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Testing the Current Account Sustainability for BRICS Countries: Evidence from a Nonlinear Framework

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Abstract

This study investigates the current account sustainability hypothesis for Brazil, Russia, India, China and South Africa (BRICS). For this purpose, a linear and a variety of nonlinear unit root tests have been applied to the current account to GDP ratios of the aforementioned countries. The study empirically shows that the current account sustainability for BRICS cannot be provided without taking into consideration the time dependent nonlinearity (i.e. structural break(s)). Besides, the current account sustainability of India and Russia can be provided by using state dependent nonlinearity and time and state dependent nonlinearity simultaneously, respectively. Furthermore, by using one of the newly developed time dependent nonlinear unit root tests, we find evidence of the fast adjustment to the equilibrium of China's relevant data. That could be an indicator of the strength of the Chinese economy. Thus, it can be concluded that neglecting the nonlinearities in the relevant data testing process leads to misleading results in the testing process of the current account sustainability hypothesis.

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1. Introduction

The sustainability of the current account has attracted considerable attention in the literature. In the earlier studies, the current account sustainability has been defined as whether or not a country meets its long-run intertemporal budget constraint (IBC) without a drastic change in private sector behavior or policy changes (Trehan and Walsh, 1991; Hakkio and Rush, 1991). According to Trehan and Walsh (1991), the weakly stationarity of current account to GDP series of a country is a sufficient condition for the intertemporal budget constraint to hold. Hence, the concept of the current account sustainability is linked to the stationarity of the current account to GDP data.

A myriad of studies testing the stationary property of current account has shaped the empirical literature in two directions. First, the linear univariate and panel unit root tests and\or cointegration tests are employed to test the sustainability of current account hypothesis (see Liu and Tanner 1996, Wu *et al*. 1996, Apergis *et al*. 2000, Wu *et al.* 2001, Baharumshah *et al*. 2003, Lau and Baharumshah 2005, Dülger and Ozdemir 2005, Matsubayashi 2005, Lau *et al.* 2006, Holmes 2006a, Chu et al. 2007, Holmes et al. 2010 for details). However, as discussed at length in the recent empirical literature, if the data generating process (DGP) presents nonlinearities, these kinds of linear econometric techniques suffer from having low power and size distortions on capturing the stochastic adjustment process to the equilibrium of the current account balances in the long run. Hence, nonlinear techniques received considerable attention for testing the sustainability of current account balances (see Raybaudi *et al.* 2004, Chortareas *et al.* 2004, Clarida *et al.* 2007, Kim *et al.* 2009, Christopoulos and Leon-Ledesma 2010, Chen 2011a, b, Chen 2014, Cecen and Xiao 2014, Chen and Xiao 2015, Tastan and Aric 2015, and Lanzafame 2012 for details). Through employing nonlinear techniques, one may able to capture the structural breaks and/or asymmetric movements in the adjustment process encompassing sign and size of the deviations from the equilibrium (Clarida et al. 2007, Ozdemir and Cakan, 2010). Market friction, transaction cost in the international capital movements, risk perceptions, possible changes in future policies, international portfolio (re)allocation, etc. are several actions affecting the determination of the equilibrium value and, hence, the adjustment path (Christopoulos and Leon-Ledesma 2010, Ozdemir et al, 2013). Therefore, the possible effects of those policies that cause such nonlinearities in the data must be taken into consideration when analysing the true DGP.

