NON-LINEAR MODELING OF DAILY EXCHANGE RATE RETURNS, VOLATILITY, AND 'NEWS' IN A SMALL DEVELOPING ECONOMY

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Abstract

This paper models daily returns, volatility, and 'news' in the parallel foreign exchange market of a small developing economy, namely the Dominican Republic, during the period 1989-2001. The research adopts a non-linear specification that encompasses several members of the *GARCH* family. A leftward tilted *news impact* reveals that positive shocks (depreciations) have a higher impact than negative ones (appreciations) on the volatility of exchange rate returns.

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Keywords: daily exchange rate returns; non-linear *GARCH* models; 'news impact'; developing countries.

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Modelling the returns and volatility of financial variables such as, for example, stock markets indexes and exchange rates has been amongst the main areas of curiosity within the empirical finance literature, given their forefront role in economic agents' decision making processes. Notably, a gargantuan literature has been spearheaded by the autoregressive conditional heteroscedasticity ($ARCH$) model advanced by Engle (1982) and generalised ($GARCH$) by Bollerslev (1986). However, this literature has chiefly focused on advanced and, more recently, emerging market economies. This gap in the research program under consideration probably arises due to a lack of systematically collected high frequency time series data for less developed countries and to the idiosyncratic phenomena driving asset-pricing mechanisms in these economies.

The objective of this paper is to contribute to this branch of the empirical asset pricing literature in a case study basis. Particularly, the project attempts to do so by inquiring into daily observations on the Dominican Republic's (DR) nominal parallel market exchange ('ask') spot rate[1] for the span ranging from January 1989 to February 2001, i.e. a total of 3,045 observations. The source of the statistical information is the Central Bank of the Dominican Republic (CBDR).

As is standard in the literature, the variable to be modelled is the percentage daily exchange rate return, which can be expressed as

[1] The DR's exchange rate system is composed of the official, banking system, and parallel markets. In the light of the fact that the price of foreign currency in the parallel market is expected to be determined mainly by 'market forces', the present study focuses on this market. Throughout the paper refers to the exchange rate of Dominican Republic Pesos (DR$) per United States Dollars (US$), since the US is by far the DR's main trading partner. Note that the way in which it has been defined implies that increases (decreases) in the exchange rate are depreciations (appreciations) of the domestic currency.

$$r_t \equiv 100 \cdot [\ln e_t - \ln e_{t-1}] \tag{1}$$

where r is the daily percentage return to the exchange rate (e) described above. Part A of Table 1 provides relevant descriptive statistics on r.

The 'baseline' econometric specification to be implemented can be expressed as

$$r_t = \mu + \sum_{i=1}^{n} \phi_i \mathrm{X}_{it} + \gamma h_t^{1/2} + \varepsilon_t , \tag{2a}$$

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i (\varepsilon_{t-i} - \delta)^2 + \lambda D_{t-1} (\varepsilon_{t-1} - \delta)^2 + \sum_{i=1}^{p} \beta_i h_{t-i} . \tag{2b}$$

Equations (2a) and (2b) are the 'mean' and 'conditional variance' equations, respectively. In equation (2a) μ stands for the constant term, X and ϕ are explanatory variables and their corresponding coefficients, respectively, and γ is a coefficient to capture the variance-in-mean effect (Engle et al, 1987), or risk-return trade-off. Also, the paper will assume that in (2a)

$$\varepsilon_t \sim t\langle \nu \rangle , \tag{3}$$

i.e. the residuals are estimated assuming a standardised t-distribution with ν degrees of freedom, as suggested by Bollerslev (1987).

Equation (2b) proposes a conditional variance (h) specification that accounts for asymmetric (δ) and threshold (λ) effects, i.e. an *ATGARCH* (q, p), with $D_{t-1} = 1$ if

$\varepsilon_{t-1} \prec \delta$, and zero otherwise. It is worthy to note that the $ATGARCH$ model encompasses several members of the $GARCH$ 'family' (see Hentschel, 1995, for a detailed exposition on the topic).

The results of estimating equations (2a) and (2b) using the maximum likelihood technique are displayed in Table 1's equation (4), along with a battery of diagnostic statistics[2]. The results, which allow for five lags, i.e. information on the previous trading week, of the dependent variable to enter the mean equation, and a standard $GARCH(1,1)$ in the variance equation, seem sensible. In the mean equation most of the coefficients are statistically significant, and display reasonable magnitudes. Additionally, the coefficient γ, which is positive and statistically well determined, unveils the presence of a non-negligible risk-return trade-off. Also, the variance equation's fit is adequate, with all coefficients significant at the 5% level, excepting the one intended to capture asymmetric effects[3].

