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Regime-switching purchasing power parity in Latin America Applied Economics, 2016

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We consider a model in which the Latin American consumer has two alternatives to buy 'one unit of a market basket of goods'.

First, the consumer can **purchase goods locally at domestic price level**, *p* **of local currency**.

Second, the consumer can **import goods from the United States** (US) by exchanging some local currency to the USD at nominal exchange rate, s and pay price, p^* . This second option costs the consumer $s \times p^*$ of local currency.

Cassel (1918) stated that if the currencies of two countries are valued for the goods that can be purchased with them, then the nominal exchange rate between the two currencies will be equal to the purchasing power between the two countries in arbitrage equilibrium, i.e. $s = p/p^*$.

This statement is termed the **absolute version of the PPP theory** (absolute PPP, APPP) or **absolute law of one price** (LOP).

According to APPP, p, p^* and s are such that the price of buying goods in Latin America or importing them from the US are identical, $p = s \times p^*$.

From this equation, we can express $s \times (p^*/p) = 1$ (i.e. RER = 1).

APPP may not hold in practice, for example, due to the interventions of the central bank on the currency exchange rate market, pegged exchange rate of local currency or sticky prices of goods.

If $p < s \times p^*$ (i.e. RER = $s \times (p^*/p) > 1$), then it will be cheaper for the Latin American consumer to buy goods locally.

Increasing RER implies that the price of goods imported from the US is getting higher for Latin American consumers, relative to the Latin American price.

If RER increases, then **the Latin American currency will depreciate against the USD**, in real terms.

If $p > s \times p^*$ (i.e. RER = $s \times (p^*/p) < 1$), then importing goods from the US will be cheaper than buying them in Latin America.

Decreasing RER means that the price of goods from the US is getting lower for Latin American consumers, relative to the Latin American price.

If RER decreases, then **the Latin American currency will appreciate against the USD**, in real terms.

Dornbusch (1976), Flood and Rose (1995), Taylor (2004), and Taylor and Taylor (2004) show that APPP does not hold in the short run, due to:

(i) in the short run, nominal exchange rate changes substantially and the relationship between foreign and local prices does not

(ii) interventions of central banks in the foreign exchange rate markets

(iii) transaction costs

(iv) not all goods are traded between all countries

(v) different countries produce differentiated goods.

The consequence is a permanent deviation from LOP that may be expressed as $RER = c \neq 1$.

This is known as the **relative version of PPP theory** (relative PPP or RPPP).

If RER has a unit root then it is inconvenient for RPPP. We use unit root tests in order to verify the RPPP. Why testing the relative version of PPP theory is important?

Real effective exchange rate

RER is bilateral as it compares the price of goods between two countries. Nevertheless, each Latin American country has several trading partners with different trading shares, w_i with 1, ..., N.

We define a cross-trading partner measure of RER by the weighted average:

$$y = \sum_{j=1}^{N} \left(w_j \times s_j \frac{p_j}{p} \right) = \sum_{j=1}^{N} w_j \operatorname{RER}_j$$



Motivation

Holmes (2002) demonstrated that Latin American **real exchange rate (RER)** series had structural breaks, motivating a number of nonlinear econometric models and unit root tests with structural changes, in order to test the **purchasing power parity theory (PPP)** for Latin America.

One of these nonlinear models was proposed by Holmes (2008), who suggested the **Markov regime-switching (MS) augmented Dickey-Fuller (ADF) unit root test** (Dickey and Fuller, 1979), in order to identify covariance stationary and unit root subperiods for Latin American RER.



Motivation

Related to this, Holmes (2008) introduced the **partial and varied versions of PPP theory**.

Partial PPP (PPPP) holds when RER switches between covariance stationary and non-stationary regimes.

Varied PPP (VPPP) holds when RER switches between two covariance stationary regimes with different persistencies.



