ARE THERE NON-LINEARITIES IN US: LATIN AMERICAN REAL EXCHANGE BEHAVIOR*

MARK J. HOLMES

Abstract

This study tests for non-linearities in the behavior of US dollar real exchange rates of thirteen Latin American countries. For this purpose, logistic and exponential smooth transition regression models are applied to quarterly data over the sample period 1973Q2-2001Q1. There is evidence of non-linearities in the behavior of seven real exchange rates where, in most of these cases, non-linearities are captured by the logistic smooth transition autoregressive model. The extent of non-linearities varies across Latin American countries with Colombia and Venezuela exhibiting the sharpest transition between regimes of low and high real exchange rates.

Resumen

Este estudio realiza test de no-linealidades en la conducta de los tipos de cambio real del dólar de EE.UU., para trece países de latinoamérica. Para este propósito, se aplican modelos de regresión con transición suavizada, logísticos y exponenciales a los datos trimestrales de la muestra sobre 1973 Q2– 2001 Q1. Hay evidencia de no-linealidades en la conducta de siete tipos de cambio real, donde, en la mayoría de estos casos, las no-linealidades son capturadas por el modelo logístico autorregresivo de transición suavizada. La magnitud de las no linealidades varía entre los países de Latinoamérica, con Colombia y Venezuela que exhiben la transición más aguda entre los regímenes de tipo de cambio real altos y bajos.

JEL: C1, F0, O0.

Keywords: *Latin America, Non-Linearities, Exchange Rate.*

---

* I am grateful for the helpful comments provided by an anonymous referee. The usual disclaimer applies.

□ Department of Economics. Loughborough University. Loughborough. Leicestershire, LE11 3TU. England.

1. INTRODUCTION

The investigation of non-linearities and asymmetries in macroeconomic behavior constitutes an increasingly popular area of empirical research. More specifically, a number of recent studies that include Iannizzotto (2001), McMillan and Speight (2001), Serletis and Gogas (2000), Sarno (2000a, 2000b), Sarantis (1999) and Michael *et al.* (1997) examine mainly OECD real exchange rates and find that non-linearities are present in a large number of cases. On the one hand, the presence of non-linearities in real exchange rates is often attributed to the heterogeneity of participants in the foreign exchange market in terms of agents' expectations formation or investors' objectives[1]. Such hypotheses are very difficult to test. On the other hand, there is the possibility of arbitrage being limited by the presence of transactions costs in the event of relatively moderate real exchange rate shocks[2]. Furthermore, non-linearities may arise within an equilibrium framework on account of policy changes on account of trade reform, fiscal policy and so on. This purpose of this paper is to investigate whether non-linearities are present in the behavior of Latin American real exchange rates. Using quarterly data for the period 1973Q2 to 2001Q1, thirteen Latin American real exchange rates are analyzed using the smooth transition autoregression (STAR) methodology advocated by Granger and Terasvirta (1993). The application of two variants of STAR modeling– logistic smooth transition autoregression (LSTAR) models and exponential smooth transition autoregression (ESTAR) models enables us to explore the possibility that non-linear adjustments are present[3].

There are several important reasons of interest attached to this study. First, this study concentrates on non-linear behavior in less developed country (LDC) real exchange rates. While Sarno (2000b) confirms the presence of non-linearities in Turkish real exchange rates with respect to the US dollar, UK sterling, German mark and French franc, this study offers a more comprehensive examination of non-linearities involving a larger sample of LDCs. Second, the Latin American economies have been subject to episodes of pronounced turbulence due to structural change, political and economic unrest and reform. This might imply a potential for complex dynamics of adjustment in the real exchange rate. In a recent paper, Parsley and Popper (2001) argue that non-linear effects in real exchange rate adjustment are most striking among currencies that have at times officially pegged with respect to the US dollar. Third, evidence on PPP for LDCs has led to mixed conclusions regarding its validity [see, *inter alia*, McNown and Wallace (1989), Liu (1992), Bahmani-Oskooee (1993), Mahdavi and Zhou (1994), Holmes (2001)]. However, the vast majority of this work is based on *linear* tests for mean-reversion in real exchange rates such as Engle-

---

1 See Sarantis (1999) and references contained therein.

2 See, inter alia, Obstfeld and Taylor (1997), Sercu et al. (1995).

3 Earlier examples of studies employing the STAR methodology include Sarantis (1999) who examines the real exchange rates of the G10 countries, Leybourne and Mizen (1997) who examine consumer prices, Mills (1995) and Ocal and Osborn (2000) who examine a range of UK macroeconomic series that includes industrial production, and Skalin and Terasvirta (1999) who examine the Swedish business cycle.

