Non-linearity in the Reaction of the Foreign Exchange Market to Interest Rate Differentials: Evidence from a Small Open Economy with a Long-Term Peg

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Abstract

This paper incorporates the Castle and Hendry (2010) portmanteau test into an EGARCH-M model to investigate non-linearities in the reaction of daily foreign exchange activity to the interest rate differential between the U.S. and Barbados – a small open economy which has been pegged to the US dollar for over 35 years. The results suggest that changes in the interest differential have a significant and non-linear effect on the Barbadian foreign exchange market. The linear spread term is positive, and so is in line with a theory of uncovered interest parity for an economy with a fixed exchange rate. But, all other spread coefficients have a negative sign, implying that asymmetry is present. Thus, it is possible that there is a threshold at which foreign currencies no longer conform to the uncovered interest parity condition but rather, are negatively correlated with interest spreads. Finally, these findings were consistent in the pre-financial crisis analysis.

1.   Introduction

The hypothesis of uncovered interest rate parity (UIP) suggests that in the absence of opportunities for arbitrage, the expected change in the exchange rate between two currencies equals the interest rate differential between those two currencies, or equivalently the forward premium. In an attempt to validate this hypothesis, most researchers undertake a regression of the changes in the spot exchange rate on the lagged interest rate premium, and then test if the slope coefficient is unity.   Evidence that this condition holds is imperative, as it is routinely assumed in models of international macroeconomics and finance (Sarno, et al., 2006).

Interestingly, a review of the empirical literature of the UIP theory revealed that: (1) an overwhelming body of this literature often reject the hypothesis, finding, in most cases, that the coefficient on the interest spread variable is very close to zero or even negative; and, (2) the majority of this work focuses on countries with a floating or managed float exchange rate regime, thus suffering from a paucity of research on this issue as it relates to economies with fixed exchange rates.

The empirical result that spot exchange rate is negatively correlated with the lagged forward premium is often referred to as the forward bias puzzle. As noted in the seminal work of Fama (1984), high interest currencies tend to appreciate, whereas one would expect investors to demand a higher interest rate if the currency is anticipated to depreciate. This would indicate that there is some level ofinformational efficiency present in foreign exchange markets.

Several theories have been proposed to explain the puzzle. But, the most prominent view is that the puzzle may due to specification error (see for instance, Sarno et al, 2006; Ballie and Kilic, 2006). Particularly, much of the related theory implies that the expected changes in exchange rates and interest differentials may be non-linear, occasioned by transactions costs from closing arbitrage conditions in financial markets, central bank intervention, or even the existence of limits to speculation. Moreover, some empirical research (Bansal and Dahlquist, 2000) find evidence to suggest the size and the extent of the anomaly depends on the interest differential. Thus, modelling for nonlinearities has the potential to shed light on the forward bias puzzle.

An interesting observation is that most of these studies on the UIP and the forward bias puzzle is almost exclusively focused on countries with free floating exchange rate regimes. This may be because very few economies have maintaned a pegged exchange rate for a long period, or managed a float which has, by and large, been relatively unchanged. So, how does UIP relate to countries with fixed exchange rates? Well, under a fixed regime, the market expectation in the spot rate is virtually zero. Thus, in the absence of exchange rate uncertainty, inflows and outflows of foreign exchange should respond to interest differentials, in a way that maintains UIP (Worrell et al, 2008). To test this hypotheseis, Worrell et al (2008) investigated the relationship between the flow of foreign currency and the interest rate spread between Barbadian dollar assets and the equivalent assets denominated in US dollars using a GARCH-M model. The distinguishing feature of Barbados, as noted by the authors, is that its currency has been pegged at BDS\$2 to U.S. \$1 since 1975 – and so, the island has one of the most credible pegs in the world. Their results suggest that once allowance is made for market frictions and large discrete events, foreign exchange flows responded to interest differentials in a way that is consistent with the UIP condition.

While the work of Worrell et al (2008) aided in filling part of the gap on research dealing with the UIP hypotheisis in countries with fixed exchange rates, it is not without its shortcomings. As in the literature on floating rates, it is highly possible that there are non-

linearities present in the reaction of foreign exchange to interest differentials – an area which was not explored in the Worrel et al's study. Also, due to lack of available daily data – as is often the case of small island developing states – the study used a short time span (1999-2004), and so its coefficient estimates may have been biased.

