E C O N O M I C S B U L L E T I N

Testing the PPP in the non-linear STAR Framework: Evidence from Africa

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Abstract

Since its introduction in 2003, a new unit-root test that incorporates non-linearity in mean reverting process of a time series variable has gained momentum in testing the Purchasing Power Parity (PPP) theory. A few studies have applied the new test to the real bilateral exchange rates and have shown that it supports the PPP more often than the standard ADF test. In this paper we apply the new test as well as the standard ADF test not to real bilateral exchange rates but to real effective exchange rates of 21 African nations and show that indeed, the PPP is validated in 11 out of 21 African countries.

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1. Introduction

The Purchasing Power Parity (PPP) theory of exchange rate determination asserts that in the long run exchange rate between two currencies is equal to the ratio of corresponding national prices. One implication of the theory is that if the PPP holds, the real exchange rate must be stationary.[1] Earlier studies that tried to test stationarity of the real exchange rates, mostly relied on the standard Augmented Dickey-Fuller (ADF) test and provided little support for the PPP. Examples include Corbae and Ouliaris (1991) and Bahmani-Oskooee (1995).

Since introduction of a new test by Kapetanios, Shin and Snell (2003) that accounts for non-linearity in mean-reversion process of a time series variable, several studies have applied the new test (hereafter KSS test) to determine whether the real bilateral exchange rates are non-linear but stationary. Examples in this group includes Michael, Nobay and Peel (1997); Baum, Barkoulas and Caglayan (2001); Parsley and Popper (2001); Taylor (2001); Taylor, Peel and Sarno (2001) and Sarno, Taylor and Chowdhury (2004), Chortareas and Kapetanios (2004), Erlat (2004), Hasan (2004) and Liew *et. al* (2004). A common feature of these studies is that they provide some support for nonlinear mean reversion in some real bilateral exchange rates.

In this paper we consider the experience of African countries which have received little attention in the literature. Since a country's currency may gain against the currency of one partner and lose against currency of another partner, a better measure to capture the movement in overall value of a currency is the *real effective exchange rate*. Thus, unlike the studies mentioned above, in this paper we try to apply the KSS test to the real effective exchange rates of 21 African countries to determine whether we can provide some support for the PPP in Africa. To this end we briefly explain the KSS test in section 2. In section 3 we introduce the method of constructing the real effective exchange rate and report the results. Section 4 concludes

2. The KSS Test

Kapetanios, Shin and Snell (2003) built upon standard ADF test and introduce a new test in which the null hypothesis is still unit root but the alternative hypothesis is nonlinear stationary smooth transition autoregressive (STAR) process. They demonstrate that this new test is more powerful than the standard ADF test and for a time-series variable Z, it could be based on the following exponential smooth transition autoregressive (ESTAR) specification:[2]

$$\Delta Z_t = \lambda Z_{t-1}[1-\exp(-\vartheta Z_{t-1}^2] + \mu_t \qquad (1)$$

Where Z_t is de-meaned or de-trended series of interest and μ is an error term with usual properties. Kapetanios *et al.* (2003) demonstrate that testing the null hypothesis of $\theta = 0$ against the alternative of $\theta > 0$ is not feasible because λ is not identifiable under the null. They then use Taylor series to approximate (1) by (2):

$$\Delta Z_t = \delta Z_{t-1}^3 + \varepsilon_t \qquad (2)$$

or its augmented form by (3):

[1] For a recent survey see Sarno (2005).
[2] This section closely follows Bahmani-Oskooee *et al.* (2006).

$$\Delta Z_t = \delta Z_{t-1}^3 + \sum_{k=1}^{n} \rho_k \Delta Z_{t-k} + \varepsilon_t \qquad (3)$$

As can be seen, (3) is similar to the standard ADF test with the difference that the lagged value of the time-series variable under consideration is raised to power three rather than to power one. In (3) the null of unit root, i.e., $\delta = 0$ is tested against the alternative of $\delta > 0$ by familiar t ratio obtained for δ with new critical values tabulated by KSS. Since this t ratio is for a non-linear model, it is denoted by t_{NL}. As for selecting the lag order in (3), KSS recommend a procedure that relies upon significance of augmented terms (KSS, p. 365).

3. The Results

As indicated most studies that tested for unit root in real exchange rates relied upon the real bilateral rate between one country and its major trading partner. However, under the current float a country's currency could depreciate against one currency and appreciate against another. Thus, the relevant rate would be the effective exchange rate. Specifically, when prices of all major trading partners are incorporated in constructing the real effective exchange rate, convergence toward long-run equilibrium between nominal exchange rates and prices could be lubricated. Unfortunately, the real effective exchange rates are not readily available for African countries over long time horizon. Thus, as a first step we construct them for each of the 21 African countries following the method in Bahmani-Oskooee (1998). Thus, the *real effective exchange rate* for country j with i trading partners (RE_J) is constructed using the following formula:

