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Modelling real exchange rate effects on output performance in Latin America

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This article empirically analyses real per capita GDP growth for six Latin American countries (Argentina, Brazil, Chile, Columbia, Mexico, Venezuela) in terms of real exchange rate depreciations, inflation and US interest rates, focussing on the role of the real exchange rate. We find evidence of nonlinearity in this relationship, which we capture through a smooth transition regression model. With the exception of Mexico, nonlinearity in economic growth is associated with changes in the real exchange rate, with depreciations leading to different relationships compared with appreciations. Regimes for Mexico are associated with the past growth rates, with effectively symmetric effects of real exchange rate changes. Although our results are in accord with other recent literature in that depreciations may have negative effects for growth, the asymmetries we uncover indicate that these effects depend on the conditioning state.

1. Introduction

The effect of the real exchange rate on output is extremely important for developing countries and is a subject of great debate among economists. The orthodox view sees a real depreciation as expansionary with the substitution of imports with home goods and increased exports putting the economy on a path of greater sustained growth (Dornbusch, 1988).¹ The *New Structuralist* school (see inter alia Díaz-Alejandro, 1963; Krugman and Taylor, 1978), on the other hand, emphasizes that a real depreciation could be contractionary. They argue

that in a typical semi-industrialized economy, inputs for manufacturing are largely imported and working capital from banks is subject to rationing. In this context, a sudden devaluation will sharply increase firms' input costs and the need for working capital, which could only be obtained at high interest rates; these effects may offset the positive impact of the depreciation on international trade and firms may choose to reduce production; see Lizondo and Montiel, (1989) for a review.

According to the empirical evidence, contractions in output are frequently preceded by overvaluation of the real exchange rate, with positive growth

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¹This has led the World Bank and the IMF to use devaluations as an important tool in their stabilization programmes. See Edwards (1989a) for an extensive analysis on this issue.

episodes accompanied by appreciation of the real exchange rate (see for example Kiguel and Liviatan, 1992; Razin and Collins, 1997; Kamin and Rogers, 2000). On the other hand, using different sets of countries and a panel approach, Edwards (1986, 1989b) and Ahmed (2003) find real exchange rate depreciations to have negative effects on growth. Although these articles have made important contributions to our understanding of the nature of depreciation effects on output in developing economies, there have been few attempts to distinguish the conditions under which depreciations can be contractionary. Exceptions are Agénor (1991) and Ahmed *et al.* (2002), who underline the difference between expected and unexpected changes in the exchange rate and between developed and developing economies, respectively.

The present article contributes to the literature on the effects of changes in the real exchange rate by applying nonlinear models to study output in six Latin American countries.² By using time series analysis focussed on individual countries, we allow their responses to differ. Further, the smooth transition regression (STR) approach we use is sufficiently flexible to capture possibly asymmetric effects and hence to explore whether real depreciations vs. real appreciations, or the magnitudes of these, have different effects. Through the STR methodology we seek to distinguish 'regimes' in the relationship between the rate of real output growth and its explanatory variables. Although our methodology searches over a number of possible regime indicators (past output growth, inflation, real exchange rate changes, US interest rates and where relevant, oil production), we find changes in the real exchange rate to be the indicator of regime switches for five of the six countries, namely Argentina, Brazil, Chile, Columbia and Venezuela. Indeed, in most cases the 'regimes' we identify can be associated with appreciations vs. depreciations in the real exchange rate, implying that changes in the real exchange rate have asymmetric effects.³ Mexico is the exception, where the regime indicator is lagged GDP growth.

The article is structured as follows. After outlining the economic framework and the variables we employ in Section II, Section III reviews the STR methodology we apply to capture nonlinearities.

Substantive empirical results are presented and discussed in Section IV, including nonlinearity test results, estimated models and dynamic multipliers for the effects of appreciations and depreciations on growth. Concluding remarks are offered in Section V.

II. The Economic Framework and Variable Definitions

As a reference to determine the variables to be included in our models, we use the economic framework suggested by Kamin and Rogers (2000). On the basis of a model where real output depends on domestic demand and net exports, they obtain the specification

$$y = f(e, \pi, i^{US}, y^{US}) \quad (1)$$

where y is real output, e is the real exchange rate, π denotes the domestic rate of inflation, i^{US} the US interest rate and y^{US} US real income. In this expression, the latter three determinants have unambiguous effects on output: the inflation rate affects it negatively because it provokes inefficient allocation of resources due to distortions in relative prices and higher administration costs for firms, for example (see De Gregorio, 1992; Sarel, 1996); the international interest rate is expected to have a negative effect, due to its impact on net capital inflows (Calvo *et al.*, 1996), and a positive effect can be anticipated for world real income through a higher demand for exports (Agénor, 1991).