Granger and Johansen cointegration tests. It can be argued that if non-linearities are present in LDC real exchange rate behavior then these linear tests are inappropriate. The identification of non-linearities in real exchange rates may therefore offer some explanation as to why PPP has not been confirmed in many cases. Fourth, insight into Latin American real exchange rate adjustment is obtained through STAR modeling. Real exchange rate movements have direct implications for the external competitiveness of the economy. This methodology allows for the possibility that economies do not necessarily jump suddenly from one real exchange rate regime to another, for example between low and high real exchange rates, on the basis of a single real exchange rate shock. It is more likely that the size of the real exchange rate shock will determine the extent to which the economy is in one regime or another where relatively moderate shocks provide a smoother adjustment between regimes. On the other hand, larger shocks may shift the economy dramatically from one exchange rate regime to another. This information may assist governments in their assessment of the impact of real exchange shocks on the regime being experienced.

The paper is organized as follows. The following section describes the data and methodology. The third section reports and discusses the results. From a sample of thirteen LDCs there is evidence that non-linearities are present in eight countries where the LSTAR model is appropriate in the majority of cases. The final section concludes.

2. Methodology and Data

The above mentioned studies of exchange rates imply non-linearities with distinct characteristics associated with different real exchange rate regimes. A variety of empirical models have been developed to capture these regime-dependent properties. The main approaches to modeling non-linearities include the Markov regime-switching models, where the switch between regimes is described by a probabilistic function [see Hamilton (1989) and others], and the threshold class of models that specify the regime switch as a function of past values [see, for example, Tsay (1989), Tong (1990)]. Both these classes of model imply that the economy must be within a single regime in each time period where there is a sharp switch between regimes. Alternatively, there are the models based on a smooth transition generalization of threshold class [see, for example, Granger and Terasvirta (1993), Terasvirta (1994), Terasvirta and Anderson (1992)]. These models allow for the possibility that the real exchange rate might be in some intermediate state between regimes where the nature of adjustment varies with the extent of deviation from equilibrium. The smooth transition methodology is followed in this paper. The smoothness of adjustment between regimes is estimated and one can judge the sharpness of switching from one regime to another.

The justification for this choice of methodology is based on recent literature that considers the possibility of arbitrage being limited by the presence of transactions costs [see, *inter alia,* Obstfeld and Taylor (1997), Sercu *et al.* (1995)]. It is argued that there may be a ‘band of inaction’ where the marginal cost of arbitrage exceeds the marginal benefit. However, it is reasonable to argue that transactions costs will differ across markets. Moreover, there might exist a series of thresholds straddling the equilibrium value of PPP so that as one moves further away from central parity, more and more arbitrage opportunities arise. In the limit, there may be a continuum of thresholds so that the real exchange rate does not move abruptly from one regime to another but engages in a somewhat smoother adjustment. A further way of justifying the presence of non-linearities in real exchange rate behavior is to view the real exchange rate as a relative price between tradable and non-tradable goods [see, for example, Yotopoulos (1996)]. In an equilibrium framework, the real exchange rate will depend on the marginal rate of substitution between tradable and non-tradable goods influenced by preferences, government expenditure, tariffs and so on. Non-linearities may arise through factors such as trade reform and fiscal policy.

For a given LDC, let p_t be the natural logarithm of the domestic price index where t = 1, 2,..., T observations, let p_t^* be the natural logarithm of the base country price index and let s_t be the natural logarithm of the country i nominal spot price of foreign currency. The real exchange rate e for country i is computed as

(1) $$e_t = s_t + p_t^* - p_t$$

Consider two possible regimes comprising a pure 'low' and pure 'high' real exchange rate with respect to the equilibrium value for e. We can then follow Granger and Terasvirta (1993) and write a STAR model of order k, for e_t that has the following specification,

(2) $$e_t = \beta_0 + \beta_1^{'} x_t + (\theta_0 + \theta_1^{'} x_t) F(e_{t-d}) + w_t$$

where $x_t = (e_{t-1}, e_{t-2}, \ldots e_{t-k})$, $\beta_1 = (\beta_1, \beta_2, \ldots \beta_k)^{'}$, $\theta_1 = (\theta_1, \theta_2, \ldots \theta_k)^{'}$, $w_t \sim iid(0,\ \sigma^2)$, $F(\cdot)$ is the continuous transition function, e_{t-d} is the switching variable, and d is the delay parameter. $F(\cdot)$ is a monotonically increasing function with $(F-\ ) = 0$ and $F(\ ) = 1$ which yields a non-linear asymmetric adjustment. Consider the following LSTAR function

