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Business cycle co-movements between South Africa and the BRIC countries

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This article examines the relationships between South African economy and the economies of the BRIC (Brazil, Russia, India and China). In particular, it identifies the nature and key features of the co-movement of South African business cycles with cycles of the BRIC countries. It uses the dynamic factor model to a set of 307 macroeconomic series during the period 1995Q2 to 2009Q4. We found significant evidence of synchronization between South Africa and the BRIC countries over the business cycle, although the magnitude of co-movement differs with each country. India portrays strong ties with South Africa over time. Moreover, Brazil, China and Russia lead South Africa in the long run, while India is contemporaneous. Further, the findings imply that the first two factors are BRICS factors while the third one is a US factor.

Keywords: dynamic factor model; international business cycles; co-movement; BRICS

JEL Classification: C3; E32

I. Introduction

The ripple caused by the recent global economic crisis has made researches to re-evaluate the role of co-movement of economic forces among countries. The international transmission of business cycles has been extensively examined by many researches (Kose *et al*., 2008, 2012; Artis and Okubo, 2009; Crucini *et al*., 2011; Antonakakis and Scharler, 2012). When business cycles of given two countries are synchronized, they portray similar pattern when they are affected by common shocks. In addition, if one cycle leads another, it is more likely that the shock originating from the first country be transmitted to the other. It is therefore essential to examine whether or not cycles co-move contemporaneously or one leads the other. Studies have found the evidence of co-movement across developed countries. Until now, there are few researches have been carried out on the business cycle co-movements across developing countries (Imbs, 2010; Yetman, 2011), not least, between South Africa (SA) and the other BRICS countries, namely, Brazil, Russia, India and China, the so-called BRICs.

The aim of this article is to examine the co-movement of business cycles between SA and the BRICs. The inclusion of SA in 2010 with the BRIC countries to establish the BRICS provides good motivation for the analysis. The question then arises as to whether the inclusion of SA within this community provides a good addition to the BRIC countries beyond its geographic location in Africa?

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To achieve this, our analysis proceeds with several component parts. First, we employ the Corbae–Ouliaris (CO) filter to extract the business cycle movements from measured real output. We compare the co-movements in the cyclical components between SA and the other BRICS countries in graphs. Second, we consider the dynamic correlations emanating from the CO filter, which works in the frequency domain rather than the time domain. Third, we consider the role of the common factors identified from the large set of macroeconomic variables for the BRICS countries and the US in explaining the movement in South African macroeconomic variables. We report three common factors – two largely incorporating BRICS information (one largely including real economic activity and the other largely financial variables) and the third one capturing the US information. Finally, we explore the component variables in the three common factors identified to provide some economic intuition as to what the common factors actually encompass.

The co-movement of output fluctuations across countries can be accounted for by several factors. First, it may arise from country-specific shocks that are quickly transmitted to other economies through either current account transactions or capital markets (Goldfajn and Valdes, 1997; Levy-Yeyati and Ubide, 2000; Frankel and Schmukler, 2011). Trade linkages could lead to co-movement in output cycles. If two given countries have strong trade ties and if the exporting country is affected by a negative shock, its exports will suffer and hence the shock will be transmitted to the importing country via trade channel leading to synchronization of business cycles. Similarly, financial linkages result in co-movement of output cycles through capital flows from one country to another. If the speed of transmission in both cases is relatively fast, one would expect to see a contemporaneous co-movement in output between countries rather than a lead and lag relationship. Second, the commonality in output fluctuations is mainly due to shocks that affect all countries in a similar way (Dellas, 1986; Fabrizio and Lopez, 1996). Third, the co-movement in aggregate output arises from shocks that are specific to a sector of the economy. For instance, Marimon and Zillibotti (1998) observe that sectoral effects are more important than country-specific effects in the long run except in the 11 European countries where they are equally important in the short run.

