Real Exchange Rate Persistence and Country Characteristics

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TEP Working Paper No. 0917

March 2017

Trinity Economics Papers

Department of Economics

Trinity College Dublin

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March 7, 2017

Abstract

This paper examines the persistence of real exchange rates across the world. We employ univariate time series techniques on a country-by-country basis allowing for deterministic structural breaks and nonlinearities in the adjustment process. Our findings suggest that bilateral exchange rates and industrial countries display the highest rates of persistence. We retrieve evidence indicating that higher inflation, nominal exchange rate volatility, trade openness and proximity to reference country are associated with faster rates of real exchange rate convergence. Conversely, international financial integration is only found to be a significant factor at the country group level, with differential effects across cohorts.

Keywords: Real Exchange Rate, Parity Deviations, Cross-Country Persistence Differences, Structural Determinants
JEL: F31, F41

*We thank the IRC for financial support. We are grateful to Gianluca Benigno, Menzie D. Chinn, Jesús Fernández-Villaverde, Vahagn Galstyan and Philip R. Lane for invaluable comments. A supplementary appendix can be found at `http://michael-curran.com/research/Persistence_SupplementaryAppendix.pdf`

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1 Introduction

Our paper contributes to the literature on the persistence of real exchange rate parity deviations. Indeed, this is a topic that has often featured at the heart of exchange rate policy debates since the rate at which the real exchange rate converges can determine the extent to which the macroeconomic system is self-equilibrating (Benigno, 2004; Taylor and Taylor, 2004; Chinn, 2012; Benigno and Romei, 2014; Bergin *et al.*, 2016; Burnside *et al.*, 2016; Engel, 2016).[1] Although a large body of empirical work in this field exists, most of it has focused on the case of the industrialized world. The relatively few studies that have considered developing countries have reached opposing conclusions about their rates of parity reversion. Importantly, many of these studies have failed to correctly capture the dynamics of the real exchange rate, which in turn has led to very high estimates of the persistence of purchasing power parity (PPP) deviations.[2] In fact, most of the investigations since 1996 adopt a linear panel data approach without recognizing the heterogeneous nature of cross-country real exchange rate series.[3]

In this paper, we compile new estimates across 151 countries on rates of both bilateral and effective real exchange rate parity reversion pertaining to the period 1973-2010. Our study is novel in that it is a global analysis, which endeavors to more accurately capture the dynamics of real exchange rates by accounting for deterministic structural breaks and adjustment nonlinearities in univariate country-by-country time series specifications.[4] Our findings are consistent with the notion of nominal rigidities presiding over the short run, with rates of mean-reversion typically higher for multilateral exchange rates. More specifically, the median half-life of real exchange rate parity deviations over the entire sample is found to be considerably less than two years in the case of bilateral exchange rates, and less than one year in the case of effective exchange rates. Furthermore, industrial countries are reported to have the slowest rates of adjustment, while, from a geographical standpoint, Latin America and Africa tend to be characterized by the fastest rates of real exchange rate convergence.

Our analysis shows that a one-size-fits-all setup may not be suitable for examining real exchange rate dynamics globally. Specifically, we find that while for some countries linear specifications of real exchange rate adjustment suffice, nonlinear dynamics are more appropriate for others. Nonlinear adjustment of the real exchange rate can be rationalized from both traded goods (Dumas, 1992; Sercu *et al.*, 1995; Heinen *et al.*, 2014) and financial market (Kilian and Taylor, 2003; Gabaix and Maggiori, 2015; Farhi and Gabaix, 2016) perspectives, although the latter of the two appears to be empirically more important.[5,6] Moreover, some series, particularly those of emerging and developing economies, exhibit deterministic structural breaks while others do not. Therefore, neglecting such discrepancies and imposing

[1] With price indices equalized in an arbitrary base year, studies analyze how fast relative prices denominated in the same currency revert to a constant long-run mean not necessarily equal to one (Alba and Papell, 2007).

[2] Carvalho and Nechio (2011) show that real exchange rates adjust very slowly even at the sectoral level.

[3] Examples include Frankel and Rose (1996), Jorion and Sweeney (1996), MacDonald (1996), Wu (1996), Papell (1997), Papell and Theodoridis (1998, 2001), Murray and Papell (2005), Alba and Papell (2007), Chinn and Wei (2013), and Lothian (2016). These studies support the doctrine of PPP as a long-run proposition.

[4] The univariate time series approach is preferred due to the high degree of heterogeneity in dynamics across countries, which may obscure results in a panel setting, and since we seek to provide an initial descriptive survey of country-specific aggregate rates of adjustment. Studies of this variety have been relatively scarce.

[5] See Michael *et al.* (1994), Michael *et al.* (1997), Obstfeld and Taylor (1997) and Taylor *et al.* (2001) for early studies on the empirical relevance of nonlinearities in real exchange rate adjustment.

[6] In a nonlinear dynamic stochastic general equilibrium setting, Seoane (2016) shows that time-varying parameters change most during periods of large real exchange rate corrections.

homogeneous dynamics may be detrimental to any cross-country study of parity convergence.

If international commodity trade only commences once price differentials between countries exceed a specific threshold, which is determined by the costs of trading (e.g. taxes, transport costs, foreign exchange cover etc.), then the real exchange rate can exhibit nonlinear dynamics. Below this threshold, the marginal cost of international arbitrage surpasses the marginal benefit leading to no trade, and the real exchange rate consequently fluctuates freely just like a random walk. However, outside this inner band, international trade becomes profitable and the real exchange rate begins to revert back to a long-run equilibrium.

From the asset market viewpoint, nonlinear exchange rate behavior may be driven by the existence of heterogeneous foreign exchange traders. Specifically, when the exchange rate is in the local neighborhood of its equilibrium level, its dynamics are driven by technical analyses as 'Chartist' tendencies prevail amongst market participants. This results in non-stationarity for small disequilibria. Equally, the closer the exchange rate is to its 'latent' equilibrium within some defined interval, the greater the uncertainty and discrepancy in beliefs surrounding whether it is under or overvalued, and the more the real exchange rate meanders like a random walk as the influence of noise traders begins to dominate. On the other hand, for increasingly larger misalignments with the equilibrium, focus is more likely to switch to fundamentals and consensus among traders regarding models to be employed is likely to rise. Thus, as beliefs concerning the direction of the deviation converge, speculation by 'Fundamentalists' prompts reversion toward equilibrium.[7]

This paper is also the first to parametrically investigate the potential factors contributing to the variation in real exchange rate persistence estimates across the world.[8,9] Previewing some of the main cross-section results, we find that real exchange rate convergence tends to be typically faster in countries characterized by higher inflation, nominal exchange rate volatility (or regime flexibility), trade openness and proximity to reference country. In addition, we obtain some modest evidence suggesting that higher productivity growth is associated with slower mean-reversion, although results are more mixed when examining country sub-samples. Conversely, the degree of de facto international financial openness is found to matter only at the country group level according to our parametric findings, with cross-country discrepancies perhaps obscuring results in full samples. In particular, we identify a positive correlation between persistence and international financial integration for developing economies, while a negative link for advanced economies. Further qualitative assessment suggests that the debt and reserve components of the financial measure may play significant roles in the result.

As far as we are aware, only two global studies examine real exchange rate parity reversion on a country-by-country basis, both of which use linear methods. Cheung and Lai (2000a) examine the dynamics of monthly bilateral real exchange rates during the post-1973 period for 94 countries vis-à-vis the U.S., reporting that PPP deviations tend to peter out faster for developing nations than for industrial countries.[10] Meanwhile, Cashin and McDermott

[7] Survey data such as that from the World Economic Survey administered quarterly by the ifo Institute for Economic Research offers some indication that market participants' views become more homogeneous as the exchange rate deviates further away from its PPP equilibrium.

[8] A survey of the relevant literature reveals that studies on the drivers of the persistence of real exchange rate misalignments are limited in number, with virtually no existing work of the global and parametric nature. Conversely, a plethora of papers can be found on the drivers of the level of the real exchange rate.

[9] The majority of studies on real exchange rate persistence to date have relied on bilateral rates. However, as Black (1986) points out in his comments on the work by Mussa (1986), while bilateral real exchange rate parity with all individual trading partners implies multilateral parity, deviations from bilateral PPP do not necessarily imply deviations from multilateral PPP.

[10] The authors note the limitations of panel methods under heterogenous country exchange rate dynamics.

(2006) examine the persistence of monthly real effective exchange rate parity deviations over the post-Bretton Woods period across 90 developed and developing countries. The authors find that the average half-life for advanced economies is about 8 years, twice as long as the estimates of previous studies. In comparison, the half-life estimates for developing countries are shown to be evenly spread, with most of the deviations from parity being permanent. The authors' result of slower parity reversion for lower-income nations coincides with the conclusions of Froot and Rogoff (1995). Our study builds on these two pieces of empirical work in three respects. First, we allow for adjustment nonlinearities and structural breaks (single or multiple) in real exchange rates. Second, we consider a much broader range of countries and more recent data. Third, we show how measures of persistence vary across specifications as well as both bilateral and multilateral real exchange rates in order to avoid bias and draw comparisons.

In relation to the potential drivers of cross-country differences in real exchange rate persistence, Cheung and Lai (2000a) non-parametrically document the cross-section link between half-lives of parity deviations and structural characteristics. They find a negative rank correlation between the half-life and inflation, and a positive correlation when considering government expenditure instead. Although they do not explicitly examine the link between real exchange rate persistence and nominal exchange rate rigidity, the authors highlight that the PPP rejection rate is significantly lower for currencies pegged to the U.S. dollar. In a later study for 24 developing economies, Cheung and Lai (2008) conclude that there is no significant evidence that greater nominal exchange rate flexibility engenders either faster or slower real rate adjustment. The importance of nominal exchange rate volatility in the adjustment process has been hotly debated at least as far back as Nurkse (1944) and Friedman (1953). Husain *et al.* (2005) suggest that the value of an increasingly flexible exchange rate system rises as a country becomes richer and more financially developed.

For 38 middle-income economies, Achy (2003) finds that higher nominal exchange rate volatility, productivity growth and government spending lead to slower mean-reversion in the bilateral real exchange rate, while higher inflation and capital mobility tend to attenuate the persistence of deviations from parity. The result pertaining to the first of these three variables runs counter to the finding of Cashin and McDermott (2006) that an inverse relation between nominal exchange rate volatility and the persistence of real exchange rate misalignments exists. Moreover, it opposes the empirical result of Alba and Papell (2007) that countries with moderate nominal exchange rate volatility display stronger evidence of (relative) PPP. Cashin and McDermott (2006) also find that mean-reversion tends to be faster in high-inflation countries. Conversely, they report that discrepancies in productivity growth, government expenditure, and trade openness are not significantly related to the observed heterogeneity in half-lives. Aside from aggregate-level studies, some research has also scrutinized the covariates of sectoral real exchange rate persistence (Cheung *et al.*, 2001; Mayoral and Gadea, 2011).

The remainder of the paper is organized as follows. Section 2 describes our empirical approach and is split into three subsections: 2.1 on estimating real exchange rate persistence, 2.2 on documenting some of the potential drivers of real exchange rate convergence as guided by economic theory and empirical evidence, and 2.3 on estimating specifications relating persistence to covariates. Section 3 describes the underlying data set employed. In section 4, we discuss results and provide a cross-country descriptive analysis of the estimated half-lives and (structural) country characteristics thought to be playing a role in the degree of real exchange rate inertia. Section 4 also offers a more refined analysis by assessing real exchange rate persistence regression results. Finally, section 5 concludes.

2 Empirical Approach

2.1 Real Exchange Rate Persistence

The first part of our empirical study produces estimates of real exchange rate persistence and ultimately entails two phases. The first step is to define a measure of the persistence of real exchange rate parity deviations and subsequently obtain estimates of this measure for different countries. The second stage involves ascertaining whether different country groups are characterized by disparate rates of mean-reversion and relies on standard differences-in-mean and median hypothesis tests.

In order to achieve our first objective, we assume three different but plausible processes for the real exchange rate and proceed to estimate each one separately, commencing with the simplest specification. Afterward, we are able to gauge the degree of shock persistence based on the parameters of the model in question. The measure of persistence we employ in our investigation is the half-life. The concept of the half-life may be defined as the duration of time it takes for a unit impulse to dissipate permanently by one half from the occurrence of the initial shock (Cashin and McDermott, 2006).

In the analysis that follows, we do not distinguish between nominal and real shocks. Rather, the error term in our equations will always refer to a 'composite shock' that incorporates the various individual disturbances. If the real exchange rate is a mean-reverting process, no type of shock should impart a permanent effect on the series in the long run.

2.1.1 AR(1) Model

The first specification of the real exchange rate we consider for each country is the following simple AR(1) process

$$\Delta r_t = \alpha + \rho r_{t-1} + \epsilon_t. \tag{1}$$

In particular, r_t denotes the natural logarithm of either the bilateral or multilateral real exchange rate. The estimate of the half-life, $\widehat{h}$, is obtained from

$$\widehat{h} = \frac{\ln 0.5}{\ln \widehat{\gamma}} \tag{2}$$

where $\widehat{\gamma} = 1 + \widehat{\rho}$ is a complete scalar measure of persistence. Essentially, under mean-reversion a proportion $\widehat{\gamma}$ of any shock will remain after one period, $\widehat{\gamma}^2$ of it will remain after two periods and, more generally, $\widehat{\gamma}^n$ of the deviation will persist after n periods.

2.1.2 General Higher-Order Autoregressive Model

Next, we augment equation (1) to account for the possibility of serial correlation in the error terms, a trend, structural breaks in the mean or trend line, and structural shifts in the slope of the trend. Specifically, we estimate the following general higher-order specification

$$\Delta r_t = \alpha + \mu t + \sum_{i=1}^{m} \theta_i D_{B(i)} + \sum_{j=1}^{n} \lambda_j D_{T(j)}(t) + \rho r_{t-1} + \sum_{k=1}^{q} \beta_k \Delta r_{t-k} + \epsilon_t \tag{3}$$

where, defining τ as the time to break, D_B is a level intercept break dummy that equals 1 when $t > \tau$ and 0 otherwise, D_T is a trend slope break dummy that equals $t - \tau$ if $t > \tau$ and 0 otherwise, and $q = p - 1$ is the lag length with p representing the order of the AR process.[11]

[11] $q_{max} = 12$. Details on lag selection are relegated to the online appendix.

As suggested by Andrews (1993) and Andrews and Chen (1994), one can again employ the formula in (2) to obtain the half-life of parity deviations. However, this formula assumes a monotonic rate of decay which is not necessarily a feature of higher-order AR models (Cheung and Lai, 2000b).[12] Consequently, in such cases it is preferable to also compute the half-life directly from the impulse response function (IRF). Formally, the IRF half-life, denoted by l_h^{IRF}, is given by $IR(l_h^{IRF}) \leq 0.5$ such that $IR(l_{h+x}^{IRF}) < 0.5$ for $x = 1, 2, \ldots$, where the IRF is given by $IR(h) = f_{11}^h$ for $h = 0, 1, 2, \ldots$, and f_{11}^h denotes the (1,1) element of $\mathbf{F}^h$ with $\mathbf{F}$ given by the $(p \times p)$ matrix[13]

$$\begin{bmatrix} \gamma + \beta_1 & \beta_2 - \beta_1 & \beta_3 - \beta_2 & \cdots & \beta_{p-1} - \beta_{p-2} & -\beta_{p-1} \\ 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}. \tag{4}$$

2.1.3 ESTAR Model

The final specification we estimate incorporates potential nonlinearities in the dynamics of the real exchange rate as mentioned in Section 1. In particular, we focus on an exponential smooth transition autoregressive (ESTAR) representation of the real exchange rate [14]

$$\Delta r_t = \alpha + \rho r_{t-1} + \sum_{k=1}^{q} \beta_k \Delta r_{t-k} + \mathbf{\Phi} \boldsymbol{Z} + \left(\alpha^* + \rho^* r_{t-1} + \sum_{k=1}^{q} \beta_k^* \Delta r_{t-k} + \mathbf{\Phi}^* \mathbf{Z} \right) F(\psi, c; r_{t-d}) + \epsilon_t \tag{5}$$

where $F(\psi, c; r_{t-d}) = 1 - \exp\left(-\psi(r_{t-d} - c)^2\right)$ is the exponential transition function and $\mathbf{Z}$ is a $(z \times 1)$ vector of structural terms that were employed in (3).

The transition function governs the nonlinear behavior of the series and ultimately the rate of mean-reversion given that each observation has the effective summary adjustment coefficient $\rho + \rho^* F(.)$. r_{t-d} is the transition variable with d acting as the delay parameter, while c is a threshold parameter representing the equilibrium level of $\{r_t\}$.[15] The "slope" or "smoothness" parameter $\psi > 0$ determines the speed of transition between the two extreme inner and outer regimes corresponding to the lower and upper bounds respectively of $F(.) \in [0, 1]$. When $r_{t-d} = c$ for a given $\psi > 0$, the inner regime is realized and (5) reduces to the linear AR(p) model

$$\Delta r_t = \alpha + \rho r_{t-1} + \sum_{k=1}^{q} \beta_k \Delta r_{t-k} + \mathbf{\Phi} \mathbf{Z} + \epsilon_t. \tag{6}$$

[12] Examining the dynamics of the real exchange rate, Crucini *et al.* (2014) illustrate that regardless of whether nominal rigidities are present in the form of sticky prices or sticky wages, monetary disturbances engender monotonically decaying impulse responses. By contrast, technology and government spending shocks may generate a more persistent, hump-shaped response of the real exchange rate by leading to immediate real interest rate changes that reinforce the initial impact of the shock soon afterward.

[13] The dimension of the square matrix is determined by the order p of the AR process. Moreover, if the IRF displays an oscillatory pattern, we locate the final point at which the 0.5 threshold is crossed. See appendix B for further information on the derivation of matrix $\mathbf{F}$ and the impulse responses.

[14] Before applying the ESTAR model, we implemented tests of linearity versus smooth transition type nonlinearities as suggested by Teräsvirta (1994). The supplementary appendix shows the linearity test results.

[15] d is the amount of time required for the real exchange rate to respond to a deviation from equilibrium. To select a value for d, we repeat the linearity test mentioned in footnote 14 for $d = 1, 2, \ldots, 12$ and choose the value of d that minimizes the p-value of the test.

Of course, if ψ is insignificantly different from zero the model of concern is also linear, with a specification of the form of (6). On the other hand, we attain the outer regime and a different AR(p) model

$$\Delta r_t = (\alpha + \alpha^*) + (\rho + \rho^*) r_{t-1} + \sum_{k=1}^{q} (\beta_k + \beta_k^*) \Delta r_{t-k} + (\mathbf{\Phi} + \mathbf{\Phi}^*) \mathbf{Z} + \epsilon_t \tag{7}$$

as $(r_{t-d} - c) \to \pm\infty$ for a given $\psi > 0$. Further note that as $\psi \to \infty$, the exponential function approaches the indicator function $I(r_{t-d} = c)$ and the model becomes linear yet again.

The fundamental idea behind the ESTAR model in (5) is that the larger the deviation from relative PPP, the higher will be the prevailing rate of parity-reversion. This has implications for the critical parameters ρ and ρ^*. While $\rho \geq 0$ is acceptable, it must be true that $\rho^* < 0$ and the whole series is globally stationary or stable with $-2 < \rho + \rho^* < 0$. Simply put, $\{r_t\}$ may be highly persistent, follow a random walk, or even be characterized by explosive behavior for sufficiently small disequilibria.

In this paper, we set $\rho = 0$ and generally find that $\mathbf{Z}$ does not have a significant role to play in the nonlinear component of the ESTAR model. We subsequently estimate the following nonlinear least squares regression[16]

$$\Delta r_t = \alpha + \sum_{k=1}^{q} \beta_k \Delta r_{t-k} + \mathbf{\Phi Z} + \left(\alpha^* + \rho^* r_{t-1} + \sum_{k=1}^{q} \beta_k^* \Delta r_{t-k} \right) F(\psi, c; r_{t-d}) + \epsilon_t. \tag{8}$$

Following Kılıç (2009), we compute the half-life for the ESTAR model conditional on the value of the transition variable, and thus transition function, using the formula

$$\widehat{hl}_{t|r_{t-d}} = \frac{\ln(0.5)}{ln(1 + \widehat{\rho^*}(1 - \exp(-\widehat{\psi}(r_{t-d} - c)^2)))}. \tag{9}$$

Note again that this measure of the half-life is approximate. We obtain results for the 100th percentile and mean of the transition function respectively, that is, conditional on higher and lower deviations from equilibrium.[17]

In the context of aggregate real exchange rate modeling, the ESTAR model is appealing for the reason that it allows a smooth transition between regimes and symmetric treatment of deviations above and below the equilibrium. In particular, discrete switching models may not be suitable when assessing the effects of international arbitrage on aggregated goods (basket) prices, particularly in the case of multilateral real exchange rates, given that firms and traded goods are clearly not all homogeneous. Furthermore, from the financial asset point of view, foreign exchange traders might learn at different speeds, thus leading to non-synchronized developments in individual information sets such that a relatively smooth transition in real

[16] First, the condition imposed on ρ was initially a theoretical assumption. However, we later found that the model attains its best fit under this assumption, with ρ being insignificant in most cases when (5) is estimated. Second, in estimation, we employ the Levenberg-Marquardt algorithm which is a lot more robust than the Gauss-Newton algorithm. More precisely, in many cases the former retrieves a solution even if the starting point is quite a distance away from the final minimum. Third, we set the initial values of ψ and c to 1 and the mean of the considered series respectively. As a precaution, we also vary these values in order to ensure the location of a global minimum. Convergence of estimates is always achieved.

[17] The other approach to obtaining the half-life in the nonlinear case is to infer it from an estimated generalized impulse response function (GIRF). However, the technique we adopt provides a number of advantages over the GIRF method. For instance, unlike the latter approach, it does not necessitate extensive dynamic stochastic simulations. Moreover, our half-life estimates are directly comparable to those of the linear AR(p) models, and thus to the majority of those reported in the literature.

exchange rate adjustment between regimes may be more appropriate. As Taylor *et al.* (2001) note, in an environment with proportional transactions costs, non-uniform adjustment with respect to both size and timing by heterogeneous agents, and time aggregation effects, much of the theory suggests that smooth aggregate regime switching is more likely. Regarding symmetric adjustments, in the context of the arbitrage argument, there are few reasons, a priori, to believe that real currency devaluations should be treated any differently to real overvaluations.[18]

2.2 Country Characteristics

In the second part of our study, we examine some of the potential determinants of real exchange rate persistence.

