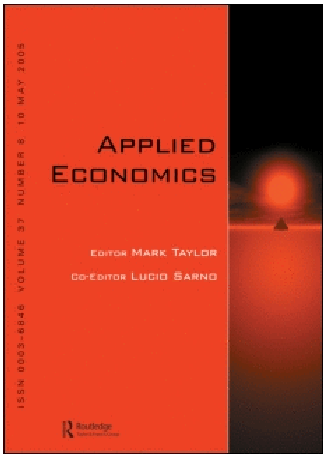


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# GARCH inadequacy for modelling exchange rates: empirical evidence from Latin America

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# GARCH inadequacy for modelling exchange rates: empirical evidence from Latin America

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This article checks for the adequacy of using GARCH models in exchange rate series. Using the Hinich portmanteau bicorrelation test, we find that a GARCH formulation or any of its variants fails to capture the data generating process of the main Latin American exchange rates. Our results highlight the potential of having misleading public policy when estimates are based in GARCH types of models. This article also complements recent similar findings encountered in European and Asian economies.

## I. Introduction

The autoregressive conditional heteroscedastic model (ARCH) introduced by Engle (1982) and its generalization GARCH introduced by Bollerslev (1986) have been widely applied to model volatility in financial time series. These models have been useful because they are a convenient representation of the persistence of variance over time, despite the lack of solid grounding in economic theory (Hall *et al.*, 1989). An important question that has received much less attention in the financial econometric literature is the statistical adequacy of these ARCH/GARCH formulations. If the formulation commonly used in the analysis of the financial data is not adequate, then any policy conclusion derived from the results can be misleading, which makes the study of the adequacy of the econometric specification of the model used really important.

Evidence of nonlinearities in the exchange rate markets have been documented in recent literature that employ nonlinearity test developed in the last two decades. One of the questions that the application of the nonlinearity tests has helped to answer is the adequacy of ARCH/GARCH formulations in exchange rates and stock markets and that is our aim in this article, but with the novelty of using Latin American exchange rates data. We check for the assumption of strict stationarity of GARCH models. To do this, we apply the Hinich third order portmanteau test to the main Latin American exchange series. To our knowledge, this is the first time that the validity of the GARCH formulation will be formally analysed for the main Latin American economies.

We found previous literature that check for ARCH/GARCH adequacy in more developed economies. For instance, Brooks and Hinich (1998) studied a set of 10 daily Sterling exchange rates and showed that there exists statistical structures present in the data, that cannot be captured by any variants of a GARCH model. Liew *et al.* (2003) analysed

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11 exchange rates for the Asian economies and found that the implementation of a linear autoregressive model is inadequate in describing real exchange rates behaviour. The nonlinear features of the series persist after the application of the autoregressive model, which is consistent with the recent findings in the literature that provides evidence in favour of non-linear structures in the exchange rates series (Sarantis, 1999; Ma and Kanas, 2000; Sarno, 2000; Brooks, 1996).

Latin American economies are an interesting subject. The political and financial instability that arises from time to time in these countries, have been shown to produce episodic nonlinearities in the stock markets indices (Bonilla *et al.*, 2006). Now, we will check if the common failure of GARCH formulation encountered in the more developed and stable economies is also a present characteristic of the Latin American economies as well. In principle, we expect to have similar results than the ones that are in the literature for the more developed countries. We think that the Latin American exchange rates are probably less efficiently traded than most of the exchange rates that have already shown to have problems with the GARCH formulation. Two reasons make us believe that. First, the volume traded of these currencies in the international markets is comparatively low with respect to the developed countries and second, the political instability and the changing public policy applied in those countries make any potential nonlinearity present in the financial time series difficult to arbitrage away.

The results of this article indicate that the usual GARCH formulation occupied for modelling exchange rates behaviour, fails to capture the data generating process of the main Latin American exchange rates.

The structure of the remainder of this article is as follows. Section II briefly describes the GARCH model. Section III introduces and explores the data to be used in this study. Section IV presents the Hinich portmanteau bicorrelation test. Section V presents the empirical results obtained. The final conclusions are given in Section VI.

## II. GARCH Models

The empirical finding that financial time series present volatility clustering effects and that volatility occurs in bursts – i.e. after a long period of tranquility, a period of rising volatility arise – makes it highly unlikely to encounter constant variance across time in financial series. To parameterize this fact, researchers make use of a conditional variance model, where the variance of the errors is allowed to change over time in an ARCH framework.