(3) $$F(e_{t-d}) = \{1 + exp[-\gamma(e_{t-d} - c)]\}^{-1}$$

where γ measures the smoothness of transition from one regime to another and c is some threshold value for e that indicates the halfway point between the two regimes. The LSTAR model assumes that different regimes may have different dynamics and that adjustment takes place in every period but the smoothness of adjustment varies with the extent of the deviation from equilibrium. The transition function of LSTAR is monotonically increasing in e_{t-d} and yields asymmetric adjustment toward equilibrium in the model. Moreover, $F(\cdot) \to 0$ as $e_{t-d} \to -\infty$ and $F(\cdot) \to 1$ as $e_{t-d} \to +\infty$ thus $F(\cdot)$ is bounded between 0 and 1 where $F(\cdot) = 0.5$ if $e_{t-d} = c$. The smaller is γ, the smoother is the transition. In the extreme, $\gamma = 0$ means that $F(\cdot)$ becomes a constant and so (2) becomes a linear model. On the other hand, as $\gamma \to \infty$ there is an ever sharper transition at $e_{t-d} = c$ where $F(\cdot)$ jumps from 0 to 1. In this latter case, (3) becomes the usual threshold transition model along the lines of Tong (1983). Terasvirta and Anderson (1992) also define the exponential (ESTAR) function as

(4) $$F\left(e_{t-d}\right) = 1 - exp\left\{-\gamma\left(e_{t-d} - c\right)^2\right\}$$

where, as before, g measures the speed of transition from one regime to another and c is some threshold value for e which indicates the halfway point between the two regimes. The ESTAR function in (4) defines a transition function about c where $F(\cdot)$ is still bounded between 0 and 1. Earlier studies such as Michael *et al*. (1997) follow a different approach. They test for cointegration between the UK:US nominal exchange rate, US and UK prices. Using an ESTAR model, they then test whether the residuals then follow a non-linear process. As pointed out by Sarantis (1999), the problem with this approach is that if the residuals follow a non-linear process then one must surely question the validity of the earlier cointegration tests. This problem can be avoided by following the approach adopted in this paper by applying the STAR models directly to real exchange rate data (e).

The initial testing for the presence of non-linearities in e_t is based on three stages. First, a linear AR model for e is specified in order to determine the lag length k. The lag length selection is based on the Schwarz information criteria and Ljung-Box statistic for autocorrelation. The residuals are saved from the chosen AR model and denoted as v. Second, having determined k, the next stage is to test for the presence of non-linearities. This is achieved through the estimation of

$$v_t = \beta_0 + \beta_1' x_t + \beta_2' x_t e_{t-d} + \beta_3' x_t e_{t-d}^2 + \beta_4' x_t e_{t-d}^3 + w_t \tag{5}$$

where the basic linearity test is on the null $H_0:\ \beta_2' = \beta_3' = \beta_4' = 0$. Equation (5) is estimated across a range of values for d where the lowest p-value attached to the linearity test determines d in the later estimation of (2). While the estimation of equation (5) resembles the application of Ramsey's RESET test, the procedure outlines here is advantageous in the sense that the third stage determines what type of functional form is most appropriate. The third stage of the non-linearity test is to see which smooth transition model– LSTAR or ESTAR– is appropriate for the real exchange rate. For this purpose, the following null hypotheses are tested.

$$H_{04}:\ \beta_4' = 0 \tag{6}$$

$$H_{03}:\ \beta_3' = 0 / \beta_4' = 0 \tag{7}$$

$$H_{02}:\ \beta_2' = 0 / \beta_4' = \beta_3' = 0 \tag{8}$$

One method of choosing the appropriate STAR model is to run the following sequence of nested tests. Rejection of H_{04} implies selecting the LSTAR model. Accepting H_{04} but rejecting H_{03} implies selecting the ESTAR model. Accepting H_{04} and H_{03} but rejecting H_{02} implies selecting the LSTAR model. Having selected the form of appropriate model, this study considers the value of γ described in (3) and (4). However, Granger and Terasvirta (1993) and Terasvirta (1994) show that the strict application of this procedure can lead to the wrong conclusion. Instead, this study follows Sarantis (1999) where the p-values for each of these F tests are computed and the choice of STAR model is made on the basis of the lowest p-value. Moreover, if the rejection of H_{04} or iH_{02} is accompanied by the lowest p-value then the LSTAR model is chosen. If the rejection of H_{03} is accompanied by the lowest *p*-value then the ESTAR model is chosen. In either case, the STAR model is estimated through non-linear least squares estimation.

The thirteen LDCs included in the sample are Argentina, Brazil, Chile, Columbia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Suriname, Uruguay and Venezuela. All price and exchange rate data are taken from the *International Financial Statistics* database. Real exchange rates are based on the consumer price index (line 64) and nominal exchange rates, which are end of period spot rates with respect to the US dollar. All real exchange rate data are expressed in natural logarithm form. Quarterly data for the period 1973Q2-01Q1 provide a sample of size of upto 112 observations on each series for each country where the use of quarterly data is dictated by data availability across this large sample. The start of 1973 is consistent with Bahmani-Oskooee (1993), Mahdavi and Zhou (1994) and Holmes (2001) in their investigations of PPP in LDCs and can be regarded as the start of modern "floating rate" period with respect to the US dollar.

