefore at least one discordant observation Y_j, signifies therefore, that the hypothesis is H_{aj}. Thus, the natural alternative hypotheses (H_a) can be taken as the union of the n hypotheses (H_{aj}). Assuming alternative hypothesis H_a and hypothesis H_{aj} is represented by the likelihood of the time series:

$$L_j(Y_1, \ldots, Y_n; \delta, \delta') = \prod_{i \neq j}^{n} f(Y_i, \delta)\, f(Y_j, \delta') \tag{2}$$

Representing for $\hat{\delta}$ the maximum likelihood estimator for δ in the null hypothesis H_o and for $\hat{\delta}_t$ the $\hat{\delta}'_t$, the maximum likelihood estimator to δ, δ´ in the alternative hypotheses H_{aj} we have, to the maximum of the likelihood function under H_o and H_{aj}, respectively $\hat{L}_o$ and $\hat{L}_j$.

To formulate the homogeneity test we use the likelihood ratio test.

That is:

$$\lambda_n = \frac{\max(H_o)\ L(Y_1,\ldots,Y_n;\delta)}{\max(H_{aj})\ L(Y_1,\ldots,Y_n;\delta,\delta')} \tag{3}$$

For the maximum likelihood principle, if the hypothesis H_o is true, we need to expect that $\hat{L}_o$ and $\hat{L}_j$ will be of small difference, so that λ_n is near to 1.

Harvey (1989) show that -2 log λ_n has χ^2 distribution with k-1 degrees of freedom for large values of n. A better aproximation consist of substitute n_j, for (n_{i-1}) and observing that the equation

$$\chi_c^2 = \frac{-2\log\lambda'}{1+\frac{1}{3(k-1)}\left[\sum_{i=1}^{k}\frac{1}{n_i}-\frac{1}{\sum_{i=1}^{k} n_i}\right]} \tag{4}$$

has χ^2 distribution with (k-1) degree of freedom.
Where λ' result from λ, substituting n_j for n_i - 1 (i = 1, 2, ...,k).

If the null hypothesis is accepted, we reject the existence of any discordant observation and finish in this phase of the analysis of outliers and go to the next step. If the null hypothesis has been rejected, accepting therefore the existence of one or more discordant observations. The observation Y_j will be identified as outlier. The index j where the statistics λ_n goes to the maximum, define the observation Y_j responsable for non homogenity in the sample.

Step 3 - Stationarity Test:

This test is made by the analysis of coeficients of autocorrelations, that is, if the autocorrelation function shows exponential declive, then the series is stationary. If the series is not stationary, some kind of transformation is necessary.

Step 4 - Causality Direction Test:

To verify the direction of causality, we use the Pierce and Haugh (1977) test, based on the analysis of the coeficients of cross-correlation of white noise errors.

$$\rho_{xy}(k) = \frac{Cov[X_t, Y_{t+k}]}{[\sigma_x^2\sigma_y^2]^{1/2}} = \frac{\gamma_{xy}(k)}{[\gamma_{xx}(0)\gamma_{yy}(0)]^{1/2}} \tag{5}$$

$r_{\alpha\eta}$ (k) is the sample cross-correlation, i.e. the estimation of $\rho_{\alpha\eta}$ (k) on (5). Under the hypothesis that the X_t series is independent of the Y_t series, you have to:

a) $r_{\alpha\eta}(k) \sim N(0, 1/n)$ (6)

b) $$Q_M = n\sum_{k=-M_1}^{M_2} r_{\alpha\eta}^2(k) \tag{7}$$

c) $$Q^*_M = n^2\sum_{k=-M_1}^{M_2}(n-k)^{-1}r_{\alpha\eta}^2(k) \sim X^2(-M_1+M_2+1) \tag{8}$$

The amplitude of the lag [-M1, M2], which should be used in these statistics depends on the analyst's own knowledge about the phenomenon being studied. Statistics Q_M and Q^*_M follows a Chi-square distribution with (-M1+ M2+ 1) degrees of freedom.

The statistic Q_M and Q^*_M test the cross-correlations, $r_{\alpha\eta}(k)$, in groups rather than individually. A test to check the individual significance of cross-correlations can be done by comparing $r_{\alpha\eta}(k)$ with two standard errors.

If the series analysed show unidirectional causality, we go the step of modelling by transfer function. If causality is not unidirectional multivariate or modelling is appropriate.