The international co-movements in aggregate economic variables have been attempted both from a theoretical and empirical perspective popularized by the seminal contribution of Backus *et al*. (1992). Since then several theoretical models have suggested the existence of certain relationships between the same economic variables in different countries (Cantor and Mark, 1988; Greenwood and Williamson, 1989). Based on technological spillovers, Henriksen *et al*. (2008) have recently suggested a theory of international co-movements in inflation and nominal interest. It is essential for policymakers to understand the degree of integration of the country into the global economy since no country operates in isolation. Positive as well as negative shocks tend to propagate rapidly across countries. The recent financial crisis which originated in the US and the turmoil in Europe speak volume.

Different statistical methods have been used in the literature to assess differences and similarities in the growth rates of output, investment, consumption and productivity across countries and regions of the world.[1] The existence of positive co-movements in different countries, especially in developed ones, has been observed by Artis *et al*. (1997) and Canova *et al*. (2007). Neely and Rapach (2011) study the international co-movements in inflation rates and the contributions of global inflation to fluctuations in national inflation rates. They found that common components in international inflation rates can be produced by common shocks, similar policy reactions, international trade and financial links. They also found evidence of world factor influence on inflation for 64 countries.

SA has received extensive attention on the co-movement and the effects of globalization on output volatility following its re-integration into the international trade and financial activities in 1994. Using the structural dynamic factor model, Kabundi (2009) studied the co-movement between SA and the US output over the period 1985 to 2003. His analysis explores various transmission mechanisms and confirms co-movement of output between the two countries. A similar study by Kabundi and Loots (2010) examines the co-movement between Germany and SA over the period 1985 to 2006. Although this study confirms the presence of co-movement of output growth between SA and Germany, but it is negative and weak over the long run. However, over the business cycle period, the co-movement is positive but weak.

Unfortunately, these studies focus on the synchronization between SA and advanced economies but, based on our knowledge, there is a few studies that consider in which Kabundi and Loots (2007) investigate the relationship between SA and the Southern African Development Community (SADC) countries. This article, therefore, is the first attempt to investigate the co-movement of business cycles between SA and the BRICs. The rationale for assessing the business cycle co-movements across SA and the BRIC countries is based on the perception that movements of cycles of SA economy may be similar with the cycles of the other BRICS countries originating from trade

[1] Among others, Nadal De Simone (2002) analyses the synchronization of output cycles between European economies and the US using a dynamic factor model, and Kose *et al.* (2008) examines the changes in the nature of G7 (group of 7 most advanced countries) business cycles in main macroeconomic aggregates using the Bayesian dynamic factor model.

and financial linkages. If cycles are highly synchronized, it is more likely that the BRICS bloc is integrated. Positive or negative shocks would propagate from one country to others. But if the bloc is heterogeneous, idiosyncratic shocks will be more prominent. We use the dynamic factor model to investigate the nature of synchronization of cycles between SA and the BRICs as well as different channels underpinning the co-movements.

Our main findings are threefold. First, the results show that the degree and the magnitude of synchronization between SA and the BRICs differ over time and across countries. For example, the analysis with dynamic correlation shows that SA's commonalities are high with Brazil, China and India but low with Russia. Brazil, China and Russia show correlation over the business cycle, but a weak and insignificant correlation over the long- and short-run period. However, India portrays a strong and significant correlation over the long run, the business cycle and the short-run periods. Second, in terms of the lead and lag relationship, which also vary across countries and over time; Brazil, China and Russia lead SA over the long run, while there is less evidence of significant lead–lag relationship between SA and India. Finally, the findings suggest that the first two factors are BRICS factors. The common factors explain most of variation in real and financial variables for the BRICS countries. The third factor can be considered as a US factor because it explains an important variation in the US variables. It suggests that co-movement of BRICS cycles is not only due to interconnection with BRICS countries, but it is also facilitated by an external shock, the US, which is common to all BRICS countries. As each country is integrated with the US, they tend to portray synchronous cycles even though they might not be integrated with one another.

The remainder of the article is organized as follows. Section II gives a brief explanation of factor models, the technique used to extract business cycles and the dynamic correlation analysis. Section III discusses the estimation of the model. It also discusses data, their transformation and the criteria used to determine the number of factors. Section IV analyses the main empirical results. Section V concludes the article.