However, as mentioned above, the effects of the real exchange rate are ambiguous. In particular, positive effects on net exports can be offset by negative impacts on output linked to (among other effects) higher costs of imported inputs and working capital; Kamin and Rogers (2000) interpret the empirical evidence on these terms. Following Edwards (1989b, c), Chinn (2006) and others, we compute the real exchange rate as $e = E \times (P_T^*/P_N)$, where the bilateral nominal exchange rate with the US is used to measure E and the US wholesale price index is adopted for P_T^* , whilst P_N is measured by the domestic Consumer Price Index.

² Most empirical studies (including Edwards, 1986, 1989a; Kamin and Rogers, 2000) assume linearity for regressions explaining the rate of growth. However, linearity is merely a convenient assumption. Moreover, by analysing each country separately, we are able to explore a rich set of possibilities for the nature of nonlinearity without imposing constancy across countries. In that sense, our approach is complementary to a panel analysis.

³ Although many studies analyse asymmetric behaviour or relationships over the business cycle, analyses of regimes defined in terms of the real exchange rate are scarce. Indeed, we are aware only of research linked to asymmetric exchange rate pass-through into import prices (see Yang, 2007, and references therein).

Our analysis treats international variables as exogenous to domestic growth. Thus, current values of US interest rates and oil production are permitted in our models since they depend primarily on the US economy and the conditions in international markets. In turn, although the real exchange rate is influenced by domestic as well as international factors, we take the view of Ahmed (2003) that economic theory points to the real exchange rate as being causally prior to output in the contemporaneous period, since feedback effects from output to the real exchange rate through changes in domestic compared with foreign productivity is a long run phenomenon.⁴ Kamin and Rogers (2000) also treat the real exchange rate as causally prior to output. However, lagged values of inflation are used in our models to avoid endogeneity problems with this variable.

In practice, we use the log of domestic inflation to reduce the otherwise extreme values of inflation observed in periods of very high inflation and to obtain a more symmetric distribution (see Sarel, 1996, for a wide discussion on this point). It should be noted that US output is not included in the reported results since it was not statistically significant.⁵

Prior to estimation, we need to decide whether the variables should be differenced. Statistically, unit root tests on the real exchange rate, inflation and interest rates do not always give clear answers. For the real exchange rate, we use the rate of depreciation (or appreciation) in preference to the level in order to eliminate the apparently nonstationary trending behaviour exhibited by some Latin American countries over our sample period. Both the level and difference of US interest rates were investigated, with essentially similar results. The reported results are based on the level, so that (through the estimation of coefficients) the model can select the difference where appropriate.

Therefore, we model output, measured in our case by the percentage growth in per capita GDP (Δy_t), as a function of the percentage change in the real bilateral exchange rate with the US (Δe), log inflation (π) and the nominal US interest rate (i^{US}). As it is important to capture the dynamics of growth, we consider up to two lags of all variables, including the dependent variable. In addition, due to its importance for these economies, growth in oil production (Δo_t) is included for Mexico and

Venezuela, but only the current value is included in order to conserve degrees of freedom. Annual data are used, with the longest sample for our estimations being 1951–2000 for Mexico. Appendix Table A1 provides details of all countries sample periods and the source of the data we analyse.

III. Smooth Transition Regression Methodology

In the following section we introduce our STR modelling methodology. The next section then outlines the dynamic analysis used to examine the properties of the models.

STR Modelling

The STR model we utilize can be defined as follows:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^n \beta_i x_{ti} + F(z_t) \left(\alpha_1 + \sum_{i=1}^n \eta_i x_{ti} \right) + \varepsilon_t \quad (2)$$

where the dependent variable (Δy_t) is the annual growth rate in per capita real GDP, x_{ti} are the observations on n explanatory variables ($i = 1, \dots, n$), ε_t is an independent and identically distributed disturbance, with mean zero and variance σ^2 . Nonlinearity is captured through the transition function, $F(z_t)$, which is a function of an explanatory variable, conveniently denoted by z_t . This function F is bounded by $0 \leq F \leq 1$, with the extremes $F=0$ and $F=1$ corresponding to distinct 'regimes'. A distinct linear relationship applies between y_t and the explanatory variables within each regime, with x_{ti} having coefficient β_i , when $F=0$, whereas when $F=1$, this coefficient becomes $\beta_i + \eta_i$, with a corresponding shift for the intercept. Intermediate values of F define situations where the model is a mixture of the linear models corresponding to these two regimes. These models are now widely applied in a univariate context, for which van Dijk *et al.* (2002) provide a review, while Teräsvirta (1998) discusses the regression counterpart we employ in Equation 2.