2.2.1 Productivity Growth

Productivity growth is a factor that has been well documented in papers seeking to rationalize the real exchange rate speed of convergence to parity (Berka and Devereux, 2013). As a country becomes more productive through traded goods, the relative price of nontraded goods rises, which raises the real exchange rate (Harrod, 1933; Balassa, 1964; Samuelson, 1964). According to Froot and Rogoff (1995), trend breaks in the real exchange rate can also be associated with changes in the relative price structure between tradable and nontradable goods. They contend that the rapid income growth frequently associated with low-income countries can stimulate such strong changes in the relative price of tradables and nontradables that the probability of parity-reversion holding in any given nation will rise with the amount of income. That is, parity-reversion will be much slower in developing countries if one does not allow for structural breaks in the data.

2.2.2 Trade Openness

Countries that display a greater degree of trade openness may exhibit a lower persistence of parity deviations. As a result of higher trade flows (due to a decline in protectionism for instance), arbitrage opportunities will be exploited more frequently in nations thus leading to evidence of faster mean-reversion in the real exchange rate (e.g. Faruqee (1995)). Lo and Wong (2006) theoretically illustrate that a more open economy is characterized by smaller deviations from parity. The authors attribute this result to the decreasing dominance of monetary factors as openness increases. However, smaller deviations may lead to greater persistence in the real exchange rate if they are relatively more expensive to arbitrage away.

2.2.3 Financial Integration

The speed of convergence to parity may also be affected by greater capital mobility through financial integration. Indeed, Rogoff (1992) develops a model that can be used to analyze the effects of capital market liberalization on the real exchange rate. In his setup, when the stochastic process for traded goods productivity is stationary in levels, the opening of capital

[18] We considered real exchange rate models of the logistic smooth transition autoregressive (LSTAR) variety and did not find any evidence of asymmetric adjustment dynamics for any country. In addition, we attempted to estimate an LSTAR model with two location parameters, that is, a model with the transition function $F(\psi, c_1, c_2; r_{t-d}) = 1/(1 + \exp(-\psi(r_{t-d} - c_1)(r_{t-d} - c_2)))$ where $c_1 \leq c_2$. However, in estimation of the LSTAR variant we failed to achieve convergence.

markets can lower the variance of real exchange rate changes by allowing agents to smooth their consumption of traded goods intertemporally so that movements in the intra-temporal price of nontraded goods need not to be as large as they otherwise would. The opposite is true if traded goods productivity shocks are stationary in growth rates. Whether, these effects on variance translate into effects on persistence remains to be seen empirically.

2.2.4 Inflation

Economic intuition would suggest that the inflation experience of a country will determine its speed of real exchange rate mean-reversion. If national price fluctuations are dominated by monetary shocks, then one would expect parity reversion to be rather swift. Given the existence of nominal rigidities, a higher inflation rate can induce larger or more regular adjustment of goods prices and therefore reduce the duration of deviations from parity (Cashin and McDermott, 2006). For the euro area, Álvarez *et al.* (2006) certainly offer evidence that the frequency of price changes at the micro level is significantly influenced, in the expected fashion, by macroeconomic conditions such as aggregate inflation. As Klenow and Malin (2010) note, the frequency of price changes across products has displayed more meaningful variation in countries characterized by higher and more volatile inflation (i.e. the duration of prices typically falls to levels below 1 year). In addition, during high inflation episodes, demand for foreign currency as an asset grows while that for domestic currency falls. Such substitution according to Bleaney *et al.* (1999) is likely to affect both the short-run dynamics and long-run equilibrium of the real exchange rate.

2.2.5 Government Expenditure

The share of government expenditure in the economy is another potential driver of the rate of parity reversion given that these outlays tend to fall more heavily on nontraded goods. In particular, the persistence of real exchange rate shocks is thought to rise with the proportion of produced goods that are nontraded. In their intertemporal two-country model with monopolistic competition, market segmentation, and staggered price contracts, Bergin and Feenstra (2001) show that the real exchange rate persistence parameter (implied by the model) can be expressed as an increasing function of the share of nontraded goods produced in the economy, or, (equivalently) as a decreasing function of (trade) openness. Indeed, this demand-side factor has been examined in a number of structural models of PPP deviations.[19] Importantly, Rogoff (1992) points out that the effects of government spending may not be long-lived if factors of production are perfectly mobile across sectors in the long-run. Equally however, Alesina and Perotti (1995) demonstrate that when public spending is financed by distortionary taxes, it can induce long-run real effects.

2.2.6 Nominal Exchange Rate Volatility

Nominal exchange rate volatility is also expected to influence the rate at which real exchange rate parity deviations peter out. For bilateral real exchange rates, Mussa (1986) finds that under a floating exchange rate regime, the real exchange rate generally exhibits substantial persistence and greater short-term volatility than under a fixed exchange rate regime. This is mainly due to the greater variability of the nominal exchange rate with little contribution from changes in the variability of the ratio of national price levels. Nominal exchange rate variability

[19] The factor is studied by Froot and Rogoff (1991, 1992) and Rogoff (1992) for example.

is sometimes used as a proxy for the exchange rate uncertainty faced by price setters. In a dynamic partial equilibrium model of a price-setting firm with menu costs, Delgado (1991) demonstrates that nominal exchange rate variability leads to greater uncertainty and, in turn, price stickiness and hence real exchange rate inertia. For a sample of OECD countries, Cheung *et al.* (2001) report that nominal exchange rate volatility positively affects sectoral real exchange rate persistence and use the former logic to justify their empirical finding.

Engel and Rogers (2001) show that adopting a fixed exchange rate regime under local-currency pricing may reduce parity deviations and the associated inefficiencies. Cashin and McDermott (2006), in comparison, argue that greater nominal exchange rate flexibility would be expected to induce faster parity reversion by encouraging more frequent adjustment of goods prices, which is in line with the findings of Goldfajn and Valdés (1999). More recently, Engel (2012) demonstrates that higher levels of price stickiness and interest-rate smoothing in the Taylor rule lead to slower real exchange rate adjustment.[20] Meanwhile, Eichenbaum *et al.* (2016) indicate that most of the adjustment in the real exchange rate occurs through changes in the nominal exchange rate under Taylor rules maintaining inflation stability.

2.2.7 Geographical Distance

Lastly, it is often argued that transportation costs and informational frictions, or familiarity bias, generate a wedge between prices across countries thus leading to larger real exchange rate parity deviations (Dumas, 1992; Baltzer *et al.*, 2013). If trade costs are proportional to geographical distances, then countries that are further apart will observe larger bilateral or multilateral parity deviations as arbitrage becomes less profitable and the exchange rate fails to adjust (Wei and Parsley, 1995). Alba and Papell (2007) find that PPP holds better and that mean-reversion is faster for countries located closer to the trading partner of concern. Furthermore, nations that are closer to each other may also be more likely to share the same or similar monetary policies through credible pegs (or currency unions or dollarization in the extreme cases), thus leading to similar inflation and interest rates across these nations. This in turn could imply smaller real exchange rate misalignments from equilibrium.

2.3 Cross-Section Regressions

To gauge the explanatory power of the country characteristics thought to be influencing real exchange rate persistence, we estimate the following cross-section regressions using OLS

$$hl_i^{BRER} = \kappa + \omega_1 inf_i + \omega_2 gov_i + \omega_3 to_i + \omega_4 PG_i + \omega_5 nerv_i + \omega_6 ifi_i + \omega_7 dist_i + \nu_i \tag{10}$$

$$hl_i^{REER} = \kappa + \omega_1 inf_i + \omega_2 gov_i + \omega_3 to_i + \omega_4 PG_i + \omega_5 nerv_i + \omega_6 ifi_i + \nu_i \tag{11}$$

where lower case Latin letters are used to denote the natural logarithm of a variable, $hl^{BRER(REER)}$ is the half-life of bilateral real exchange rate (real effective exchange rate) parity deviations, inf is the inflation rate, gov is government expenditure, to is trade openness, PG is productivity growth, $nerv$ is bilateral nominal exchange rate volatility in the case of (10) and nominal effective exchange rate volatility in the case of (11), ifi is international financial integration, $dist$ is the geographical distance between country i and the U.S. included only in bilateral real exchange rate persistence regressions, and ν_i is the error term. We estimate (10) and (11) for

[20] Based on numerical exercises, Benigno (2004) also reports that when inflation-targeting in monetary policy is replaced by an interest rate smoothing rule there is endogenous real exchange rate persistence which depends on the sluggishness of price dynamics.

the overall samples and sub-samples defined by different economic development classification schemes in order to gain additional insight.

Unlike previous work which only examined rank gross correlations, our study adopts parametric methods. Past studies validate their approach on the grounds that the data are nonnormally distributed, and so not amenable to regression analysis (Cheung and Lai, 2000a; Cashin and McDermott, 2006). However, we contend that it is only the degree of nonnormality that matters and not nonnormality per se. This feature of the data will not necessarily invalidate the parametric results (see e.g. Glass *et al.* (1972)). Moreover, logarithms of variables considerably attenuate any skewness issues.[21]

3 Data

The analysis employs both average monthly bilateral real exchange rates (BRERs) and real effective exchange rates (REERs) over the period 1973:1 to 2010:12.[22,23] Both real exchange rates are CPI-based. In the case of the bilateral rate 141 countries are employed, while for the multilateral rate only 93 countries are available.[24] Of these countries, 83 are common to both BRER and REER series. We note that monthly real exchange rate data are used in order to avoid any temporal aggregation bias issues (Ahmad and Craighead, 2011) and also to assist in the computation of half-lives from IRFs. All data pertaining to real exchange rates are obtained from the IMF's International Financial Statistics (IFS).

The BRER index for a given country i is not readily available and is therefore constructed as follows

$$\frac{BRER_{i,t}}{BRER_{i,2005:1}} = \frac{\left(\frac{P_{i,t}}{P_{i,2005:1}}\right)}{\left(\frac{E_{i,t}}{E_{i,2005:1}}\right)\left(\frac{P_{US,t}}{P_{US,2005:1}}\right)} \tag{12}$$

where the base period is January of the year 2005 and the base or foreign country for all BRERs is the U.S., P_i is country i's price index, P_{US} is the U.S. price index, and E_i is the nominal exchange rate between the currencies of country i and the U.S. quoted in national currency per U.S. dollar terms. Nominal exchange rate series for euro zone countries end with the year 1998 and consequently must be synthetically extended to the end of 2010. This is achieved by applying individual monthly growth rates in the Euro per USD series (1998:12 value in this series is attained from the ECU exchange rate) to the euro zone national currency per USD series from 1998:12 onwards. That is, the 1999:1-2010:12 missing values in the individual series are generated as follows

$$(NC\ per\ USD)_{i,t} = (NC\ per\ USD)_{i,t-1}\left[\frac{(Euro\ per\ USD)_{i,t}}{(Euro\ per\ USD)_{i,t-1}}\right] \tag{13}$$

[21] We were unable to find significant evidence of severe nonnormality for any of the variables used in the regressions on the basis of both qualitative (graphical) and quantitative statistical procedures. In the case of the latter, the null hypothesis of normality across the different variables and samples cannot be rejected at the 10 percent level using the Shapiro-Wilk test. Alternative numerical tests based on skewness and kurtosis yield consistent results.

[22] We provide a more comprehensive analysis by employing both bilateral and multilateral rates. Indeed, most studies are divided along this line, which may be a contributing factor to conflicting general conclusions. Moreover, Black (1986) notes that although it is true that bilateral PPP with all trading partners implies multilateral PPP, bilateral deviations from PPP do not necessarily suggest multilateral deviations from PPP. This may also imply differences in mean-reverting dynamics across BRER and REER series.

[23] The time dimension of our sample is dictated by data availability.

[24] See appendix A for the list of countries used.

where $(NC\ per\ USD)_{i,t}$ is time t national currency per U.S. dollar of euro area country i.

The REER indices are directly available from the IMF database. Every REER index is rebased to the period 2005:1 and rescaled accordingly for consistency with the BRER series. The REER represents the weighted geometric average of a country's currency relative to a basket of other major currencies adjusted for the effects of inflation. The weight attached to each foreign country in the index is determined by its share in trade. In essence, this multilateral real exchange rate captures the domestic country's trade linkages with the rest of the world and acts as an indicator of its international competitiveness.

Formally, the IMF's definition of the REER for country i is

$$REER_{i,t} = \Pi_{i \neq j} \left(\frac{E_{i,t} P_{i,t}}{E_{j,t} P_{j,t}} \right)^{W_{ij}} \tag{14}$$

where j is an index that runs over country i's trade partners, W_{ij} is the competitiveness weight attached by country i to country j that is updated discretely and is based on the composition of trade, and E_i and E_j are the nominal exchange rates of countries i and j respectively now expressed in (period-average) U.S. dollars per unit of national currency terms.[25] Thus, the IMF's REER is dollar denominated. An increase in either the BRER or REER indicates a real currency appreciation and so a decrease in either competitiveness relative to the U.S. or international competitiveness. We also note that given the start and end values of a series, any in-between missing values are linearly interpolated.[26]

Data on the potential covariates of real exchange rate persistence are annual, unless stated otherwise, and are obtained from the following databases: World Bank's World Development Indicators (WB's WDI), International Monetary Fund's (IMF's) International Financial Statistics (IFS) and World Economic Outlook (WEO), Penn World Tables (6.1.0) (PWT), updated External Wealth of Nations II (EWN II) of Lane and Milesi-Ferretti (2007), and Centre d'Études Prospectives et d'Informations Internationales's GeoDist (CEPII's GeoDist) developed by De Sousa *et al.* (2012). For the purposes of cross-section regressions (10) and (11), and any preceding preliminary descriptive analyses, period averages of the variables for each country are taken, except in the cases of volatility measures and geographical distance as explained next.[27]

The utilized variables on country characteristics are defined as follows (with data sources in brackets). The inflation rate is the percentage change in the CPI (IMF's IFS). Government expenditure is defined as general government total spending as a percentage share of GDP (WEO).[28] Trade openness is the sum of exports and imports of goods and services expressed as a percentage share of GDP (WB's WDI). Productivity growth is proxied by the growth rate of real GDP per capita (PWT). Nominal exchange rate volatility is defined as the standard deviation of the monthly change in the logarithm of the nominal exchange rate and is computed for both bilateral and effective rates (IMF's IFS).

[25] W_{ij} may be interpreted as the sum over all markets of a gauge of the degree of competition between producers of countries i and j respectively, divided by the sum over all markets of a gauge of the degree of competition between producers of country i and all other producers.

[26] In the few cases where this occurs, cubic-spline interpolation does not alter the results. The use of non-interpolated series, resulting in reduced sample sizes, does not significantly change findings either.

[27] Regressors, where applicable, are not based on data relative to those of the U.S. in equation (10) or to those of trading partners (or the sample of countries used) in equation (11). This approach is ultimately consistent with those of past studies. However, in robustness checks, we did employ covariates based on relative data where appropriate and found almost identical results.

[28] In robustness checks we also used the alternative measure of general government final consumption spending as a percentage share of GDP (WB's WDI) and reached similar conclusions.

Two de facto measures of international financial integration (IFI) or capital market openness are considered in the framework. Both measures are constructed using data from EWN II. The first of these is the volume-based measure of IFI, $(FA_{it} + FL_{it})/GDP_{it}$ where FA and FL are the stocks of aggregate foreign assets and liabilities respectively. This is the primary IFI measure of interest and the one employed in regression analysis. As international trade in debt instruments may be driven by different factors, Lane and Milesi-Ferretti (2007) also propose an equity-based measure of IFI, $(PEQA_{it} + FDIA_{it} + PEQL_{it} + FDIL_{it})/GDP_{it}$ where $PEQA(L)$ and $FDIA(L)$ are the stocks of portfolio equity and foreign direct investment assets (liabilities). This is the secondary IFI measure of interest and is only inspected qualitatively through graphical analysis. All data used to construct the IFI indicators are reported in current U.S. dollars.

Lastly, geographic distance (in kilometers) in our study is a weighted dyadic measure that uses data on principal cities in each country (CEPII's GeoDist). The fundamental idea is to compute the distance between two countries using bilateral distances between the largest cities of those two countries, with those inter-city distances being weighted by the share of the cities in the countries' respective overall populations. Specifically, the bilateral geographic distance between country i and the U.S. is given by

$$d_{i,US} = \left(\sum_{k \in i} \left(\frac{pop_k}{pop_i} \right) \sum_{l \in US} \left(\frac{pop_l}{pop_{US}} \right) d_{kl}^{\theta} \right)^{\frac{1}{\theta}} \tag{15}$$

where $d_{x,y}$ is the bilateral distance between two places x and y, pop_k denotes the population of agglomeration k belonging to country i, and θ is the parameter that gauges the sensitivity of trade flows to the bilateral distance d_{kl}. We use the measure that sets $\theta = -1$, consistent with estimates from gravity models of bilateral trade flows.

4 Empirical Results

4.1 On the Stationarity of Real Exchange Rates

Estimation results reveal that the AR(1) process typically does a poor job at yielding mean-reverting real exchange rates. Tables in the supplementary appendix show that one is able to reject non-stationarity for only 30 countries in the case of BRERs and 24 in the case of REERs.[29] Interestingly, all of these economies are either transitional or developing with the exception of France and Norway which have stationary AR(1) REERs. Consequently, finding slow mean-reverting real exchange rate dynamics in panels of the AR(1) variety, particularly for the industrialized world, should not be surprising.[30]

Linear augmented AR models on the other hand tend to have a better success rate in attaining a significant ρ coefficient. Under these specifications we attain parity-reversion for 72 economies when using BRERs, and 55 economies when employing REERs (roughly half of the respective samples). 11/72 from the former sample are advanced countries of which 9 have significant ρ coefficients at only the 10 percent level, while this is true for 12/55 and only 3/12 from the latter sample. For emerging and developing nations in particular, one can see the importance of taking into account structural changes in the series.[31]

[29] The results do not cohere with the claims of Gómez-Zaldívar *et al.* (2014) that it is more difficult to find evidence of PPP in multilateral exchange rate data.

[30] See Chinn and Wei (2013) for instance.

[31] Parity-reversion may be non-existent in developing countries if one does not allow for structural breaks in the data (Froot and Rogoff, 1995).

Scrutinizing the estimated ESTAR specifications, we find that both the mean-reversion and transition parameters (ρ^* and ψ) respectively are significant for 106 countries in the case of bilateral rates, and 76 in the case of effective rates. In the first instance, 16 of the economies are advanced (80 percent of industrialized sample), while in the second instance 15 are advanced (65 percent of industrialized sample). In most of these industrial country cases, the linearity test result coincides with the significance of the transition parameter, thus providing additional evidence of the presence of nonlinearities.[32] We noted earlier that most of the advanced economies are characterized by a mean-reversion coefficient that is either insignificant or marginally significant at the 10 percent level under a linear augmented AR model. This result in itself may be viewed as consistent with the existence of nonlinearities due to transaction costs for example. If the true process for the real exchange rate is given by the ESTAR specification, the mean-reversion coefficient in the augmented AR will lie between ρ and $\rho + \rho^*$ in the ESTAR (or 0 and ρ^* in our case). Therefore, even if the true nonlinear process is globally stationary, one may still find an insignificant parity-reversion coefficient in the linear specification. In other words, the estimated linear augmented AR model may to a certain extent be reflecting the non-stationary or slower mean-reverting inner regime dynamics of the ESTAR.

Tables in the supplementary appendix highlight the real exchange rate specification selected for each country. Two factors determine our choice of model: (i) linearity vs. nonlinearity; and (ii) stationarity vs. non-stationarity. First, we identify whether a linear or nonlinear model is appropriate on the basis of the significance of the transition parameter in the ESTAR model and the linearity test. If the two indicators are not consistent with one another, we place greater weight on the former and choose accordingly. However, in the rare event that the indicators point to nonlinearity but the mean-reversion coefficient is insignificant while that of the linear model is significant, we choose the stationary linear model. Second, whenever we are led to a linear model we choose between the simple AR(1) and augmented AR on the basis of the p-value of ρ. Specifically, we select the specification that rejects $H_0 : \rho = 0$ at the lowest significance level.[33] Of the elected models, mean-reversion is attained in 125 cases when considering BRERs and 87 cases when inspecting REERs, with 71/83 countries achieving convergence across both series. From the final column of these tables, we also see that the selected models are predominantly nonlinear, with the ESTAR making 106 appearances under BRERs and 76 appearances under REERs (of which only one in either case does not display significant mean-reverting dynamics).

4.2 Bilateral vs. Multilateral Real Exchange Rate Persistence

Figure 1 plots the persistence estimates of BRERs against those of REERs for the 83 countries common to both sets of series. A cursory glance at the graphs reveals that the half-life estimates over bilateral rates are unequivocally positively correlated with the estimates over effective rates. Indeed, this prominent visual feature is further supported by the positive and highly significant Spearman rank correlation coefficients. As the persistence rates are imperfectly positively correlated, we might expect to find some notable discrepancies between the estimates in the graphs. Using the dashed reference lines at the one-year half-life values, one can deduce that REERs exhibit much lower inertia in adjustment toward parity than BRERs. In particular, the lower right quadrants are almost devoid of observations while

[32] Ultimately, we place greater weight on the significance of the transition parameter as an indicator of nonlinearity than on the linearity test itself.