A salient fact portrayed by the estimations is that both δ and λ are pushing the 'news impact' schedule (Pagan and Schwert, 1990; Engle and Ng, 1993) in the same direction, implying that volatility rises more for positive than for negative shocks. Such a relationship can be clearly perceived by inspecting the 'news impact' plot exhibited in Figure 1. Economically, this graph conveys that depreciations (a positive r) increase the conditional volatility of the exchange rate to a greater extent than appreciations (a negative r). In a small developing economy where foreign currency is a scarce asset

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[2] All the econometric results presented in this paper were computed using the GARCH module in PcGive 10 (see Doornik and Hendry, 2001).

[3] Dropping this coefficient, however, only mildly improves the fit according to the AIC test, which goes from –0.6266 to –0.6668. In contrast, the likelihood is 965.26 when the asymmetric effect is present and 964.54 otherwise. Henceforth, the asymmetric effect is accounted for in subsequent estimations.

these results are compelling. Finally, the tests for the presence of $ARCH$ and autocorrelation are not accepted, supporting the model's adequacy.

Having estimated a sensible model for daily exchange returns in the DR, assessing the relevance of additional factors that are expected to impinge on such a market should prove a valuable exercise. The subsequent modelling will consider (1) market opening effects, (2) the repercussion of a momentous IMF stabilisation program, and (3) seasonal inflows of foreign currency.

In order to gauge the impact of opening days on the DR's exchange rate market, a dummy variable was included for Mondays, or the first trading day of the week, as in Bollerslev and Ghysels (1996). Specifically, $Ftrade$ takes a value of 1 for Mondays or the first trading day of the week, and 0 otherwise. The results displayed in equation (5) reflect negligible changes in relation to the mean and variance equations' coefficients in (4), and satisfactory diagnostic statistics. However, the constant term in the variance equation is now statistically insignificant, whereas the added $Ftrade$ dummy is significant at roughly the 9% level. The reader should note that after the inclusion of $Ftrade$ the constant term in the variance equation is given by $\alpha_0 + Ftrade$. Therefore, it seems that opening days have a more significant impact on exchange rate returns than the rest of the week. Also, both the loglikelihood and information criterion model comparison statistics support model (5) over (4).

Between 1989 and 1991 a series of adverse domestic and international economic and political events (e.g. a domestic banking crisis and the Gulf War) undermined the credibility of the DR's exchange rate regime, as well as that of the economy as whole. Given the time span under scrutiny, it is straightforward to ask: Did the August 1991 agreement the DR signed with the IMF had a significant impact on the foreign exchange market? Equation (6) shows that the coefficient affecting the variable $IMF1991$ (included in the mean equation and taking a value of 1 after August 1991 and 0 before that date) has the expected negative sign, suggesting that the 1991 agreement with the IMF was indeed successful in 'pulling down' the Dominican currency[4]. However, the coefficient affecting $IMF1991$ is not statistically well determined. In spite of that, the likelihood statistic displayed in Table 1 is slightly higher for equation (6) than for equation (5), although the information criterion is minimised for the latter.

A further characteristic of the DR's exchange rate market to be investigated is the high seasonal inflow of foreign currency recurrently occurring during the Christmas period[5]. Dominican emigrants who massively return to the country (mainly) during this time of the year generate this pattern. The phenomenon at hand is proxied by a dummy variable ($December$) added to the mean equation of the model, taking a value of 1 during the month of December and 0 otherwise.

Equation (7) portrays the results of accounting for the $December$ effect. Once more, the overall characteristics of the general $ATGARCH - M - t(1,1)$ specification are mostly invariant. The seasonal effect spelt out above seems to have a negative effect on exchange rate returns that can be read as a supply shock. However, $December$'s coefficient is not statistically well determined. In spite of that, note that the

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[4] In a recent IMF report, Young et al (1999, page 8) state that "Since 1992, the Dominican Republic has experienced an extended period of robust economic growth, declining unemployment rates, modest consumer price inflation, and a generally manageable external position".

[5] Remittances are a key variable in the DR's foreign exchange market, due to the large amount of Dominicans living abroad, mainly in the US. For example, in 1999 net foreign transfers totalled almost 12% of GDP, according to calculations made using numbers from the World Bank (2000).

loglikelihood statistic is higher for model (7) than for model (6), whereas the information criterion is minimised for model (6).

References

Bollerslev, Tim (1986) Generalised autoregressive conditional heterocedasticity, *Journal of Econometrics*, **31**, 307-27.

Bollerslev, Tim (1987) A conditional heteroskedastic time series model for speculative prices and rates of return, *Review of Economics and Statistics*, **69**, 542-547.

Bollerslev, Tim, and Eric Ghysels (1996) Periodic autoregressive conditional heterocedasticity, *Journal of Business and Economic Statistics*, **14**, 139-151.

Doornik, Jurgen A., and David F, Hendry (2001) *Econometric modelling using PcGive 10, Volume III,* Timberlake Consultants LTD, UK.