In this paper, the work of Worrell et al (2008) is extended in two ways: one, it investigates the possible non-linearity in the reaction of the foreign exchange market to interest rate differentials between Barbados and the U.S. In this vein, this is the first article (to the best of the authors's knowledge) to test for non-linearities in the UIP hypothesis for a small open economy with a long-term peg. To carry out this task, the paper incorporates the Castle and Hendry (2010) test for non-linearity – which is a highly flexible non-linear approximation based on a third order polynomial with additional exponential functions – into an EGARCH-M model. The EGARCH-M model (instead of the GARCH-M as in Worrell et. al) is employed as the authors believe that there may be asymmetries in the volatility of foreign exchange flows. Two, the authors update the daily data set of Worrell et al. (to July 2011), which allows for the evaluation of how the crisis – which began in the latter half of 2007 – may have impacted the foreign market, and by extension, its reaction to interest rate differentials.

The remainder of this paper is outlined as follows: Section 2 provides the theoretical framework and empirical model; section 3 discusses the data, methodology and results; and finally, section 4 concludes.

2.   Theoretical Framework and Empirical Model

Drawing on the work of Worrell et al. (2008), this section presents the theoretical considerations which motivated the empirical model. Most studies on UIP start with the condition:

(1) $\Delta_k s_{t+k}^e = i_{t,k} - i_{t,k}^*$

which states that the change in the expected spot exchange rate $(\Delta s^e)k$ periods ahead is compensated for by the difference between the domestic $(i_{t,k})$ and foreign interest rate $(i_{t,k}^*)$. But in an economy with a credible peg, such as Barbados, the market expectation of the change in the spot rate is zero. So, rather than the changes in the spot rate, it is the inflow and outflow of foreign exchange which reacts to the interest spread.

The central bank in this type of economy is a last resort for sales and purchases of foreign exchange (FX); it only intervenes in periods of excess deficits or surpluses (Worrell et al, 2011). The FX transactions on the central bank's books are therefore a reflection of the daily balance of supply and demand on the FX market, and so, the behavior of the market can be analyzed solely on the basis of central bank activity. Thus, the market equilibrium in Equation (1) may be written as:

(2) $Central\ Bank\ Intervention_t = CA_t + \Delta K_t$

where CA_t s the external current account balance and ΔK_t is the net change in foreign flows on the capital and financial account. Further, because the central bank rarely actively intervenes in the market but simply buys or sells FX to the market, Equation (2) may be expressed as

(3) $Net\ Purchases_t = CA_t + \Delta K_t$

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Changes in the current account usually appears as persistent net demand or supply of FX by the central bank to the market for many days. Thus, net purchases should exhibit strong autoregressive behavior as shown in the reformulation of Equation (3) below:

(4) $Net\ Purchases_t = f[ARMA(p, q)] + \Delta K_t$

where $ARMA(p,q)$ represents an autoregressive moving average model with p autoregressive terms and q moving average terms.

At the daily frequency, the change in net demand for capital inflows is the main driver of fluctuations in the Central Bank's net purchase of foreign exchange. Theoretically, one of the main determinants that determine ΔK_t is the size of the interest differential $(i_{t,k} - i_{t,k}^*)$. Thus, Equation (4) can be rewritten as:

(5) $Net\ Purchases_t = f\left[ARMA(p, q), g\left(i_{t,k} - i_{t,k}^*\right)\right]$

Traditionally, the function $g(i_{t,k} - i_{t,k}^*)$ is assumed to be linear and positively related to the dependent variable. However, recent studies on the UIP hypothesis suggest $g(i_{t,k} - i_{t,k}^*)$ may be non-linear in floating regimes (see for instance, Baldwin, 1990; Obstfeld and Rogoff, 2000; Sercu and Wu, 2000; Lyons, 2001; Sarno et al, 2006; and Mark and Moh, 2007). The reasons for the potential non-linearity include transactions costs, heterogeneous traders, and the limits-to-speculation hypothesis. Motivated by this empirical and theoretical literature, this study postulates that it is possible that there are also non-linearities in the reaction of net purchases to interest rate spreads in fixed exchange rate economies. Hence, in this paper, $g(i_{t,k} - i_{t,k}^*)$ is assumed to be non-linear.

While Equation (5) would provide a first step in testing the non-linear reaction of FX trades to interest differentials, there are other factors influencing net purchases of FX in Barbados which are not taken into account in this specification. For example, a plot of the average monthly net purchase of FX (Figure 1), suggests that the buoyancy of inflows is highly seasonal. This largely reflects the fact that the majority of the island's FX earnings come from tourism (over 50 percent). As such, the mean values of monthly net purchases tends to be significantly higher during the peak tourist season (December to April), with the system acting as a net seller of FX during the off-peak months – the only outlier being May. Other features determining the fluctuations in net purchases are exceptional FX trades and the volatility of net demand for FX. "Exceptional FX Trades" relate to large discrete payments for debt operations, energy, capital equipment, bulk supplies or large receipts relating to Central Bank FX policies[†]. Meanwhile, the volatility of net demand for FX is interpreted as a reflection of the effects of transactions and information costs, or other frictions in the FX market. Taking these into consideration, the empirical model is defined as:

[†] In 2005 the Central Bank of Barbados introduced an FX requirement which required all authorized financial institutions to surrender 25% of the proceeds of foreign currency loans by the private sector to the Central Bank and 100% in the case of the public sector.