Following Bollerslev (1986), the GARTCH(1,1) model can be represented in the following form: Let $\{y(t)\}$ be the time series of an exchange rate return, then:

$$y(t) = \varepsilon_t h_t^{1/2}$$
$$\frac{\varepsilon_t}{\psi_{t-1}} \sim N(0, h_t)$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

This GARCH formulation captures the fact that volatility is changing in time. The change corresponds to a weighted average among the long-term average variance, the volatility in the previous period and the fitted variance in the previous period.

Higher-order GARCH formulation is not usually necessary in finance because current variance ($h_t$) implies infinitely long memory of past innovation. Therefore the previous formulation is the standard model used to parameterize any financial time series and in particular the exchange rates (see Bollerslev *et al.*, 1992 for an account of the use of the use of ARCH models in finance).

In this study, we inquire whether the major Latin American currencies are correctly modelled using the GARCH formulation. If not, any policy conclusion derived from previous studies using ARCH models are potentially misleading.

## III. The Data

The analysis presented here is based on daily spot exchange rates, denominated in American dollars, of the five most important Latin American economies. The data was obtained from Bloomberg and the sample period span from 15 March 1995 to 15 March 2005. The currencies are the Mexican Peso, the Brazilian Real, the Colombian Peso, the Peruvian Nuevo Sol and the Chilean Peso. The data are split into a set of 102 nonoverlapping windows of length 25 observations (i.e. approximately 5 trading weeks). The raw data is transformed in the following way: $r_t = \ln(p_t/p_{t-1})$, where $p_t$ is the closing price of the spot exchange rate in day $t$. This can be interpreted as a continuously compounded daily return of the exchange rate, which is the standard way to treat returns in the financial econometric literature (Brock *et al.*, 1991).

## IV. The Hinich Portmanteau Bicorrelation Test and the C-test

We now proceed to describe the windowed test procedure used in this article, the Hinich portmanteau bicorrelation test statistic (denoted as $H$-statistic) and the $C$-statistic. Let the sequence $\{z(t_k)\}$ denote the standardized sampled data process, where the time unit $t$ is an integer. The standardization is $z(t_k)=(y(t_k)-\mu_y)/\sigma_y$ where $\mu_y$ is the expected value of the process and $\sigma_y^2$ is its variance. The Hinich tests employ nonoverlapped data window, thus if $n$ is the window length, then the $k$th window is $\{z(t_k), z(t_k+1), \ldots, z(t_k+n-1)\}$. The next nonoverlapped window is $\{z(t_{k+1}), z(t_{k+1}+1), \ldots, z(t_{k+1}+n-1)\}$, where $t_{k+1}=t_k+n$. The null hypothesis for each window is that $y(t)$ are realizations of a stationary pure noise process that has zero bicorrelation. The alternative hypothesis is that the process generated within the window is random with some nonzero bicorrelations $C_{zzz}(r,s)=E[z(t)z(t+r)z(t+s)]$ in the set $0<r<s<L$, where $L$ is the number of lags that define the window. For a mathematical derivation of these statistics and its small sample properties the interested reader is referred to Hinich (1996). We thus state without derivation the test statistics, denoted $H$ and $C$, respectively.

$$H=\sum_{s=2}^{L}\sum_{r=1}^{s-1}\left[\frac{G^2(r,s)}{(T-s)}\right]\sim\chi^2\left(\frac{(L-1)L}{2}\right) \tag{1}$$

where

$$G(r,s)=(n-s)^{1/2}C_{ZZZ}(r,s)$$

and

$$C=\sum_{r=1}^{L}\left[\frac{C^2(r)}{(T-r-1)}\right]\sim\chi^2(L) \tag{2}$$

where

$$C(r)=\sum_{k=1}^{T-s}Z(t_k)Z(t_{k+r})$$

The $Z(t)$ are the standardized observations, obtained by subtracting the sample mean of the window and dividing by its SD. The number of lags $L$ is specified as $L=n^b$ with $0<b<0.5$, where $b$ is a parameter under the choice of the analyst. Based on results from Monte Carlo simulations (Hinich and Patterson, 1995), the recommended use of $b$ is $b=0.4$ in order to maximize the power of the test while ensuring a valid approximation to the asymptotic theory. In this test procedure, a window is significant if the $H$- or the $C$-statistic rejects the null of pure noise at the specified threshold level.

Checking if the data can be represented by a GARCH formulation is not difficult using the earlier-mentioned test. This is achieved by transforming the returns into a set of binary data denoted by $\{x_p(t_k)\}$ where $x_p(t_k)=1$ if $z_p(t_k)>0$ and $x_p(t_k)=-1$ if $z_p(t_k)<0$. If the original $\{z_p(t_k)\}$ are generated by an ARCH or GARCH process, then $\{x_p(t_k)\}$ will be a stationary independently distributed Bernoulli sequence since we have assumed that the innovations are symmetrically distributed around a zero mean. The binary transformed data has moments which are well-behaved with respect to the asymptotic theory (Hinich, 1996).