[33] Akaike and Schwarz-Bayesian information criteria lead to the same model selections.

the upper left quadrants are normally more densely populated. For instance, in the case of selected model I, 52 of the REER half-lives are in fact below one year whereas only 23 BRER half-lives are found to lie below one. This ratio of more than 2:1 roughly holds throughout most of the specifications.[34]

The observed pattern indicates that mean reversion in the real exchange rate vis-à-vis a basket of trading partners is more pronounced than in the case where the U.S. is the sole reference country. Noting that the multilateral real exchange rate is effectively a geometrically weighted average of bilateral real exchange rates, it may be that the rate of adjustment is significantly higher for bilateral rates vis-à-vis the most important trading partners of the home country. With those more heavily-weighted bilateral rates dictating the dynamics of the effective rate, this 'might' be resulting in faster REER convergence. In cases where the U.S. has been convincingly the leading export market and import source, we do find that the U.S.-based bilateral and multilateral rates of persistence can be similar. One such example is the Dominican Republic which is characterized by a half-life of less than 9 months and almost identical real exchange rate specifications across both bilateral and effective series.[35]

4.3 Cross-Section Analysis of Half-Lives

Tables 1–2 present summary persistence statistics in the case of the BRER and REER country samples. More precisely, these tables report the median half-life estimates based on the different real exchange rate specifications for the overall sample and each country group, and give medians based on the selected specifications for the same categories. We also provide the results of group differences tests.[36,37]

Referring to these tables, we first note that as one augments the real exchange rate specification, the half-life dramatically decreases for all samples. In particular, after allowing for all of the possible features in the real exchange rate process discussed in section 2, we find that the half-life is reduced to a level that is consistent with the theoretical predictions of both traditional and DSGE sticky-price macroeconomic models. The half-lives tend to be at their lowest when considering ESTAR models in the case of larger real exchange rate misalignments i.e. at the maximum of the ESTAR transition function. Moreover, our results are further strengthened by the fact that the literature has produced more evidence in favor of faster PPP-reversion for German-based than U.S.-based real exchange rates. In general, it appears that U.S.-based real exchange rates display higher persistence than others. Thus, in this sense, one may regard our BRER half-lives as upper bound estimates.

Second, we observe that the arithmetic mean is not the best measure of central tendency in the distribution of half-lives for the different country cohorts. In fact, we find that the median is often substantially lower than the mean. Specifically, conclusions based on mean statistics can be misleading due to the significant degree of positive skewness present particularly in the emerging and developing country group distributions.[38] Figure 2 visually illustrates this point

[34]Non-parametric tests indicate statistically significant differences between BRER and REER half-lives.

[35]Other similar examples include St. Lucia and Trinidad and Tobago.

[36]In the supplementary appendix, we report the average half-life estimates. Due to the skewness inherent in the data, we confine our discussion in this paper to median estimates.

[37]We repeated the analysis for the 83 countries common to both BRER and REER series. This is done for the purposes of a more direct comparison across the two types of real exchange rate. The conclusions based on these sub-samples are broadly consistent with those drawn from the respective full sample analyses. See online supplementary appendix.

[38]We do note however that the augmented models provide better fits and reduce much of the skewness and variance of half-lives present in the simple AR and AR(p) specifications (not shown here).

in the case of selected model I and II half-lives. The figure also indicates that the variance of these persistence levels is much lower for REERs than BRERs. Given that heavy right-sided outliers are inflating the average rate of mean-reversion, in some cases more than others, and distorting comparison-making between groups, we concentrate on median estimates.

An assessment of the median half-lives in tables 1–2 overall indicates that group differences are statistically significant with developing nations exhibiting the lowest rate of real exchange rate persistence, followed by emerging, and then industrial countries. Evidence in favor of faster parity convergence for developing economies, relative to the other two groups, is especially overwhelming in the REER sample. In the BRER sample on the other hand, while developing countries converge faster to parity than industrial countries, the same cannot be said when they are compared to transitional economies. In this latter instance, the bilateral difference is insignificant. Focusing on the selected model estimates, we find that the half-life of BRER parity deviations stands at around 2.5 years for industrial countries and around 1.5 years for emerging and developing countries. Doing the same for REERs, we find that the half-life tends to be less than 2 years for industrial countries, less than 1 year for emerging economies, and less than 6 months for developing nations. These findings corroborate those of Cheung and Lai (2000a), although the estimates we produce are much smaller. Conversely, they oppose the results of Cashin and McDermott (2006).

Figure 3 plots the transition function of the BRER ESTAR model against both the transition variable and time for selected industrial, emerging and developing economies. Inspection of the graphs reveals that countries visit both extreme regimes. In addition, those on the left confirm that the higher the transition parameter, the faster the transition between regimes. From the graphs, we observe that advanced economies spend more time in the local neighborhood of the extreme inner regime than both emerging and developing nations. Put differently, industrial countries on average display smaller, yet more persistent, deviations from parity than the other two groups of countries. In the case of BRERs, we find that the average value of the transition function for the typical industrial country is 0.60, the typical emerging country is 0.65, and the typical developing country is 0.72 (while they are 0.66, 0.72, and 0.81 respectively for the median country). A similar pattern holds for REERs.

Categorizing countries by income, in line with the World Bank's income classification scheme, we find that group differences are no longer significant for BRERs, although high-income countries display greater persistence on the basis of the selected model estimates alone. Our result implies that the finding of significant differences across these groups in Cheung and Lai (2000a) may have been subject to sample selection bias. Conversely, group differences are highly significant when one considers REER selected model half-lives with high-income countries needing around 1 year, middle-income countries less than a year, and low-income countries less than 6 months for a deviation from equilibrium to dissipate by 50 percent.

Tables 1–2 also show results for different regions of the world. Yet again, group differences only appear to be significant in the REER case. Overall, the speed of real exchange rate parity convergence seems to be fastest in Latin America and Africa, followed by Europe, and then Asia and Oceania. Examining the BRER sample, Latin America has the lowest half-life which may potentially be explained by its geographical proximity to the U.S.. Meanwhile African nations, many of which are heavily indebted poor countries, have the highest rate of mean reversion in the REER sample (followed closely by Latin America). Figure 4 graphs the BRER selected model rates of persistence against countries' respective distances (in kilometers) from the U.S.. The plots indicate a weak positive correlation between the two variables, where the x-axis dashed reference line now marks the distance of 8000 kilometers.

4.4 Cross-Section Analysis of Determinants

Table 3 presents the cross-section median values of explanatory macroeconomic variables over different country groups defined by stage of economic development and regional location. Moreover, the table displays the results of differences-in-median tests.[39] The summary statistics on country characteristics are significantly different across sub-samples. The table indeed suggests that there is plenty of heterogeneity in the data. Firstly, the median inflation rate across advanced economies stands at a much lower rate than for either emerging or developing nations, with a similar observation holding for high- versus middle- and low-income countries. More specifically, Latin America and Africa are shown to have the highest inflation rates.[40] As we noted earlier, developed nations display a much slower rate of real exchange rate adjustment than other countries. A plot of bilateral and multilateral real exchange rate persistence levels against the average inflation rate in figure 5 illustrates qualitatively the existence of an inverse unconditional relation. The graph offers support for the conventional claim that PPP holds better for high-inflation countries.

Following the literature, we also examine the public sector's involvement in the economy. From our tables, it is clear that government size, as measured by the state expenditure to GDP ratio, is largest for industrial countries (over 40 percent of GDP), followed by emerging and developing nations. The trend is identical across income groups. Regionally, European nations are characterized by much larger shares of public spending. As discussed, the outlays may be contributing positively to these countries' real exchange rate half-lives.

Median trade openness differences also tend to be statistically significant, although less so along the regional level. Table 3 indicates that emerging and high-income country groups exhibit the highest levels of trade openness. In particular, Asia boasts high levels of openness, a reflection of its trade-driven economies. At the same time however, such openness can expose a country to larger and more frequent macroeconomic shocks, such as terms of trade shocks (Clower and Ito, 2012). Cheung *et al.* (2001) argue that the inflation effect on real exchange rate inertia arising from increased openness or trade liberalization can be so strong that it may dominate the trade openness effect itself, thus resulting in a nonnegative link between openness and persistence.[41]

International financial openness or integration decreases as we move from the industrial (high income) country group to the developing (low income) country group. This is true for both volume- and equity-based measures, with the former reported on the left and the latter reported on the right under *international financial integration* in the table. In addition, the quantitative difference between these two variables suggests that debt plays a major part in international capital flows, given that reserves generally carry a much lower weight.

Figure 6 shows that real exchange rate persistence is positively associated with IFI.[42] One possible interpretation is that with more internationally open capital markets, a country can actively pursue asset buying and selling strategies that keep the currency persistently undervalued vis-à-vis trading partners, thus sustaining the competitiveness position. Figures 7 and 8 provide the plots separately for industrial, emerging and developing country groups. In

[39] Tables in the supplementary appendix present the means of these variables. In addition, these tables are reproduced for the sub-sample of countries common to both BRER and REER samples.

[40] The supplementary appendix also shows that the average inflation rate of a country is highly positively correlated with inflation volatility over the period.

[41] In line with Romer (1993) and Cheung *et al.* (2001), the supplementary appendix reveals a negative gross correlation between inflation and trade openness.

[42] The positive correlation is still maintained when Luxembourg is removed from the overall samples.

all cases the correlations are now weak and statistically insignificant, although they remain mostly positive. Based on the insignificant correlation coefficients, advanced economies exhibit some evidence of a negative comovement between persistence and IFI (with Luxembourg being a significant driver). Interestingly, in the case of the bilateral real exchange rate sample of developing countries in figure 7, a negative correlation coefficient is found when using the equity-based IFI measure. Ignoring significance, this broadly implies that higher international trade in debt instruments or lower trade in equity instruments increases the persistence of bilateral real exchange rate parity deviations. Alternatively, the inverse relation may also be due to the removal of international reserves from the equation, which are generally thought to increase persistence. However, in all other sub-sample cases across figures 7 and 8, the insignificant correlation coefficients increase when the equity-based IFI measure is employed. This may suggest that the debt component hastens real exchange rate adjustment.

Productivity growth figures, as proxied by per capita GDP growth, also vary significantly across groups with emerging market and high-income economies having the highest growth rates. Along the regional level, Asia and Europe experienced the highest median levels of growth. Unlike emerging markets which are catching up, developing countries on average observed lower productivity growth than industrial countries.[43] Cheung and Lai (2000a) explain that such a result is possible according to endogenous growth theory. The theory implies that productivity growth in advanced economies may still remain high in steady state. Figure 9 points to a positive connection between real exchange rate persistence and productivity growth, although the link is significantly weaker in the bilateral case.

Lastly, the statistics indicate greater nominal exchange rate volatility along all country classification schemes for the non-industrialized world. In particular, developing and emerging economies, low- and middle-income countries, and Latin America and Africa are characterized by the highest exchange rate variability levels. Certainly, over the past 40 years, these economies have observed sizable nominal exchange rate movements due to the liberalization of capital flows and the tremendous rise in the scale and type of cross-border financial transactions. The currency crises in emerging markets that occurred during our sample period were also notable instances of large exchange rate volatility. Moreover, the phases of transition to a market-based system in CEE economies often entailed major adjustments in the international value of these countries' currencies. For both bilateral and multilateral cases, figure 10 yields some preliminary evidence of a relatively strong inverse relation between real exchange rate persistence and nominal exchange rate volatility. Using the average *de jure* IMF exchange rate regime classification for each country over the sample period, the graphs also show that fixers generally observe higher real exchange rate persistence and lower nominal exchange rate volatility than intermediate and flexible exchange rate regime countries.[44]

4.5 Regression Analysis

Table 4 presents the results of cross-section bilateral and multilateral real exchange rate persistence regressions (10) and (11) respectively. The findings in the table are given for full samples of countries and the different sets of half-life estimates.[45] Investigating further, tables 5–8 pro-

[43] From table 3 we can see that there is no evidence of catching-up or convergence for groupings by income.

[44] The supplementary appendix plots average inflation and real exchange rate volatility against nominal exchange rate volatility and reports statistically significant large positive correlation coefficients, with countries that were peggers on average normally displaying lower inflation and real/nominal exchange rate volatility.

[45] The supplementary appendix contains a table that tenders results for the sample of countries that is common across both bilateral and multilateral rates of persistence. This sample yields very similar findings.

vide regression results for different country groups defined by stage of economic development. Overall, the collective explanatory power of the country characteristics is reasonably good on the basis of R-squared values which generally tend to improve with half-lives from more elaborate real exchange rate specifications. In the case of full samples, the right-hand side variables can account for up to a maximum of 46 percent of the variation in cross-country real exchange rate inertia levels.

Our results offer considerable support for the proposition that a higher inflation rate enhances the speed of mean-reversion in the real exchange rate. For the full bilateral real exchange rate sample of countries, this result seems to be robust across different specifications and consistent with the findings of Bleaney *et al.* (1999). As columns (4), (8) and (9) show, the point estimate in the case of large parity deviations is around -0.40 suggesting that a 10 percent increase (percentage change) in the growth rate of prices is associated with a 4 percent decline in the bilateral real exchange rate half-life. In all other cases, including smaller parity deviations in columns (5), (6) and (7), the estimate lies around -0.18. The result implies that larger percentage changes in inflation are required in order to more significantly influence the persistence of smaller real exchange rate misalignments. Concerning the multilateral real exchange rate sample in table 4, the inflation coefficients are mostly negative and statistically insignificant, with a similar pattern holding for smaller and larger parity deviation half-lives. Returning to figure 5, the right panel illustrates how the outlying observations of Ukraine and Brazil are obscuring the estimates. Dropping these two cases of very high average inflation, significant negative estimates are once again attained throughout.

On the whole, the evidence across sub-samples in tables 5–8 also indicates a negative comovement between real exchange rate inertia and inflation. However, there are some groups with insufficient cross-country variation and thus insignificant coefficients. In the bilateral case, there appears to be sufficient variation in the developing and middle-income country cohorts to engender significant negative estimates. On the other hand, in the multilateral case, the coefficients are significant and negative primarily in the industrial and high-income groups, with the U.S., New Zealand and Australia being the notable advanced economy additions to the sample. For the other groups in the multilateral case, observation numbers are substantially reduced.[46] In contrast to Alba and Papell (2007), we do not find any support in the bilateral sample for the notion that countries with low inflation rates, similar to that of the U.S., are more likely to be characterized by faster real exchange rate convergence. The authors argue that countries with notably different inflation rates and fixed exchange rates can intervene in the foreign exchange market to suppress adjustment so that PPP may not hold. As table 9 shows, low-inflation fixed exchange rate economies in fact observed the highest levels of bilateral real exchange rate persistence. In such economies, the deviations from parity may have been relatively small but highly persistent.

Our parametric analysis corroborates the earlier observation of an inverse relation between real exchange rate persistence and nominal exchange rate volatility. Indeed, the corresponding slope coefficient is consistently significant across virtually all specifications given in tables 4–8. The average point estimate for the overall samples in table 4 is around -0.63 indicating that a 10 percent rise in nominal exchange rate volatility is tied to a 6.3 percent decline in the real exchange rate half-life. Moreover, the volatility effect on the different selected model half-lives (columns (5)-(9)) displays little variation. Table 9 also confirms that countries which were typically characterized by a fixed exchange rate regime had much lower nominal exchange rate volatility. Certainly, if exchange rate arrangement instead of volatility was used

[46]The outlier of Ukraine drives the positive coefficients for the developing group in the REER sample.

in the regressions, one would observe that more flexible regimes are associated with lower real exchange rate inertia.[47] In line with Cheung *et al.* (2004), our empirical findings suggest that nominal exchange rate adjustment is more important than price adjustment in governing the speed of parity convergence.

The coefficient for trade openness is around -0.45 on average when considering the entire samples. Apart from middle-income countries, trade openness does not appear to be a significant factor across sub-samples due to the homogeneity within country groups. For instance, industrial countries have low average levels of trade openness and exhibit slow real exchange rate convergence. Overall, we find sufficient evidence in favor of the theoretical arguments of Bergin and Feenstra (2001).

Focusing on distance in the bilateral real exchange rate persistence case in table 4, we obtain unequivocal support for the notion that countries exhibiting greater geographical proximity to the U.S. observe faster mean-reversion, despite controlling for a number of other macroeconomic factors. Except for industrial and high-income groups, the same conclusion can be reached in sub-samples (tables 5–8) as indicated by the statistically significant positive coefficients. This result is in opposition to that of Cheung *et al.* (2001) who state that the distance effect is absorbed by other determinants, such as nominal exchange rate volatility which happens to be positively correlated with the variable. Distance may be representing transportation costs and/or monetary policy similarities. However, these factors to some extent may already be accounted for by the nonlinear estimation of real exchange rate dynamics and the inclusion of inflation and nominal exchange rate flexibility/volatility variables in the cross-section regressions.

Despite recognizing that our measure of productivity growth is not ideal, we still note that there is some evidence of a positive link between growth and the persistence of smaller real effective exchange rate parity deviations for the full sample. Specifically, a 1 percentage point rise in productivity growth is correlated with a +10 percent change in persistence. In the bilateral case nevertheless, the results are insignificant.[48] Tables 5–8 show mixed results, with significantly negative slope coefficients in a couple of country groups.

Table 4 reveals almost no evidence in full samples of higher government spending leading to slower parity reversion. As Galstyan and Lane (2009) demonstrate, while government consumption unambiguously leads to a real exchange rate appreciation, government investment may potentially depreciate a country's real currency if it improves the relative productivity of the nontraded sector. If these dynamics offset each other, then we may observe no effect on real exchange rate persistence. Tables 5–8 overall display mixed results regarding government spending in sub-samples, with mostly insignificant estimates yet again.

The relation between international financial integration and the persistence of parity deviations is virtually non-existent for overall samples.[49] Nonetheless, some support in favor of a relation between the two variables is found at sub-sample level. In particular, the sign of the correlation changes across country groups which may obscure results at the aggregate level. Tables 5–8 report a positive link between financial integration and the real exchange rate half-life for developing countries. Conversely, high-income, industrial and emerging economies display some evidence of a negative link.

As mentioned in section 4.4, the debt component of the volume-based measure of IFI may be driving upward the partial effect in the wider bilateral exchange rate persistence sample

[47] This was checked using the data and verified to be the case.

[48] See Cheung and Lai (2000a) for an explanation.

[49] The results do not change if one uses the *de jure* Chinn and Ito index of financial openness instead.

of developing economies. Indeed, an excessive reliance on debt finance is often associated with greater vulnerability. More generally, Devereux and Lane (2003) find that nominal exchange rate volatility in developing countries is reduced by external financial liabilities via its impact on the choice of exchange rate regime. Specifically, external debt tightens financial constraints and attenuates the efficiency of the exchange rate in responding to external shocks. Furthermore, the accumulation of international reserves in non-industrialized economies may have contributed toward higher real exchange rate inertia by affording the ability to defend currency pegs. While figure 11 displays effectively a zero correlation between real exchange rate persistence and reserves in full samples, the same figure shows that a significant positive link between the two variables holds for developing and emerging nations collectively.[50]

5 Conclusion

This paper estimates the persistence of real exchange rates across the globe and explores the potential factors driving the cross-country variation in persistence estimates. Our analysis indicates that allowing for deterministic structural breaks and adjustment nonlinearities in the real exchange rate can reduce the half-life of parity deviations to a level consistent with the predictions of sticky-price models. We find that developing countries typically display the fastest rate of mean reversion in the real exchange rate, while, more generally, multilateral exchange rates exhibit faster convergence than bilateral exchange rates. Given the vast heterogeneity present in cross-country real exchange rate specifications, we conclude that global homogeneous panel studies of exchange rate dynamics may lead to inaccurate results.

Analyzing the factors contributing to the persistence of real exchange rate misalignments, we find that higher inflation, nominal exchange rate volatility, trade openness and proximity to reference country are associated with faster real exchange rate convergence. In contrast, the degree of international financial openness only plays a role at the country group level. The results suggest that developing economies tend to display a positive link between persistence and international financial integration while more advanced economies show signs of a negative link between the two variables.

[50] International reserves exclude gold holdings. We also inspected the connection between the net foreign asset position and real exchange rate persistence. Overall, the results indicated no significant link.

