GARCH Inadequacy for Modelling Exchange Rates: Empirical Evidence from Latin America

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Abstract

This paper 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 paper also complements recent similar findings encountered in European and Asian economies.

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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 convenient representation of the persistence of variance over time despite of 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 really important the study of the adequacy of the econometric specification of the model used.

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 paper, 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 analyzed 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 ten daily Sterling exchange rates and showed that there exists statistical structures presents in the data that can not be capture by any variants of a GARCH model. Liew at al (2003) analyzed eleven exchange rates for the Asian economies and found that the implementation of a linear autoregressive model is inadequate in describing real exchange rates behavior. 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 favor of nonlinear structures in the exchange rates series (see for example Ma and Kanas, 2000; Sarno, 2000 or Sarantis, 1999)

Latin American economies are an interested 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, Hinich, and Romero-Meza, 2005). 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 difficult to arbitrage away any potential nonlinearity present in the financial time series.

The results of the papers indicate that the usual GARCH formulation occupied for modeling exchange rates behavior, fails to capture the data generating process of the main Latin American exchange rates.

The structure of the remainder of the papers 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 – that is, after a long period of tranquility, a period of rising volatility arise -, makes 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 autoregressive conditional heteroskedasticity framework

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

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

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 as well.

Higher order GARCH formulation are 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 modeled using the GARCH formulation. If not, any policy conclusion derived from previous studies using autoregressive conditional heteroskedasticity 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, the Peruvian Nuevo Sol and the Chilean Peso. The data are split into a set of 102 non-overlapping windows of lengh 25 observations (i.e. approximately five 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 (see 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 paper, 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 $z(t_k) = \frac{y(t_k) - \mu_y}{\sigma_y}$ where μ_y is the expected value of the process and σ_y^2 is its variance. The Hinich tests employ non-overlapped data window, thus if n is the window length, then the $k-th$ window is $\{z(t_k), z(t_k+1), ..., z(t_k+n-1)\}$. The next non-overlapped window is $\{z(t_{k+1}), z(t_{k+1}+1), ..., z(t_{k+1}+n-1)\}$, 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 non-zero bicorrelations $C_{zzz}(r,s) = E\left[z(t)z(t+r)z(t+s)\right]$ in the set $0 < r < s < L$, where L is the number of lags that define the window. For a mathematical derivation of this 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.

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

where

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

and

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

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 standard deviation. 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 (see 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 above test. This is achieved by transforming the returns into a set of binary data denoted $\{x_p(t_k)\}$ 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 a 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 (see 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 iid), 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 non-overlapped 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.

Insert Table 1 here

The results show that a larger number of windows are significant than the 0.1% threshold level. 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 analyzed the inadequacy of using GARCH type of models in Asian Countries (V. K. 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 hypothesizes 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 behavior. Second, the economic and political instability of this region has an importance effect on financial market efficiency. Since it is a well documented fact that politics affects economics, and that this region is famous for having recurrently political crises, we expected - in principle - to find a considerable amount of non-overlapped windows significant.

We should mention that the Argentinean Peso and the Venezuelan Bolivar were nor considered in the sample because during an important part of the sample period analyzed, those 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 paper uses the Hinich portmanteau bicorrelation test to check for the adequacy of using a GARCH formulation to model the behavior 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 analyzed the exchange rate behavior of European and Asian countries.

Our results however, present a larger number significant windows than our benchmark studies (Brooks and Hinich, 1998 and Liw et al, 2003) where the GARCH assumption was also questioned. We hypothesizes 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 analyzes the political and economic events that provoke potential non-linearities and chaos within the significant windows for each country has to be performed in the future.

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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
Std. Dev.	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
Obs.	2478	2478	2478	2478	2478