In the theoretical literature, the sources of nonlinearities are classified in three ways. First, the time dependent nonlinearity can be included in the series as structural break(s) in the deterministic part. While interpreting structural break(s) in terms of testing the current account sustainability, one may say that the series has a stationary process around a nonlinear deterministic trend with a time varying equilibrium (Chen and Xie 2015). The empirical part of this study utilizes the Leybourne, Newbold and Vougas (1998), Çorakcı, Emirmahmutoglu and Omay (2017) and Omay (2015) unit root tests to model the nonlinearity stemming from structural breaks. Second, the state dependent nonlinearity can provide the information about the sign and size of adjustment towards equilibrium. According to Clarida et al. (2007), if the stochastic adjustment process of current account balances has a nonlinear property, then both the sign and size of the adjustment process matter to the adjustment path. The size of the adjustment implies the speed of the deviations to the equilibrium whereas a sign of adjustment means that the reaction of the relevant variable would differ as to the sign of the shock (Chen and Xie 2015). In other words, by sign nonlinearity, the asymmetry between the different regimes matters. In terms of state dependent size nonlinearity, one may conclude that the further the deviation from the equilibrium, the faster the adjustment process will be, especially if the deviation has a negative sign (i.e. current account deficit). Therefore, in this study, the size nonlinearity is considered by using Kapetanios, Shin and Snell (2003) and Sollis (2009) unit root tests. Additionally, the Enders and Granger (1999) test is employed for sign nonlinearity. Lastly, the hybrid nonlinearity is the existence of the time and state dependent nonlinearities simultaneously. This study employs the unit root tests proposed by Omay and Yıldırım (2014) and Omay, Emirmahmutoglu and Hasanov (2018) in order to consider both the time and state dependent nonlinearity. By using these newly proposed tests, we have considered different kinds of nonlinearities in current account data which limit the misspecifications problems, and hence, misleading conclusions.

The following section introduces the theoretical foundations of current account sustainability hypothesis. The data and methodology part are discussed in sections 3 and the empirical results are displayed in section 4. The last section concludes.

2. Theoretical Framework for Current Account Sustainability

The studies by Trehan and Walsh (1991) and Hakkio and Rush (1991) provided a theoretical framework to show the necessary conditions to have a sustainable current account. According to these studies, as long as a country's long-run intertemporal budget constraint (LRBC) is satisfied, a current account balance is sustainable. Following these earlier studies, let us consider an open economy with the following two-period budget constraint:

$$C_t + I_t + G_t + B_t = Y_t + (1 + r_t)B_{t-1} \tag{1}$$

where C_t, I_t, G_t, B_t, Y_t and r_t are consumption, investment, government expenditures, net foreign assets, income and world interest rate, respectively. Rearranging Equation (1) and applying national income account identity, Equation (2) is obtained:

$$B_t - B_{t-1} = r_t B_{t-1} + NX_t \tag{2}$$

where $NX_t = Y_t - C_t - I_t - G_t$ and NX_t is the country's net exports. Equation (2) implies that change in stock of net foreign assets equals interest on foreign assets plus the net exports.

Let I_{t-1} be the information set at the beginning of period *t*. A stochastic interest rate, r_t with an expected value $E(r_{t+j} \setminus I_{t-1}) = r$ for all $j \geq 1$ is assumed. Employing the specifications by Trehan and Walsh (1991), $R_t = 1 + r_t$ with expected value $E(R_{t+j} \setminus I_{t-1}) = R$, the following equation is derived by iterating Equation (2) forward in time:

$$B_{t-1} = -\sum_{j=0}^{\infty} R^{-(j+1)} E(NX_{t+j} \setminus \mathrm{I}_{t-1}) + \lim_{j \to \infty} R^{-(j+1)} E(B_{t+j} \setminus \mathrm{I}_{t-1}) \tag{3}$$

Hence, the first term in the right-hand side of Equation (3) is the present-value of the future net exports; the second term is the present discounted value of the stock of assets. Defining the LRBC to be that the second term in Equation (3) must equal to zero:

$$\lim_{j \to \infty} R^{-(j+1)} E(B_{t+j} \setminus \mathrm{I}_{t-1}) = 0 \tag{4}$$

which states that the present discounted value of the stock of foreign assets approaches 0 as t goes to infinity. What makes the current account sustainability possible is the tranversality condition expressed in Equation (4). Trehan and Walsh (1991) show that as long as the current account has a stationary process, then the LRBC holds. In the case of positive economic growth, the current account sustainability holds if the current account balance to GDP ratio is weakly stationary (Cecen and Xiao 2014, and Chen and Xie, 2014).