(6) $Net\ Purchases_t = f\left[ARMA(p,q), g\left(i_{t,k} - i_{t,k}^*\right),\ Exceptional\ FX\ Trades, Tourist\ Season_t, h_t \right]$

The "exceptional FX trade" regressor is a discrete variable indicating large net purchases or net sales, with the threshold value taken to be BDS $10 million in absolute value. The tourism season determinant is also a discrete variable. It is used to differentiate between the peak period of tourism (December 15 to April 14) and the low period. Finally, the market frictions indicator h_t – which will be described more thoroughly in section 3 – is represented by the volatility of net demand.

Figure 1 – Average Monthly Net Purchases of Foreign Exchange Jan-99 to July-11
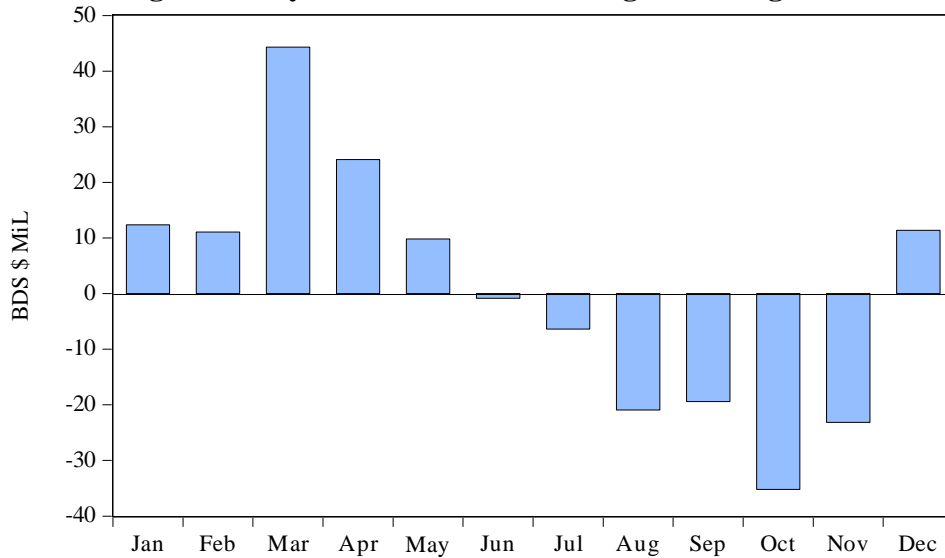

3.   Data, Methodology and Results

3.1   Data

The foreign exchange transactions information available to the authors covers U.S. dollars, regional currencies and other monies. However U.S. dollar transactions dominate the sample, with mean values for daily purchases and sales that are about twice those for non-U.S. currencies (see Figure 2). Consequently, this paper focuses on the U.S. currency transactions. The choice of U.S. dollar transactions is also prompted by the fact that the main interest of this paper lies in testing the impact of the interest rate differential on net foreign exchange purchases. As the Barbadian dollar is tied to the U.S. dollar, the U.S. rate seems most suitable for such tests.

Since the "*Exceptional FX Trades*"and"*Tourist Season*" are discrete variables, and *h* measures the volatility of net demand for foreign exchange, the only data required to estimate model (6) above are the sales and purchases of U.S. dollars plus the local and U.S. treasury bill interest rates. Except for the latter rate, whose source is the Federal Reserve (http://www.federalreserve.gov/), all information is taken from the Central Bank of Barbados data files. The frequency of the data is daily spanning the period January 1999 to July 2011, which allows for an analysis of the pre-world financial crisis.