3. The Results

The application and estimation of the STAR models require stationary series. Table 1, reports univariate ADF unit root tests on real exchange rates for the full sample of thirteen countries. The results for e_t indicate that the null of non-

TABLE 1
ADF UNIT ROOT TESTS ON REAL EXCHANGE RATES

	e	
	ADF (no trend)	ADF (trend)
Argentina	-3.864^{***}	-2.674
Brazil	-1.938	-2.080
Chile	-1.515	-1.661
Columbia	-1.643	-2.072
Costa Rica	-2.768^{*}	-3.043
Ecuador	-1.196	$-2.546^{\#}$
El Salvador	-1.804	$-4.130^{***,\#}$
Guatemala	-2.048	-2.877
Honduras	-2.180	$-3.002^{\#}$
Mexico	-2.982^{**}	-2.898
Suriname	-3.047^{**}	-3.004
Uruguay	-2.598^{*}	-2.669
Venezuela	-1.855	-1.751

These are Augmented Dickey Fuller (ADF) unit root tests conducted on the levels of the real exchange rate with respect to the US dollar. The full sample period is 1973Q2-2001Q1. For each test, the lag length was chosen using the Schwarz Bayesian Information Criteria. ***, ** and * indicate rejection of the null of non-stationarity at the 1, 5 and 10% levels of significance respectively in the ADF tests, # indicates significance of the time trend at the 5% level. Relevant ADF critical values taken from Fuller (1976) are –3.51, –2.89 and –2.58, while for regressions including a trend, these are –4.04, –3.45 and –3.15 respectively.

stationarity is rejected at the 10% significance level in all almost half the cases– Argentina, Costa Rica, El Salvador, Mexico, Suriname and Uruguay. However, recent evidence suggests that real exchange rate series are most likely to be stationary if one considers a long enough sample period [Lothian and Taylor (1996), Taylor (2002)]. For this reason, we proceed to apply the tests directly to the real exchange rate series.

Table 2 reports the tests for non-linearities in the first differenced real exchange rate series, e_t. Following the selection of the lag length k for each AR process, the delay parameter d is constrained to be 1 d $D = 8$. Given k and the value of d that minimizes the p-value associated with H_0 in equation (5), the null of linearity is rejected at 10% significance level in seven cases– Brazil, Columbia, Costa Rica, Ecuador, El Salvador, Uruguay and Venezuela. Table 3 reports the test results for the specific form of non-linearity present. Using the hypothesis tests outlined in equations (6)-(8), the results indicate that the LSTAR model is the more appropriate non-linear model in all cases except Costa Rica. The LSTAR model implies that regimes based on low and high exchange rates have different dynamics whereas the ESTAR model implies that the two regimes have similar dynamics but the transition period can have different dynamics.

Table 4 reports estimates of the transition parameter γ. These estimates are derived from the non-linear least squares estimate of (2). In line with other studies, the LSTAR and ESTAR models are scaled by the standard deviation and variance of e respectively. As well as assisting convergence during estimation,

TABLE 2

TESTS FOR NON-LINEARITIES

	k	d	*p*-value	Q(4)
Argentina	1	2	0.516	0.634
Brazil	1	2	0.068	0.329
Chile	5	7	0.835	0.000
Columbia	5	4	0.042	0.314
Costa Rica	1	3	0.015	0.081
Ecuador	1	6	0.100	0.458
El Salvador	1	8	0.013	0.988
Guatemala	1	1	0.476	0.980
Honduras	2	1	0.530	0.990
Mexico	1	4	0.402	0.100
Suriname	1	2	0.332	0.999
Uruguay	1	3	0.009	0.952
Venezuela	2	8	0.005	0.940

These tests are based on the first difference of the natural logarithm of the real exchange rate. The null of linearity is based on equation (5). The column headed 'p-value' corresponds to the test H_0 where the null is linearity. It should be noted that the Schwarz criteria is used to determine lag length k of AR process. The residuals from AR processes were then saved. Having determined k, a range of delay parameters d (d is between 1 and $D = 8$) were employed. The value of d chosen is that which gives rise to the lowest p-value of the linearity test using the data for the residuals of the AR process. The linearity test is itself a variable-deletion F test on the restriction applied to equation (5). The column headed Q(4) refers to the p-value associated with the Ljung-Box Q statistic for serial correlation among the residuals.

TABLE 3
SPECIFICATION OF THE NON-LINEAR MODEL

	H_{04}	H_{03}	H_{02}	Type of Model
Brazil	0.063#	0.103	0.319	LSTAR
Columbia	0.073#	0.189	0.154	LSTAR
Costa Rica	0.220	0.003#	0.575	ESTAR
Ecuador	0.016#	0.513	0.979	LSTAR
El Salvador	0.471	0.067	0.008#	LSTAR
Uruguay	0.002#	0.498	0.183	LSTAR
Venezuela	0.011#	0.104	0.075	LSTAR

See equations (5), (6), (7) and (8). # denotes the lowest *p*-value associated with the variable-deletion tests and therefore the determination of the relevant STAR model. The values for *k* and *d* are reported in Table 2.