3. Data and Methodology

The current account sustainability hypothesis is tested by using the quarterly current account balance to GDP ($\mathrm{CA_t}/\ \mathrm{GDP_t}$) data for Brazil, Russia, India, China and South Africa covering the period of 1998: Q1- 2017: Q1[1].

[1] All data are obtained from Datastream and are seasonally adjusted.

Figure 1 presents the evolution of the percentage of the current account balance to GDP ratio for each BRICS country during our study periods.

Figure 1: Percentage of $\mathrm{CA_t}/\ \mathrm{GDP_t}$ ratio

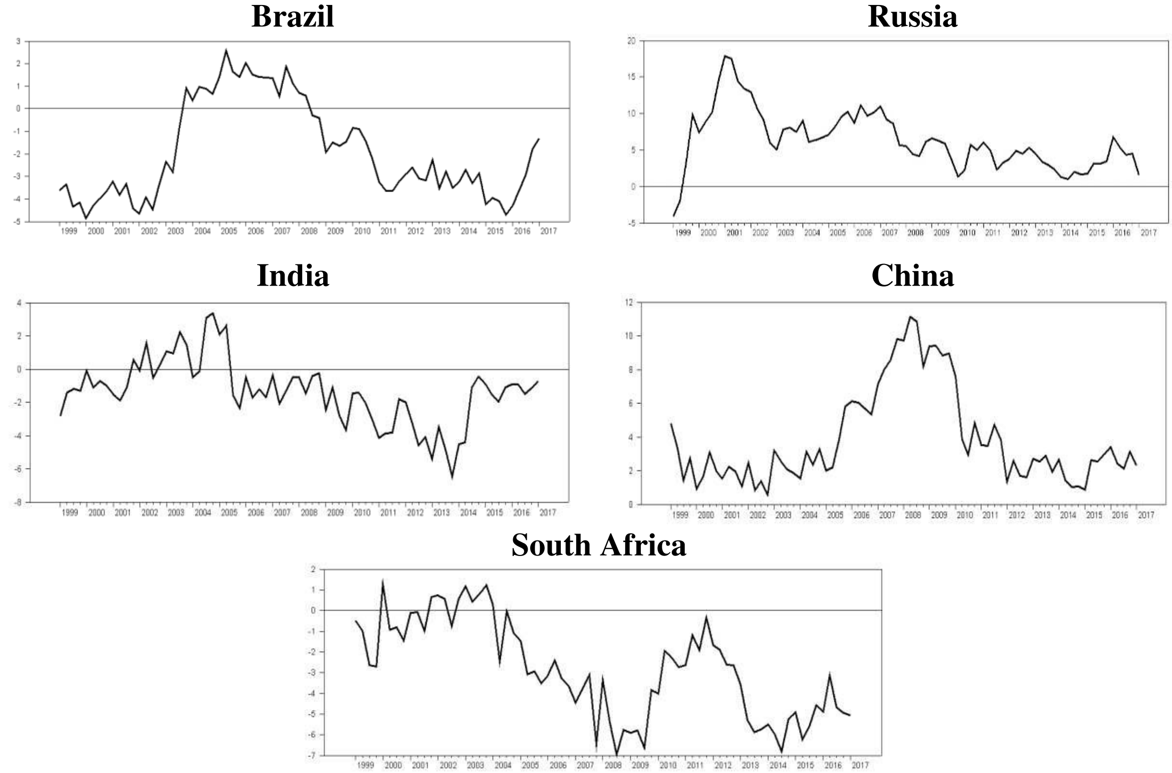

Figure 1 presents that China and Russia (with an exceptions of Q1:1998 and Q2:1998 periods) have been running current account surplus for the sample period. However, Brazil, India, and South Africa have been running current account deficits for a wide range of the sample period.

For the empirical analysis, a variety of nonlinear unit root tests are used to empirically determine whether the BRICS countries have sustainable current account balances in the long run[2]. The nonlinear unit root tests used in this study are classified according to their abilities to capture three different types of nonlinearities in the series, namely *time dependent nonlinearity*, *state dependent nonlinearity* and *hybrid nonlinearity*, which is the combination of both.