We do not specify *a priori* the transition variable z_t that determines the regimes in Equation 2. Nevertheless, for plausible transition variables such as real depreciation or lagged growth, we anticipate regimes associated with high vs. low values of z_t .

⁴ Our exchange rate measure is an annual average, and not an end-of-year value, as the latter would imply output reacting to a future exchange rate.

⁵ This result is not surprising, given that several authors have reported that US and Latin American business cycles are largely independent (see Mejia-Reyes, 2000; Kose *et al.*, 2003; Carrasco and Reis, 2006).

this could, for example, reflect regimes associated with the business cycle, as in Sensier *et al.* (2002). To ensure F is a monotonically increasing function of z_t , we use the logistic function⁶

$$F(z_t) = \frac{1}{1 + \exp\{-\gamma(z_t - c)\}}, \quad \gamma > 0 \quad (3)$$

where γ is the slope of the transition function, and c is the threshold parameter that indicates its location in relation to observations on z_t at $z_t = c$, then $F = 0.5$.

We use the methodology of Öcal and Osborn (2000) and Sensier *et al.* (2002) to specify the STR model. At the first stage, a linear model based on Equation 1 is estimated by following a 'general-to-specific' strategy in order to determine the relevant explanatory variables; the initial general model contains contemporaneous and lagged values of the explanatory variables as indicated above. The final linear model selected is the one minimizing the Akaike Information Criterion (AIC).

Based on this (specific) linear model, two non-linearity tests are computed. The first is obtained by testing the joint significance of the cross-product terms arising from a first-order Taylor series expansion of $F(z_t)$ in Equation 2, while the second tests a simple version of a threshold model where the intercept (only) changes in relation to the unknown threshold value of z_t (see Hansen, 1997). For both tests, we consider the possibility that the nonlinearity is associated with each explanatory variable, one by one. Although the former test is more general, it may suffer from power problems due to the relatively large number of parameters (namely, 10 or 11) subject to test in samples of only moderate size. As a single parameter test, the latter is more parsimonious; see Mejía-Reyes *et al.* (2004) for further details.

If linearity is rejected, we do not necessarily associate this with the variable giving the strongest evidence of nonlinearity. Rather, our procedure searches over all explanatory variables (including lags), in order to find the one that yields the lowest residual sum of squares in the STR model of Equation 2. Subsequent to this selection, and in order to produce a reasonably parsimonious model, we drop redundant explanatory variables using the AIC. Estimation of the final model consisting of Equations 2 and 3 is undertaken by nonlinear least squares. Statistics presented for the final STR

model include AIC, the Schwarz information criterion (SIC) and the conventional R^2 for model comparison purposes. In addition, results of the specification tests of Eitrheim and Teräsvirta (1996) are reported.

Dynamic analysis

To aid interpretation of our models, we compute dynamic multipliers for the effects on growth of depreciation and appreciation in the real exchange rate. Because the STR model is nonlinear, the response to a depreciation and an appreciation are not necessarily symmetric. Further, the effects of these changes are (in general) regime-dependent, so that the values taken by other explanatory variables can play a role in the estimated responses to changes in the real exchange rate. Our results report dynamic multipliers calculated assuming that the control variables (the inflation rate and the US interest rate) take values equal to their sample mean, with lagged growth rates needed to initialize the model also set at their sample means.

Provided that the transition variable is exogenous, the dynamic multipliers can be obtained analytically. However, if the transition variable is a lag of y_t then regime switches are endogenous and the computation of dynamic multipliers requires the use of simulation techniques, as developed by Koop *et al.* (1996) for impulse response analysis in nonlinear models.⁷ In our case this applies for Mexico.

To examine the effects of a change in the real exchange rate, we compute three sets of dynamic forecasts for the per capita GDP growth rate. The first 'baseline' set specifies changes to the real exchange rate as zero. The two further sets assume a given rate of depreciation or appreciation (as appropriate), with the dynamic multipliers then obtained by subtracting the baseline forecasts from these values. These latter sets assume a ten percent depreciation or appreciation for each of the first three periods, with no further changes in the real exchange rate thereafter. While we could examine the effect of a one-off depreciation/appreciation, we prefer to more fully reflect dynamic interactions between the transition function and lagged changes in real exchange rates by examining the effects of a sustained change. Dynamic multipliers are reported for the

⁶ An exponential transition function is also sometimes used in an STR model. However, the logistic form is more appropriate in our context, where real exchange rate appreciations vs. depreciations may have different effects.