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Figure 2: Average Daily Values of FX Purchases and Sales in Barbados: Jan-99 to July-11
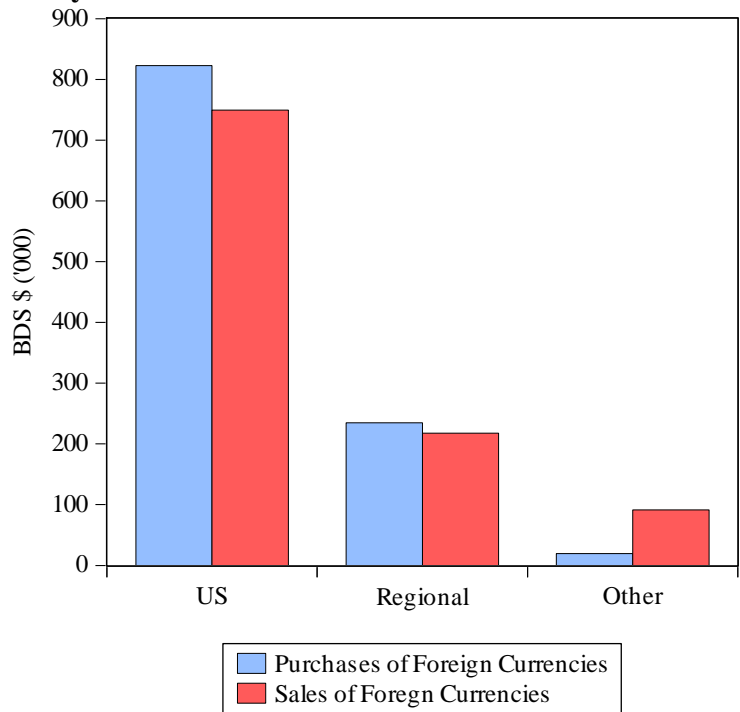
As is customary in the literature on volatile markets, a moving average process is used to smooth out the random fluctuations in the data, making it easier to spot the trends and cycles. As in Worrell et al (2008) an arbitrary 10-day period was chosen, guided by the need to compromise between a period that was too short to eliminate day-to-day idiosyncrasies, and one that was so long as to obscure changing volatility patterns. Figure 3 plots the transformed foreign exchange and interest differential data for the entire sample, while Figures 4a and 4b give the summary statistics of this transformed daily data over the full sample (05-January-1999 to 27-July-2011) and the pre-financial crisis period (05-January-1999 to 29-June-2007). Generally, the transformed series exhibit similar characteristics as in the raw data: skewness, leptokurtosis, and non-normality.

**Figure 3: Plot of Net Purchases of US dollars and the Interest Rate differential –
(Transformed)**
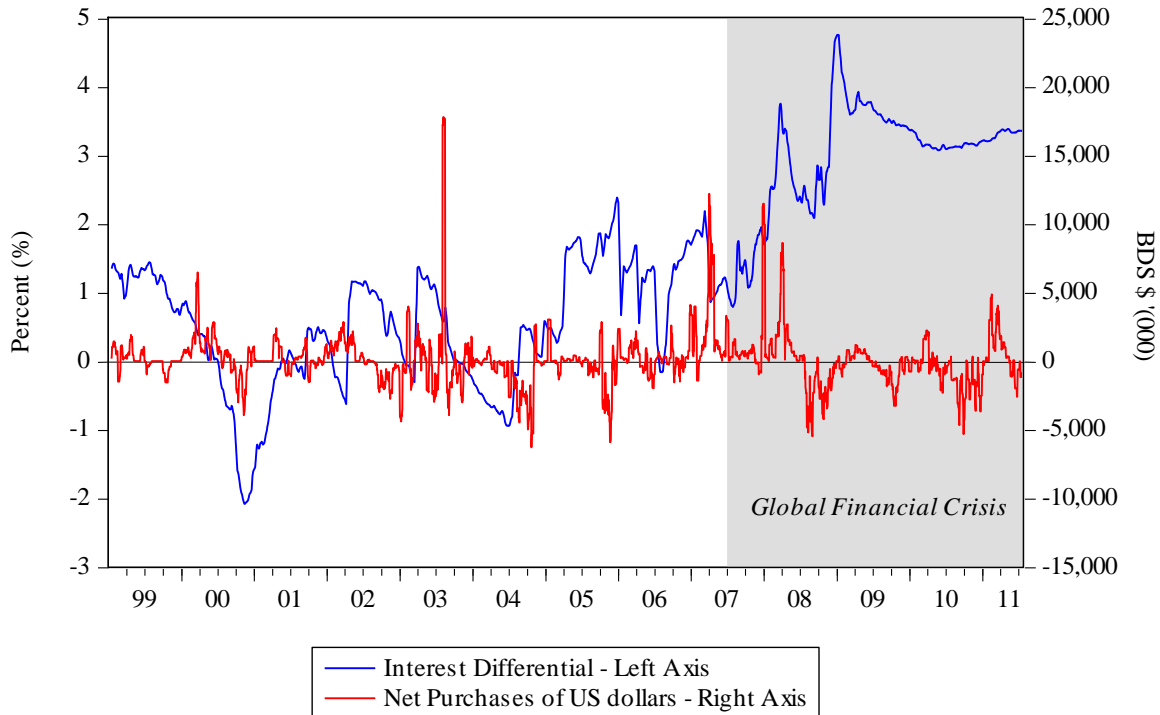
Looking first at the (unconditional) distributions of net purchases of U.S. dollars over the full and pre-crisis periods, there are some apparent similarities: both series seem to be heavily skewed, with most of the observations clustering between a net purchase of $3.0 million and a net sale of the same amount (see Figure 4a). In addition, the fluctuations in day-to-day values occur in bursts of increasing and decreasing amplitude, appearing as cycles of volatility expansions followed by contractions (Figure 3). The major difference between the two series seems to be the mean value of net foreign exchange purchases, which is twice as large for the pre-crisis period as that for the full period. The standard deviation (a measure of volatility) is also higher in the full sample period, but marginally so. Taken at face value, these figures hint that the crisis may have affected the levels and volatility of foreign exchange trades in Barbados.