Engle, Robert F. (1982) Autoregressive conditional heteroscedasticty with estimates of the variance of United Kingdom inflation, *Econometrica*, **50**, 987-1007.

Engle, Robert F., D.M. Lilien and R.P. Robins (1987) Estimating time varying risk premia in the term structure: the ARCH-M model, *Econometrica*, **55**, 391-407.

Engle, Robert F., and Victor K. Ng (1993) Measuring and testing the impact of news on volatility, *Journal of Finance*, **48**, 1749-1778.

Hentschel, Ludger (1995) All in the family: Nesting symmetric and asymmetric GARCH models, *Journal of Financial Economics*, **39**, 71-104.

Pagan, Adrian R, and G.William Schwert (1990) Alternative models for conditional stock volatility, *Journal of Econometrics*, **45**, 267-290.

The World Bank (2000) *World Development Report 2000/2001*, Washington, D.C.

Young, P., D. Dunn, A. Giustiniani, F. Nadal De-Simone, E. Tanner, and J. McHugh (1999) Dominican Republic: selected issues, IMF Staff Report No. 99/117, International Monetary Fund, Washington, D.C., October.

Table 1
Descriptive statistics for r
and *ATGARCH - M - t(1,1)* (Equations 2a and 2b) maximum likelihood estimation
based on daily data for the period January 1989-February 2001

A. Descriptive statistics r					
Mean 0.0319	Standard deviation 0.4991	Skewness -2.9882	Kurtosis 81.296	Minimum -8.7937	Maximum 5.0488

B. *ATGARCH - M - t(1,1)* (Equations 2a and 2b) maximum likelihood estimation				
I. Mean equation				
Variables	Coefficients			
Equation numbers $\Rightarrow$	(4)	(5)	(6)	(7)
μ	-0.005 (2.02)	-0.004 (1.48)	-0.002 (1.03)	-0.002 (1.03)
ϕ_{t-1}	0.064 (3.13)	0.064 (3.07)	0.063 (3.06)	0.062 (3.00)
ϕ_{t-2}	0.101 (6.07)	0.101 (6.14)	0.101 (6.13)	0.099(6.04)
ϕ_{t-3}	0.042 (2.64)	0.042 (2.65)	0.042 (2.64)	0.041 (2.60)
ϕ_{t-4}	0.023 (1.67)	0.023 (1.70)	0.028 (1.70)	0.022 (1.63)
ϕ_{t-5}	0.027 (1.91)	0.027 (1.89)	0.027 (1.90)	0.026 (1.88)
γ	0.061 (2.99)	0.055 (2.81)	0.055 (2.82)	0.056 (2.88)
*IMF*1991	-	-	-0.001 (0.592)	-0.001 (0.371)
December	-	-	-	-0.009 (1.10)
II. Variance equation				
α_0	0.003 (2.38)	0.001 (0.580)	0.001 (0.579)	0.001 (0.57)
Ftrade	-	0.013 (1.72)	0.013 (1.71)	0.013 (1.73)
α_{t-1}	1.379 (2.17)	1.329 (2.18)	1.327 (2.17)	1.294 (2.23)
β_{t-1}	0.650 (17.1)	0.649 (17.2)	0.649 (17.2)	0.649 (17.2)
δ	-0.009 (1.45)	-0.009 (1.49)	-0.010 (1.52)	-0.011 (1.64)
λ	-0.643 (3.75)	-0.626 (3.70)	-0.623 (3.68)	-0.608 (3.73)
III. Diagnostic and model comparison statistics				
N	3,039	3,039	3,039	3,039
ε_t □ t	2.308 (14.6)	2.322 (14.2)	2.323 (14.1)	2.333 (14.1)
l	965.26	970.46	970.51	971.40
AIC	-0.626698	-0.629461	-0.628833	-0.628763
$ARCH1-2-F$	0.8474	0.8844	0.8862	0.8870
$P.manteau-\chi^2$	0.0838	0.0777	0.0761	0.0829

Notes on Table 1.

Coefficients' absolute t-ratios are included in parentheses. N denotes the number of observations used in the estimation of each equation. Estimations are based on t-student distributed errors, as suggested by Bollerslev (1987); $\varepsilon_t \sim t$ denotes the coefficient of such errors. l is the log-likelihood of the estimated model. AIC is an information criterion calculated as $AIC = -2l + 2s$, where s denotes the number of parameters estimated. $ARCH$ and $P.manteau$ are tests of the null of residual autoregressive conditional heteroscedasticty and autocorrelation, with F and χ^2 distributions, respectively. For both tests probability values are provided, with * and ** denoting significance at the 1% and 5% levels, respectively.

Figure 1 'News impact' plot from $ATGARCH - M - t(1,1)$ model Equation (4), Table 1