II. Methodology

This section introduces the dynamic factor model[2] and the CO filter to extract the business cycles. Then, the dynamic correlation measure is applied to describe the relation between SA and the BRIC countries and to evaluate the structure of the co-movement of cycles at different frequencies.

The dynamic factor model

Factor analysis has been successfully considered in models consisting of large number of variables. Classical factor models were initiated by Sargent and Sims (1977) and Geweke (1977).[3] The main idea of factor models is that all the information included in a large data set could be captured by a few key common factors. These factors represent the hidden forces underlying the co-movement of observable series. The co-movement of contemporaneous time series is due to the fact that they are arising largely from a relatively few key economic factors, such as productivity, monetary policy, trade linkages, financial linkages and oil price shock. Various methods have been proposed to construct these common factors, the simplest is the principal component analysis introduced by Stock and Watson (2002a).

Recently, the dynamic factor model has become very popular in economics.[4] Suppose there are N numbers of different observable economic variables, each one consisting of T observations. It is assumed that, for each observation in time t, all the N individuals partially depend on a small number, r, of nonobservable or latent common factors.

Assume that Y_t follows an approximate dynamic factor model of Stock and Watson (1998, 2002a), then

$$Y_t = X_t + \Xi_t = \Lambda F_t + \Xi t \tag{1}$$

where $X_t = (x_{1t}, x_{2t}, \ldots, x_{Nt})'$ and $\Xi_t = (\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{Nt})'$ are $N \times 1$ vector of common and idiosyncratic components. The elements of Ξ_t are assumed to be cross-sectionally and temporarily uncorrelated. Λ is the $N \times r$ matrix of factor loadings and comprises all nonzero columns of $\Lambda = (\lambda_1', \lambda_2', \ldots, \lambda_N')'$ with $r \ll N$. $F_t = (f_{1t}, f_{2t}, \ldots, f_{rt})'$ is a vector of r common factors. Therefore, Y_t is represented as the sum of the two latent components, one is common component, $X_t = \Lambda F_t$, and another is idiosyncratic component, Ξ_t. The common component of each series, which is driven by a small number of shocks common to all variables, is the part of the series that depends on the common factors. However, the effects of the common shocks are different for each variable because of the different factor loadings. The idiosyncratic component is the part of the series driven by shocks that are specific to each variable and it is orthogonal to

[2] More details can be found in Forni and Lippi (2001), and Stock and Watson (2002a, b).

[3] These models have been applied by Singleton (1980), Chamberlain and Rothschild (1983), Quah and Sargent (1983) and Stock and Watson (1998), among others.

[4] It has been used by Forni and Lippi (2001), Stock and Watson (2002a, b), Bai and Ng (2002), Forni *et al.* (2005), Kabundi (2009), Kabundi and Nadal De Simone (2011), Doz *et al.* (2011), and Crucini *et al.* (2011).

common factors. The estimation of the parameters of Equation 1 generally lies in the analysis of the variance–covariance matrix of the observable data X. In turn, all components of the variance–covariance matrix of the observable data can be summarized by an $N \times 1$ vector of eigenvalues of the matrix Y, each one representing a space dimension. It states that all the N series depend on r factors, i.e. there is an r-dimensional matrix leading the N series. This dimension-reduction matrix corresponds to the choice of the largest eigenvalues of the variance–covariance matrix of Y. Therefore, the first largest r eigenvalues and eigenvectors are calculated from the variance–covariance matrix $cov\ (Y_t)$,

$$X_t = VV'Y_t \tag{2}$$

where V' is the $N \times r$ matrix of eigenvectors corresponding to the largest r eigenvalues of the correlation matrix of Y_t. The common factors, F_t, are estimated in a consistent manner using standard principal component analysis to Y_t,

$$F_t = V'Y_t \tag{3}$$

where the factor loadings, Λ, are equal to V. Hence, the idiosyncratic components are

$$\Xi_t = Y_t - X_t \tag{4}$$

Then, the number of static factors, r, for the above-mentioned dynamic factor model, is determined using the information criterion of Bai and Ng (2002) and Alessi *et al*. (2010). Finally, the common factors are estimated by a vector autoregressive representation of an order of 1 as in Forni *et al*. (2005) and represented as

$$F_t = \Psi F_{t-1} - \mu_t \tag{5}$$

where Ψ is an $r \times$ r matrix and μ_t a $r \times t$ is a vector of error terms. Equation 5 characterizes the evolution of common factors. We follow the approach proposed by Chamberlain (1983) and Chamberlain and Rothschild (1983) which allows for a mild serial correlation of the idiosyncratic errors, but the weak correlation vanishes with the law of large numbers.