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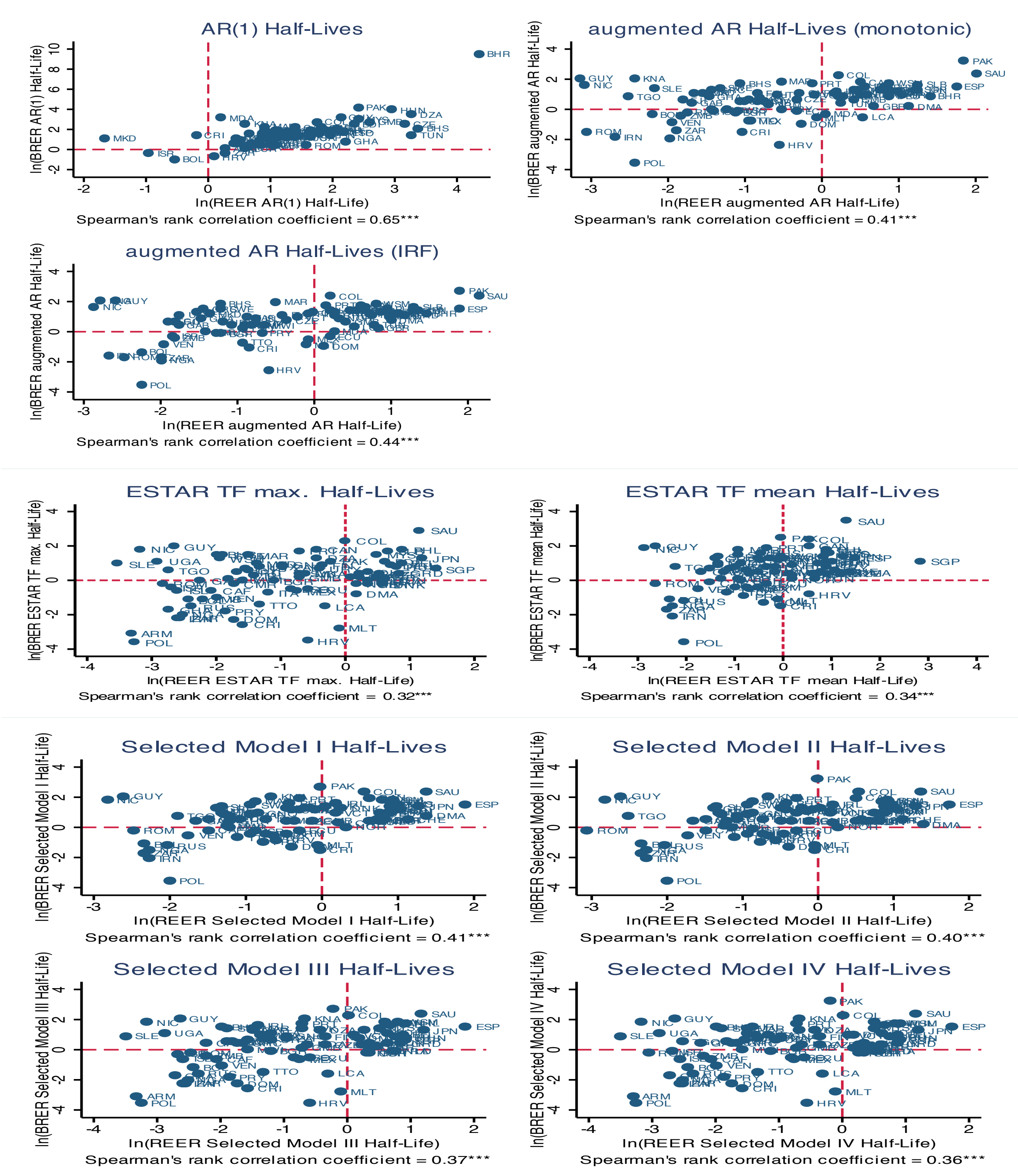
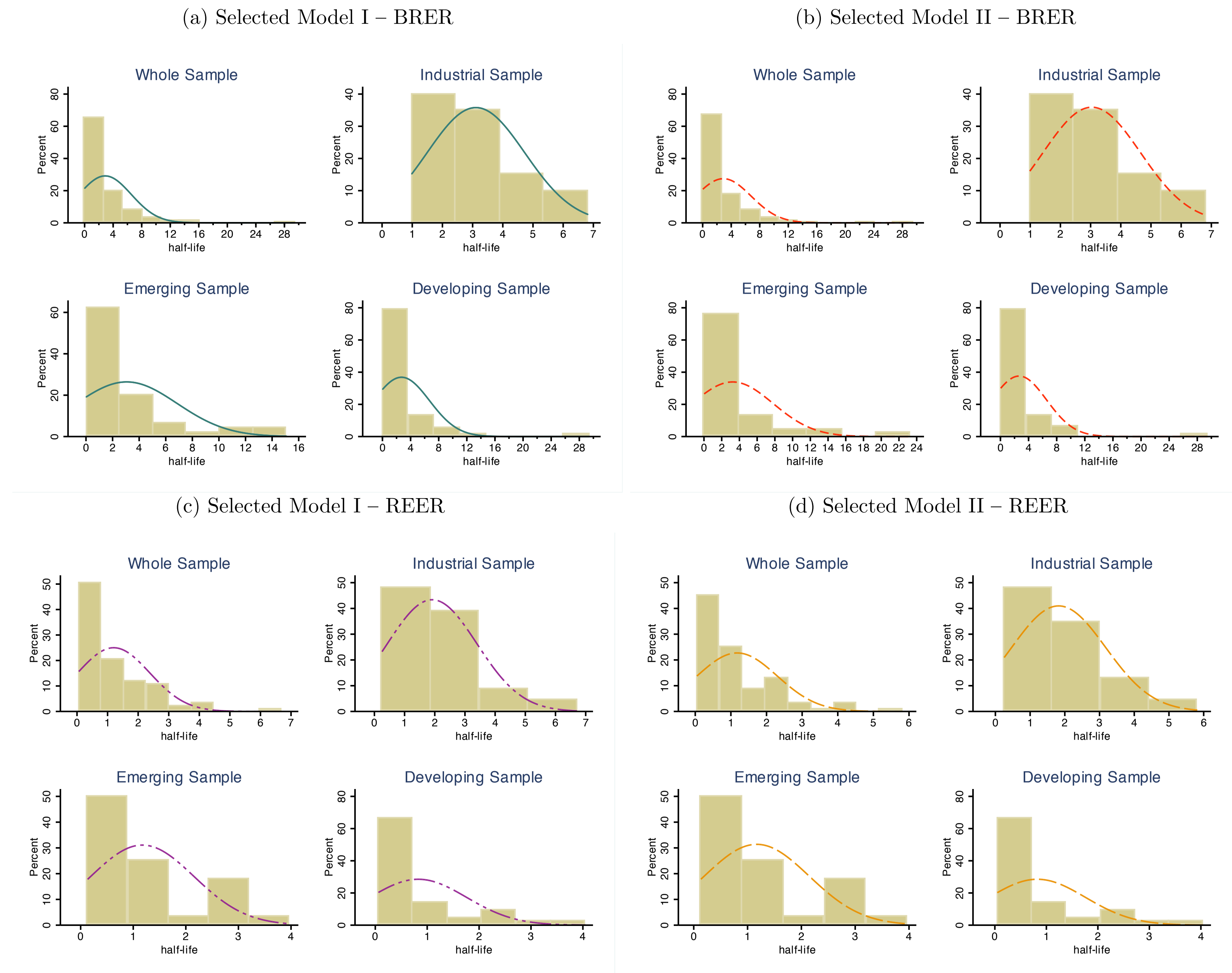
Figure 1: BRER vs REER Half-Life – Linear, Nonlinear and Selected Model Estimates



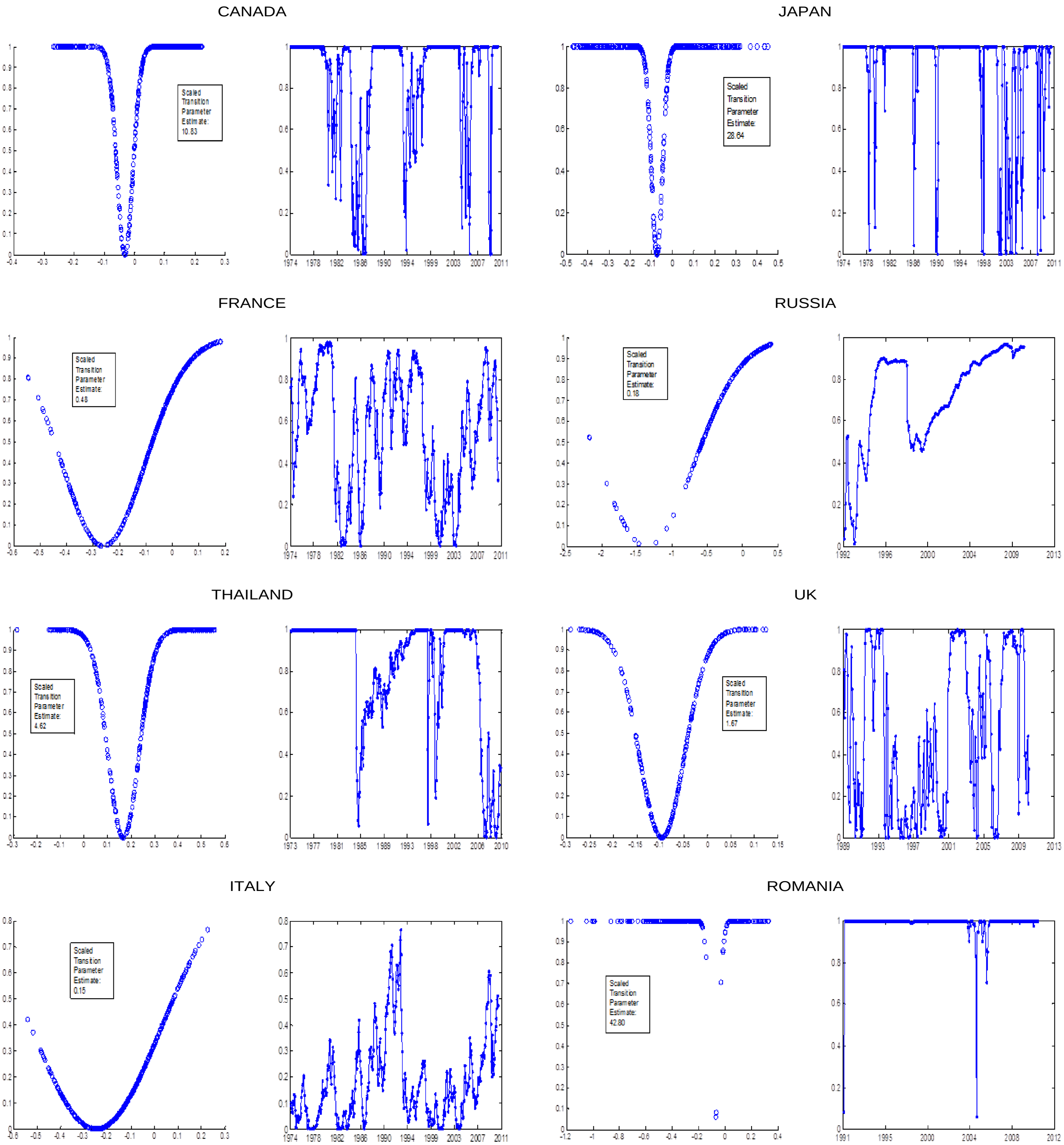
* significant at 10%; ** significant at 5%; *** significant at 1%. BRER (REER) denotes bilateral real exchange rate (real effective exchange rate). TF max. (mean) denotes the 100th percentile or maximum value (average value) of the transition function. Selected Model I Half-Lives: when nonlinear model is chosen monotonic half-life is based on mean of transition function, and when linear model is chosen IRF half-life is employed. Selected Model II Half-Lives: when nonlinear model is chosen monotonic half-life is based on mean of transition function, and when linear model is chosen monotonic half-life is employed. Selected Model III Half-Lives: when nonlinear model is chosen monotonic half-life is based on maximum of transition function, and when linear model is chosen IRF half-life is employed. Selected Model IV Half-Lives: when nonlinear model is chosen monotonic half-life is based on maximum of transition function, and when linear model is chosen monotonic half-life is employed. Sample consists of 83 countries. Time period: 1973:1-2010:12. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales i.e. half-life in years – our measure of real exchange rate persistence. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -4 = "0.02", -3 = "0.05" $(0.02 \times e)$, -2 = "0.14" $(0.05 \times e)$, -1 = "0.37" $(0.14 \times e)$, 0 = "1" $(0.37 \times e)$, 1 = "2.72" $(1 \times e)$, 2 = "7.39" $(2.72 \times e)$, 3 = "20.09" $(7.39 \times e)$, 4 = "54.60" $(20.09 \times e)$, 5 = "148.41" $(54.60 \times e)$.

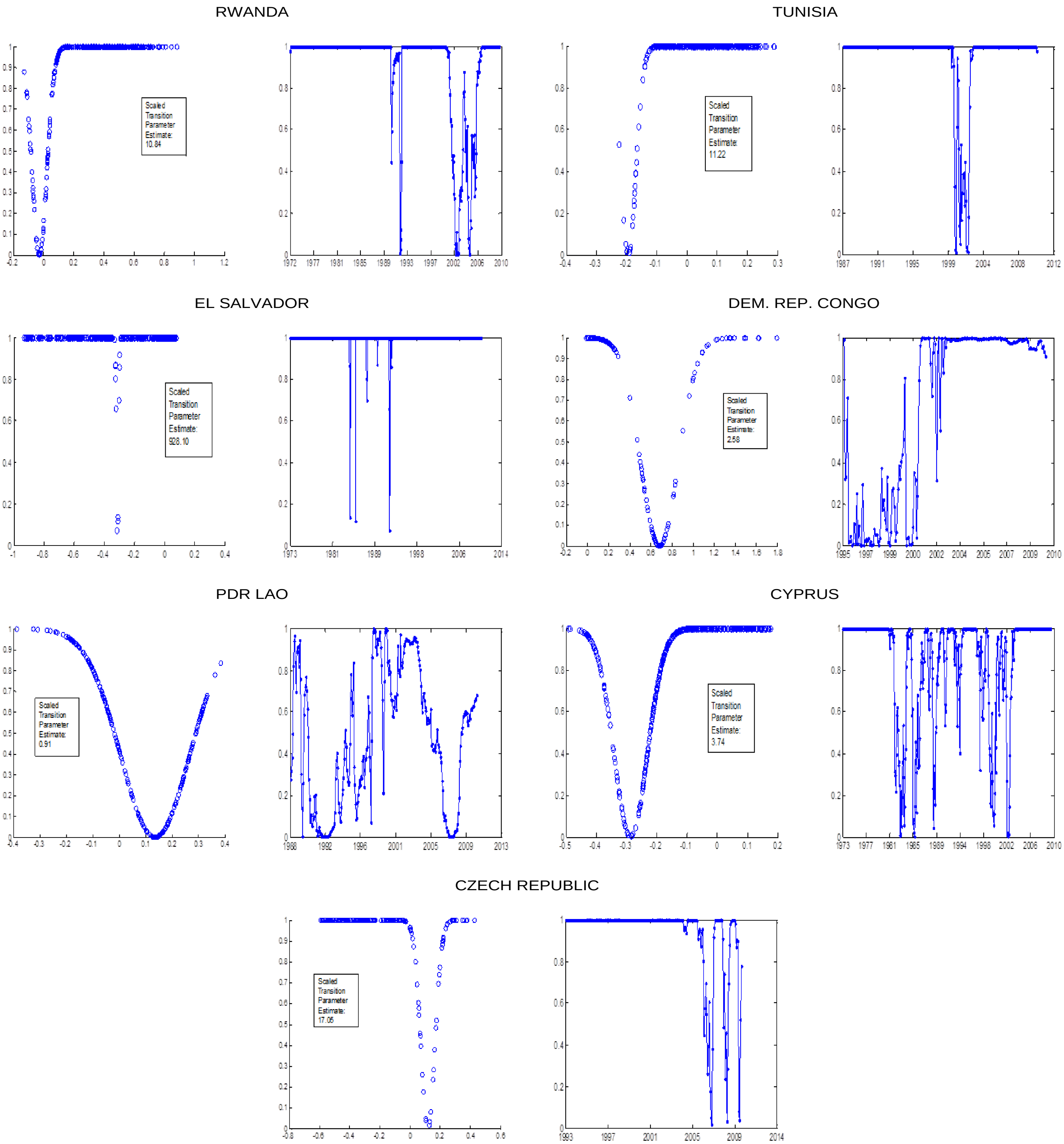
Figure 2: Half-Life Distributions



BRER (REER) denotes bilateral real exchange rate (real effective exchange rate). Selected Model I Half-Life (in years); whenever nonlinear model is chosen monotonic half-life is based on mean of transition function, and whenever linear model is chosen IRF half-life is employed.

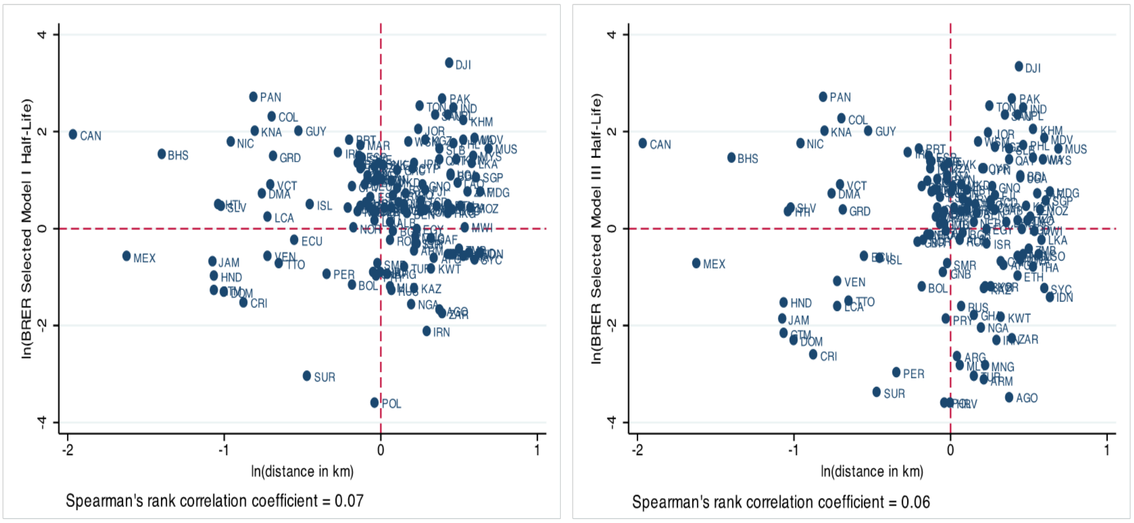
Figure 3: Transition Function vs. Transition Variable on Left, Transition Function vs Time on Right, BRERs (selected countries)





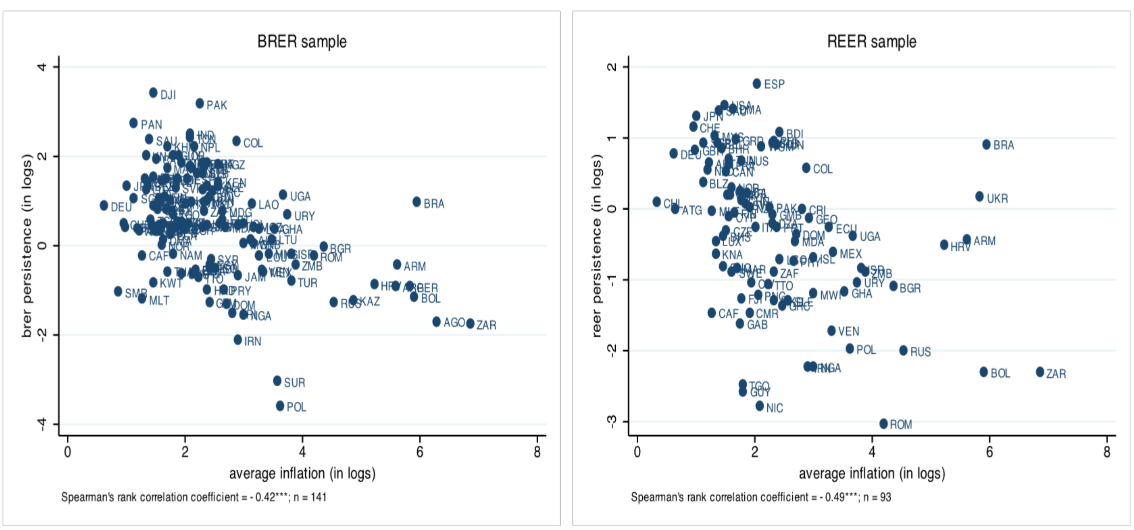
BRERs denotes bilateral real exchange rate sample. Industrial Countries: Canada, France, Italy, Japan, United Kingdom (UK). Emerging Countries: Cyprus, Czech Republic, Russia, Thailand. Developing Countries: Congo, Dem. Rep., El Salvador, Lao, PDR, Romania, Rwanda, Tunisia. Scaled transition parameter estimate is equal to the original transition parameter estimate multiplied by the variance of (the log of) the bilateral real exchange rate in question. Parameter estimate is scaled by real exchange rate variance as in Michael *et al.* (1997) for purposes of comparison.

Figure 4: BRER Selected Model Half-Life vs Distance from US



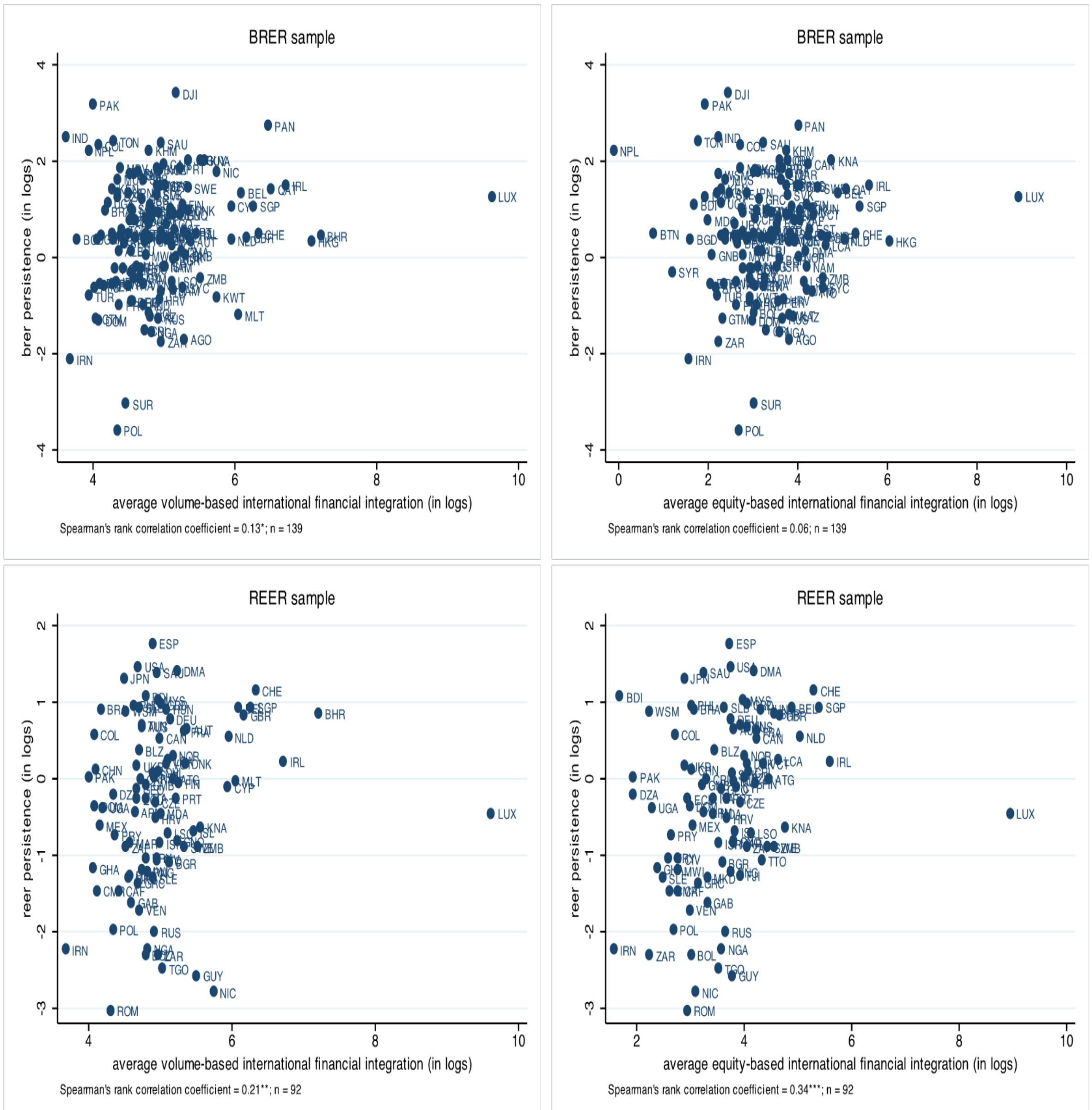
BRER denotes bilateral real exchange rate. Selected Model I (III) Half-Life; whenever nonlinear model is chosen monotonic half-life is based on mean (maximum) of transition function, and whenever linear model is chosen IRF half-life is employed. The distance (in kilometers) between the US and country j is based on bilateral distances between the largest cities of the two countries, with those inter-city distances being weighted by the share of the cities in the countries' respective overall populations – source: CEPII's GeoDist database (variable name: distwces). With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -4 = "0.02", -3 = "0.05" ($0.02 \times e$), -2 = "0.14" ($0.05 \times e$), -1 = "0.37" ($0.14 \times e$), 0 = "1" ($0.37 \times e$), 1 = "2.72" ($1 \times e$), 2 = "7.39" ($2.72 \times e$), 3 = "20.09" ($7.39 \times e$), 4 = "54.60" ($20.09 \times e$). Original distance data is divided by 8000 so that $\ln(1) = 0$ on the x-axis represents approximately 8000km.