First, the time dependent nonlinearity appears in the form of structural breaks in the deterministic part of a variable. Two smooth transition type of functions, namely a logistic smooth transition (LTR) and an exponential smooth transition (EST) are employed for modelling the time dependent nonlinearity in the literature. The study by Leybourne, Newbold and Vougas (1998; LNV hereafter) employs an LTR nonlinear trend to capture one smooth or sharp break depending on the smoothness of the parameter (γ). On the other hand, the EST function captures one temporary break in the mean or trend of the series. This type of function is employed in the CEO test that is proposed by Çorakcı, Emirmahmutoglu and Omay (2017).

The second strand of literature for modelling time dependent nonlinearity makes use of Flexible Fourier function (FFF) to capture the multiple smooth structural breaks. Enders and Lee (2012a, b; EL hereafter) propose an Augmented-Dickey Fuller (ADF) type unit root test allowing for a flexible nonlinear trend using a Fourier approximation in an integer frequency Fourier form. Omay (2015) extends the EL methodology to the case in which a fractional

[2] We give brief explanations on the econometric theory of the unit root tests for brevity purposes. Please see the relevant studies for the detailed steps.

flexible frequency Fourier function is used. Therefore, the test proposed by Omay (2015) eliminates the type two error and over-filtration problems of integer frequency form of the EL test.

To introduce the methodology of the LNV and the CEO tests, the following three logistic smooth transition models are considered as in Leybourne, Newbold and Vougas (1998):

$$y_t = \alpha_1 + \alpha_2 S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model A} \tag{5}$$

$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model B} \tag{6}$$

$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + \beta_1 t S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model C} \tag{7}$$

where ε_t is I(0) process and $S_t(\gamma, \tau)$ is an LTR function. The residuals of each model are calculated by applying nonlinear least squares:

$$\hat{\varepsilon}_t = y_t - \hat{\alpha} - \hat{\alpha}_2 S_t(\gamma, \tau) \qquad \text{Model A} \tag{8}$$

$$\hat{\varepsilon}_t = y_t - \hat{\alpha} - \hat{\beta}_1 t - \hat{\alpha}_2 S_t(\gamma, \tau) \quad \text{Model B} \tag{9}$$

$$\hat{\varepsilon}_t = y_t - \hat{\alpha} - \hat{\beta}_1 t - \hat{\alpha}_2 S_t(\gamma, \tau) - \hat{\beta}_2 t S_t(\gamma, \tau) \quad \text{Model C} \tag{10}$$

After calculating the residuals, we can apply the testing models of the unit root tests. Given that the LTR and EST functions are expressed in Equations (11) and (13), respectively, the testing models of the LNV and CEO tests are given in Equations (12) and (14), respectively:

LNV

$$S_t(\gamma, \tau) = [1 + \exp\{-\gamma(t - \tau T)\}]^{-1}, \quad \gamma_i > 0 \tag{11}$$

$$\Delta\hat{\varepsilon}_t = \hat{\delta}\hat{\varepsilon}_{t-1} + \sum_{j=1}^{k} \hat{\delta}_j \Delta\hat{\varepsilon}_{t-1} + \hat{\upsilon}_t \tag{12}$$

CEO

$$S_t(\gamma, \tau) = 1 - exp[-\gamma(t - \tau)^2], \qquad \gamma > 0 \tag{13}$$

$$\Delta\hat{\varepsilon}_t = \rho\hat{\varepsilon}_{t-1} + \sum_{j=1}^{k} \delta_j \Delta\hat{\varepsilon}_{t-1} + \upsilon_t \tag{14}$$

The testing models of Omay (2015) test for the model with *intercept* and *intercept and trend* cases are in Equation (15) and (16), respectively.