Figure 4a: Summary Statistics of Net Purchases (Transformed): Full Sample and Pre-Crisis Period

Series: Net Purchases of US Dollars, BDS $('000)	
Sample Jan-1999 July-2011	
Observations 3267	
Mean	71.77799
Median	5.400000
Maximum	17791.80
Minimum	-6288.800
Std. Dev.	2036.146
Skewness	2.863133
Kurtosis	23.71863
Jarque-Bera	62896.79
Probability	0.000000

Series: Net Purchases of US Dollars, BDS $ ('000)	
Sample Jan-1999 June-2007	
Observations 2204	
Mean	148.1852
Median	12.05000
Maximum	17791.80
Minimum	-6288.800
Std. Dev.	2039.827
Skewness	3.388937
Kurtosis	29.16500
Jarque-Bera	67088.56
Probability	0.000000

As for the interest rate differentials between the Barbadian and the U.S. Treasury bill rate, both the pre-crisis period and the full sample exhibit skewness, leptokurtosis and non-normality (Figure 4b). However, the distribution of the observations appears to be a bit more evenly spread during the pre-crisis period. The mean spread of the full sample is about 1.33, which seems large by the standards of the developed diversified financial markets, but is quite common for small emerging markets - reflecting diseconomies of size and a relative lack of diversity in financial instruments (see Laurens, 2005; Worrell et al, 2008). An interesting development is that the spread in the full sample is more than twice the size of the pre-crisis sample. This drastic rise in the spread is largely a reflection of the aggressive monetary easing by the U.S. Federal Reserve during the crisis – which resulted in U.S. interest rates hitting an all-time low (virtually zero). While the Central Bank of Barbados also lowered interest rates in response to the crisis, monetary policy in Barbados did not reach the ground level of the U.S., resulting in wider spreads.

Figure 4b: Summary Statistics of Interest Differentials (Transformed): Full Sample and Pre-Crisis Period

Series: Interest Differential (%)	
Sample Jan-1999 July-2011	
Observations 3267	
Mean	1.329363
Median	1.192000
Maximum	4.758000
Minimum	-2.084000
Std. Dev.	1.442739
Skewness	0.150630
Kurtosis	2.292501
Jarque-Bera	80.49243
Probability	0.000000

Series: Interest Differential (%)	
Sample Jan-1999 June-2007	
Observations 2204	
Mean	0.528857
Median	0.570000
Maximum	2.385000
Minimum	-2.084000
Std. Dev.	0.897826
Skewness	-0.556753
Kurtosis	2.944293
Jarque-Bera	114.1486
Probability	0.000000

3.2   Methodology

Given the volatile nature of the data, the underlying pattern of volatility persistence (which appears to be present from inspection of the raw and adjusted data) and the possibility of asymmetries to shocks, an E-GARCH-M specification is utilized to test Equation (6).

An E-GARCH-M model for a set of observations Y_t ($t = 1, 2, ...,T$) is:

(6) $Y_t \mid \Phi_{t-1} = F(X;\theta) + \mu_t$

(7) $\mu_t = \varepsilon_t - \Sigma_j^q \gamma_j \varepsilon_{t-j}$

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(8) $\varepsilon_t \mid \Phi_{t-1} \approx \Omega(0, h_t)$

(9) $h_t = f(\varepsilon_{t-j}, h_{t-j}) + \xi'Z$

This general model has three components: a mean process *(F)*, where the variable *h* is an element of *X*; the error distribution *(Ω)* and a variance process*(f)*.