TABLE 4
ESTIMATES OF THE STAR MODELS

	γ	sig	c	Q(1)	Q(2)	St. Err.	Type of Model
Brazil	0.217	0.000	0.466	0.763	0.078	0.240	LSTAR
Columbia	57.987	0.000	-0.059	0.348	0.588	0.000	LSTAR
Costa Rica	2.280	0.000	4.944	0.836	0.757	0.017	ESTAR
Ecuador	0.031	0.000	10.701	0.260	0.291	0.014	LSTAR
El Salvador	0.149	0.000	2.358	0.999	0.935	0.031	LSTAR
Uruguay	0.029	0.001	2.174	0.769	0.958	0.073	LSTAR
Venezuela	13.648	0.000	-2.789	0.848	0.693	0.028	LSTAR

Non-linear least squares estimation of equation (2) is by the Gauss-Newton method. The column headed *sig* refers to the *p*-value associated with a variable-deletion *F* test on the smoothness of adjustment coefficient γ, *c* is the estimated threshold value for the switching variable (see equations (3) and (4)), Q(1) and Q(2) refer to the *p*-values associated with the Ljung-Box *Q* statistic concerning serial correlation in the residuals, *St. err* is the standard error of the non-linear regression expressed as a proportion of the mean value of the real exchange rate ($\bar{e}$). With the exception of Costa Rica, *c* was insignificantly different from $\bar{e}$ at the 5% significance level.

this normalizes the deviations in the switching variable and facilitates interpretation of the smoothness parameter. Thus (3) and (4) may be rewritten as

$$F(e_{t-d}) = \left[1 + exp\left\{-\gamma(1/\sigma_e)(e_{t-d} - c)\right\}\right]^{-1} \tag{9}$$

$$F(e_{t-d}) = 1 - exp\left\{-\gamma(1/\sigma_e^2)(e_{t-d} - c)^2\right\} \tag{10}$$

In all cases, γ is correctly signed and significantly different from zero at the 5% level. While Sarantis (1999) points to the difficulty in estimating γ, Sarno (2000b) argues that the statistical significance of γ is in a sense not questionable because linearity has already been rejected in the earlier tests. Let us consider the LSTAR results first. The results suggest that countries such as Ecuador and Uruguay are characterized by a very smooth transition from one regime to another while Colombia and Venezuela, which feature much larger values of γ, exhibit a much sharper transition. It would be useful here to comment on what the estimated values for actually mean. Let us designate $F(e_{t-d}) = 0$ and $F(e_{t-d}) = 1$ as regimes of a pure "high real exchange rate" and "low real exchange rate" with respect to the equilibrium (PPP) value. These regimes are synonymous with "reduced competitiveness" and "increased competitiveness". Table 4, for example, reports that $c = 0.466$ and $\gamma = 0.217$ in the case of Brazil. Suppose we are initially at the equilibrium real exchange rate where the weights attached to the two pure regimes are equal at [0.500,0.500]. This means that a one standard deviation positive shock to e_{t-d} yields $F(e_{t-d}) = 0.530$. The new regime is therefore a linear combination of regimes 1 and 2 with the weights [0.530,0.470]. There is slightly more weight attached to the pure low real exchange rate regime. In the case of a two standard deviation shock to e_{t-d}, we have $F(e_{t-d}) = 0.582$ and so these weights become [0.582,0.418]. If there is a three standard deviation positive shock to the real exchange rate these weights will now become [0.634, 0.366]. There is a larger leaning towards $F(e_{t-d}) = 1$ on account of a larger positive shock to the real exchange rate. In the case of Venezuela, the smoothness parameter is estimated at $\gamma = 13.648$. This higher value means that small deviations of the switching variable from the threshold level are more likely to place the real exchange rate almost entirely in one regime or the other. Figure 1 presents plots of the LSTAR transition functions for Brazil, Columbia, Ecuador, El Salvador, Uruguay and Venezuela. The stark contrast between Brazil and Venezuela is brought out clearly. In the latter case, it might be interesting to employ threshold models given the rapid shift between regimes.

In terms of the ESTAR model, Costa Rica exhibits a relatively high value for *g* and therefore fairly sharp transitions from one regime to another with $\gamma = 2.280$. In this case, a one standard deviation shock to e_{t-d} leads to a new regime that is weighted almost entirely towards one regime or the other. Figure 2 plots the ESTAR transition function for Costa Rica and highlights the nature of transition.