⁷ The calculation of the dynamic multipliers for a real depreciation/appreciation in the two regimes for Mexico is discussed in Appendix 2 of Mejía-Reyes *et al.* (2004).

Table 1. Nonlinearity test results

Transition variable	Argentina	Brazil	Chile	Colombia	Mexico	Venezuela
Δy_{t-1}	0.878 0.379	0.186 0.158	0.177 0.878	0.754 0.350	0.079 0.910	0.559 0.696
Δy_{t-2}	0.524 0.658	0.752 0.852	0.118 0.609	0.964 0.456	0.474 0.017	0.163 0.934
Δe_t	0.267 0.004	0.243 0.024	0.003 0.892	0.521 0.800	0.452 0.966	0.013 0.889
Δe_{t-1}	0.371 0.503	0.825 0.952	0.322 0.810	0.235 0.233	0.182 0.354	0.152 0.107
Δe_{t-2}	0.548 0.247	0.434 0.432	0.343 0.078	0.576 0.160	0.406 0.962	0.017 0.069
π_{t-1}	0.316 0.018	0.680 0.098	0.069 0.763	0.411 0.479	0.134 0.058	0.104 0.525
π_{t-2}	0.016 0.042	0.594 0.196	0.510 0.399	0.693 0.949	0.046 0.244	0.291 0.243
i_t^{US}	0.287 0.586	0.237 0.308	0.009 0.889	0.274 0.296	0.006 0.353	0.049 0.118
i_{t-1}^{US}	0.169 0.741	0.242 0.774	0.006 0.076	0.652 0.532	0.037 0.437	0.344 0.428
i_{t-2}^{US}	0.325 0.206	0.117 0.371	0.004 0.410	0.661 0.869	0.174 0.139	0.401 0.546
Δo_t	N/A N/A	N/A N/A	N/A N/A	N/A N/A	0.117 0.020	0.172 0.581

Notes: For each potential transition variable, the results of two tests are presented as p -values; the first is STR test and the second is the threshold test. N/A indicates not available because Δo_t does not appear in the regression model for that country.

period of the initial change and ten subsequent periods.

IV. Results

Our primary interest focuses on the nature of the relationship given by Equation 1, acknowledging the possibility that this relationship may be nonlinear. This section, therefore, discusses both the nonlinearity test results and the estimated nonlinear STR models.

Nonlinearity tests

Results for the nonlinearity tests described in Section 'STR Modelling' are presented (in the form of p -values) in Table 1. Two p -values are reported in each cell: the first corresponds to the first-order Taylor series approximation of the STR model Equation 2, while the second is the corresponding value for the threshold model approximation. Thus, each gives a p -value for testing the null of linearity against the nonlinear alternative where the

explanatory variable in the first column acts as the transition variable.

With the single exception of Colombia, Table 1 provides evidence of nonlinearity for each country. Although the test yielding the lowest p -value differs, this lowest p -value is obtained for Argentina, Brazil, Chile and Venezuela when the nonlinearity is a function of changes in the current real exchange rate. Except for Brazil, the statistic is significant at around 1% or less. Thus, it appears that real exchange rate depreciations above some value for these countries may trigger different responses of the growth rate to the variables of the model. The evidence of the table is generally clear that nonlinearities are associated with real exchange rates, since the p -value for this case is markedly lower than that for other variables.⁸ Of these four countries, it is only for Chile that another variable (namely, US interest rates) achieves a similar significance level.

Little evidence of nonlinearity related to real exchange rate changes is uncovered for Mexico, but evidence (significant at 2% or less) is found in relation to past growth rates, values of US interest rates and/or oil production. It is noteworthy

⁸ Note that the lowest p -value for Venezuela is for lagged, rather than current, real exchange rate depreciations.

that although nonlinearity in relation to inflation is considered as a possibility through the tests of Table 1, in no case is such a test statistic significant at the 1% level.

Although the results of Table 1 indicate that nonlinearity may be associated primarily with changes in the real exchange rate, nevertheless we reconsider the appropriate variable generating the nonlinearity as part of our nonlinear modelling strategy in the next subsection.