The mean process *(F)* is equivalent to Equation (6) presented in Section 2. However, as noted in the previous section, the interest rate spread is assumed to have a non-linear relationship with net purchases of foreign exchange. To checkthis hypothesis, a low dimension portmanteau test for non-linearity proposed by Castle and Hendry (2010) is employed, which is essentially an extension of the Kolmogorov-Gabor polynomial based statistics for non-linearity. The main advantage of this approach is that it circumvents problems of high dimensionality; is equivariant to collinearity; and includes exponential functions - thus giving the test power against a wide range of possible alternatives. As such, the non-linear specification of $g(i_{t,k} - i_{t,k}^*)$ may be written as:

$$
\begin{aligned}
g(i_{t,k} - i_{t,k}^*) = &\sum_{i=1}^{n} \Big[\beta_i (i_{t,k} - i_{t,k}^*) + \kappa_{1,i}(i_{t,k} - i_{t,k}^*)^2 + \kappa_{2,i}(i_{t,k} - i_{t,k}^*)^3 \\
&+ \kappa_{3,i}(i_{t,k} - i_{t,k}^*)e^{-|i_{t,k} - i_{t,k}^*|} \Big] \\
\approx &\sum_{i=1}^{n} \Big[\beta_i(i_{t,k} - i_{t,k}^*) + \gamma_i(i_{t,k} - i_{t,k}^*)(1 - |i_{t,k} - i_{t,k}^*|) + \kappa_{1,i}(i_{t,k} - i_{t,k}^*)^2 \\
&+ \kappa_{2,i}(i_{t,k} - i_{t,k}^*)^3 + \theta_i(i_{t,k} - i_{t,k}^*)^3 \left(1 - \frac{1}{3}|i_{t,k} - i_{t,k}^*|\right) \Big]
\end{aligned}
$$

This approximation is quite flexible: the interest differential has no impact on net purchases once $\beta = \kappa_1 = \kappa_2 = \kappa_3 = 0$; linear if $\kappa_1 = \kappa_2 = \kappa_3 = 0$; quadratic if $\kappa_2 = \kappa_3 = 0$; cubic if $\kappa_3 = 0$; 'bi-linear with bi-quadratic' once $\beta = \kappa_2 = 0$; and fairly general if all coefficients are non-zero.

The variance process *(f)*,defined by the Nelson (1991) E-GARCH model, isspecified as:

$$
\log(h_t) = \alpha + \sum_{j=1}^{p} \delta_j \log(h_{t-j}) + \sum_{j=1}^{q} \gamma_j \frac{\varepsilon_{t-j}}{\sqrt{h_{t-j}}} + \sum_{j=1}^{q} \psi_j \left| \frac{\varepsilon_{t-j}}{\sqrt{h_{t-j}}} \right|
$$

The main advantage of the E-GARCH specification is that it allows for the testing of asymmetries. If $\gamma_j \neq 0$, then volatility is asymmetric and, if$\gamma_j < 0$, then negative shocks generate more volatility than positive ones.

The system of equations (6-9) may be estimated by computing the mean-variance combination for each distribution, starting at the same initial parameters for each combination, and comparing likelihoods, parameter constraints, and other characteristics of the resulting matrices. The problem with this approach is that the distributions, in general, are not nested.

An alternative strategy (see Worrell et al, 2008), employed in this paper, is to start by comparing the unconditional distributions (standardized on their means) with commonly used distributions such as the normal and *t* distributions, using the quantile plots found in the econometric software package EVIEWS. This provides a first sense of the nature of the

distribution. After this step, consider the conditional mean derived from Equation (5), utilising an equation specification that ensures that the residuals are "white noise". Next, test the distribution of the residuals against normal, *t*, and other commonly used distributions, in order to determine the nature of the conditional distribution. For that mean and conditional distribution, the maximum EGARCH lag is set, check for congruency, and sequentially decrease the variance and mean. (This is an example of the general-to-specific approach.) Within each class of distribution, the usual likelihood ratio tests may be performed. One may also do a second round of checks to investigate the robustness of the specification, estimating the parsimonious E-GARCH-M model with the alternative distributions and comparing the results, using the quantile plots. However, it must be borne in mind that the reduced (parsimonious) model will most probably reflect the initial parametric choice of the distribution, and subjective evaluation is needed to bring all of these factors together, including the interpretation of parameters.