Figure 5: Real Exchange Rate Persistence vs. Inflation Rate



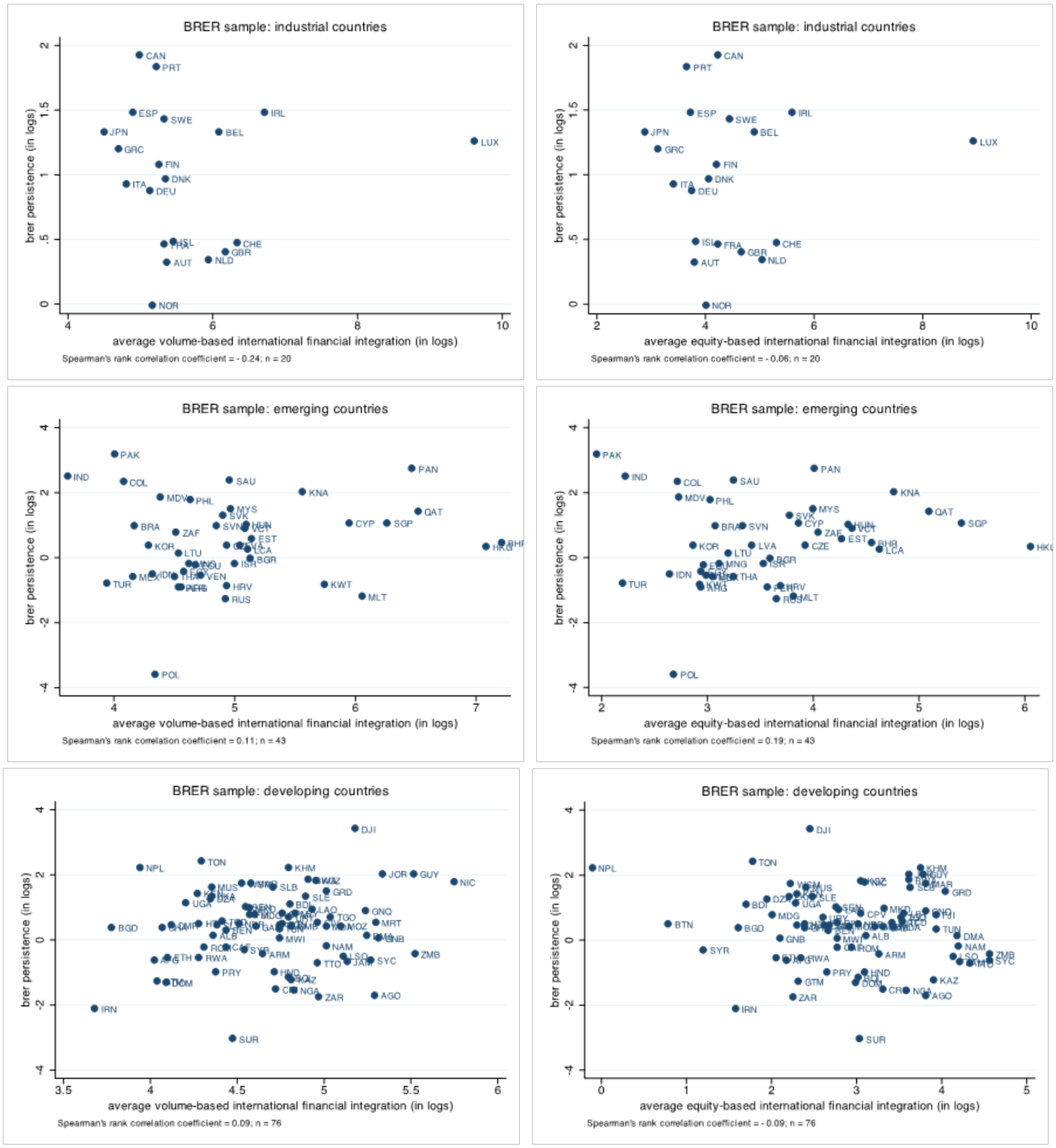
* significant at 10%; ** significant at 5%; *** significant at 1%. BRER denotes bilateral real exchange rate. REER denotes real effective exchange rate. n is the country sample size. Time period: 1973-2010. CPI-based inflation (%) is used. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -4 = "0.02", -3 = "0.05" ($0.02 \times e$), -2 = "0.14" ($0.05 \times e$), -1 = "0.37" ($0.14 \times e$), 0 = "1" ($0.37 \times e$), 1 = "2.72" ($1 \times e$), 2 = "7.39" ($2.72 \times e$), 3 = "20.09" ($7.39 \times e$), 4 = "54.60" ($20.09 \times e$), 5 = "148.41" ($54.60 \times e$), 6 = "403.43" ($148.41 \times e$), 7 = "1096.63" ($403.43 \times e$).

Figure 6: Real Exchange Rate Persistence vs. International Financial Integration



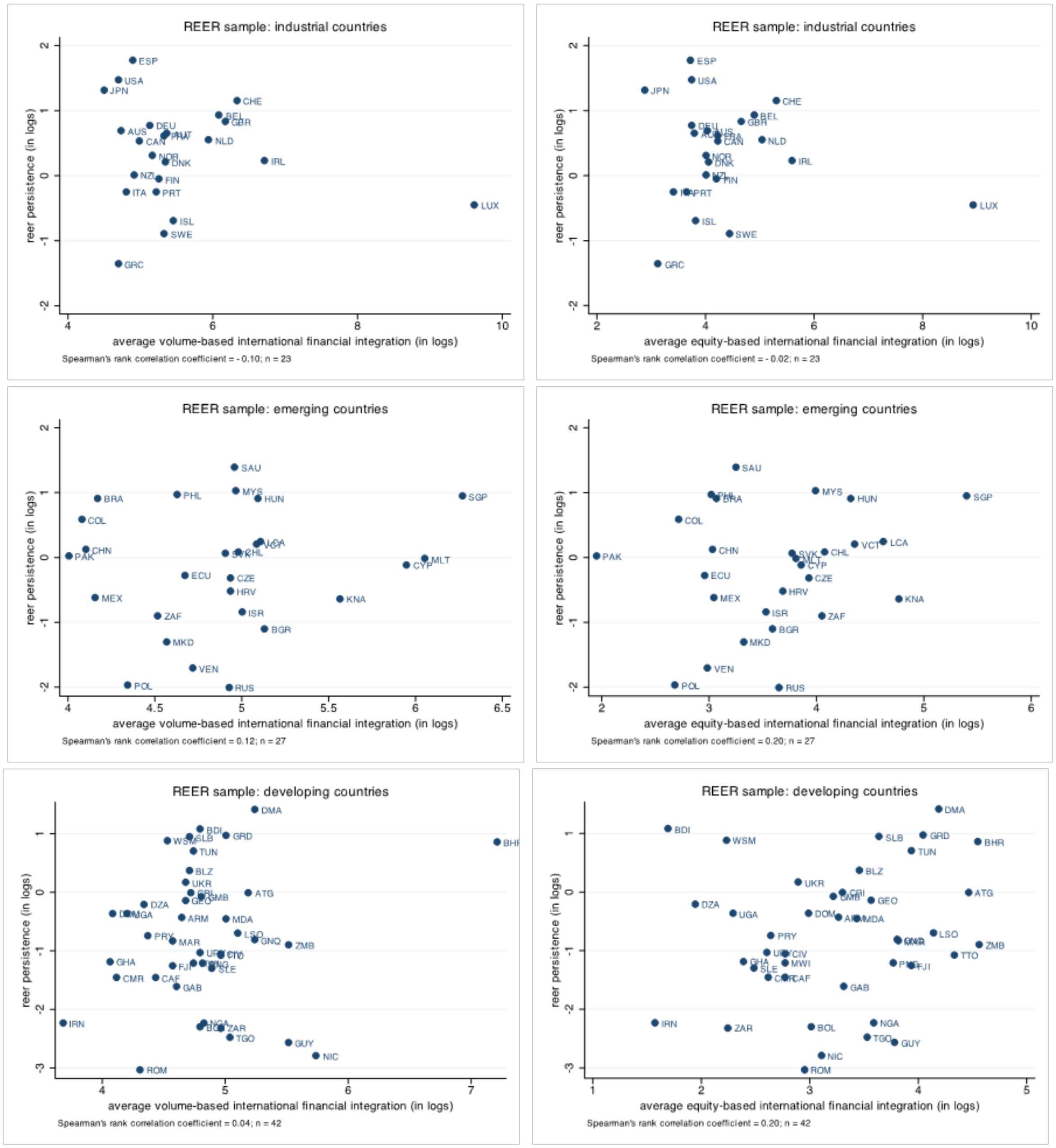
* significant at 10%; ** significant at 5%; *** significant at 1%. BRER (REER) denotes bilateral real exchange rate (real effective exchange rate). n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Volume (equity)-based integration is defined as total external assets (portfolio equity and FDI assets) plus total external liabilities (portfolio equity and FDI liabilities) expressed as a percentage of GDP. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: $-4 =$ "0.02", $-3 =$ "0.05" $(0.02 \times e)$, $-2 =$ "0.14" $(0.05 \times e)$, $-1 =$ "0.37" $(0.14 \times e)$, $0 =$ "1" $(0.37 \times e)$, $1 =$ "2.72" $(1 \times e)$, $2 =$ "7.39" $(2.72 \times e)$, $3 =$ "20.09" $(7.39 \times e)$, $4 =$ "54.60" $(20.09 \times e)$, $5 =$ "148.41" $(54.60 \times e)$, $6 =$ "403.43" $(148.41 \times e)$, $7 =$ "1096.63" $(403.43 \times e)$, $8 =$ "2980.96" $(1096.63 \times e)$.

Figure 7: Bilateral Real Exchange Rate Persistence vs. International Financial Integration by Stage of Economic Development



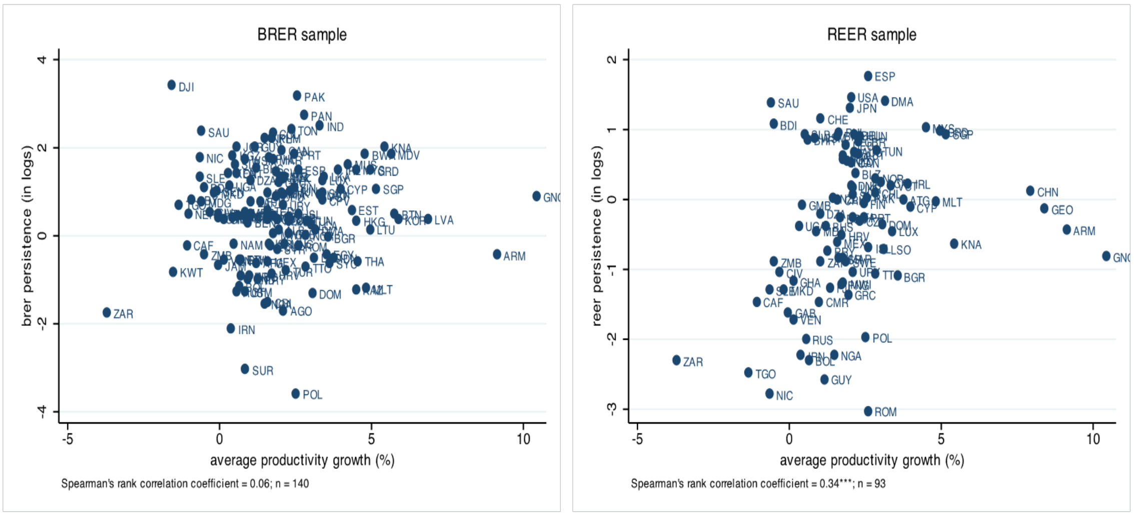
* significant at 10%; ** significant at 5%; *** significant at 1%. BRER denotes bilateral real exchange rate. n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Volume (equity)-based integration is defined as total external assets (portfolio equity and FDI assets) plus total external liabilities (portfolio equity and FDI liabilities) expressed as a percentage of GDP. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: $-4 =$ "0.02", $-3 =$ "0.05" $(0.02 \times e)$, $-2 =$ "0.14" $(0.05 \times e)$, $-1 =$ "0.37" $(0.14 \times e)$, $0 =$ "1" $(0.37 \times e)$, $1 =$ "2.72" $(1 \times e)$, $2 =$ "7.39" $(2.72 \times e)$, $3 =$ "20.09" $(7.39 \times e)$, $4 =$ "54.60" $(20.09 \times e)$, $5 =$ "148.41" $(54.60 \times e)$, $6 =$ "403.43" $(148.41 \times e)$, $7 =$ "1096.63" $(403.43 \times e)$, $8 =$ "2980.96" $(1096.63 \times e)$.

Figure 8: Multilateral Real Exchange Rate Persistence vs. International Financial Integration by Stage of Economic Development



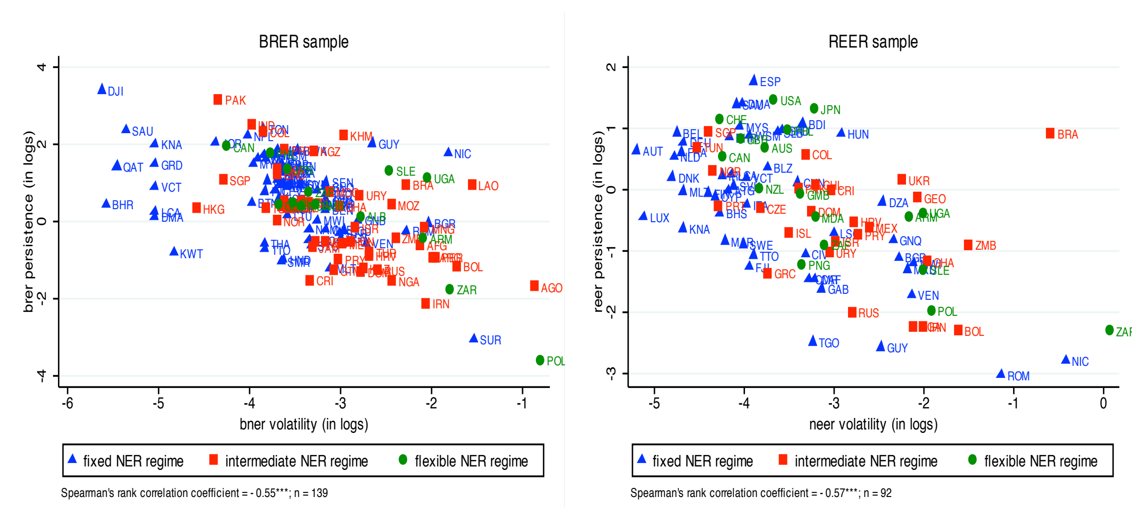
* significant at 10%; ** significant at 5%; *** significant at 1%. REER denotes real effective exchange rate. n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Volume (equity)-based integration is defined as total external assets (portfolio equity and FDI assets) plus total external liabilities (portfolio equity and FDI liabilities) expressed as a percentage of GDP. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -3 = "0.05", -2 = "0.14" ($0.05 \times e$), -1 = "0.37" ($0.14 \times e$), 0 = "1" ($0.37 \times e$), 1 = "2.72" ($1 \times e$), 2 = "7.39" ($2.72 \times e$), 3 = "20.09" ($7.39 \times e$), 4 = "54.60" ($20.09 \times e$), 5 = "148.41" ($54.60 \times e$), 6 = "403.43" ($148.41 \times e$), 7 = "1096.63" ($403.43 \times e$), 8 = "2980.96" ($1096.63 \times e$).

Figure 9: Real Exchange Rate Persistence vs. Productivity Growth



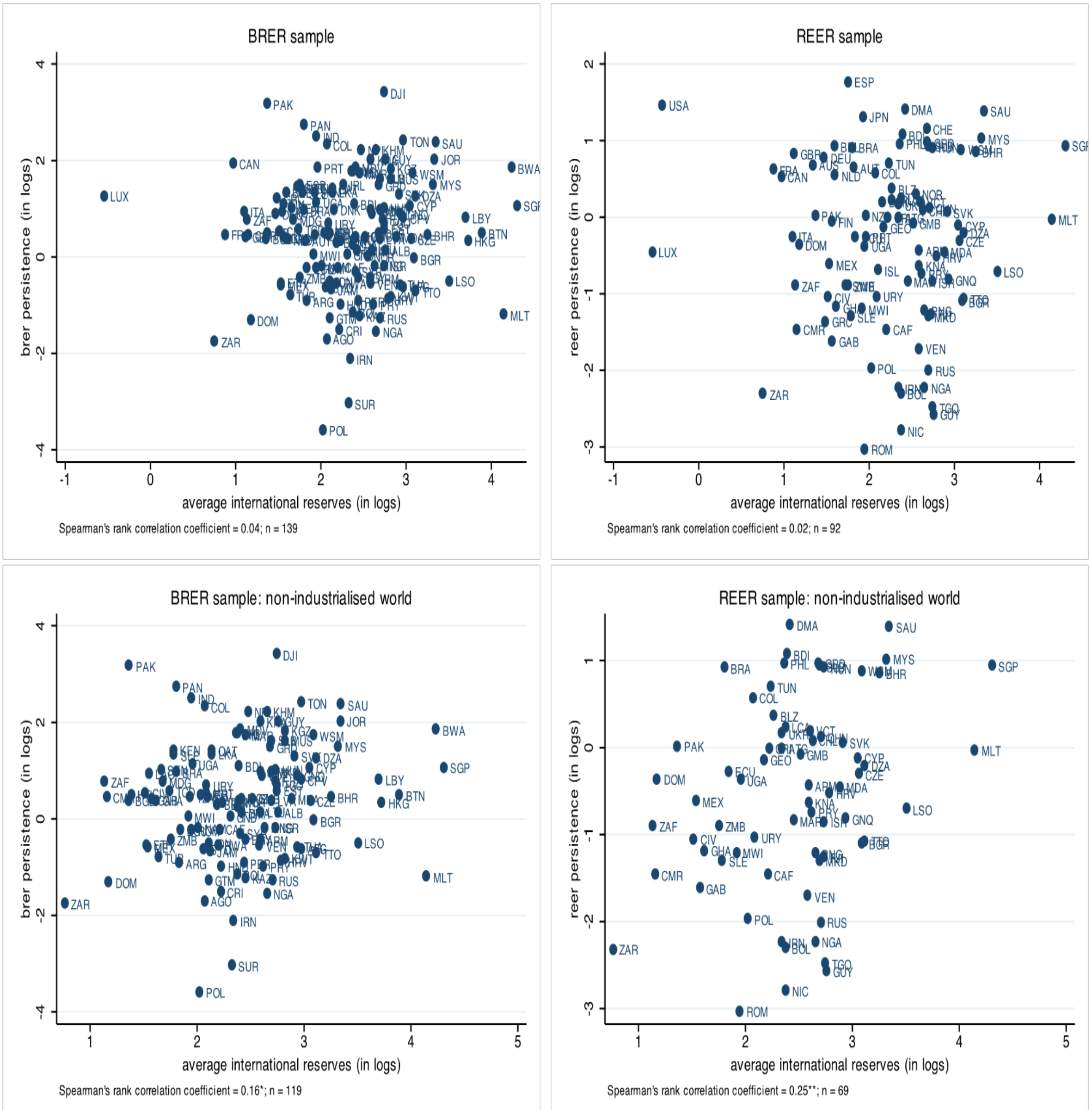
* significant at 10%; ** significant at 5%; *** significant at 1%. BRER denotes bilateral real exchange rate. REER denotes real effective exchange rate. n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Productivity growth is proxied by per capita GDP growth. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -4 = "0.02", -3 = "0.05" $(0.02 \times e)$, -2 = "0.14" $(0.05 \times e)$, -1 = "0.37" $(0.14 \times e)$, 0 = "1" $(0.37 \times e)$, 1 = "2.72" $(1 \times e)$, 2 = "7.39" $(2.72 \times e)$, 3 = "20.09" $(7.39 \times e)$, 4 = "54.60" $(20.09 \times e)$.

Figure 10: Real Exchange Rate Persistence vs. Nominal Exchange Rate Volatility



* significant at 10%; ** significant at 5%; *** significant at 1%. brer (bner) denotes bilateral real (nominal) exchange rate. reer (neer) denotes real (nominal) effective exchange rate. n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). Nominal exchange rate volatility is defined as the standard deviation of the change in the natural logarithm of the monthly nominal exchange rate. Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: -6 = "0.00", -5 = "0.01" $(0.00 \times e)$, -4 = "0.02" $(0.01 \times e)$, -3 = "0.05" $(0.02 \times e)$, -2 = "0.14" $(0.05 \times e)$, -1 = "0.37" $(0.14 \times e)$, 0 = "1" $(0.37 \times e)$, 1 = "2.72" $(1 \times e)$, 2 = "7.39" $(2.72 \times e)$, 3 = "20.09" $(7.39 \times e)$, 4 = "54.60" $(20.09 \times e)$.

Figure 11: Real Exchange Rate Persistence vs. International Reserves



* significant at 10%; ** significant at 5%; *** significant at 1%. brer (bner) denotes bilateral real (nominal) exchange rate. reer (neer) denotes real (nominal) effective exchange rate. n is the country sample size. Time period: 1973-2010. Real exchange rate persistence is gauged by the selected model II half-life (monotonic half-life based on mean of transition function is reported in nonlinear case; monotonic half-life is reported in linear case; half-life is given in years). International reserves exclude gold holdings and are expressed as a percentage of GDP (source: EWN II). Noting that the mathematical constant $e \approx 2.72$ is the base of the natural logarithm, it is easy to convert the log scales back to the original variable scales. With log scale data on the left of the equality and approximate original variable data in inverted commas on the right of the equality: $-4 =$ “0.02”, $-3 =$ “0.05” $(0.02 \times e)$, $-2 =$ “0.14” $(0.05 \times e)$, $-1 =$ “0.37” $(0.14 \times e)$, $0 =$ “1” $(0.37 \times e)$, $1 =$ “2.72” $(1 \times e)$, $2 =$ “7.39” $(2.72 \times e)$, $3 =$ “20.09” $(7.39 \times e)$, $4 =$ “54.60” $(20.09 \times e)$, $5 =$ “148.41” $(54.60 \times e)$.