Estimated models

Our search procedure over all explanatory variables selects current depreciation as the transition variable for the nonoil producing countries, namely Argentina, Brazil, Chile and Columbia. Therefore, the resulting STR models, reported in Table 2, have transition variable $z_t = \Delta e_t$, reinforcing the role found for this variable in the nonlinearity tests. Note, however, that in the case of Argentina, the regime-dependent coefficients are restricted to apply only to the variables of central interest, namely lagged growth and (current or lagged) depreciation, in order to obtain satisfactory results.⁹

Although the STR models are specified and estimated separately for each country, there is a remarkable similarity in the estimated transition functions.¹⁰ Specifically, the logistic transition functions for all four countries are centred very close to zero with a steep slope (associated with the relatively large estimated values for γ) indicating that the regimes detected by the nonlinear model relate to depreciations, with $F(z_t) = 1$, vs. appreciations, $F(z_t) = 0$. In other words, there appear to be asymmetric responses of growth to positive and negative Δe . Our procedure does not impose this or even impose depreciation as the transition variable; rather this outcome is selected as the 'best fit' nonlinear model for these countries. Despite the lack of evidence of nonlinearity for Columbia in Table 1, these comments apply to this country as well. The only exception is a partial one for Argentina, which has a smoother transition function.

As the general modelling methodology of Section III also leads to some difficulties in the cases of the oil-producing countries of Mexico and Venezuela,¹¹ we restrict the models for these countries in the same manner as for Argentina. In the case of Mexico, the selected transition variable is the second lag of growth in per capita GDP, while for Venezuela it is the second lag of depreciation, both of which are compatible with the results of Table 1.¹² In this latter case, the transition function is very steep and centred at a value close to zero, again implying different responses to appreciations and depreciations, although now after a lag of two years. Transition between regimes for Mexico is also steep, with past per capita growth rates above and below 3.4% implying different relationships.

Table 2 presents the estimated models for all countries, using explanatory variables listed in the first column, with the coefficient estimates (and t statistics) corresponding to the 'lower' regime ($F = 0$) in the upper part of the table. As indicated in Equation 2, estimates associated with the 'higher' regime ($F = 1$) are obtained by summing the values in the upper and lower parts of the table for a given explanatory variable.

A quick glance at the table indicates the presence of asymmetric effects. In the case of Argentina, for example, the variation of the real exchange rate has an overall (taking into account the effect of lagged values) positive effect on output growth within the appreciation regime, but a negative impact when the economy is in the depreciation regime. In turn, for Chile, the real exchange rate has a short-lived negative effect within the depreciation regime, but an overall positive impact in both regimes. Depreciation is expansionary for Brazil and Colombia, but only in the depreciation regime; in the appreciation regime there is no effect. For Mexico and Venezuela, depreciations are contractionary and expansionary, respectively, but are not regime-dependent.

Nevertheless, a simple analysis based on looking at the coefficients of depreciation is fraught with difficulty, because these coefficients do not take

⁹ For Argentina, the procedure of Section III leads to a highly parameterized model with 19 estimated coefficients, which is unreliable given the relatively small sample size available. In line with the nonlinearity test results of Table 1, current depreciation is selected as the transition variable in the restricted specification.

¹⁰ For the transition function graphs and results showing the estimated models separately for the two regimes of $F(z_t) = 0$ and $F(z_t) = 1$, see Mejía-Reyes *et al.* (2004).

¹¹ When all parameters are allowed to change over regimes, the models were not satisfactory from an economic perspective. We attribute these difficulties to the relative small sample sizes available in order to estimate these models. See Mejía-Reyes *et al.* (2004) for details.

¹² The smallest p -value for Venezuela in Table 1 results from current real depreciation as the transition variable, although this is not substantially smaller than that for the second lag of this variable.