3.3.   Results

A preliminary step in the estimation procedure is to check the temporal properties of the variables. In this respect, the familiar ADF, PP and KPSS unit root tests are employed. Because the data is in the moving average format, the Elliot, Rothenberg, and Stock (*ERS)* Point Optimal test (1996) is also applied. Based on these results, it can be concluded that net purchases is I(0) stationary with a drift while the interest rate differential is also I(0) stationary but with drift and a linear deterministic trend. Consequently, Equation (6) is estimated in levels, with the interest rate differential de-trended using a simple deterministic trend.

Table 1: Unit Root Tests

Sample	Variable	ADF Test	KPSS	PP Test	ERS Test	Nature of Test	Decision
Full	Net Purchases	-7.535***	0.163	-10.050***	0.441	Intercept	I(0)
	$(i_{t,k} - i_{t,k}^*)$	-3.369*	0.679***	-3.230*	10.185***	Trend and Intercept	Trend Stationary
Pre-Crisis	Net Purchases	-5.122***	0.156	-10.010***	0.401	Intercept	I(0)
	$(i_{t,k} - i_{t,k}^*)$	-3.357	0.682	-3.219*	10.240***	Trend and Intercept	Trend Stationary

Note: ***, ** and * represent significance at the 1, 5 and 10 percent respectively. The maximum lag length was set to 60 and the SIC criterion was used to determine the optimal lag length.

Employing the strategy outlined in Section 3.2, the empirical model is estimated as an-E-GARCH-M process for the full sample and pre crisis data (see Table 2). Both models seem to be well fitted (evidenced by R-squares above 93 percent) and well specified.

Focusing first on the variance equations, the variance for the pre-crisis sample followed an E-GARCH(1,1) process, while that of the full sample was fitted to an E-GARCH(1,2) model. This may be interpreted that the economic and financial crisis changed the volatility patterns of net purchases: it lengthened the GARCH effects. In both specifications, there is evidence of asymmetry: the coefficient γ_1 is negative and significant, thus implying that negative shocks have a greater effect on the volatility of net purchases of US dollars than positive shocks. But, the

magnitude and statistical significance of γ_1 is greatest in the full sample and may be indicating that the crisis increased the level of asymmetry present in the volatility.

Turning now to the mean equation, based on the Box-Jenkins methodology, the ARMA(1,10) model was chosen as the best representation of the autoregressive nature of net purchases. The parameters on the lagged dependent variables are positive and worryingly close to one. At first glance, these seem in contrary to the conclusions drawn from the various unit root tests discussed above. So, as a measure of caution, the two models were also estimated in first differences. The underlying results – which are available upon request from the authors – were quite similar to those in levels. As such, the paper continues to focus on the equations ran in levels.

The coefficient that captures the impact of activity during the peak tourism season on foreign exchange volume is statistically significant, with the mean value of daily net purchases in the high season exceeding that of the low season by about BDS $326, 900 in the full sample and $586, 900 in the pre-crisis sample[‡]. The greater impact in the pre-crisis period is more likely reflecting the fact that since the onset of the crisis, tourism receipts in Barbados has been on the decline. The effect of the 'exceptional FX trades' variable is stronger than that of tourism (comparing the coefficient values in Table 2) and is positively related to the dependent variable. This probably reflects the fact that because the total or average value of exceptional receipts outpaced those of the payments. For instance, in the full sample, the total value of net receipts over $10 million is $1092.7 million, while that of net sales is $926.9 million. Interestingly, the coefficient of this variable in the pre-crisis sample is almost twice that for the full sample. A close look at the 'exceptional FX trades' data revealed that most of the extraordinary net sales of US currencies (about 50 percent) occurred after July-2007, thus explaining these findings.

The volatility of net purchases also affects the mean equation, but, for the full sample, the sign of the $\sqrt{h_t}$ is positive – implying that higher volatility is associated with larger net purchases of foreign exchange – while in the pre-crisis period, it is negative. One possible explanation is that this variable may be capturing economies of scale and scope in Treasury management. That being said, November 2009 marked the merger of the Treasury Departments of two commercial banks in Barbados – one of which engages in the most foreign transactions in the banking sector. Thus, the change in the coefficient of $\sqrt{h_t}$ could be influenced by the adjustment in Treasury management which occurred in latter part of the sample.

Finally, this section evaluates the link between net purchases of US currencies and the spread between Barbadian interest rates and those of the US. In both samples, all terms in the Castle and Hendry (2010) specification of interest spread are very significant, indicating a highly general non-linear impact of the interest differential on foreign exchange activity. The first spread term (linear) is positive – as expected – with an implied elasticity of 0.07 in the pre-crisis period and 0.35 in the full sample period. The non-linear dynamics uncovered in this study suggest that the FX-interest spread relationship is asymmetric, evidenced by the negative coefficient on all the non-linear spread terms, i.e. there exists some threshold(s) at which FX activity in Barbados deviates from the UIP. An interesting observation is that this behavior holds across the full and pre-crisis sample and, with the exception of κ_1, the coefficients of the spread terms are of similar magnitude. This implies that crisis, though affecting the control variables, did not have a substantial impact on the FX-interest spread relation.