$$RE_J = \sum_{i=1}^{21} \lambda_{ij} \left[\frac{\left(\frac{P_J . E_{iJ}}{P_i}\right)_t}{\left(\frac{P_J . E_{ij}}{P_i}\right)_{2003}} x100 \right] \qquad (4)$$

where P_J is the price level in country j, P_i is the price level in trading partner i, and E_{ij} is the nominal bilateral exchange rate defined as the number of units of i's currency per unit of j's currency. Note that the numerator in (4) is the real bilateral exchange rate which is set in an index form by dviding it by its own value in a base year (2003 in our case). The weighted average of these indices is then taken to arrive at the real effective exchange rate. The weights identified by λ_{ij} are measured by import shares of country j from each of her trading partners such that $\sum \lambda_{ij} = 1$.[3] The real effective exchange rates are constructed for each of the 21 African nations using quarterly data over the 1971I-2004III period. The data come from the CD-ROM of the International Financial Statistics of the IMF.

The results of the unit root tests applied to the real effective exchange rates are reported in Table 1. There are total of five t ratios reported. ADF_C is the t ratio from standard ADF test that includes only a constant term. ADF_t is the t-ratio from, again, the standard ADF test that includes a constant and a trend. These two statistics are reported to compare the results from linear ADF to those from non-linear ADF. For non-linear ADF test, following KSS we report

[3] Trading partners for each country were mostly OECD countries. The composition differed somewhat for some countries, dropping minor partners and adding major ones from Africa. A table is available upon request from the authors showing exact partners for each country.

three statistics. First, we use the raw data of the real effective exchange rate and apply the non-linear ADF test outlined by equation (3) to the raw data and report the t ratio as t_{NL1}. Next, we subtract the mean of the real effective rate from the raw data and apply (3) to de-meaned data and report the t ratio as t_{NL2}. Finally, we de trend the raw data following the procedure in KSS (2003, p. 364) and apply (3) to de-trended data and report the t ratio as t_{NL3}.

Concentrating on the standard ADF test (with or without trend) we gather from Table 1 that the null of unit root is rejected in favor of stationarity of the real effective exchange rate in three countries. They are Burkina Faso, Cote d'lvoire and South Africa. Only in these three cases the calculated ADF statistics are greater than their critical values in absolute term supporting the PPP. However, when we shift to non-linear ADF test results, number of cases in which the PPP is supported is increased to six no matter which statistic we consider, though the composition of the countries varies somewhat in each test. For example, by t_{NL1} statistic the null is rejected in favor of non-linear stationarity in the results for Burkino Faso, Burundi, Egypt, Ghana, Sierra Leone, and Tanzania, validating the PPP in these six countries. However, when we consider the t_{NL2} support for the PPP in the cases of Burkino Faso and Burundi is lost but Ethiopia and Gabon are added to the list. Similarly, when we shift to t_{NL3} Niger is added to the list.

Considering the non-linear tests as one group and validating the PPP by at least one of the three statistics in the group, the PPP is supported in nine countries of Burkino Faso, Burundi, Egypt, Ethiopia, Gabon, Ghana, Niger, Sierra Leone, and Tanzania. Clearly, this is a substantial increase in the cases for which the null of unit rot is rejected when we compare them to the cases under the two standard ADF tests, where, there are only three countries for which the null is rejected. Putting the results of both groups of tests together, the PPP is supported in total of 11 out of 21 countries. The nine countries mentioned above plus Cote d'lvoire and South Africa.

4. Summary and conclusion

Since its introduction by Kapetanios *et al.* (2003) of a unit root test that accounts for non-linearity in a time series variable, testing for unit root in the real exchange rate as a way of validating the Purchasing Power Parity (PPP) has gained momentum. However, most studies have used the real bilateral exchange rates to show that the new test rejects the null of unit root and supports non-linear stationarity, thus, the PPP more often than the standard ADF test.

In this paper we apply the standard ADF test as well as the new ADF test that accounts for non-linearity in a time-series variable to the *real effective exchange rate* of 21 African countries, a region of the world that has been ignored by researchers. The PPP is supported in nine countries when non-linearity in the real effective exchange rates are considered as compared to only three countries when the real effective rates were assumed to follow a linear stationary process.

References

Bahmani-Oskooee, Mohsen., 1995. Real Effective Exchange Rates and the Purchasing Power Parity: Experiences of 19 Industrial Countries, *Economic Notes***,** Vol. 24, pp. 239-250.

Bahmani-Oskooee, Mohsen, 1998. Do Exchange Rates Follow a Random Walk Process in Middle Eastern Countries? *Economics Letters,* Volume 58 , pp. 339-344.

Bahmani-Oskooee, M., A. Kutan and S. Zhou, 2006. "Testing PPP in the non-Linear STAR Framework", Economics Letters, forthcoming.

Baum, C.F., Barkoulas, J.T. and Caglayan, M., 2001. Nonlinear Adjustment to Purchasing Power Parity in the Post-Bretton Woods Era. *Journal of International Money and Finance*, Volume 20, Issue 3, pp. 379–399.