Table 2. Estimation results for nonlinear models

Coefficient	Argentina	Brazil	Chile	Colombia	Mexico	Venezuela
Intercept	13.87 (-0.477)	6.011 (4.895)	4.246 (2.333)	1.645 (1.799)	3.157 (6.641)	3.158 (1.947)
Δy_{t-1}						
Δy_{t-2}						
Δe_t	0.260 (1.875)		0.174 (1.816)			-0.174 (-1.343)
Δe_{t-1}	-0.057 (-3.585)		-3.752 (-4.062)		-0.165 (-8.759)	
π_{t-1}			3.021 (3.521)		-0.036 (-1.859)	0.123 (3.640)
π_{t-2}				-0.280 (-1.285)	-1.097 (-6.494)	
i_t^{US}	-0.632 (-2.271)	-1.367 (-6.241)	-0.828 (-2.171)	0.409 (1.912)	0.202 (1.798)	-0.736 (-3.185)
i_{t-1}^{US}			1.451 (3.265)	-1.302 (-3.431)		
i_{t-2}^{US}				0.941 (2.650)		
Δo_t		0.706 (3.123)				
$F(z_t)$		N/A	N/A	N/A	0.201 (4.540)	0.448 (2.804)
$F(z_t) \times \Delta y_{t-1}$	-11.85 (-2.392)				-7.697 (-3.472)	3.133 (2.847)
$F(z_t) \times \Delta y_{t-2}$	0.537 (1.495)	0.500 (3.937)	-0.290 (-1.903)	5.859 (2.643)		-0.205 (-0.841)
$F(z_t) \times \Delta e_t$	-0.571 (-2.297)		-0.313 (-1.877)	-0.599 (-2.129)		
$F(z_t) \times \Delta e_{t-1}$	-0.265 (-1.936)		-0.238 (-2.063)		1.020 (2.506)	
$F(z_t) \times \Delta e_{t-2}$		0.158 (3.207)	0.139 (2.255)	0.209 (3.034)		
$F(z_t) \times \pi_{t-1}$	3.205 (3.922)			-4.527 (-4.870)		
$F(z_t) \times \pi_{t-2}$	-2.020 (-2.764)			0.737 (2.192)		
$F(z_t) \times i_t^{US}$		2.966 (7.131)	3.994 (5.726)			
$F(z_t) \times i_{t-1}^{US}$		-3.473 (-6.858)	-3.715 (-3.754)	1.824 (3.370)		
$F(z_t) \times i_{t-2}^{US}$			-1.054 (-1.840)	-1.217 (-2.540)		
$F(z_t) \times \Delta o_t$		N/A	N/A	N/A		
z_t	Δe_t	Δe_t	Δe_t	Δe_t	Δy_{t-2}	Δe_{t-2}
γ	8.873 (1.716)	999.50 (3617.0)	6711.00 (0.00002)	37.60 (0.932)	16760 (0.001)	896.1 (3601)
c	-3.179 (-0.833)	-0.719 (-46.38)	1.850 (457.1)	1.003 (3.581)	3.416 (4.988)	-1.166 (-4.676)

Notes: Values in parentheses are t -ratios. See main text for notation and model specification.

full account of the dynamics. Further, the estimated intercept is regime-dependent for Argentina and Columbia, and this also affects comparisons of growth over regimes. To analyse the depreciation effects more fully, we later undertake a dynamic multiplier analysis.

Regarding other variables, there is evidence of negative and asymmetric effects of inflation for Chile and Colombia in Table 2, but positive and asymmetric for Brazil. Inflation seems to be irrelevant for Argentina. Our models for Mexico and Venezuela do not allow inflation effects to be regime-dependent, and we find negative effects in the former case and positive in the latter. Another interesting result is that US interest rates have positive contemporaneous effects on output growth in Brazil, Chile and Columbia during depreciation regimes and in Mexico in both regimes.¹³ One interpretation is that US interest rates may here proxy the US (or international) business cycle, implying that conditions for export-led growth in Brazil, Chile, Columbia and Mexico may require both real exchange rate depreciation and rising world demand. However, the interactions are complex, since the effects of lagged US interest rates are negative for Brazil and Chile within a depreciation regime. Not surprisingly, the nonlinear models continue to show that increases in oil production are good for per capita GDP growth in Mexico and Venezuela. In general, however, the regime-dependent coefficients indicate that the impact of a depreciation (or appreciation) on growth will depend on the national and international environment applying at the time.

The diagnostic test results presented in Appendix Table A2 show that the nonlinearity evident in Table 1 is satisfactorily accounted for by our models. Other diagnostics for the nonlinear models are also generally satisfactory, although some indication of possible nonconstancy over time for the intercept remains in the model for Mexico.

Dynamic analysis

Mexico is the only case where regime changes depend on lagged growth, and hence are endogenous in our single equation context, and we begin our dynamic analysis with this case. Figure 1 shows the generalized impulse responses to a disturbance shock of ± 1 and ± 2 residual SDs for Mexico, with moderate/negative

growth being considered separately from high growth. When the initial regime is the 'normal' one (moderate/negative growth), the impulse response is close to being linear. However, at a horizon of two years there is evidence of asymmetry to positive and negative shocks, because the shock at t may be sufficiently large and positive to cause a switch to the high-growth regime ($F=1$) for $t+2$. When such a switch occurs, the lower intercept results in larger reductions in growth at the horizon of 2 in comparison with the responses to negative shocks in period 0.

For the high Mexican growth regime, note that the dynamic responses are stable despite the apparently unstable coefficient on lagged growth in Table 2, with this stability a consequence of endogenous regime-switching. Also note the clear asymmetry between large positive and negative shocks of ± 2 SDs, with both implying positive growth after two periods. Overall, the model implies that positive shocks tend to enhance subsequent growth in the high-growth regime, but not in the moderate/negative growth one.

Dynamic multipliers for all estimated nonlinear models are shown in Fig. 2 for the effect of a 10% depreciation (appreciation) per year for three years (see subsection 'Dynamic analysis' in Section III). As noted above, with the single exception of Mexico, the regimes are defined in terms of the real exchange rate.