If the number of windows of binary transformed rates which have significant $C$- or $H$-statistic rejecting the null of whiteness at a specified threshold level for the $p$-value is much larger than $p$, then the original process is unlikely to be generated by a GARCH process. The rejection may be due to serial dependence in the innovations but this violates a critical assumption for ARCH and GARCH models. If the innovations are dependent (not i.i.d), then the statistical properties of the parameter estimates are unknown.

## V. Empirical Results

In running the program, we have defined a 0.1% nominal threshold for the $p$-values of the Hinich portmanteau test. This means that we would expect to have a 0.1% of the nonoverlapped windows significant only by chance. Our results however, show a totally different story. Table 1 presents the number and percentage of significant windows for the binary transformed data.

The results show that a larger number of windows are significant than the 0.1% threshold level.

**Table 1. Number and percentage of significant windows of the binary transformed data for Latin American exchange rates**

| Exchange rate series | Number of significant windows | Percentage of significant windows |
|---|---|---|
| Brazilian real | 15 | 14.71% |
| Chilean peso | 3 | 2.94% |
| Colombian peso | 8 | 7.69% |
| Mexican peso | 7 | 6.8% |
| Peruvian nuevo sol | 6 | 5.05% |

**Table 2. Summary statistics of the data**

| | Brazil | Chile | Colombia | Mexico | Peru |
|---|---|---|---|---|---|
| Mean | 0.000466 | 0.000159 | 0.000431 | 0.000203 | 0.000150 |
| SD | 0.009543 | 0.004744 | 0.004903 | 0.006108 | 0.002463 |
| Skewness | 0.407067 | 0.161028 | 1.098123 | 1.123602 | 0.034056 |
| Kurtosis | 29.44343 | 6.751309 | 15.66910 | 19.78967 | 13.95796 |
| J–B | 72266.52 | 1463.676 | 17070.27 | 29626.84 | 12398.41 |
| Probability | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Observations | 2478 | 2478 | 2478 | 2478 | 2478 |

Therefore, the data are unlikely to be generated by a stationary GARCH model. This result provides evidence of the inadequacy of using GARCH models for the Latin American exchange rates series. The results encountered here are similar to ones in recent previous studies that have analysed the inadequacy of using GARCH type of models in Asian Countries (Liew *et al.*, 2003) and North American and European countries (Brooks and Hinich, 1998).

As expected, Latin American exchange rates present a considerable larger number of significant windows than the ones encounter in studies of more developed countries that used the same methodology. We hypothesize that this happens for two reasons. First, the relative importance of the Latin American economies in the global context is limited if we compare it with the relative importance of the North American, European or even the Asian economies. In consequence, the deepness of the Latin American exchange rates market is limited as well, leaving room for speculations, nonlinear episodes and chaotic behaviour. Second, the economic and political instability of this region has an important effect on financial market efficiency. Since it is a well-documented fact that politics affects economics and that this region is famous for having recurrent political crises, we expected – in principle – to find a considerable amount of nonoverlapped windows significant.

We should mention that the Argentinean Peso and the Venezuelan Bolivar were not considered in the sample because during an important part of the sample period analysed, these countries embraced a fixed exchanged rate policy with sporadic devaluations. This obviously depart from the market game, where the market forces decide the real exchange rate level and, once the equilibrium is achieved, the exchange rate is expected to behave as a random walk with zero mean if the market is really efficient. On the contrary, if the market mechanism is not the way to determine the prices, discretionary policy for setting the prices will probably be far from a smooth random walk or anything like it, therefore, running the Hinich bicorrelation test over these currencies would not be valid.

## VI. Conclusions

This article uses the Hinich portmanteau bicorrelation test to check for the adequacy of using a GARCH formulation to model the behaviour of the main Latin American exchange rates. Our results indicate that the GARCH formulation fails to capture the data generating process of the real exchange rates for all the currencies studied. This is consistent with previous related literature that, using similar methodologies, have analysed the exchange rate behaviour of European and Asian countries.

Our results however, present larger a number of significant windows than our benchmark studies (Brooks and Hinich, 1998; Liew *et al.*, 2003) where the GARCH assumption was also questioned. We hypothesize that this is due to political instability and low relative importance of this economies in the world context and its consequent far-from-efficient exchange market. A further investigation that analyses the political and economic events that provoke potential nonlinearities and chaos within the significant windows for each country has to be performed in the future.

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