Table 1: Median Half-Life Estimates (in Years)

Sample	*Size*	*simple AR model half-life*	*augmented AR model monotonic half-life*	*augmented AR model IRF half-life*	*augmented ESTAR model TF max. half-life*	*augmented ESTAR model TF mean half-life*
BRER						
Whole	141	4.32	1.93	2.17	1.11	1.54
Industrial	20	3.87	2.77	3.22	1.35	2.30
Emerging	45	5.07	1.93	2.03	0.88	1.37
Developing	76	4.43	1.45	1.53	1.10	1.55
Test of Equal		0.99	16.18***	20.48***	1.35	7.68**
Sub-Group Medians		[0.61]	[0.00]	[0.00]	[0.51]	[0.02]
High Income	42	4.57	2.60	3.08	1.15	1.79
Middle Income	74	3.91	1.34	1.43	0.90	1.44
Low Income	25	6.64	2.17	2.17	1.25	1.61
Test of Equal		0.57	10.51***	12.13***	2.73	1.76
Sub-Group Medians		[0.75]	[0.01]	[0.00]	[0.26]	[0.42]
Africa	41	4.11	1.54	1.54	1.11	1.61
Asia	32	6.39	2.67	3.21	1.13	1.79
Europe	35	3.53	2.35	2.75	1.08	1.49
Latin America	28	3.85	1.11	1.22	0.38	1.01
Oceania	4	7.00	5.23	5.49	3.78	4.31
Test of Equal		11.61**	7.20	8.70*	5.46	6.66
Sub-Group Medians		[0.02]	[0.12]	[0.07]	[0.24]	[0.16]
REER						
Whole	93	3.57	0.73	0.92	0.50	0.86
Industrial	23	3.65	1.68	1.89	1.22	1.88
Emerging	28	3.93	0.84	0.97	0.67	1.03
Developing	42	2.95	0.39	0.42	0.18	0.45
Test of Equal		1.98	15.62***	17.63***	13.51***	14.25***
Sub-Group Medians		[0.37]	[0.00]	[0.00]	[0.00]	[0.00]
High Income	38	3.67	1.29	1.37	0.78	1.51
Middle Income	47	3.03	0.48	0.52	0.34	0.64
Low Income	8	2.83	0.22	0.23	0.11	0.28
Test of Equal		2.36	7.50**	7.50**	9.32***	9.72***
Sub-Group Medians		[0.31]	[0.02]	[0.02]	[0.01]	[0.01]
Africa	20	3.09	0.32	0.38	0.17	0.37
Asia	13	4.11	1.61	1.78	1.10	1.11
Europe	30	3.63	1.01	1.22	0.61	1.10
Latin America	22	2.91	0.67	0.79	0.55	0.79
Oceania	6	4.33	1.88	1.85	0.24	1.00
Test of Equal		4.91	6.99	7.84*	10.54**	11.69**
Sub-Group Medians		[0.30]	[0.13]	[0.10]	[0.03]	[0.02]

* significant at 10%; ** significant at 5%; *** significant at 1%
'Test of equal sub-group medians' tests the null hypothesis of equal medians across the relevant sub-groups using the non-parametric Mood's median test. For the tests, the Pearson χ^2 statistic and corresponding p-value in square brackets are reported. The Pearson χ^2 and Fisher exact versions of the test lead to consistent conclusions. The results of the median test are consistent with those of the Kruskal-Wallis test. Unlike Mood's median test, the Kruskal-Wallis test assumes that the variances across the sub-group samples of concern are approximately equal. Nevertheless, it is a more powerful (efficient) test for moderate to large samples. TF: Transition Function.

Table 2: Median Half-Life Estimates (in Years) based on Selected Models

Sample	*Size*	*Selected Model I half-life*	*Selected Model II half-life*	*Selected Model III half-life*	*Selected Model IV half-life*	*Sample*	*Size*	*Selected Model I half-life*	*Selected Model II half-life*	*Selected Model III half-life*	*Selected Model IV half-life*
BRER						*REER*					
Whole	141	1.60	1.59	1.38	1.38	Whole	93	0.77	0.77	0.50	0.50
Industrial	20	3.13	2.78	2.20	2.20	Industrial	23	1.88	1.68	1.40	1.34
Emerging	45	1.42	1.42	1.13	1.13	Emerging	28	0.92	0.92	0.64	0.66
Developing	76	1.54	1.54	1.35	1.29	Developing	42	0.43	0.43	0.20	0.20
Test of Equal		3.96	3.96	4.34*	4.34*	Test of Equal		10.06***	10.06***	13.51***	13.51***
Sub-Group Medians		[0.13]	[0.13]	[0.10]	[0.10]	Sub-Group Medians		[0.01]	[0.01]	[0.00]	[0.00]
High Income	42	2.56	2.46	1.98	1.92	High Income	38	1.15	1.13	0.78	0.78
Middle Income	74	1.47	1.44	1.17	1.14	Middle Income	47	0.63	0.63	0.31	0.35
Low Income	25	1.61	1.61	1.33	1.33	Low Income	8	0.28	0.28	0.14	0.11
Test of Equal		2.91	2.91	2.42	2.42	Test of Equal		5.66*	5.66*	9.32***	9.32***
Sub-Group Medians		[0.23]	[0.23]	[0.30]	[0.30]	Sub-Group Medians		[0.06]	[0.06]	[0.01]	[0.01]
Africa	41	1.54	1.54	1.46	1.44	Africa	20	0.37	0.37	0.17	0.17
Asia	32	2.06	2.06	1.14	1.14	Asia	13	1.11	1.11	1.10	1.10
Europe	35	1.59	1.59	1.38	1.38	Europe	30	0.95	0.95	0.61	0.62
Latin America	28	1.01	0.94	0.52	0.52	Latin America	22	0.72	0.72	0.51	0.51
Oceania	4	5.52	5.26	5.52	5.26	Oceania	6	1.48	1.48	0.55	0.55
Test of Equal		4.75	5.46	5.32	5.32	Test of Equal		9.02*	9.02*	9.36**	9.36**
Sub-Group Medians		[0.31]	[0.24]	[0.26]	[0.26]	Sub-Group Medians		[0.06]	[0.06]	[0.05]	[0.05]

* significant at 10%; ** significant at 5%; *** significant at 1%
'Test of equal sub-group medians' tests the null hypothesis of equal medians across the relevant sub-groups using the non-parametric Mood's median test. For the tests, the Pearson χ^2 statistic and corresponding p-value in square brackets are reported. The Pearson χ^2 and Fisher exact versions of the test lead to consistent conclusions. The results of the median test are consistent with those of the Kruskal-Wallis test. Unlike Mood's median test, the Kruskal-Wallis test assumes that the variances across the sub-group samples of concern are approximately equal. Nevertheless, it is a more powerful (efficient) test for moderate to large samples. TF: Transition Function.
Selected Model I: whenever ESTAR is chosen, half-life is based on mean of TF; whenever linear augmented AR is chosen, IRF half-life is picked.
Selected Model II: whenever ESTAR is chosen, half-life is based on mean of TF; whenever linear augmented AR is chosen, monotonic half-life is picked.
Selected Model III: whenever ESTAR is chosen, half-life is based on max. of TF; whenever linear augmented AR is chosen, IRF half-life is picked.
Selected Model IV: whenever ESTAR is chosen, half-life is based on max of TF; whenever linear augmented AR is chosen, monotonic half-life is picked.

Table 3: Medians of Macroeconomic Variables

Sample	***Size***	***Inflation Rate***	***Government Expenditure***	***Trade Openness***	***International Financial Integration***	***Productivity Growth***	***Nominal Exchange Rate Volatility***
BRER							
Whole	141	8.90	31.20	74.08	123.32, 26.28	1.78	0.03
Industrial	20	4.88	44.69	67.06	209.57, 63.59	2.15	0.03
Emerging	45	9.62	34.83	94.85	135.60, 30.92	2.44	0.03
Developing	76	10.20	26.28	71.60	114.05, 20.28	1.02	0.04
Test of Equal		11.71***	33.64***	4.29*	14.3***,18.3***	28.79***	26.89***
Sub-Group Medians		[0.00]	[0.00]	[0.10]	[0.00], [0.00]	[0.00]	[0.00]
High Income	42	4.73	42.04	87.23	191.51, 53.34	2.29	0.03
Middle Income	74	10.95	28.94	76.30	103.78, 22.32	1.72	0.04
Low Income	25	10.18	19.79	50.81	99.86, 10.95	0.70	0.04
Test of Equal		19.47***	40.41***	9.77***	32.3***,33.1***	33.10***	29.61***
Sub-Group Medians		[0.00]	[0.00]	[0.01]	[0.00], [0.00]	[0.00]	[0.00]
Africa	41	9.28	25.58	59.85	115.29, 18.44	0.87	0.04
Asia	32	8.05	25.37	80.70	103.78, 19.75	2.18	0.03
Europe	35	7.51	42.13	77.42	170.87, 44.64	2.31	0.03
Latin America	28	14.04	28.03	68.89	112.33, 21.74	1.45	0.04
Oceania	4	8.25	30.19	91.03	95.19, 23.86	1.10	0.02
Test of Equal		6.63	42.01***	9.85**	21.8***,23.0***	31.44***	24.47***
Sub-Group Medians		[0.16]	[0.00]	[0.04]	[0.00], [0.00]	[0.00]	[0.00]
REER							
Whole	93	7.51	32.49	73.70	136.64, 39.25	1.92	0.03
Industrial	23	4.94	43.59	60.90	193.77, 57.64	2.13	0.01
Emerging	28	9.95	33.75	88.86	139.81, 38.98	2.22	0.03
Developing	42	10.15	29.15	78.19	118.54, 26.90	1.23	0.05
Test of Equal		13.34***	36.71***	4.46*	10.3***,18.7***	10.06***	28.73***
Sub-Group Medians		[0.00]	[0.00]	[0.10]	[0.01], [0.00]	[0.01]	[0.00]
High Income	38	4.83	42.26	77.42	186.22, 55.59	2.18	0.02
Middle Income	47	10.28	28.85	73.70	111.43, 27.70	1.65	0.04
Low Income	8	12.27	19.78	49.97	122.84, 14.06	−0.57	0.08
Test of Equal		17.30***	35.92***	2.43	20.1***,31.0***	16.45***	32.83***
Sub-Group Medians		[0.00]	[0.00]	[0.30]	[0.00], [0.00]	[0.00]	[0.00]
Africa	20	10.23	26.02	59.44	118.70, 20.71	0.39	0.05
Asia	13	5.98	24.21	79.55	107.88, 26.28	2.59	0.03
Europe	30	6.46	43.31	76.42	174.50, 45.55	2.23	0.02
Latin America	22	8.72	29.15	75.54	121.85, 27.51	1.94	0.04
Oceania	6	7.35	32.86	91.03	113.41, 47.45	1.41	0.02
Test of Equal		2.25	48.26***	4.68	12.5***,12.8***	19.68***	21.39***
Sub-Group Medians		[0.69]	[0.00]	[0.32]	[0.01], [0.01]	[0.00]	[0.00]

* significant at 10%; ** significant at 5%; *** significant at 1%

'Test of equal sub-group medians' tests the null hypothesis of equal medians across the relevant sub-groups using the non-parametric Mood's median test. For the tests, the Pearson χ^2 statistic and corresponding p-value in square brackets are reported. The Pearson χ^2 and Fisher exact versions of the test lead to consistent conclusions. The results of the median test are consistent with those of the Kruskal-Wallis test. Unlike Mood's median test, the Kruskal-Wallis test assumes that the variances across the sub-group samples of concern are approximately equal. Nevertheless, it is a more powerful (efficient) test for moderate to large samples.

Table 4: Cross-section regression results for full BRER and REER samples

	simple AR model half-life	**augmented AR model monotonic half-life**	**augmented AR model IRF half-life**	**augmented ESTAR model TF max.**	**augmented ESTAR model TF mean**	**selected model I half-life**	**selected model II half-life**	**selected model III half-life**	**selected model IV half-life**
BRER-based	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.283**	−0.093	−0.183	−0.406***	−0.169*	−0.183*	−0.178*	−0.408***	−0.403***
(inf)	(0.131)	(0.112)	(0.115)	(0.127)	(0.099)	(0.096)	(0.097)	(0.127)	(0.127)
govt. exp.	−0.395	−0.205	−0.222	0.076	−0.002	0.078	0.020	0.215	0.157
(gov)	(0.299)	(0.271)	(0.269)	(0.318)	(0.255)	(0.258)	(0.257)	(0.331)	(0.331)
trade open.	0.175	−0.617***	−0.668***	−0.326	−0.352	−0.398*	−0.421*	−0.428	−0.451
(to)	(0.239)	(0.237)	(0.238)	(0.290)	(0.227)	(0.222)	(0.223)	(0.288)	(0.290)
prod. growth	−0.106**	0.026	0.032	−0.061	0.003	0.021	0.020	−0.029	−0.029
(PG)	(0.049)	(0.041)	(0.044)	(0.060)	(0.045)	(0.043)	(0.043)	(0.059)	(0.059)
ner volatility	−0.555**	−0.735***	−0.826***	−0.508**	−0.651***	−0.689***	−0.682***	−0.666***	−0.659***
(nerv)	(0.254)	(0.194)	(0.186)	(0.227)	(0.206)	(0.198)	(0.200)	(0.222)	(0.223)
financial int.	−0.051	0.244*	0.206	−0.029	0.025	0.035	0.058	−0.024	−0.001
(ifi)	(0.246)	(0.135)	(0.134)	(0.170)	(0.149)	(0.143)	(0.140)	(0.169)	(0.168)
geo. distance	0.367**	0.572***	0.477**	0.540**	0.438**	0.363*	0.381*	0.462*	0.480*
(dist)	(0.175)	(0.209)	(0.196)	(0.259)	(0.209)	(0.199)	(0.202)	(0.246)	(0.248)
Observations	138	138	138	138	138	138	138	138	138
R^2	0.34	0.38	0.46	0.34	0.36	0.39	0.39	0.39	0.38
REER-based	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.304***	0.006	−0.031	−0.115	0.095	0.009	0.023	−0.132	−0.118
(inf)	(0.104)	(0.110)	(0.105)	(0.137)	(0.112)	(0.102)	(0.101)	(0.132)	(0.133)
govt. exp.	−0.102	−0.288	−0.212	0.422	0.004	0.085	0.067	0.523	0.505
(gov)	(0.355)	(0.389)	(0.378)	(0.473)	(0.436)	(0.329)	(0.340)	(0.448)	(0.452)
trade open.	−0.198	−0.723***	−0.720***	−0.437	−0.506*	−0.580**	−0.596**	−0.393	−0.409
(to)	(0.226)	(0.289)	(0.277)	(0.329)	(0.312)	(0.258)	(0.258)	(0.315)	(0.315)
prod. growth	−0.038	0.063	0.055	0.054	0.108***	0.092***	0.097**	0.030	0.035
(PG)	(0.038)	(0.049)	(0.047)	(0.057)	(0.040)	(0.037)	(0.039)	(0.053)	(0.054)
ner volatility	−0.028	−0.760***	−0.715***	−0.608***	−0.707***	−0.636***	−0.651***	−0.640***	−0.655***
(nerv)	(0.148)	(0.153)	(0.144)	(0.147)	(0.135)	(0.130)	(0.133)	(0.146)	(0.147)
financial int.	−0.016	0.135	0.122	−0.048	0.086	0.053	0.060	−0.136	−0.129
(ifi)	(0.190)	(0.159)	(0.157)	(0.199)	(0.201)	(0.171)	(0.173)	(0.181)	(0.182)
Observations	90	91	91	91	91	91	91	91	91
R^2	0.18	0.39	0.39	0.38	0.40	0.42	0.42	0.40	0.40

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is the natural logarithm of the bilateral real exchange rate (BRER) half-life for BRER-based regression results and the natural logarithm of the real effective exchange rate (REER) half-life for REER-based regression results. The half-life is our measure of persistence. All regressors except for productivity growth (PG) are also expressed in logarithms. A test of normality of residuals is also performed for every specification using the Shapiro-Wilk test, and in each case the null hypothesis of normality cannot be rejected at the 10 percent level (all p-values are found to be notably larger than 0.10). Alternative numerical normality tests based on skewness and kurtosis yield consistent results. TF: Transition Function.

Table 5: BRER-based cross-section regression results by economic development group

	simple AR model half-life	**augmented AR model monotonic half-life**	**augmented AR model IRF half-life**	**augmented ESTAR model TF max.**	**augmented ESTAR model TF mean**	**selected model I half-life**	**selected model II half-life**	**selected model III half-life**	**selected model IV half-life**
Industrial Countries	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	0.353**	0.208	0.263	−0.055	0.363	0.364	0.349	0.127	0.112
(inf)	(0.153)	(0.179)	(0.170)	(0.404)	(0.269)	(0.269)	(0.267)	(0.418)	(0.409)
govt. exp.	0.018	−0.515	−0.410	−0.741	−0.207	0.024	−0.136	−0.077	−0.237
(gov)	(0.551)	(0.589)	(0.539)	(1.545)	(1.062)	(1.049)	(1.021)	(1.584)	(1.524)
trade open.	0.266	0.302	0.230	0.084	−0.334	−0.264	−0.243	−0.123	−0.102
(to)	(0.442)	(0.429)	(0.451)	(0.823)	(0.668)	(0.714)	(0.698)	(0.965)	(0.938)
prod. growth	−0.031	0.031	−0.026	−0.151	−0.110	0.065	0.061	0.191	0.187
(PG)	(0.140)	(0.143)	(0.139)	(0.241)	(0.220)	(0.270)	(0.259)	(0.397)	(0.380)
ner volatility	−1.932***	−1.956**	−1.657**	−2.218**	−2.080**	−2.233**	−2.183**	−3.039	−2.988
(nerv)	(0.527)	(0.784)	(0.645)	(1.040)	(0.756)	(0.959)	(0.922)	(1.915)	(1.857)
financial int.	−0.015	−0.097	−0.043	0.039	0.209	0.151	0.144	0.011	0.004
(ifi)	(0.189)	(0.184)	(0.194)	(0.327)	(0.286)	(0.327)	(0.318)	(0.421)	(0.410)
geo. distance	0.285	0.338	0.322	0.069	0.126	0.227	0.200	0.468	0.441
(dist)	(0.207)	(0.288)	(0.244)	(0.381)	(0.280)	(0.356)	(0.342)	(0.696)	(0.674)
Observations	20	20	20	20	20	20	20	20	20
R^2	0.48	0.38	0.31	0.23	0.32	0.33	0.33	0.25	0.26
Emerging Countries	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.768***	0.119	0.088	−0.038	0.236	0.126	0.153	−0.162	−0.134
(inf)	(0.218)	(0.264)	(0.259)	(0.311)	(0.190)	(0.182)	(0.177)	(0.301)	(0.297)
govt. exp.	−0.338	−0.197	−0.243	−0.207	−0.293	−0.005	−0.077	0.335	0.263
(gov)	(0.612)	(0.434)	(0.446)	(0.676)	(0.435)	(0.443)	(0.443)	(0.666)	(0.666)
trade open.	−0.916	−0.858*	−0.812*	0.118	0.232	−0.190	−0.153	−0.495	−0.458
(to)	(0.671)	(0.499)	(0.464)	(0.665)	(0.393)	(0.374)	(0.372)	(0.636)	(0.629)
prod. growth	−0.121	0.151*	0.161**	0.022	0.003	0.115	0.104	0.166	0.155
(PG)	(0.132)	(0.078)	(0.073)	(0.149)	(0.096)	(0.094)	(0.093)	(0.138)	(0.136)
ner volatility	−0.028	−1.091***	−1.166***	−1.053***	−1.157***	−1.127***	−1.170***	−1.200***	−1.242***
(nerv)	(0.342)	(0.283)	(0.249)	(0.322)	(0.259)	(0.254)	(0.246)	(0.328)	(0.321)
financial int.	0.751	−0.129	−0.128	−0.946**	−0.866***	−0.593**	−0.640***	−0.652	−0.700*
(ifi)	(0.742)	(0.322)	(0.299)	(0.398)	(0.267)	(0.251)	(0.243)	(0.416)	(0.404)
geo. distance	0.521	0.731***	0.571**	0.707	0.703***	0.408	0.433*	0.333	0.359
(dist)	(0.338)	(0.280)	(0.242)	(0.462)	(0.268)	(0.259)	(0.264)	(0.409)	(0.414)
Observations	42	42	42	42	42	42	42	42	42
R^2	0.41	0.58	0.64	0.44	0.58	0.59	0.60	0.50	0.51
Developing Countries	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.354***	−0.162	−0.272	−0.504***	−0.286**	−0.280*	−0.290**	−0.500***	−0.509***
(inf)	(0.124)	(0.168)	(0.174)	(0.148)	(0.141)	(0.144)	(0.143)	(0.151)	(0.149)
govt. exp.	−0.079	−1.328***	−1.189**	−0.197	−0.676	−0.539	−0.619	−0.217	−0.297
(gov)	(0.532)	(0.511)	(0.492)	(0.540)	(0.459)	(0.474)	(0.463)	(0.542)	(0.535)
trade open.	0.283	−0.009	−0.110	−0.398	−0.132	−0.096	−0.145	−0.277	−0.326
(to)	(0.379)	(0.421)	(0.458)	(0.448)	(0.417)	(0.437)	(0.413)	(0.479)	(0.462)
prod. growth	−0.104**	−0.006	−0.003	−0.077*	0.005	−0.007	−0.005	−0.077*	−0.074*
(PG)	(0.053)	(0.049)	(0.057)	(0.043)	(0.039)	(0.041)	(0.040)	(0.041)	(0.040)
ner volatility	−0.485***	−0.713***	−0.818***	−0.489**	−0.619***	−0.653***	−0.618***	−0.596***	−0.561**
(nerv)	(0.182)	(0.226)	(0.235)	(0.237)	(0.223)	(0.233)	(0.232)	(0.231)	(0.228)
financial int.	−0.314	1.061***	0.813*	0.995**	0.881**	0.718*	0.819**	0.893**	0.994**
(ifi)	(0.286)	(0.402)	(0.429)	(0.406)	(0.383)	(0.431)	(0.397)	(0.427)	(0.404)
geo. distance	0.237	0.979***	0.861***	0.889***	0.756***	0.732***	0.764***	0.900***	0.932***
(dist)	(0.201)	(0.257)	(0.262)	(0.298)	(0.252)	(0.254)	(0.250)	(0.301)	(0.296)
Observations	76	76	76	76	76	76	76	76	76
R^2	0.40	0.45	0.48	0.48	0.46	0.44	0.45	0.49	0.49

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is the natural logarithm of the bilateral real exchange rate (BRER) half-life. The half-life is our measure of persistence. All regressors except for productivity growth (PG) are also expressed in logarithms. A test of normality of residuals is also performed for every specification using the Shapiro-Wilk test, and in each case the null hypothesis of normality cannot be rejected at the 10 percent level (all p-values are found to be notably larger than 0.10). Alternative numerical normality tests based on skewness and kurtosis yield consistent results. TF: Transition Function.