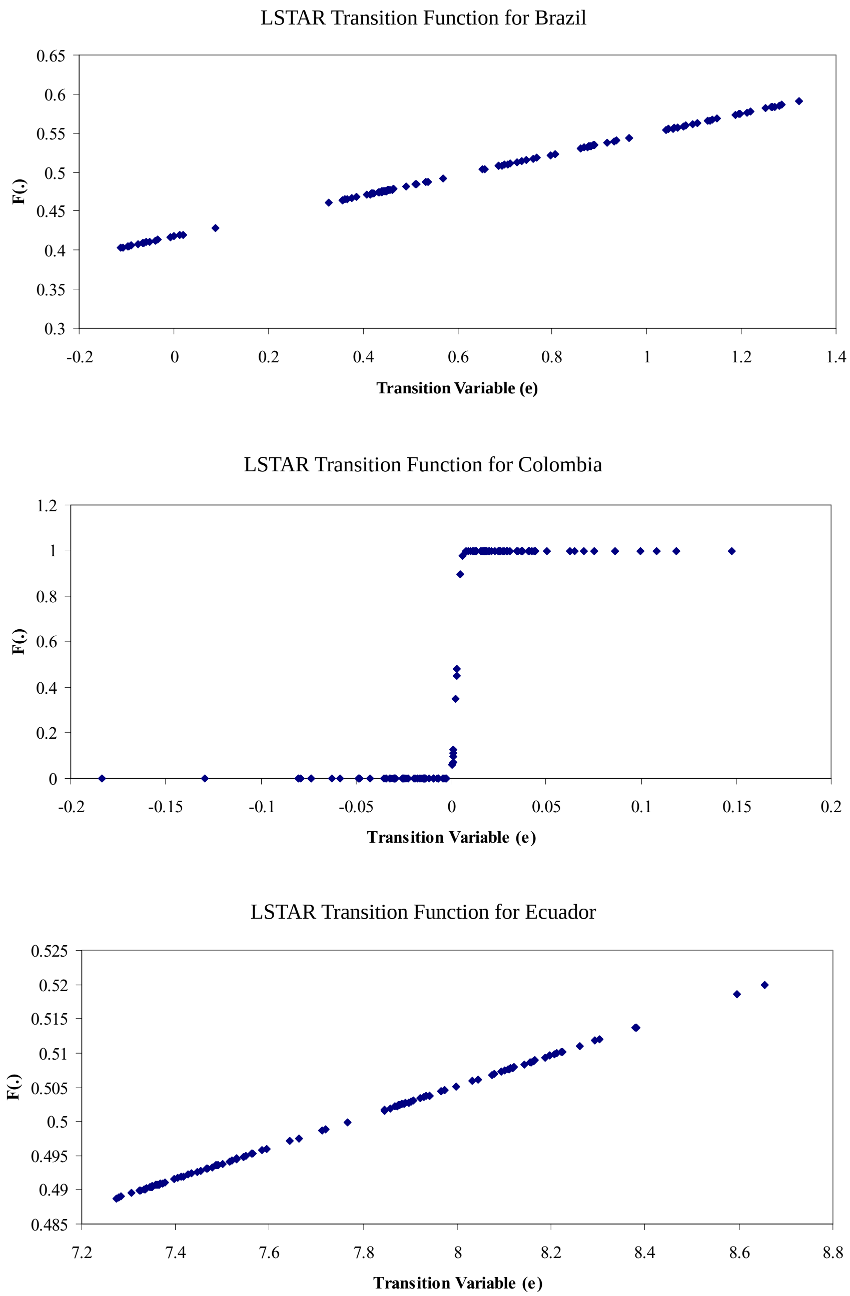
Table 4 also reports estimates of the halfway points, *c*, or thresholds between the two pure regimes. In all cases except Costa Rica, *c* was insignificantly different from the mean real exchange rate, $\bar{e}$. This makes it most likely that the observations associated with the LSTAR function lie with equal probability on either side of the transition function. In the case of Costa Rica, there was evidence that *c* was less than $\bar{e}$. This suggests that positive shocks to the real exchange rate (increased competitiveness) are more likely to trigger regime switches than negative shocks. This lends support to the notion of an asymmetric adjustment towards PPP in the case of Costa Rica[4].

---

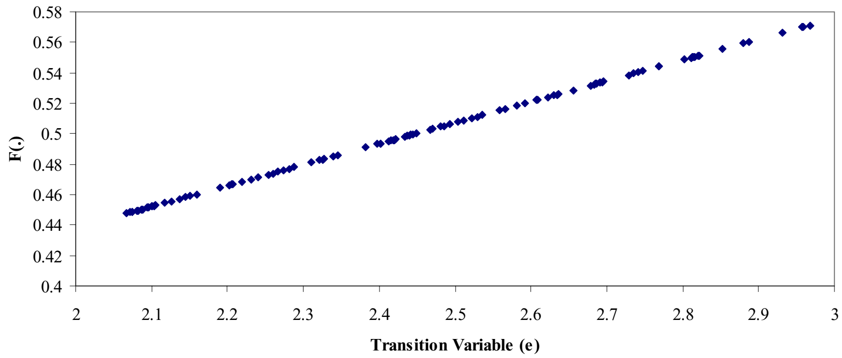
4 The recent work by Enders and Dibooglu (2001) investigates the possibility of asymmetric long-run adjustment towards PPP in the case of the major OECD economies.