Omay (2015)

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 sin\left(\frac{2\pi k^{fr} t}{T}\right) + c_3 cos\left(\frac{2\pi k^{fr} t}{T}\right) + e_t \tag{15}$$

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 t + c_3 sin\left(\frac{2\pi k^{fr} t}{T}\right) + c_4 cos\left(\frac{2\pi k^{fr} t}{T}\right) + e_t \tag{16}$$

Second, the state dependent nonlinearity provides information about the sign and size of the adjustment to the equilibrium (see also Chen 2014, and Chen and Xie 2015). In this study, in order to control the state dependent nonlinearity, Engle and Granger (1998; EG hereafter), Kapetanios, Snell and Shin (2003; KSS hereafter) and Sollis (2009) unit root tests are utilized. The EG test identifies the existence of the sign nonlinearity by employing the threshold autoregressive (TAR) function expressed in Equation (17):

$$\Delta y_t = \alpha + \rho_1 I_t y_{t-1} + \rho_2(1 - I_t)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + e_t \tag{17}$$

where

$$I_t = \begin{cases} 1 \; if y_{t-1} \geq 0 \\ 1 \; if y_{t-1} < 0 \end{cases}$$

where I_t is a Heaviside indicator function.

The KSS test uses an exponential smooth transition autoregressive (ESTAR) function in order to model the size nonlinearity. The ESTAR model and testing model of the KSS test are given in Equation (18) and (19), respectively. Recently, Sollis (2009) has proposed an asymmetric version of the KSS test by using a logistic smooth transition autoregressive

(LSTAR) function embedded into an exponential smooth transition autoregressive (ESTAR) function. Thus, the Sollis (2009) test accounts for the sign of the asymmetry and the speed of the mean reversion to the equilibrium at the same time. The Sollis (2009) AESTAR model is expressed in Equation (20) along with the testing model in Equation (21):

KSS

$$\Delta y_t = \theta y_{t-1} + \gamma y_{t-1}[1 - \exp(-\phi y_{t-d}^2)] + \varepsilon_t \qquad (18)$$

$$\Delta y_t = \delta y_{t-d}^3 + \sum_{j=1}^{k} \rho_j \Delta y_{t-j} + e_t \qquad (19)$$

Sollis (2009)

$$\Delta y_t = G_t(\gamma_1, y_{t-1})\{S_t(\gamma_2, y_{t-1})\rho_1 + \left(1 - S_t(\gamma_2, y_{t-1})\right)\rho_2\} y_{t-1} + \varepsilon_t \qquad (20)$$

$$\Delta y_t = \delta_1 y_{t-1}^3 + \delta_2 y_{t-1}^4 + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + e_t \qquad (21)$$

In order to account for the possibility that the DGP exhibits time and state dependent nonlinearities at the same time, the unit root tests by Omay and Yıldırım (2014; OY hereafter) and Omay, Emirmahmutoglu and Hasanov (2018; OEH hereafter) are utilized in this study. The OY test is a hybrid test that is a combination of the LNV and KSS tests. The LNV test captures one structural break and the KSS test captures the state dependent behaviour around the nonlinear trend by using an ESTAR function. So, rejecting the null hypothesis of a linear unit root by the OY test implies that the current account to GDP ratio is stationary around a nonlinear trend with a symmetric size nonlinearity convergence. The testing model of OY test is given in Equation (22).

$$\Delta\hat{\varepsilon}_t = \hat{\delta}\hat{\varepsilon}_{t-1}^3 + \sum_{j=1}^{k} \hat{\delta}_j \Delta\hat{\varepsilon}_{t-1} + \hat{\upsilon}_t \qquad (22)$$

The Omay, Emirmahmutoglu and Hasanov (2018)'s study proposes a unit root test that allows for a single and multiple structural breaks in the deterministic part of the series including nonlinear adjustment to the equilibrium. The Omay et al. (2018) study utilizes three logistic trend functions given in Equation (23)- (25).

$$\phi(t) = \alpha_1 + \alpha_2 S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model 1} \qquad (23)$$

$$\phi(t) = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model 2} \qquad (24)$$

$$\phi(t) = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + \beta_1 t S_t(\gamma, \tau) + \varepsilon_t \quad \text{Model 3} \qquad (25)$$

where $S_t(\gamma, \tau)$ is an LTR given in the Equation (11). Due to the fact that using LTR function is inadequate for capturing the multiple structural breaks, Omay et al. (2018) employs the Fourier function to allow for multiple structural breaks. The Fourier function is given in Equation (26).