Kapetainos, Shin and Snell (2003): first-order exponential smooth transition autoregressive (ESTAR) model based unit root test

Becker, Enders and Lee (2006): Fourier function based unit root test (sine and cosine functions)

Breitung and Candelon (2005): panel data ADF test with exogenous breaks



Caporale and Gil-Alana (2010): fractional integration with breaks

Astorga (2012): unit root test with several endogenous structural breaks

Pan et al. (2012) and Lu et al. (2013): threshold autoregressive (TAR) model based unit roots tests

Contribution

We extend Holmes' (2008) work and suggest a new Monte Carlo simulation based MS unit root test that, under the alternative hypothesis, incorporates MS-ARMA (Box and Jenkins, 1970) plus MS volatility dynamics.

MS volatility dynamics have not been considered yet in the Latin American PPP literature, although we show that they are significant in Latin American REER series and the correct specification of dynamic volatility improves the precision of parameter estimates.

Data

We use time-series data on the **real effective exchange rate** (REER) of 14 Latin American countries.

REER is preferred to RER, as REER is a more general cross-trading partner measure of the exchange rate, while RER is bilateral.

See Table 1.





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Unit root test for REER time series

H0: unit root process with breaks

H1: mean reverting process with breaks

We model breaks by Markov regime-switching (MS) models.

Advantages of MS models: (i) many different forms of structural breaks are recovered endogenously; (ii) in the literature there are results about conditions of covariance stationarity of MS models; (iii) in the literature there are several MS volatility models.

HO: unit root process with breaks

Conditional location:

$$\mu_t(s_t) = c(s_t) + y_{t-1}$$

For the conditional volatility the same models are used as for MS-ARMA.



We consider three formulations for the conditional scale of REER. However, for all of them we use the same model for conditional location:

$$\mu_t(s_t) = c(s_t) + \sum_{i=1}^p \phi_i(s_t) y_{t-i} + \sum_{j=1}^q \theta_j(s_t) v_{t-j}(s_t)$$

We consider the lag orders p = 1 and q = 1,2,3.

For all models:
$$\epsilon_t(s_t) \sim t[\nu(s_t)]$$
 i.i.d.

H1: MS-ARMA models

Model 1 (MS model with scale parameter $\lambda(s_t)$)

$$y_t = \mu_t(s_t) + v_t(s_t) = \mu_t(s_t) + \sqrt{\lambda(s_t)\epsilon_t(s_t)}$$

Model 2 (MS *t*-GARCH(1,1))

$$y_t = \mu_t(s_t) + v_t(s_t) = \mu_t(s_t) + \sqrt{\lambda_t(s_t)}\epsilon_t(s_t)$$
$$\lambda_t(s_t) = \omega(s_t) + \beta(s_t)\lambda_{t-1}(s_t) + \alpha(s_t)u_{t-1}(s_t)$$
$$u_t(s_t) = \lambda_t(s_t)\epsilon_t^2(s_t) = v_t^2(s_t)$$



Model 3 (MS Beta-*t*-EGARCH(1,1)) $y_t = \mu_t(s_t) + v_t(s_t) = \mu_t(s_t) + \exp[\lambda_t(s_t)]\epsilon_t(s_t)$ $\lambda_t(s_t) = \omega(s_t) + \beta(s_t)\lambda_{t-1}(s_t) + \alpha(s_t)u_{t-1}(s_t)$ $[\nu(s_t) + 1]\epsilon_t^2(s_t) = [\nu(s_t) + 1]v_t^2(s_t)$

$$u_t(s_t) = \frac{[\nu(s_t) + 1]\epsilon_t^2(s_t)}{\nu(s_t) + \epsilon_t^2(s_t)} - 1 = \frac{[\nu(s_t) + 1]v_t^2(s_t)}{\nu(s_t) \exp[2\lambda_t(s_t)] + v_t^2(s_t)} - 1$$

Estimation and model selection

We jointly estimate the conditional location and scale equations by the **maximum likelihood method** for different lag orders of ARMA(p,q).

We identify the most parsimonious ARMA specification by the **Bayesian information criterion (BIC)** and the **non-nested likelihood-ratio test**.