FIGURE 1

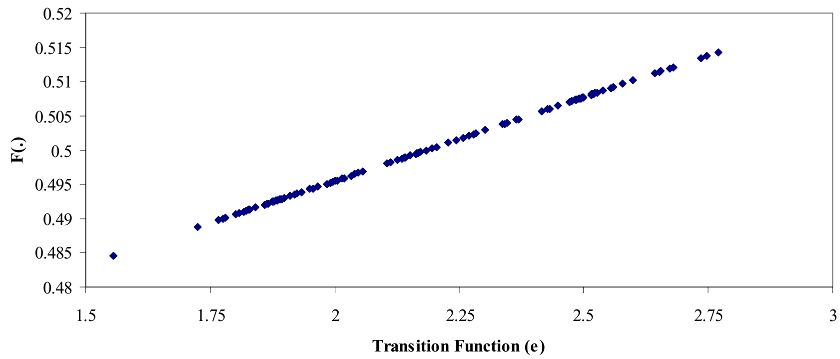
LSTAR TRANSITION FUNCTIONS FOR LATIN AMERICAN COUNTRIES



LSTAR Transition Function for El Salvador



LSTAR Transition Function for Uruguay



LSTAR Transition Function for Venezuela

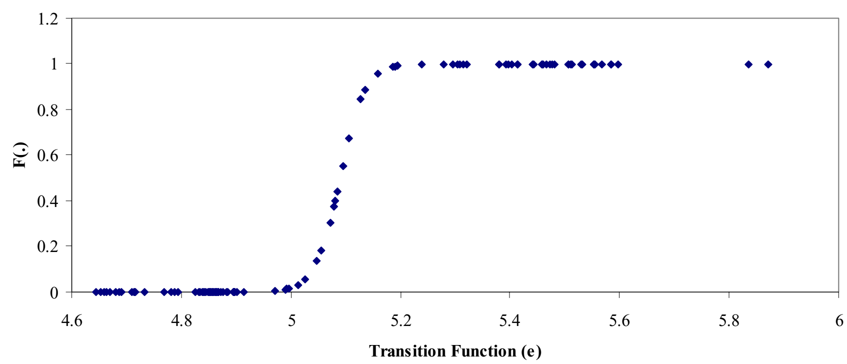
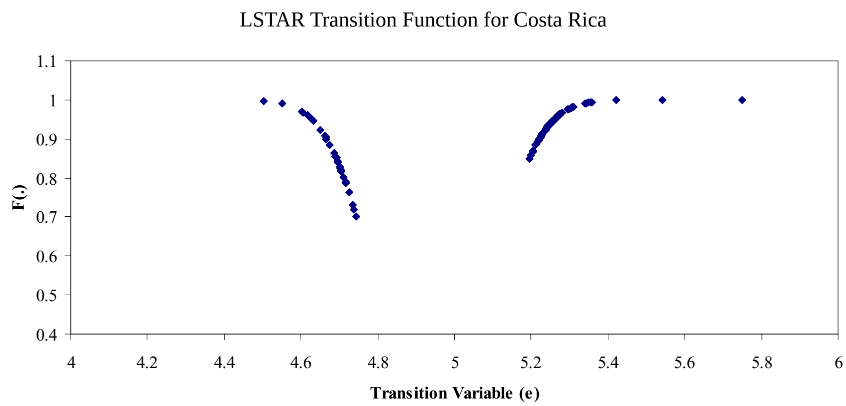


FIGURE 2
TRANSITION FUNCTIONS FOR LATIN AMERICAN COUNTRIES



4. Summary and Conclusion

Given the existing literature on non-linearities in OECD real exchange rates, this is the first study that takes a more comprehensive examination of non-linearities in the case of Latin American LDCs. The application of smooth transition autoregressive modeling to thirteen LDCs suggests that there is evidence of non-linear adjustment in seven cases. These findings may help explain why the hitherto linear tests for cointegration have been unsuccessful in the identification of purchasing power parity. While Colombia and Venezuela feature rapid shifts between regimes of a low and high real exchange rate, there is considerable variation in the smoothness of adjustment from one regime to another. Moreover, many of the sample are characterized by a smooth transition from one regime to another where swings in the degree of competitiveness are much milder. This study raises a number of avenues for future research. First, the very sharp transitions in some Latin American real exchange rates from one regime to another suggest that it would be interesting to also investigate non-linearities within a Markov switching or threshold model framework. Second, future research might consider whether forms of non-linearities, other than those tested for here, are appropriate.

References

Bahmani-Oskooee, M. (1993). “Purchasing Power Parity Based on Effective Exchange Rate and Cointegration: 25 LDCs’ Experience with its Absolute Formulation”, *World Development*, 21, 1023-31..

Enders, W. and Dibooglu, S. (2001). ‘Long-Run Purchasing Power Parity with Asymmetric Adjustment’, *Southern Economic Journal*, 68, 2, 433-45.

Fuller, W. A. (1976). *Introduction to Time-Series Analysis*, New York: John Wiley & Sons.