$$\phi(t) = \alpha_0 + \delta t + \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} b_k \cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_t; n < \frac{T}{2} \qquad (26)$$

The OEH test consists of two parts. The first part of the OEH, OEHa, is a combination of LNV and Sollis (2009) tests, so that it considers both a single structural break and the size of the disequilibrium in the adjustment process. In a similar fashion, the second part of the OEH, OEHb, combines the Fourier ADF and Sollis (2009) tests to capture multiple smooth structural breaks with an asymmetric ESTAR type of behaviour around the nonlinear trend. The OEHb uses the integer form of FFF in order to capture multiple structural breaks. The testing procedure of the OEH starts with the estimation of the models given in Equation (23)-(25) and obtains the residuals from every model. Afterwards, the obtained residuals are used in the testing the regression models of OEHa and OEHb, given in Equation (27) and (28)-(29), respectively.

OEHa

$$\Delta\varepsilon_t = \delta_1\varepsilon_{t-1}^3 + \delta_2\varepsilon_{t-1}^4 + \sum_{j=1}^{k}\delta_j\Delta\varepsilon_{t-1} + \upsilon_t \quad (27)$$

OEHb

$$\Delta y_t = \rho y_{t-1}^3 + \rho_2 y_{t-1}^4 + c_1 + c_2 sin\left(\frac{2\pi kt}{T}\right) + c_3 cos\left(\frac{2\pi kt}{T}\right) + e_t \quad (28)$$

$$\Delta y_t = \rho y_{t-1}^3 + \rho_2 y_{t-1}^4 + c_1 + c_2 t + c_3 sin\left(\frac{2\pi kt}{T}\right) + c_4 cos\left(\frac{2\pi kt}{T}\right) + e_t \quad (29)$$

If the null hypothesis of a linear unit root is rejected against the alternative hypothesis of the OEHa test, it implies that the current account to GDP series is stationary around a nonlinear trend with an asymmetric size nonlinearity convergence. If the null hypothesis of a linear unit root is rejected against the alternative hypothesis of the OEHb test, it implies that the current account to GDP series is stationary around multiple structural breaks in trend with an asymmetric size nonlinearity convergence.

4. Empirical Results

Before applying the nonlinear unit root tests for the current account to GDP ratios of BRICS countries, the linear ADF unit root test with a trend is applied. According to the ADF unit root test results, the null hypothesis of a linear unit root cannot be rejected for any country of BRICS. Therefore, it can be concluded that the BRICS countries don't have sustainable current account balances in the long run.

The empirical results of the LNV, CEO and Omay (2015) unit root tests are tabulated in Table I and Table II, respectively. It is important to note that that the common feature of the nonlinear unit root tests used in this study is to have the null hypothesis of a linear unit root against the nonlinear stationarity. The type of nonlinear stationarity in the alternative hypothesis of unit root tests would differ according to the test applied.

Table I. The LNV and CEO unit root test results allowing the time dependent nonlinearity

Country	**LNV**			**CEO**		
Test statistics	s_{α}	$s_{\alpha(\beta)}$	$s_{\alpha\beta}$	$\tilde{s}_{\alpha}$	$\tilde{s}_{\alpha(\beta)}$	$\tilde{s}_{\alpha\beta}$
Brazil	-2.759	**-4.736***	-4.693	-3.005	-2.445	-2.601
Russia	**-4.565****	**--4.645***	**-5.006***	-1.225	-2.149	-1.979
India	2.655	-4.226	-4.215	-1.884	-2.166	-2.497
China	-1.738	-3.026	3.031	-3.249	-3.794	**-5.473****
South Africa	**3.914***	-3.872	-3.871	-2.019	-2.805	-2.687
Critical values						
1%	-4.882	-5.479	-5.650	-5.017	-5.544	-5.797
5%	-4.232	-4.771	-5.011	-4.374	-4.900	-5.166
10%	-3.909	-4.427	-4.697	-4.051	-4.572	-4.844

Note: Both LNV and CEO test statistics refer to the model with the raw data; with intercept; and with intercept and trend, respectively.; * * denotes the 10% significance level, **denotes the 5% significance level, *** denotes the 1% significance level