Table 6: BRER-based cross-section regression results by income group

	simple AR model half-life	augmented AR model monotonic half-life	augmented AR model IRF half-life	augmented ESTAR model TF max.	augmented ESTAR model TF mean	selected model I half-life	selected model II half-life	selected model III half-life	selected model IV half-life
High Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.259	−0.297	−0.309	−0.522*	−0.078	−0.037	−0.030	−0.345	−0.337
(inf)	(0.380)	(0.187)	(0.208)	(0.278)	(0.150)	(0.136)	(0.136)	(0.303)	(0.307)
govt. exp.	−0.558	0.807	0.747	0.526	0.454	0.967	0.899	1.506*	1.438*
(gov)	(0.780)	(0.544)	(0.580)	(0.875)	(0.668)	(0.620)	(0.616)	(0.822)	(0.816)
trade open.	1.100*	−0.530	−0.640*	−0.411	−0.620	−0.631	−0.631	−0.588	−0.588
(to)	(0.635)	(0.328)	(0.356)	(0.495)	(0.389)	(0.392)	(0.388)	(0.557)	(0.552)
prod. growth	−0.248*	0.182*	0.167*	0.065	0.127	0.238**	0.230**	0.256**	0.248**
(PG)	(0.141)	(0.094)	(0.101)	(0.163)	(0.122)	(0.097)	(0.094)	(0.108)	(0.105)
ner volatility	−0.494	−1.061***	−1.078***	−0.567	−0.884**	−1.051***	−1.044***	−1.069***	−1.062***
(nerv)	(0.618)	(0.240)	(0.241)	(0.448)	(0.416)	(0.298)	(0.298)	(0.259)	(0.258)
financial int.	−0.163	0.047	0.103	−0.011	0.075	0.101	0.103	−0.005	−0.003
(ifi)	(0.345)	(0.169)	(0.175)	(0.254)	(0.238)	(0.194)	(0.194)	(0.252)	(0.251)
geo. distance	−0.130	−0.004	0.018	−0.033	−0.034	−0.195	−0.206	−0.187	−0.198
(dist)	(0.330)	(0.282)	(0.287)	(0.587)	(0.415)	(0.287)	(0.286)	(0.352)	(0.351)
Observations	40	40	40	40	40	40	40	40	40
R^2	0.30	0.65	0.65	0.32	0.40	0.53	0.53	0.46	0.46
Middle Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.588***	−0.008	−0.167	−0.497**	−0.231	−0.240	−0.228	−0.518**	−0.506**
(inf)	(0.143)	(0.194)	(0.207)	(0.215)	(0.194)	(0.186)	(0.191)	(0.211)	(0.214)
govt. exp.	0.068	−0.473	−0.485	0.483	−0.098	−0.010	−0.114	0.311	0.206
(gov)	(0.460)	(0.432)	(0.463)	(0.647)	(0.492)	(0.477)	(0.487)	(0.646)	(0.653)
trade open.	−0.646**	−1.015**	−1.197**	−1.024*	−0.853*	−0.972**	−0.955**	−1.183**	−1.166**
(to)	(0.316)	(0.491)	(0.497)	(0.598)	(0.498)	(0.462)	(0.474)	(0.570)	(0.580)
prod. growth	−0.049	0.004	0.042	−0.045	0.007	0.010	0.000	−0.039	−0.048
(PG)	(0.060)	(0.057)	(0.063)	(0.064)	(0.057)	(0.056)	(0.056)	(0.061)	(0.061)
ner volatility	−0.270	−0.824***	−0.910***	−0.648**	−0.728***	−0.767***	−0.771***	−0.774***	−0.778***
(nerv)	(0.187)	(0.272)	(0.258)	(0.298)	(0.262)	(0.255)	(0.263)	(0.287)	(0.294)
financial int.	−0.104	0.837	0.893*	0.767	0.673	0.739	0.726	0.916	0.904
(ifi)	(0.303)	(0.575)	(0.541)	(0.637)	(0.554)	(0.532)	(0.542)	(0.600)	(0.608)
geo. distance	0.454**	0.924***	0.752***	0.749***	0.727***	0.684***	0.735***	0.803***	0.853***
(dist)	(0.196)	(0.233)	(0.224)	(0.290)	(0.232)	(0.223)	(0.230)	(0.282)	(0.288)
Observations	73	73	73	73	73	73	73	73	73
R^2	0.47	0.43	0.51	0.46	0.46	0.49	0.48	0.50	0.50
Low Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	0.011	−0.024	−0.010	−0.175	−0.133	−0.131	−0.121	−0.151	−0.140
(inf)	(0.198)	(0.279)	(0.286)	(0.239)	(0.236)	(0.258)	(0.246)	(0.266)	(0.251)
govt. exp.	−0.171	−1.203	−0.517	−0.068	−0.245	−0.031	−0.204	−0.004	−0.177
(gov)	(0.834)	(1.136)	(1.081)	(0.985)	(0.944)	(1.028)	(0.976)	(1.060)	(1.005)
trade open.	1.053**	0.637	0.944	0.429	0.429	0.722	0.506	0.586	0.370
(to)	(0.463)	(0.709)	(0.696)	(0.660)	(0.638)	(0.716)	(0.656)	(0.725)	(0.658)
prod. growth	−0.023	0.115	0.081	0.139	0.116	0.015	0.094	0.097	0.176
(PG)	(0.135)	(0.169)	(0.191)	(0.137)	(0.113)	(0.153)	(0.123)	(0.165)	(0.134)
ner volatility	−1.205***	−1.139*	−1.090*	−0.406	−0.481	−0.640	−0.573	−0.567	−0.500
(nerv)	(0.265)	(0.625)	(0.584)	(0.565)	(0.554)	(0.630)	(0.592)	(0.648)	(0.609)
financial int.	−0.483	0.795	−0.086	0.261	0.304	−0.233	0.120	−0.072	0.280
(ifi)	(0.453)	(0.788)	(0.796)	(0.652)	(0.625)	(0.778)	(0.656)	(0.773)	(0.631)
geo. distance	0.225	0.864*	0.707	0.298	0.283	0.460	0.341	0.410	0.291
(dist)	(0.496)	(0.509)	(0.571)	(0.512)	(0.423)	(0.495)	(0.433)	(0.537)	(0.472)
Observations	25	25	25	25	25	25	25	25	25
R^2	0.55	0.42	0.38	0.30	0.29	0.30	0.30	0.29	0.31

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is the natural logarithm of the bilateral real exchange rate (BRER) half-life. The half-life is our measure of persistence. All other regressors except for productivity growth (PG) are also expressed in logarithms. A test of normality of residuals is also performed for every specification using the Shapiro-Wilk test, and in each case the null hypothesis of normality cannot be rejected at the 10 percent level (all p-values are found to be notably larger than 0.10). Alternative numerical normality tests based on skewness and kurtosis yield consistent results. TF: Transition Function.

Table 7: REER-based cross-section regression results by economic development group

	simple AR model half-life	**augmented AR model monotonic half-life**	**augmented AR model IRF half-life**	**augmented ESTAR model TF max.**	**augmented ESTAR model TF mean**	**selected model I half-life**	**selected model II half-life**	**selected model III half-life**	**selected model IV half-life**
Industrial	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	0.255	−0.727**	−0.694**	−1.138***	−0.781**	−0.822**	−0.829***	−1.138***	−1.144***
(inf)	(0.266)	(0.276)	(0.295)	(0.292)	(0.314)	(0.313)	(0.297)	(0.339)	(0.322)
govt. exp.	0.119	−3.562***	−3.227***	−1.322	−1.890*	−2.214**	−2.173**	−2.027	−1.986
(gov)	(0.770)	(0.764)	(0.707)	(1.456)	(0.968)	(0.921)	(0.870)	(1.618)	(1.559)
trade open.	−0.387	−0.563	−0.588	−1.186*	−0.544	−0.408	−0.418	−1.013	−1.023
(to)	(0.449)	(0.536)	(0.497)	(0.710)	(0.503)	(0.495)	(0.476)	(0.724)	(0.701)
prod. growth	0.171	0.656***	0.685***	0.254	0.257	0.331	0.336	0.402	0.408
(PG)	(0.248)	(0.215)	(0.222)	(0.207)	(0.224)	(0.234)	(0.226)	(0.326)	(0.314)
ner volatility	−0.080	−1.174***	−1.186***	−1.256**	−0.720*	−0.649*	−0.589*	−1.389**	−1.328**
(nerv)	(0.352)	(0.285)	(0.287)	(0.575)	(0.399)	(0.366)	(0.340)	(0.616)	(0.584)
financial int.	−0.016	−0.367**	−0.383*	−0.261	−0.246	−0.307	−0.285	−0.455*	−0.433*
(ifi)	(0.227)	(0.177)	(0.192)	(0.251)	(0.221)	(0.209)	(0.198)	(0.266)	(0.250)
Observations	23	23	23	23	23	23	23	23	23
R^2	0.27	0.65	0.65	0.73	0.57	0.56	0.59	0.63	0.65
Emerging	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.272	−0.210	−0.210	−0.157	0.048	−0.094	−0.082	−0.149	−0.137
(inf)	(0.293)	(0.257)	(0.239)	(0.254)	(0.270)	(0.211)	(0.210)	(0.254)	(0.254)
govt. exp.	0.727	−1.381*	−1.637*	−1.265	−1.176	−0.617	−0.631	−1.204	−1.219
(gov)	(0.905)	(0.824)	(0.824)	(0.848)	(0.915)	(0.638)	(0.627)	(0.791)	(0.782)
trade open.	−0.679	−0.393	−0.421	0.211	0.498	−0.140	−0.127	0.049	0.063
(to)	(0.794)	(0.752)	(0.738)	(0.752)	(0.739)	(0.643)	(0.640)	(0.722)	(0.720)
prod. growth	0.061	−0.088	−0.119	0.000	0.021	0.007	0.009	−0.003	−0.001
(PG)	(0.107)	(0.159)	(0.162)	(0.137)	(0.138)	(0.129)	(0.130)	(0.137)	(0.138)
ner volatility	−0.334	−0.224	−0.195	−0.170	−0.211	−0.282	−0.286	−0.198	−0.202
(nerv)	(0.524)	(0.560)	(0.551)	(0.501)	(0.512)	(0.445)	(0.442)	(0.492)	(0.490)
financial int.	−0.256	0.221	0.253	−0.031	0.080	0.039	0.037	0.001	−0.001
(ifi)	(0.698)	(0.696)	(0.673)	(0.771)	(0.708)	(0.609)	(0.607)	(0.730)	(0.728)
Observations	25	26	26	26	26	26	26	26	26
R^2	0.23	0.27	0.29	0.29	0.26	0.22	0.22	0.28	0.28
Developing	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.347**	0.225*	0.172	0.121	0.278**	0.218*	0.232*	0.102	0.116
(inf)	(0.140)	(0.132)	(0.125)	(0.160)	(0.127)	(0.122)	(0.123)	(0.149)	(0.153)
govt. exp.	−0.041	0.348	0.487	1.478***	0.594	0.462	0.483	1.641***	1.663***
(gov)	(0.602)	(0.596)	(0.559)	(0.548)	(0.429)	(0.464)	(0.514)	(0.494)	(0.525)
trade open.	−0.429	−0.683	−0.553	−0.584	−1.182***	−0.611	−0.719	−0.143	−0.251
(to)	(0.386)	(0.608)	(0.594)	(0.506)	(0.399)	(0.597)	(0.578)	(0.573)	(0.553)
prod. growth	−0.055	0.058	0.049	0.018	0.129***	0.097**	0.105**	−0.028	−0.020
(PG)	(0.041)	(0.049)	(0.046)	(0.071)	(0.042)	(0.043)	(0.046)	(0.067)	(0.070)
ner volatility	−0.129	−1.048***	−0.966***	−0.844***	−0.984***	−0.890***	−0.930***	−0.856***	−0.895***
(nerv)	(0.221)	(0.181)	(0.169)	(0.164)	(0.149)	(0.169)	(0.175)	(0.166)	(0.169)
financial int.	0.446	0.508*	0.447	0.485**	0.665***	0.413*	0.466*	0.198	0.252
(ifi)	(0.500)	(0.299)	(0.297)	(0.219)	(0.185)	(0.248)	(0.251)	(0.233)	(0.229)
Observations	42	42	42	42	42	42	42	42	42
R^2	0.33	0.52	0.53	0.57	0.58	0.51	0.51	0.61	0.61

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is the natural logarithm of the real effective exchange rate (REER) half-life. The half-life is our measure of persistence. All regressors except for productivity growth (PG) are also expressed in logarithms. A test of normality of residuals is also performed for every specification using the Shapiro-Wilk test, and in each case the null hypothesis of normality cannot be rejected at the 10 percent level (all p-values are found to be notably larger than 0.10). Alternative numerical normality tests based on skewness and kurtosis yield consistent results. TF: Transition Function.

Table 8: REER-based cross-section regression results by income group

	simple AR model half-life	augmented AR model monotonic half-life	augmented AR model IRF half-life	augmented ESTAR model TF max.	augmented ESTAR model TF mean	selected model I half-life	selected model II half-life	selected model III half-life	selected model IV half-life
High Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.588**	−0.532*	−0.560*	−0.776*	−0.408	−0.509**	−0.499**	−0.700	−0.690
(ifi)	(0.262)	(0.291)	(0.300)	(0.464)	(0.348)	(0.249)	(0.248)	(0.460)	(0.462)
govt. exp.	0.066	−1.544*	−1.430*	−1.142	−1.712*	−0.968	−1.016	−1.101	−1.149
(gov)	(0.738)	(0.825)	(0.846)	(1.005)	(1.042)	(0.744)	(0.727)	(1.022)	(1.005)
trade open.	0.525	−0.187	−0.243	0.180	0.177	−0.255	−0.251	−0.090	−0.087
(to)	(0.418)	(0.348)	(0.346)	(0.456)	(0.388)	(0.322)	(0.310)	(0.464)	(0.453)
prod. growth	−0.248**	−0.269**	−0.281**	−0.182**	−0.203***	−0.179***	−0.179***	−0.156*	−0.156*
(PG)	(0.123)	(0.117)	(0.129)	(0.075)	(0.063)	(0.058)	(0.056)	(0.088)	(0.086)
ner volatility	0.570	−0.037	−0.067	−0.189	−0.193	−0.074	−0.060	−0.279	−0.264
(nerv)	(0.340)	(0.454)	(0.469)	(0.446)	(0.386)	(0.342)	(0.335)	(0.479)	(0.472)
financial int.	−0.066	0.096	0.100	−0.325**	−0.187	0.005	0.012	−0.275**	−0.268**
(ifi)	(0.190)	(0.148)	(0.165)	(0.139)	(0.172)	(0.148)	(0.146)	(0.132)	(0.130)
Observations	36	37	37	37	37	37	37	37	37
R^2	0.23	0.44	0.44	0.44	0.38	0.47	0.48	0.40	0.41
Middle Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	−0.400***	−0.073	−0.092	−0.136	0.114	0.039	0.058	−0.176	−0.157
(inf)	(0.152)	(0.145)	(0.139)	(0.160)	(0.154)	(0.143)	(0.145)	(0.150)	(0.151)
govt. exp.	0.326	0.862	0.910	1.836**	0.782	0.795	0.735	2.208***	2.148***
(gov)	(0.623)	(0.733)	(0.696)	(0.730)	(0.697)	(0.766)	(0.784)	(0.706)	(0.714)
trade open.	−0.549	−1.366**	−1.244**	−1.391***	−1.012**	−0.625	−0.703	−1.138**	−1.215**
(to)	(0.471)	(0.606)	(0.591)	(0.450)	(0.504)	(0.561)	(0.570)	(0.486)	(0.492)
prod. growth	0.010	0.128**	0.134**	0.093	0.171***	0.161***	0.157***	0.070	0.066
(PG)	(0.056)	(0.058)	(0.055)	(0.066)	(0.056)	(0.052)	(0.053)	(0.058)	(0.057)
ner volatility	−0.003	−0.932***	−0.864***	−0.830***	−0.854***	−0.745***	−0.800***	−0.835***	−0.890***
(nerv)	(0.265)	(0.234)	(0.211)	(0.206)	(0.208)	(0.210)	(0.227)	(0.203)	(0.211)
financial int.	−0.260	0.171	0.074	0.284	0.394	0.027	0.133	−0.095	0.010
(ifi)	(0.515)	(0.494)	(0.489)	(0.356)	(0.399)	(0.445)	(0.461)	(0.388)	(0.391)
Observations	46	46	46	46	46	46	46	46	46
R^2	0.25	0.50	0.50	0.50	0.49	0.45	0.45	0.54	0.55
Low Income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
inflation	0.400	1.292	0.956	1.390	0.918	0.899*	0.934	1.343	1.378
(inf)	(0.450)	(0.697)	(0.566)	(0.702)	(0.168)	(0.077)	(0.252)	(0.469)	(0.643)
govt. exp.	−2.925	−1.190	−0.770	2.900	−2.466	−2.150	−2.757	3.713	3.106
(gov)	(2.988)	(4.633)	(3.758)	(4.667)	(1.117)	(0.515)	(1.672)	(3.117)	(4.275)
trade open.	−2.486	−2.241	−2.035	0.349	−3.820	−3.464*	−4.149	1.267	0.581
(to)	(2.347)	(3.640)	(2.952)	(3.666)	(0.877)	(0.404)	(1.314)	(2.449)	(3.358)
prod. growth	0.576	0.537	0.554	−0.290	0.854	0.763*	0.938	−0.524	−0.349
(PG)	(0.780)	(1.210)	(0.981)	(1.218)	(0.292)	(0.134)	(0.437)	(0.814)	(1.116)
ner volatility	−1.047	−2.105	−1.670	−2.459	−1.555*	−1.580**	−1.533*	−2.522*	−2.475
(nerv)	(0.424)	(0.657)	(0.533)	(0.662)	(0.158)	(0.073)	(0.237)	(0.442)	(0.606)
financial int.	3.777	2.663	3.156	−1.062	3.829	3.515*	4.119	−1.870	−1.267
(ifi)	(3.463)	(5.370)	(4.355)	(5.409)	(1.294)	(0.596)	(1.938)	(3.613)	(4.954)
Observations	8	8	8	8	8	8	8	8	8
R^2	0.82	0.79	0.84	0.82	0.98	0.99	0.97	0.91	0.85

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is the natural logarithm of the real effective exchange rate (REER) half-life. The half-life is our measure of persistence. All regressors except for productivity growth (PG) are also expressed in logarithms. A test of normality of residuals is also performed for every specification using the Shapiro-Wilk test, and in each case the null hypothesis of normality cannot be rejected at the 10 percent level (all p-values are found to be notably larger than 0.10). Alternative numerical normality tests based on skewness and kurtosis yield consistent results. TF: Transition Function.

Table 9: Nominal exchange rate volatility, inflation, and real exchange rate persistence by nominal exchange rate regime

Nominal Exchange Rate Regime Classification (IMF, de jure)	Size	Average Nominal Exchange Rate Volatility	Median Nominal Exchange Rate Volatility	Average Inflation Rate	Median Inflation Rate	Average Selected Model II Half-Life	Median Selected Model II Half-Life
BRER sample							
Fixed	80	0.03	0.03	10.26	6.27	3.30	2.20
Intermediate	47	0.07	0.05	63.71	15.12	2.37	0.98
Flexible	14	0.09	0.04	100.55	11.69	2.37	1.55
Test of Equal Sub-Group Means/Medians		3.73** [0.04]	16.02*** [0.00]	2.13 [0.15]	25.07*** [0.00]	1.38 [0.25]	8.27*** [0.01]
REER sample							
Fixed	50	0.05	0.02	9.75	5.87	1.26	0.91
Intermediate	26	0.09	0.05	68.71	18.60	0.83	0.64
Flexible	17	0.11	0.04	82.93	10.18	1.45	0.90
Test of Equal Sub-Group Means/Medians		0.88 [0.43]	10.66*** [0.01]	1.79 [0.19]	18.37*** [0.00]	1.93 [0.16]	1.75 [0.42]
Common Group: BRER sample							
Fixed	47	0.03	0.03	10.14	5.89	2.92	2.52
Intermediate	23	0.06	0.05	61.63	18.32	2.66	0.98
Flexible	13	0.09	0.04	106.51	10.28	2.46	1.59
Test of Equal Sub-Group Means/Medians		2.60* [0.10]	10.22*** [0.01]	1.61 [0.23]	21.08*** [0.00]	0.11 [0.90]	7.90** [0.02]
Common Group: REER sample							
Fixed	47	0.05	0.02	10.14	5.89	1.26	0.81
Intermediate	23	0.09	0.05	61.63	18.32	0.81	0.53
Flexible	13	0.14	0.04	106.51	10.28	1.32	0.68
Test of Equal Sub-Group Means/Medians		0.99 [0.39]	7.18** [0.03]	1.61 [0.23]	21.08*** [0.00]	1.60 [0.22]	1.68 [0.43]

* significant at 10%; ** significant at 5%; *** significant at 1%
'Test of equal sub-group means' tests the null hypothesis of equal means across the relevant sub-groups using the F*-test. Since the Levene and Bartlett tests often reject the null of equal variances across the sub-groups of concern, the F*-test of equal means is employed. This test is more robust to violations of the homogeneity of variances across sub-groups assumption than the traditional F-test. For the tests, the F* statistic and corresponding p-value in square brackets are reported. The results of the F*-test are consistent with those of the W test of equal means. 'Test of equal sub-group medians' tests the null hypothesis of equal medians across the relevant sub-groups using the non-parametric Mood's median test. For the tests, the Pearson χ^2 statistic and corresponding p-value in square brackets are reported. The Pearson χ^2 and Fisher exact versions of the test lead to consistent conclusions. The results of the median test are consistent with those of the Kruskal-Wallis test. Unlike Mood's median test, the Kruskal-Wallis test assumes that the variances across the sub-group samples of concern are approximately equal. Nevertheless, it is a more powerful (efficient) test for moderate to large samples. 'Common group' results refer to the sample of countries common to both bilateral real exchange rate (BRER) and real effective exchange rate (REER) series. A country is characterized by the nominal exchange rate regime that accounts for more than 50 percent of its total number of arrangement observations over the period, or alternatively by the typical regime prevailing over the period if the former rule does not apply. Selected Model II half-life: whenever nonlinear real exchange rate specification is chosen, monotonic half-life is based on mean of transition function (TF); and whenever linear real exchange rate specification is chosen, monotonic half-life is reported. Half-life is given in years.