Granger, C. and T. Terasvirta (1993). *Modeling Nonlinear Economic Relationships*, New York: Oxford University Press.

Hamilton, J.D. (1989). 'A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle', *Econometrica*, 57, 357-384.

Holmes, M. J., "New Evidence on Real Exchange Rate Stationarity and PPP in Less Developed Countries", *Journal of Macroeconomics*, Vol. 23, No. 4, 2001, pp. 601-15.

Iannizzotto, M. (2001). "Exchange Rate Misalignment and Nonlinear Convergence to Purchasing Power Parity in European Exchange Rate Mechanism", *Applied Financial Economics*, 11, 511-26.

Lothian, J.R. and M.P. Taylor (1996). 'Real Exchange Rate Behavior: The Recent Float from the Perspective of the Past Two Centuries', *Journal of Political Economy*, 104, 488-509.

Leyborne S. and P. Mizen (1997). 'Disinflation and Central Bank Independence in Australia, Canada and New Zealand: Evidence from Smooth Transition Analysis', Discussion Paper 97/6, Department of Economics, University of Nottingham.

Liu, P. (1992). "Purchasing Power Parity in Latin America: A Cointegration Analysis", *Weltwirtschaftliches Archiv*, 128, 662-80.

Mahdavi, S., and S. Zhou (1994). "Purchasing Power Parity in High Inflation Countries: Further Evidence", *Journal of Macroeconomics*, 16, 403-22.

McNown, R., and M. Wallace (1989). "National Price Levels, Purchasing Power Parity, and Cointegration: A Test of Four High Inflation Economies", *Journal of International Money and Finance*, 8, 533-45.

McMillan, D. and A. Speight (2001). 'Non-linearities in the Black Market Zloty-Dollar Exchange Rate: Some Further Evidence', *Scottish Journal of Political Economy*, 11, 2, 209-20.

Michael, P., Nobay, A. R. and D. Peel (1997). 'Transactions Costs and Nonlinear Adjustments in Real Exchange Rates: An Empirical Investigation', *Journal of Political Economy*, 105, 862-79.

Mills, T. (1995). 'Business Cycle Asymmetries and Non-linearities in UK Macroeconomic Time-Series', *Ricerche Economiche*, 49, 97-24.

Obstfeld, M. and A.M. Taylor (1997). "Nonlinear Aspects of Goods Market Arbitrage and Adjustment: Heckscher's Commodity Points Revisited", Discussion Paper No. 1672, CEPR.

Ocal, N. and D. Osborn (2000). 'Business Cycle Non-Linearities in UK Consumption and Production', *Journal of Applied Econometrics*, 15, 27-43.

Parsley, D. and H. Popper (2001). "Official exchange rate arrangements and real exchange rate behavior", *Journal of Money, Credit and Banking*, 33, 976-93.

Rogoff, K. (1996). "The Purchasing Power Parity Puzzle", *Journal of Economic Literature*, 34, 647-68.

Sarno, L. (2000a). 'Systematic Sampling and Real Exchange Rates', *Weltwirtschaftliches Archiv*, 136, 1, 24-57.

Sarno, L. (2000b). 'Real Exchange Rate Behavior in High Inflation Countries: Empirical Evidence from Turkey, 1980-97', *Applied Economics Letters*, 7, 285-91.

Sarantis, N. (1999). "Modeling Non-Linearities in Real Effective Exchange Rates", *Journal of International Money and Finance*, 18, 27-45.

Sercu, P. Uppal, R. and C. van Hulle (1995). "The Exchange Rate in the Presence of Transactions Costs", *Journal of Finance*, 50, 1309-19.

Serletis, A. and P. Gogas (2000). 'Purchasing Power Parity, Non-linearity and Chaos', *Applied Financial Economics*, 10, 6, 615-22.

Skalin J. and T. Terasvirta (1999). 'Another Look at Swedish Business Cycles, 1861-1988', *Journal of Applied Econometrics*, 14, 359-78.

Taylor, A.M. (2002). 'A Century of Purchasing Power Parity', *Review of Economics and Statistics*, 84, 139-50.

Terasvirta, T. (1994). 'Specification, estimation, and evaluation of smooth transition autoregressive models', *Journal of American Statistic Association*, 89, 281-12.

Terasvirta, T. and H. M. Anderson (1992). 'Characterizing Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Models', *Journal of Applied Econometrics*, 7, S119-36.

Tong, H. (1983). *Threshold Models in Nonlinear Time Series Analysis*, New York: Springer-Verlag.

Tong, H. (1990). *Non-linear Time Series: A Dynamical System Approach*, Oxford University Press, Oxford.

Tsay, R. (1989). 'Testing and Modeling Threshold Autoregressive Processes', *Journal of the American Statistical Association*, 84, 231-40.

Yotopoulos, P.A. (1996). *Exchange Rate Policy for Trade and Development,* Oxford University Press.