Chortareas, G and Kapetanios, G., 2004. The Yen Real Exchange Rate may be Stationary after all: Evidence from Non-linear Unit-root Tests. *Oxford Bulletin of Economics and Statistics* Volume 66, Issue 1, pp. 113-131.

Corbae, Dean and Sam Ouliaris,, "A Test of Long-run Purchasing Power Parity Allowing for Structural Breaks," *The Economic Record,* Vol. 67, March 1991, pp. 26-33.

Erlat, H., 2004. Unit roots or nonlinear stationarity in Turkish real exchange rates *Applied Economics Letters* Volume 11, Issue 10, pp. 645-650.

Hasan, M.S.,2004. Univariate time series behaviour of the real exchange rate: Evidence from colonial India *Economics Letters* Volume 84, Issue 1, pp. 75-80.

Kapetanios, G., Shin, Y., Snell, A., 2003. Testing for a unit root in the nonlinear STAR framework, *Journal of Econometrics*, Volume 112, Issue 2, pp. 359-379.

Kwiatkowski, Denis; Peter C.B. Phillips; Peter Schmidt and Yongcheol Shin, "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics,* Vol. 54 (1992), pp. 159-178.

Parsley, D.C. and Popper, H.A., 2001. Official Exchange Rate Arrangements and Real Exchange Rate Behavior. *Journal of Money, Credit and Banking,* Volume 33**,** Issue 4, pp. 976–993.

Michael, P., Nobay, A.R. and Peel, D.A., 1997. Transaction Costs and Nonlinear Adjustment in Real Exchange Rates: An Empirical Investigation. *Journal of Political Economy,* Volume 105, Issue 4, pp. 862–879.

Sarno, Lucio., 2005. Viewpoint: Towards a solution to the puzzles in exchange rate economics: where do we stand?. *Canadian Journal of Economics* Volume 38, Issue 3, pp. 673-708.

Sarno Lucio, Taylor, Mark P. and Chowdhury, Ibrahim, 2004**.** Nonlinear dynamics in deviations from the law of one price: a broad-based empirical study. *Journal of International Money and Finance*, Volume 23, Issue 1, pp. 1–25.

Taylor, A.M., 2001. Potential pitfalls for the PPP Puzzle? Sampling and specification biases in mean-reversion tests of the Law of One Price. *Econometrica,* Volume 69, Issue 2, pp. 473–498.

Taylor, M.P., Peel, D.A. and Sarno, L., 2001. Nonlinear mean-Reversion in real exchange rates: Toward a solution to the Purchasing Power Parity puzzles. *International Economics Review* Volume 42, Issue 4, pp. 1015–1042.

Liew, Venus Khim-sen , Ahmad Zubaidi, Baharumshah and Terence Tai-leung ,Chong. 2004. Are Asian Real Exchange Rates Stationary? *Economic Letters,* Volume 83, pp. 313-316.

Table 1. Unit root test results of real effective exchange rates for 21 African Countries.

Country	ADF_c	ADF_t	t_{NL1}	t_{NL2}	t_{NL3}
Burkina Faso	-1.49	-4.02*	-2.45*	-1.00	-2.51
Burundi	-1.72	-2.76	-2.15*	-1.32	-2.88
Cameroon	-1.88	-2.29	-0.83	-1.91	-1.77
Côte d'lvoire	-2.68*	-2.70	-0.66	-2.54	-2.22
Egypt	-2.31	-2.56	-2.53*	-5.27*	-5.35*
Ethiopia	-1.18	-1.83	-1.86	-4.30*	-4.76*
Gabon	-2.12	-2.82	-1.54	-2.96*	-2.87
Ghana	-2.19	-2.58	-7.62*	-8.22*	-8.36*
Kenya	-0.73	-1.22	-0.20	-2.34	-0.69
Madagascar	-1.04	-2.27	-1.13	-1.93	-2.19
Mauritius	-1.91	-1.93	-1.14	-2.43	-1.82
Morocco	-1.30	-2.30	-1.52	-1.43	-1.71
Niger	-0.24	-2.00	-1.47	-1.61	-3.66*
Nigeria	-1.87	-2.43	-1.65	-1.63	-1.90
Rwanda	-1.58	-1.91	-0.61	-0.76	-0.75
Senegal	-1.09	-2.48	-1.02	-1.41	-2.33
Seychelles	-1.99	-1.95	-0.70	-2.21	-1.90
Sierra Leone	-2.37	-2.27	-2.20*	-3.25*	-3.19*
South Africa	-2.76*	-3.05	-1.08	-2.52	-2.88
Tanzania	-1.88	-2.42	-3.56*	-5.68*	-5.89*
Togo	-1.30	-2.77	-1.35	-1.75	-1.50
10% Critical Value	**-2.57**	**-3.12**	**-1.92**	**-2.66**	**-3.13**

Note: Critical values come from Kapetanios et al. (2003, p. 364).