Appendices

A Country Lists

BRER sample of countries
Afghanistan (AFG), Albania (ALB), Algeria (DZA), Angola (AGO), Argentina (ARG), Armenia (ARM), Austria (AUT), Bahamas, The (BHS), Bahrain (BHR), Bangladesh (BGD), Belgium (BEL), Benin (BEN), Bhutan (BTN), Bolivia (BOL), Botswana (BWA), Brazil (BRA), Bulgaria (BGR), Burundi (BDI), Cambodia (KHM), Cameroon (CMR), Canada (CAN), Cape Verde (CPV), Central African Republic (CAF), Chad (TCD), Colombia (COL), Congo, Dem. Rep. (ZAR), Costa Rica (CRI), Côte d'Ivoire (CIV), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Djibouti (DJI), Dominica (DMA), Dominican Republic (DOM), Ecuador (ECU), Egypt, Arab Rep. (EGY), El Salvador (SLV), Equatorial Guinea (GNQ), Estonia (EST), Ethiopia (ETH), Fiji (FJI), Finland (FIN), France (FRA), Gabon (GAB), Gambia, The (GMB), Germany (DEU), Ghana (GHA), Greece (GRC), Grenada (GRD), Guatemala (GTM), Guinea-Bissau (GNB), Guyana (GUY), Haiti (HTI), Honduras (HND), Hong Kong S.A.R. (HKG), Hungary (HUN), Iceland (ISL), India (IND), Indonesia (IDN), Iran, Islamic Republic of (IRN), Ireland (IRL), Israel (ISR), Italy (ITA), Jamaica (JAM), Japan (JPN), Jordan (JOR), Kazakhstan (KAZ), Kenya (KEN), Korea (KOR), Kuwait (KWT), Kyrgyz Republic (KGZ), Lao, PDR (LAO), Latvia (LVA), Lesotho (LSO), Libya (LBY), Lithuania (LTU), Luxembourg (LUX), Macedonia, FYR (MKD), Madagascar (MDG), Malawi (MWI), Malaysia (MYS), Maldives (MDV), Malta (MLT), Mauritania (MRT), Mauritius (MUS), Mexico (MEX), Moldova (MDA), Mongolia (MNG), Morocco (MAR), Mozambique (MOZ), Namibia (NAM), Nepal (NPL), Netherlands (NLD), Nicaragua (NIC), Niger (NER), Nigeria (NGA), Norway (NOR), Pakistan (PAK), Panama (PAN), Paraguay (PRY), Peru (PER), Philippines (PHL), Poland (POL), Portugal (PRT), Qatar (QAT), Romania (ROM), Russia (RUS), Rwanda (RWA), Samoa (WSM), San Marino (SMR), Saudi Arabia (SAU), Senegal (SEN), Seychelles (SYC), Sierra Leone (SLE), Singapore (SGP), Slovak Republic (SVK), Slovenia (SVN), Solomon Islands (SLB), South Africa (ZAF), Spain (ESP), Sri Lanka (LKA), St. Kitts and Nevis (KNA), St. Lucia (LCA), St. Vincent and the Grenadines (VCT), Suriname (SUR), Sweden (SWE), Switzerland (CHE), Syrian Arab Republic (SYR), Tanzania (TZA), Thailand (THA), Togo (TGO), Tonga (TON), Trinidad and Tobago (TTO), Tunisia (TUN), Turkey (TUR), Uganda (UGA), United Kingdom (GBR), Uruguay (URY), Venezuela, Rep. Bol. (VEN), Zambia (ZMB).

REER sample of countries
Algeria (DZA), Antigua and Barbuda (ATG), Armenia (ARM), Australia (AUS), Austria (AUT), Bahamas, The (BHS), Bahrain (BHR), Belgium (BEL), Belize (BLZ), Bolivia (BOL), Brazil (BRA), Bulgaria (BGR), Burundi (BDI), Cameroon (CMR), Canada (CAN), Central African Republic (CAF), Chile (CHL), China (CHN), Colombia (COL), Congo, Dem. Rep. (ZAR), Costa Rica (CRI), Côte d'Ivoire (CIV), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Dominica (DMA), Dominican Republic (DOM), Ecuador (ECU), Equatorial Guinea (GNQ), Fiji (FJI), Finland (FIN), France (FRA), Gabon (GAB), Gambia, The (GMB), Georgia (GEO), Germany (DEU), Ghana (GHA), Greece (GRC), Grenada (GRD), Guyana (GUY), Hungary (HUN), Iceland (ISL), Iran, Islamic Republic of (IRN), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Lesotho (LSO), Luxembourg (LUX), Macedonia, FYR (MKD), Malawi (MWI), Malaysia (MYS), Malta (MLT), Mexico (MEX), Moldova (MDA), Morocco (MAR), Netherlands (NLD), New Zealand (NZL), Nicaragua (NIC), Nigeria (NGA), Norway (NOR), Pakistan (PAK), Papua New Guinea (PNG), Paraguay (PRY), Philippines (PHL), Poland (POL), Portugal (PRT), Romania (ROM), Russia (RUS), Samoa (WSM), Saudi Arabia (SAU), Sierra Leone (SLE), Singapore (SGP), Slovak Republic (SVK), Solomon Islands (SLB), South Africa (ZAF), Spain (ESP), St. Kitts and Nevis (KNA), St. Lucia (LCA), St. Vincent and the Grenadines (VCT), Sweden (SWE), Switzerland (CHE), Togo (TGO), Trinidad and Tobago (TTO), Tunisia (TUN), Uganda (UGA), Ukraine (UKR), United Kingdom (GBR), United States (USA), Uruguay (URY), Venezuela, Rep. Bol. (VEN), Zambia (ZMB).

Industrial Countries
Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Iceland (ISL), Ireland (IRL), Italy (ITA), Japan (JPN), Luxembourg (LUX), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden

(SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).[51]

Emerging Countries: Argentina (ARG), Bahamas, The (BHS), Bahrain (BHR), Brazil (BRA), Bulgaria (BGR), Chile (CHL), China (Mainland) (CHN), Colombia (COL), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Ecuador (ECU), Egypt, Arab Rep. (EGY), Estonia (EST), Hong Kong S.A.R. (HKG), Hungary (HUN), India (IND), Indonesia (IDN), Israel (ISR), Korea Rep. (KOR), Kuwait (KWT), Latvia (LVA), Lithuania (LTU), Malaysia (MYS), Maldives (MDV), Malta (MLT), Mexico (MEX), Mongolia (MNG), Pakistan (PAK), Panama (PAN), Peru (PER), Philippines (PHL), Poland (POL), Qatar (QAT), Russian Federation (RUS), San Marino (SMR), Saudi Arabia (SAU), Singapore (SGP), Slovak Republic (SVK), Slovenia (SVN), South Africa (ZAF), St. Kitts and Nevis (KNA), St. Lucia (LCA), St. Vincent and the Grenadines (VCT), Thailand (THA), Turkey (TUR), Venezuela, Rep. Bol. (VEN).

Developing Countries
Afghanistan (AFG), Albania (ALB), Algeria (DZA), Angola (AGO), Antigua and Barbuda (ATG), Armenia (ARM), Bangladesh (BGD), Belize (BLZ), Benin (BEN), Bhutan (BTN), Bolivia (BOL), Botswana (BWA), Burundi (BDI), Cambodia (KHM), Cameroon (CMR), Cape Verde (CPV), Central African Republic (CAF), Chad (TCD), Congo, Dem. Rep. (ZAR), Costa Rica (CRI), Côte d'Ivoire (CIV), Djibouti (DJI), Dominica (DMA), Dominican Republic (DOM), El Salvador (SLV), Equatorial Guinea (GNQ), Ethiopia (ETH), Fiji (FJI), Gabon (GAB), Gambia, The (GMB), Georgia (GEO), Ghana (GHA), Grenada (GRD), Guatemala (GTM), Guinea-Bissau (GNB), Guyana (GUY), Haiti (HTI), Honduras (HND), Iran, Islamic Republic of (IRN), Jamaica (JAM), Jordan (JOR), Kazakhstan (KAZ), Kenya (KEN), Kyrgyz Republic (KGZ), Lao, PDR (LAO), Lesotho (LSO), Libya (LBY), Macedonia, FYR (MKD), Madagascar (MDG), Malawi (MWI), Mauritania (MRT), Mauritius (MUS), Moldova (MDA), Morocco (MAR), Mozambique (MOZ), Namibia (NAM), Nepal (NPL), Nicaragua (NIC), Niger (NER), Nigeria (NGA), Papua New Guinea (PNG), Paraguay (PRY), Romania (ROM), Rwanda (RWA), Samoa (WSM), Senegal (SEN), Seychelles (SYC), Sierra Leone (SLE), Solomon Islands (SLB), Sri Lanka (LKA), Suriname (SUR), Syrian Arab Republic (SYR), Tanzania (TZA), Togo (TGO), Tonga (TON), Trinidad and Tobago (TTO), Tunisia (TUN), Uganda (UGA), Ukraine (UKR), Uruguay (URY), Zambia (ZMB).

By Income, World Bank 2010 Classification

High Income
Australia (AUS), Austria (AUT), Bahamas, The (BHS), Bahrain (BHR), Belgium (BEL), Canada (CAN), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Equatorial Guinea (GNQ), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hong Kong S.A.R. China (HKG), Hungary (HUN), Iceland (ISL), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Korea Rep. (KOR), Kuwait (KWT), Luxembourg (LUX), Macau S.A.R. China (MAC), Malta (MLT), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Poland (POL), Portugal (PRT), Qatar (QAT), San Marino (SMR), Saudi Arabia (SAU), Singapore (SGP), Slovak Republic (SVK), Slovenia (SVN), Spain (ESP), St. Kitts and Nevis (KNA), Sweden (SWE), Switzerland (CHE), Trinidad and Tobago (TTO), United Kingdom (GBR), United States (USA).

Middle Income
Albania (ALB), Algeria (DZA), Angola (AGO), Antigua and Barbuda (ATG), Argentina (ARG), Armenia (ARM), Belize (BLZ), Bhutan (BTN), Bolivia (BOL), Botswana (BWA), Brazil (BRA), Bulgaria (BGR), Cameroon (CMR), Cape Verde (CPV), Chile (CHL), China (Mainland) (CHN), Colombia (COL), Congo, Dem. Rep. (ZAR), Costa Rica (CRI), Côte d'Ivoire (CIV), Djibouti (DJI), Dominica (DMA), Dominican Republic (DOM), Ecuador (ECU), Egypt, Arab Rep. (EGY), El Salvador (SLV), Fiji (FJI), Gabon (GAB), Georgia (GEO), Ghana (GHA), Grenada (GRD), Guatemala (GTM), Guyana (GUY), Honduras (HND), India (IND), Indonesia (IDN), Iran Islamic Rep. of (IRN), Jamaica (JAM), Jordan (JOR), Kazakhstan (KAZ),

[51]Note: The list of industrial countries is taken from the paper "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004" by Lane and Milesi-Ferretti (2007) published in the Journal of International Economics. Emerging countries are predominantly those that are included in the Morgan Stanley Capital International (MSCI), Standard and Poor's (S&P), Dow Jones, Financial Times Stock Exchange (FTSE), Russell Investments, Emerging Market Index, Columbia University Emerging Market Global Players (EMGP), Banco Bilbao Vizcaya Argentaria (BBVA) Research, The Economist, and International Monetary Fund (IMF) emerging market lists. The remaining economies form the developing countries group.

Lao PDR (LAO), Latvia (LVA), Lesotho (LSO), Libya (LBY), Lithuania (LTU), Macedonia FYR (MKD), Malaysia (MYS), Maldives (MDV), Mauritius (MUS), Mexico (MEX), Moldova (MDA), Mongolia (MNG), Morocco (MAR), Namibia (NAM), Nicaragua (NIC), Nigeria (NGA), Pakistan (PAK), Panama (PAN), Papua New Guinea (PNG), Paraguay (PRY), Peru (PER), Philippines (PHL), Romania (ROM), Russian Federation (RUS), Samoa (WSM), Senegal (SEN), Seychelles (SYC), Solomon Islands (SLB), South Africa (ZAF), Sri Lanka (LKA), St. Lucia (LCA), St. Vincent and the Grenadines (VCT), Suriname (SUR), Syrian Arab Republic (SYR), Thailand (THA), Tonga (TON), Tunisia (TUN), Turkey (TUR), Ukraine (UKR), Uruguay (URY), Venezuela RB (VEN), Zambia (ZMB).

Low Income
Afghanistan (AFG), Bangladesh (BGD), Benin (BEN), Burundi (BDI), Cambodia (KHM), Central African Republic (CAF), Chad (TCD), Congo, Dem. Rep. of (ZAR), Ethiopia (ETH), Gambia, The (GMB), Guinea-Bissau (GNB), Haiti (HTI), Kenya (KEN), Kyrgyz Republic (KGZ), Madagascar (MDG), Malawi (MWI), Mauritania (MRT), Mozambique (MOZ), Nepal (NPL), Niger (NER), Rwanda (RWA), Sierra Leone (SLE), Tanzania (TZA), Togo (TGO), Uganda (UGA).

By Region, United Nations Classification

Africa
Algeria (DZA), Angola (AGO), Benin (BEN), Botswana (BWA), Burundi (BDI), Cameroon (CMR), Cape Verde (CPV), Central African Republic (CAF), Chad (TCD), Congo, Dem. Rep. of (ZAR), Côte d'Ivoire (CIV), Djibouti (DJI), Egypt, Arab Rep. (EGY), Equatorial Guinea (GNQ), Ethiopia (ETH), Gabon (GAB), Gambia, The (GMB), Ghana (GHA), Guinea-Bissau (GNB), Kenya (KEN), Lesotho (LSO), Libya (LBY), Madagascar (MDG), Malawi (MWI), Mauritania (MRT), Mauritius (MUS), Morocco (MAR), Mozambique (MOZ), Namibia (NAM), Niger (NER), Nigeria (NGA), Rwanda (RWA), Senegal (SEN), Seychelles (SYC), Sierra Leone (SLE), South Africa (ZAF), Tanzania (TZA), Togo (TGO), Tunisia (TUN), Uganda (UGA), Zambia (ZMB).

Asia
Afghanistan (AFG), Armenia (ARM), Bahrain (BHR), Bangladesh (BGD), Bhutan (BTN), Cambodia (KHM), China (Mainland) (CHN), Cyprus (CYP), Georgia (GEO), Hong Kong S.A.R. (HKG), India (IND), Indonesia (IDN), Iran, Islamic Rep. of (IRN), Israel (ISR), Japan (JPN), Jordan (JOR), Kazakhstan (KAZ), Korea, Rep. of (KOR), Kuwait (KWT), Kyrgyz Republic (KGZ), Lao PDR (LAO), Malaysia (MYS), Maldives (MDV), Mongolia (MNG), Nepal (NPL), Pakistan (PAK), Philippines (PHL), Qatar (QAT), Saudi Arabia (SAU), Singapore (SGP), Sri Lanka (LKA), Syrian Arab Republic (SYR), Thailand (THA), Turkey (TUR).

Europe
Albania (ALB), Austria (AUT), Belgium (BEL), Bulgaria (BGR), Croatia (HRV), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Iceland (ISL), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Macedonia FYR (MKD), Malta (MLT), Moldova (MDA), Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Romania (ROM), Russian Federation (RUS), San Marino (SMR), Slovak Republic (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), Ukraine (UKR), United Kingdom (GBR).

Latin America
Argentina (ARG), Antigua and Barbuda (ATG), Bahamas, The (BHS), Belize (BLZ), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Dominica (DMA), Dominican Republic (DOM), Ecuador (ECU), El Salvador (SLV), Grenada (GRD), Guatemala (GTM), Guyana (GUY), Haiti (HTI), Honduras (HND), Jamaica (JAM), Mexico (MEX), Nicaragua (NIC), Panama (PAN), Paraguay (PRY), Peru (PER), St. Kitts and Nevis (KNA), St. Lucia (LCA), St. Vincent and the Grenadines (VCT), Suriname (SUR), Trinidad and Tobago (TTO), Uruguay (URY), Venezuela RB (VEN).

Northern America
Canada (CAN), United States (USA).

Oceania
Australia (AUS), Fiji (FJI), New Zealand (NZL), Papua New Guinea (PNG), Samoa (WSM), Solomon Islands (SLB), Tonga (TON).

B Derivation of IRF matrix elements

Consider the following non-homogeneous stochastic p-th order difference equation (AR(p) process)

$$r_t = \alpha + \sum_{k=1}^{p} \gamma_k r_{t-k} + \epsilon_t \tag{B.1}$$

which can alternatively be written as

$$\Delta r_t = \alpha + \rho r_{t-1} + \sum_{k=1}^{q} \beta_k \Delta r_{t-k} + \epsilon_t \tag{B.2}$$

where $\rho = -(1 - \sum_{k=1}^{p} \gamma_k) = -A(L) = -A(1)$ and $\beta_k = -\sum_{s=k}^{p-1} \gamma_{s+1}$.

The general solution (in the case of all distinct real characteristic roots lying inside the unit circle) to the non-homogeneous difference equation in (B.1) is composed of the particular integral (r_t^p) and complementary function (r_t^c)

$$r_t = r_t^p + r_t^c = \underbrace{\underbrace{\frac{\alpha}{1 - \sum_{k=1}^{p} \gamma_k}}_{\textit{deterministic component}} + \underbrace{\sum_{i=0}^{\infty} \delta_i \epsilon_{t-i}}_{\textit{stochastic component}}}_{\textbf{particular solution}} + \underbrace{\sum_{j=1}^{p} A_j (b_j)^t}_{\textbf{complementary function}} \tag{B.3}$$

where $\delta_0 = 1$, $\delta_1 = \gamma_1 \delta_0$, $\delta_2 = \gamma_1 \delta_1 + \gamma_2 \delta_0$, $\delta_3 = \gamma_1 \delta_2 + \gamma_2 \delta_1 + \gamma_3 \delta_0$, ... and $\delta_j = \gamma_1 \delta_{j-1} + \gamma_2 \delta_{j-2} + \gamma_3 \delta_{j-3} + \cdots + \gamma_p \delta_{j-p}$ $\forall j \geq p$. Let $\gamma = \sum_{k=1}^{p} \gamma_k \neq 1$.

The impulse responses of the real exchange rate to a one unit disturbance/shock (whether it be emanating from the real or nominal/monetary side) are given by

$$\text{Impact Multiplier: } IR(0) = f_{11}^{(0)} = \frac{\delta r_t}{\delta \epsilon_t} = \delta_0 = 1$$

$$\text{One-Period Multiplier: } IR(1) = f_{11}^{(1)} = \frac{\delta r_{t+1}}{\delta \epsilon_t} = \delta_1 = \gamma_1 \delta_0 = \gamma_1 = \gamma + \beta_1$$

$$\begin{aligned}\text{Two-Period Multiplier: } IR(2) = f_{11}^{(2)} = \frac{\delta r_{t+2}}{\delta \epsilon_t} = \delta_2 &= \gamma_1 \delta_1 + \gamma_2 \delta_0 = \gamma_1^2 + \gamma_2 \\ &= (\gamma + \beta_1)^2 + (\beta_2 - \beta_1)\end{aligned}$$

and so on with the n-period multiplier given by δ_n. More generally, $\frac{\delta r_{t+j}}{\delta \epsilon_t} = \frac{\delta r_t}{\delta \epsilon_{t-j}}$. The time path of all such multipliers yields the impulse response function. Stated differently, for the univariate linear model, the impulse response function is equivalent to a plot of the coefficients of the moving average (MA) representation.

We note that adding a structural/deterministic term to (B.1), such as a linear deterministic time trend, t, only influences the form of the deterministic part of the particular solution. Consequently, augmenting (B.1) in such a manner has no impact on the construction of the impulse response function. When (B.1) is augmented to include a linear time trend (like in (3)), one can easily show that the deterministic component of the particular solution changes to

$$\underbrace{\frac{\alpha}{1-\gamma} - \frac{\mu \sum_{i=0}^{p-1} (p-i) \gamma_{p-i}}{(1-\gamma)^2} + \frac{\mu}{1-\gamma} t}_{\textit{deterministic part of } r_t^p}$$

where μ is the original slope parameter on t.

We also note that the stability conditions underlie the conditions for stationarity. Specifically, if r_t is a linear stochastic difference equation, the stability condition for convergence (to equilibrium), that the roots of the inverse characteristic equation $1 - \sum \gamma_i L^i$ must lie outside the unit circle, is a necessary condition for the time series $\{r_t\}$ to be stationary. Moreover, the homogeneous solution(s) (complementary function in (B.3)) must drop out if the $\{r_t\}$ sequence is to be stationary. This occurs if the sequence started sufficiently long ago (i.e. t must be sufficiently large, that is, (one must assume that) the data generating process has been occurring for an infinitely/sufficiently long time) or the arbitrary constant(s) (A_j) is (are) zero.