Monte Carlo unit root test – complete sample period

We find that the covariance stationarity in the mean test statistic under H1 is near to one for all countries, hence the true data generating process may have a unit root.

For the case of unit root, the asymptotic results of the maximum likelihood estimator do not hold. Hence, we cannot use them to test whether the test statistic is significantly less than one.

We undertake a Monte Carlo simulation based unit root test.

Monte Carlo unit root test – complete sample period

Step 1: We estimate the model with unit root under H0 for each country

Step 2: We simulate 5,000 independent trajectories of REER from the unit root model under H0.

Step 3: We estimate for each simulation the MS-ARMA model under H1, and save the covariance stationarity test statistic for each simulation. The *critical values* are given by the 5%, 10% and 15% quantiles of the covariance stationarity test statistic.

Monte Carlo unit root test – complete sample period

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	ARG	BOL	BRZ	CHI	COL	CRI	DOM
5% critical value	0.9566	0.9774	0.9809	0.9745	0.9735	0.9677	0.9682
10% critical value	0.9619	0.9890	0.9880	0.9857	0.9804	0.9826	0.9790
15% critical value	0.9745	0.9928	0.9959	0.9910	0.9851	0.9958	0.9883
Test statistic	0.9975	0.9895^{*}	0.9523^{***}	0.9882^{*}	0.9650^{***}	0.9564^{***}	0.9814^{*}
	ECU	MEX	NIC	PRY	PER	URY	VEN
5% critical value	0.9510	0.9748	0.9532	0.9797	0.9558	0.8818	0.9695
10% critical value	0.9665	0.9814	0.9686	0.9855	0.9712	0.9239	0.9808
15% critical value	0.9790	0.9943	0.9823	0.9883	0.9875	0.9746	0.9917
Test statistic	0.9771^{*}	0.9397***	0.9754^{*}	0.9873^{*}	0.9524^{***}	1.0015	1.0301

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Time dependent Monte Carlo unit root test

Holmes (2008):

- **Partial PPP (PPPP)** holds when RER switches between covariance stationary and non-stationary regimes.
- **Varied PPP (VPPP)** holds when RER switches between two covariance stationary regimes with different persistencies.

Time dependent Monte Carlo unit root test

We test PPPP and VPPP by studying the evolution of the filtered estimate of the first-order AR(1) coefficient φ_{1t}^* for each country, which is given by

$$\phi_{1t}^{*} = \phi_{1}(0)\pi_{t}(0) + \phi_{1}(1)\pi_{t}(1)$$

$$\pi_{t}(0) = \Pr(s_{t} = 0 | y_{1}, \dots, y_{t-1}) \quad \text{Filtered}$$

$$\pi_{t}(1) = \Pr(s_{t} = 1 | y_{1}, \dots, y_{t-1}) \quad \text{probabilities}$$

We compare φ_{1t}^* with the critical values of the unit root test.



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PPPP is supported

Chile ϕ_{1t}^*



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Robustness analysis

We check the robustness of the MS-ARMA plus MS volatility models under the alternative hypothesis with respect to the **STAR model with Fourier function**. This alternative model is motivated by those recent works from the Latin American PPP literature which combine the Kapetanios, Shin and Snell (2003) test with the Fourier function.

A) The Kapetanios, Shin and Snell (2003) test assumes ESTAR(1, l) formulation for structural changes.

B) Holmes (2002) demonstrates that higher-order ESTAR and LSTAR models may dominate the first-order ESTAR formulation.

Robustness analysis

We consider both ESTAR(1, l) plus Fourier function(m) and STAR(k, l) plus Fourier function(m) models, in order to verify the robustness of MS-ARMA.

We use the lag orders k, l = 1, ..., 10 and m = 1, ..., 5 for ESTAR and LSTAR. In total, 1000 STAR plus Fourier specifications are estimated for each Latin American country.

We use the Bayesian information criterion (BIC) to compare models.

We find that MS-ARMA is always superior to STAR plus Fourier.

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