Figure 2 indicates that the effects of a depreciation are severe for some countries. For instance, a depreciation in Argentina immediately leads to an estimated reduction in growth of more than 3% points, which increases to a 4% reduction after a year. If the depreciation is sustained for three years, growth does not rise above the baseline level (associated with no change in the real exchange rate) until three years after the initial depreciation. Notice that although the model for Argentina is asymmetric, this asymmetry is not very marked in practice despite Δe_t being the transition variable. In addition to Argentina, substantial negative effects of depreciation are seen in Fig. 2 for Chile and particularly Mexico, with lesser negative effects for Columbia.

The case of Columbia is interesting, because although the pattern of response to a sustained depreciation is similar to (though less marked than) Argentina, there is effectively no response of growth

¹³ Although they do not comment on this feature, it is notable that the linear impulse response functions plotted by Kamin and Rogers (Figure 3) also imply a positive dynamic effect of US interest rates on growth in Mexico. It is plausible that nominal US interest rates here proxy real rates that are procyclical, and hence high rates are consistent with rising Latin American exports to their main market.

Fig. 1. Generalized impulse response functions for nonlinear model for Mexico

to an appreciation. However, the effects here are relatively small and it should be recalled that our initial results (Table 1) give little support for the existence of nonlinearity in the model for Columbia. It is only in the case of Brazil that the dynamic multipliers unambiguously suggest that depreciation increases growth, while an appreciation decreases it. Although in Venezuela there is an initial increase in growth after a depreciation, this is later partially reversed. Real appreciations in both Brazil and Venezuela are associated with lower growth of around 4% points after two years.

As already discussed, Mexico is the only case where regimes are not associated with changes in the real exchange rate. It is clear, however, that despite the coefficients on the depreciation variables being constant over regimes, the endogenous regime switching leads to substantial asymmetries in the effects of depreciation vs. appreciation.¹⁴ The sustained real exchange rate depreciation is estimated to reduce growth on average by 8% points at a lag of a year, compared with an average increase of 2% for a corresponding appreciation.

It needs to be emphasized that the dynamic multipliers presented in Fig. 2 are only indications of the responses implied by the nonlinear models to positive and negative changes in the real exchange rate. Indeed, the reason for a particular outcome can lie in the apparently innocuous assumptions made. One such point is the implied growth response in Chile to a depreciation. While the coefficient estimates of Table 2 indicate that the initial effect of a depreciation in Chile is negative, positive effects feed through after a lag of two years. However, the effects in Fig. 2 for a three-year depreciation are always negative, with the initial impact of a 10% depreciation being negative and around 6% points. In terms of the model, this large effect is due primarily to the US interest rate, which has an estimated overall negative effect in the depreciation regime, but an overall positive one in the appreciation regime. Since $F=0$ in the baseline simulation with $\Delta e=0$, then the effect of a depreciation shown in Fig. 2 (compared with the baseline model) also reflects the differential effects of US interest rates in the two regimes.

¹⁴In fact, by setting the initial lagged growth rate to its sample mean when computing the dynamic responses, changes in regime can occur, because the threshold value for the regimes is fairly close to this mean.

Fig. 2. Estimated dynamic response to change in the real exchange rate

Note: In all cases it is assumed that a 10% real depreciation or appreciation takes place in each of three successive years.

V. Conclusions

This article analyses the determination of real per capita GDP growth for six important Latin American countries using nonlinear smooth transition regression models focusing on the effects of the real exchange rate. Our primary finding is that different growth effects apply depending on the sign and magnitude of real exchange rate changes. Indeed, a strong result emerging from our study of these countries is that changes in the real exchange rate generally acts as the transition variable in our growth rate regressions. Indeed, without any imposition in the form of this function, the overall implication is that appreciations and depreciations act as different 'regimes', between which the nature of the economic determination of growth differs. The exception is

Mexico where past growth acts as the transition variable.

We find that real depreciations have particularly severe contractionary consequences for Argentina, Chile and Mexico in the short-run, with less severe negative effects for Colombia. Yet, some caution must be shown regarding the policy implications, since real depreciations may have followed periods of sustained real appreciation of domestic currencies. Thus, for policy purposes, it is important that overvaluation should not be allowed given that the correction of the exchange rate will have severe consequences.¹⁵ On the other hand, most of the countries we study have implemented deep reforms that have transformed the structure of their economies, which may imply different effects from changes in the exchange rate in the future. For example, increased openness to

¹⁵ This result is evident with the currency crisis in Argentina in 2001/02 when the release from the peg with the US dollar saw Argentina's peso devalue by 70%. This was accompanied by recession and unemployment reached 30%.