[‡] These mean values can be calculated by multiplying the coefficients of the 'tourist season' variables by the mean of the net purchases in both samples.

Table 2: Empirical Results

	Full Sample (05-Jan-99 to 27-July-11)	Pre-Crisis Sample (05-Jan-99 to 29-Jun-07)
Mean Equation		
$\sqrt{h_t}$	0.020*** [0.000]	-0.012*** [0.000]
Net Purchases (-1)	0.998*** [0.000]	0.997 [0.000]
MA(10)	-0.992*** [0.000]	-0.983*** [0.000]
β	18.917*** [0.000]	20.637*** [0.000]
κ_1	-0.181*** [0.000]	-0.860*** [0.000]
κ_2	-4.298*** [0.000]	-5.275*** [0.000]
κ_3	-35.077*** [0.000]	-34.659*** [0.000]
Exceptional FX Trades	7.404*** [0.000]	14.477*** [0.000]
Tourist Season	4.555*** [0.000]	3.839*** [0.000]
Constant	-11.994*** [0.000]	7.709*** [0.000]
Variance Equation		
α	0.754*** [0.000]	0.239*** [0.000]
ψ_1	0.186*** [0.000]	0.131*** [0.000]
γ_1	-0.027*** [0.000]	-0.019* [0.081]
δ_1	0.455*** [0.000]	0.974*** [0.000]
δ_2	0.471*** [0.000]	----------
R-squared	0.957	0.933
ARCH(10)	8.156 [0.614]	0.089 [1.000]

Note: ***,** and * denote significance at the 1 percent, 5 percent and 10 percent levels of significance, respectively. P-values are in squared parentheses.

4.   Concluding Remarks

This paper investigates the possibilities of non-linearities in the behavior of the foreign exchange market of Barbados to interest differentials over the period Jan-1999 to July-2011. The distinguishing feature of Barbados is that it has been pegged to the US dollar for over 30 years, and thus has a highly credible peg. The empirical evidence suggest that when allowance is made for market frictions and large discrete events, capital flows have a general non-linear reaction to the interest spread between U.S. and Barbadian interest rates. The linear term is positive, which is consistent with the UIP condition; however, the remaining non-linear terms are all negative. This indicates that a form of asymmetry is present, implying that there is a threshold at which net purchases of the U.S. currency deviates from the UIP condition, and acts in line with the 'forward bias puzzle' – which in the context of an economy with a long-term peg – suggests a negative association between net purchases of U.S. currencies and the interest spread.

Another interesting dynamic explored in this study was how the recent global crisis, which began in late 2007, may have impacted the reaction of net purchases of U.S. currencies to the interest rate spread. The paper concludes that the crisis did not significantly affect the UIP condition. However, it did influence the effect that market frictions, tourism activity and exceptional FX trades have on net purchases of FX. In particular, the impact of tourism activity and extraordinary FX trades are significantly reduced when the sample includes the crisis period. More interestingly, market frictions had a positive effect on net purchases of U.S. currencies in the pre-crisis period, while for the full sample the influence of this variable is negative. One possible explanation for the apparent 'sign switching' could be a significant change in Treasury management which occurred in the crisis period of the sample.

The novelty of this paper is that it has explored non-linearities in the reaction of the foreign exchange market in a small open economy with a long-term peg to its interest-differential. The main policy implication emanating from this study is that the dynamics of FX reaction to interest rate differentials is much more complicated than initial work suggests (for instance, Worrell et al, 2008). Particularly, there seems to be a tipping point where FX flows no longer react to interest rate differentials in a way which maintains the UIP. Thus, policy makers in Barbados must be careful in adopting interest rate policies (i.e. raising domestic interest rates relative to international rates) as a means of attracting foreign capital.

While the findings of this study has added new insight into the relationship between FX flows and interest rate differential in fixed exchange rate regimes, further research is still needed to better understand the complexity of the market. Possible extensions (which are beyond the scope of this study) could include estimation procedures which allow for the possibility of discontinuities or specification of a model which determines the threshold(s) for which net purchases of U.S. are no longer consistent with the UIP condition   Finally, though the sample is a much needed expansion of that of Worrell et al, the time period only spans eleven and a half years. Thus a follow-up investigation employing the use of an even longer time series is necessary.

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