Table II. The Omay (2015) unit root test results allowing the time dependent nonlinearity

Country	Omay (2015)	
Test statistics	$\tau_{DF\_C}^{fr}$	$\tau_{DF\_\tau}^{fr}$
Brazil	-1.064	-3.359
Russia	**-3.727****	**-4.568****
India	**-3.938****	**-4.411***
China	-2.120	-2.150
South Africa	-1.953	-2.389
Note: The test statistics of Omay (2015) refer to the model with intercept; with intercept and trend, respectively.		

The null hypothesis of a linear unit root against the alternative of a stationary nonlinear time trend is tested by the LNV and CEO tests. The LNV test results tabulated in Table I suggest that the null hypothesis of the linear unit root can be rejected for Brazil, Russia and South Africa. That is, the current account to GDP ratios of Brazil, Russia and South Africa have a stationary process and nonlinear trend around the deterministic component at various significance levels. The null of linear unit root is rejected for China based on the CEO test in Table I suggesting one temporary structural break in the deterministic part at the 5% significance level. Omay (2015) employs the fractional FFF function and accounts for the multiple smooth structural breaks in the relevant series. Table II suggests that Russia and India have a stationary process and nonlinear trend around the deterministic component in their relevant series.

Therefore, it can be concluded that the time dependent nonlinearity is an essential feature of the current account to GDP ratios for BRICS countries. After considering the time dependent nonlinearity (i.e. structurak break(s)), one may conlude that BRICS countries have sustainable current account balances in the long-run.

The empirical results of the EG, KSS and Sollis (2009) unit root tests are displayed in Table III. These three tests account for the state dependent nonlinearity in the forms of size and/or sign adjustment towards the equilibrium.

Table III. The EG, KSS and Sollis (2009) unit root test results allowing the state dependent nonlinearity

	EG		KSS		Sollis (2009)	
Country	Φ_{μ}	Φ_{τ}	$t_{NL,\mu}$	$t_{NL,\tau}$	$F_{AE,\mu}$	$F_{AE,t}$
Brazil	3.576	3.74	-2.519	-2.53	3.743	3.845
Russia	1.432	2.071	-1.220	-1.338	1.180	1.106
India	1.731	2.408	**-2.674***	-2.838	3.510	3.956
China	1.603	1.625	-1.968	-1.982	2.333	2.403
South Africa	1.732	2.237	-2.135	-2.233	2.475	2.612
Critical values						
1 %	6.57	8.58	-3.48	-3.93	6.883	8.531
5%	4.64	6.30	-2.93	-3.40	4.954	6.463
10%	3.79	5.27	-2.66	-3.13	4.157	5.460
Note: The test statistics of EG, KSS and Sollis (2009) refer to the model with intercept; with intercept and trend, respectively; *denotes the 10% significance level, **denotes the 5% significance level, *** denotes the 1% significance level						

According to the EG tests results none of the countries exhibit nonlinear asymmetric stationarity to the equilibrium. Based on the KSS test results, the current account to GDP series of India exhibits a globally stationary nonlinear ESTAR process. Hence, the current account balance for India is sustainable in the long run. The Sollis (2009) test accounts for the sign and size nonlinearity at the same time. The sign and size nonlinearity are essential to determine whether the ratio of current account balance to GDP series displays the mean-reverting behaviour in the long run. The results of the Sollis (2009) test display that the null of linear nonstationarity cannot be rejected for every country, so there is not a symmetric or an asymmetric ESTAR nonlinear stationary process in the relevant series of every country (See study by Ozdemir, 2008 for similiar empiricial results for the purchasing power parity hypothesis).

The results of the unit root tests allowing for the hybrid type nonlinearity can be seen in Table IV.