Fig. 2. Continued

international trade and capital transfers may, in the medium term, lead to the tradable sectors having a larger share in domestic production, in which case real depreciations could have positive impacts overall on output growth.¹⁶

In our models, the effects of depreciations are positive for growth in Brazil and Venezuela, which may be linked to the former country being a more open economy than the others during our sample period. However, in both of these countries, the asymmetric responses imply larger negative growth consequences of real appreciation than the positive effects of depreciation. Although on different grounds to that above, we would argue in favour of avoiding overvaluation of the real exchange rate, since for Brazil and Venezuela it would imply a loss of competitiveness that slows down economic growth.

However, depreciation is not recommended either, given that its benefits for growth are relatively small and short-lived.

Overall, in the new context of more open economies and floating exchange rate regimes, it is appropriate to adopt policies that maintain the real exchange rate around its equilibrium level. However, the definition of such a level is beyond the scope of this article.

On the basis of the findings in this article, we believe that the asymmetric effects of the real exchange rate on output is a topic worthy of further analysis from both empirical and theoretical perspectives. Meanwhile, our study has emphasized that a linear framework may be too restrictive to satisfactorily capture these effects for Latin American countries.

¹⁶ Recently, Nucci and Pozolo (2001) and Hutchinson and Noy (2006) have emphasized the importance of the external sector in this process: the negative effects of depreciation on output can be stronger for a more closed economy and in the presence of capital flows reversals.

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Appendix

Table A1. Annual data

Country	Sample	GDP volume (1995 = 100)	Population	Exchange rate to US dollar	Consumer prices	Petroleum production
Argentina	1963–2000	21399BVPZF ...	21399Z..ZF ...	213..RF.ZF ...	21364...ZF ...	
Brazil	1964–2000	22399BVPZF ...	22399Z..ZF ...	223..RF.ZF ...	22364...ZF ...	
Chile	1952–2000	22899BVPZF ...	22899Z..ZF ...	228..RF.ZF ...	22864...ZF ...	
Colombia	1952–2000	23399BVPZF ...	23399Z..ZF ...	233..RF.ZF ...	23364...ZF ...	
Mexico	1951–2000	27399BVRZF ...	27399Z..ZF ...	273..WF.ZF ...	27364...ZF ...	27366AA.ZF ...
Venezuela	1958–2000	29999BVPZF ...	29999Z..ZF ...	299..RF.ZF ...	29964...ZF ...	29966AA.ZF ...

Notes: The source for all data is International Financial Statistics, published by the IMF. The Consumer Prices Index of Brazil was available electronically from the IFS from 1980, prior to this the data were taken from the IFS Yearbook 1981. The GDP of Chile and Colombia were available electronically from the IFS from 1960 and 1968, respectively, prior to this the data were taken from the IFS Yearbook 1981 in 1975 prices for both cases. Also used is the US Treasury Bill Rate (code: 11160C..ZF ...).

Table A2. Diagnostic tests for nonlinear models

Test	Argentina	Brazil	Chile	Colombia	México	Venezuela
ARCH (2)	0.713	0.509	0.295	0.903	0.562	0.134
Autocorr. (2)	0.405	0.160	0.039	0.984	0.708	0.210
Intercept constancy	0.498	0.644	0.563	0.027	0.033	0.313
Additional nonlinearity tests (<i>p</i> -value for each possible transition variable)						
y_{t-1}	0.657	0.137	0.754	0.768	0.700	0.251
y_{t-2}	0.830	0.790	0.490	0.563	0.682	0.814
e_t	0.587	0.811	0.429	0.172	0.949	0.046
e_{t-1}	0.701	0.589	0.407	0.342	0.450	0.120
e_{t-2}	0.591	0.717	0.214	0.507	0.941	0.030
π_{t-1}	0.733	0.222	0.702	0.904	0.429	0.366
π_{t-2}	0.555	0.299	0.848	0.998	0.412	0.332
i_t^{US}	0.447	0.988	0.343	0.966	0.219	0.843
i_{t-1}^{US}	0.381	0.996	0.311	0.963	0.415	0.850
i_{t-2}^{US}	0.495	0.991	0.582	0.956	0.706	0.500
o_t	N/A	N/A	N/A	N/A	0.828	0.426

Notes: All results are presented as *p*-values. ARCH (2) is the Lagrange multiplier test of second order of Engle (1982). Tests of no autocorrelation to order 2 and Intercept constancy are those of Eitrheim and Teräsvirta (1996). The additional nonlinearity test (Eitrheim and Teräsvirta, 1996) is the test of no missing linear terms, and no additional nonlinearity (not ignoring the 'holes').