Step 5 – Modelling:

In this stage we can use classic or Bayesian methodology (Harrison and Stevens, 1976; Harvey, 1984; Harvey, 1989).

Empirical Analysis:

In this analysis the following variables were used: means of payment (M1, M2, M3, M4) and of the monetary base (BM) exchange rate (TC) mean wage of the capital goods sector inter governament deluit rate interested, general index of prices (IGP-DI), all wich were measured month in percent grouth, for the period from January of 1971 to December of 1991.

Initialy all these series were subdivided in subseries of size 12. An exploratory analysis in all data was made, as well us the normality of the series, was accepted by the Chisquare test. All the variables, in a significance level of 5% presented normality, so can proceed to the test for homogeneity.

In the homogenity test the hipotesis that no outliers exist in the original series was rejected, because the statistic proposed in the monitoring algorihtm was near zero, and the value of the statistc χ^2 change between 72, 24 and 86, 46, while the tabled statistic $X^2_{5\%,20}$ was 31,41. Sequentialy we go to the fase detecting what observation is considered as outlier. The first observation that provides the maximization of the statistic (λ_n) was refer so to the year 1979, also confirmed in almost all the variables by intervention analysis of Box-Jenkins, and by Bayesian analysis realized throngh the Bayes factor automatic option.

So, in accord with the results we have two sample sub-periods to the analysis of economic variables involved in this empirical study, that is, the first sub-period that is from January of 1971 to December of 1979 and the second sub-period that is from January of 1980 to December of 1991.

In according with Marques (1991) the year of 1979 appear as water divide between inflation rates at the band of 30% and 40% by year and a inflation of three digits, until inedited. At the truth volume of inflactionary accumulated pressures in 1974 was substantial. Happened the second petrolium crash, the administred sofred strong real changes, was realized the first maxidevaluation of the cruzeiro and the salary polices sofred profundity changes, and elevation of the rales of interested in the international market. This was the time that the cambial politics was uncertain with the of leave of the explicit cambial rules and suport for wide periods. All these factors afect desagree the inflation rate and the inflactionary expectative

Verify if There are Changes at Direction of Causality:

To verify is the shock of offer verified in the brasilian economy in 1979, detected by the proposed algorithm, change the direction of causality between the studied variables was calculated the cross correlation, between the residuals of al variables related to the prices to the both sample sub-period. The result show that:

The monetary base was exogeneous in the two sub-periods, while that the payment mean in the conceptions (M1, M2, M3, M4) show unidirectional causality at the first sub-period and was endogenous at the second period.

So, this results agree with the results encontred for Cardoso (1977), Contador (1978), Marques (1983), Brandão (1985) that evaluate the relation of causality between payment mean and/or monetary base about the prices variation, concluding that the payment means is endogenous and monetary base is exogenous; here we note that the sample analysis to period are not the same.

This results don't agree with the result encontered for Marques (1991), where the expansion rates of money offering was been positive about the inflaction; confirming the stairs sucessively greater of the rate of variation of the precis, explained for shocks of offering and/or demand at the period from 1974 to 1979, with monthly and quarterly data for monetary base.

About the wage politic mesured for the monthly variation of the mean salary of ABDIB, we can say that in the sub-period from January of 1971 to december of 1979 was endogenous, going to exogenous in the period from January of 1980 to December of 1991. This results are very interesting, having saw that it was salary rules dictated by the governament that was vigent in the period from 1971 to 1979, and the power of syndicate's pressure was very reduced, so this results are in concordance with the placement made for Camargo (1990) p.306 where say "develop a model in which the variation rate of the nominal salary is determined by the salary politics adopted by the governament (which we get the name institutional salary) and by the power of modelization of the syndicates of workers".

The political change for the sub-period from 1971 to December of 1979 about the prices changes show bidirectional causality that is, in a moment influence the prices changes, in an other was been influenced by them, but for the sub-period from January 1980 to december 1991, will be exogenes, that is, the causality go from the change rate variation to the prices.

The variables interested rate and governament debit were exogenous related to the prices changes in both sub-periods.

Conclusion:

With the proposed monitoration of data algorithm we can detect the separation of two interest sub-periods to the brasilian economic, that is, the priori and posteriori period of the 70 decad. The period in what the algorithm detected changes in the variables , that is, 1979, was the year is, what occured significant structural changes in the contry, because as yet mentioned, was from 1979, that the brasilian economy go in the more

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