Table IV. The OY, OEHa, OEHb unit root test results allowing the hybrid nonlinearity

				OEH				
	OY			**OEHa (F_{LBAE})**			**OEHb(F_{FSAE})**	
Country	$s_{nl,\alpha}$	$s_{nl,\tau}$	$s_{nl,(\tau)}$	$s_{Anl,\alpha}$	$s_{Anl,\tau}$	$s_{Anl,(\tau)}$	τ_{NL,DF_C}	τ_{NL,DF_τ}
Brazil	-2.494	-1.682	-1.189	3.083	4.074	2.799	0.774(1)	4.890(1)
Russia	-1.657	-1.789	-1.781	1.352	1.575	1.577	5.763(1)	**7.193****(4)
India	-2.649	-1.268	-1.264	3.507	0.826	0.824	4.935(1)	3.954(1)
China	-1.612	-2.889	-2.719	2.736	3.746	3.687	1.284(1)	0.723(1)
South A.	-2.336	-2.208	-2.079	5.052	4.848	4.118	2.394(1)	1.865(3)

Note: The test statistics of OY refer to the model with the raw data; with intercept; with intercept and trend, respectively.
The test statistics of OEHa refer to the model with the raw data (Model 1); with intercept(Model 2); with intercept and trend (Model 3), respectively. The test statistics of OEHb refer to the models with intercept and intercept and trend, respectively. The numbers in parenthesis in OEHb indicate the number of frequency components in the Fourier series.
*denotes the 10% significance level, **denotes the 5% significance level, *** denotes the 1% significance level

The OY and OEHa test results in Table IV indicate that the null of the unit root can not be rejected for any of the BRICS` countries. That is, the current account balance to GDP ratios of BRICS do not exhibit nonlinearity and stationarity around nonlinear trend and intercept as well as globally stationary asymmetric ESTAR nonlinearity. In other words, the current account balances of BRICS are not sustainable in the long run according to OY and OEHa tests. The other important conclusion that Table IV suggests is that the relevant data of Russia shows multiple structural breaks with an asymmetric ESTAR type of behaviour around the nonlinear trend in its structure. Taking into account the OEHb test, the null of the linear unit root can be rejected for Russia.

5. Conclusion

This study empirically examines the current account sustainability of Brazil, Russia, India, China and South Africa (BRICS). In this study, sustainability is empirically examined by the unit root tests allowing for three types of nonlinearities, namely time dependent nonlinearity (structural breaks), state dependent nonlinearity (size and sign) and hybrid nonlinearity.

To be consistent with the empirical literature, the ADF unit root test is used to test the underlying current account sustainability hypothesis. The ADF failed to reject the null of the linear unit root suggesting that none of the BRICS countries have a sustainable current account balances in the long run. This result may be attributed to the existence of nonlinearity in the ratio of current account balance to GDP series. Therefore, a variety of nonlinear unit root tests are employed to check the validity of current account sustainability in the long run for BRICS countries.

There is evidence that the current account to GDP ratios of BRICS countries exhibit the time dependent nonlinearity stemming from structural breaks (i.e. permanent or temporary; single/multiple breaks). Therefore, overlooking such a crucial factor-structural break would provide us misleading results for the long run current account sustainability hypothesis.

Our study period includes the Global Financial Crisis of 2008. Therefore, it is not surprising that the stationary process of current account is provided by nonlinear unit root tests that allow for structural breaks. In addition, the relevant data of India exhibit size nonlinearities that might arise from market friction, transaction cost in the international capital movements, risk perceptions, possible changes in future policies, and international portfolio (re)allocation actions. And, Russia`s current account to GDP ratio has multiple structural breaks with an asymmetric ESTAR type of behaviour in its DGP.

Finally, the most original finding of this study is the fast adjustment speed of China's current account to GDP ratio to its equilibrium level. In other words, China is the only BRICS country that has one temporary structural break in its relevant data, so that one can conclude that the China's economy moves to its long-run equilibrium in a short time span. The reason behind this might be its GDP growth or increase in its current account surplus. Even though investigating the underlying reasons for the strong Chinese economy could be a motivation for a further study, we can conclude that China has a strong economy by the means of its current account balance adjusting itself to the equilibrium level very quickly. We can conclude that possible effects of such nonlinearities in the data structure must be taken into consideration when analysing the current account sustainability in order not to reach misleading results.

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