Measuring the business cycle components

Various approaches have been proposed to estimate the cyclical component of an economic time series, including Hodrick and Prescott, hereafter HP, (1997) filter, the Baxter and King, hereafter BK, (1999) filter and Christiano and Fitzgerald (2003) filter. The limitations of the HP and BK filters are well documented in the literature (Harvey and Jaeger, 1993; Guay and St-Amant, 1996).

The CO filter is used to extract the business cycles from real output of the BRICS countries. Like all ideal band-pass filters, the CO filter extracts the cyclical component in time series by retaining fluctuations of a specified duration and eliminating the rest. Literature shows that only economic cycle with periodic fluctuations between 6 and 32 quarters, i.e. 1.5 to 8 years, are used. This corresponds to the most popular National Bureau of Economic Research (NBER) cycle and is in line with the original specification and definition of business cycle by Burns and Mitchell (1946). Corbae and Ouliaris (2006) prove, using Monte Carlo simulations, that the CO filter has superior statistical properties and overcomes the limitations of the HP and BK filters. Particularly, they indicate that the CO filter is statistically reliable in the sense that the filtered series asymptotically converges to the true growth cycle. This filter does not suffer from end-points problems.

Let us assume that $X_t(t = 1, \ldots, n)$ is an observable time series produced by

$$X_t = \Psi_2' z_t + x_t \tag{6}$$

where z_t is a $(p + 1)$-dimensional deterministic sequence and x_t is a zero-mean time series. The series X_t, therefore, has both a deterministic component involving the sequence and a stochastic component x_t.

The following assumptions are made by Corbae and Ouliaris (2006) about z_t and x_t in developing their approach to estimate the CO filter. The first assumption is that $z_t = (1, t, \ldots, t^p)'$ is an pth order polynomial in time, while the second assumption is that x_t is an I(1) process satisfying $\Delta X_t = \upsilon_t$ initialized at $t = 0$ by any O_p (1) random variable, such that υ_t has a Wold representation as

$$\upsilon_t = \sum_{j=0}^{\infty} cj\xi_{t-j}$$

where $\xi_t = iid(0, \sigma^2)$ with finite fourth moments and coefficients c_j satisfying $\sum_{j=0}^{\infty} j^{1/2}|cj| < \infty$. The spectral density of υ_t is $f\upsilon\upsilon\ (\lambda) > 0$, for all λ.

Let x_t be an I(1) process satisfying the second assumption, then the discrete Fourier transform of x_t for $\lambda_t \neq 0$ is given by

$$w_x(\lambda_s) = \frac{1}{1 - e^{i\lambda s}} w_\upsilon(\lambda_s) - \frac{e^{i\lambda_s}}{1 - e^{i\lambda_s}} \frac{[x_n - x_0]}{n^{1/2}} \tag{7}$$

where $\lambda_s = \frac{2\pi s}{n}$, $s = 0, 1, \ldots, n-1$, the discrete Fourier transform, are the fundamental frequencies. The second term in Equation 7 makes it clear that the discrete Fourier transform of an I(1) process are not asymptotically independent across fundamental frequencies, as it is a deterministic trend in the frequency domain with a random coefficient of $\frac{[x_n - x_0]}{n^{1/2}}$. They are essentially frequency-wise dependent by virtue of the component $n^{-1/2}x_n$, which produces a common leakage to all frequencies $\lambda_t \neq 0$, even in the limit $n \to \infty$.

According to Corbae *et al*. (2002), the leakage is still obvious when the data series are first de-trended in the time domain and, at any frequency domain, the estimate of the cyclical component of a time series, say real GDP, will be badly distorted. Corbae and Ouliaris (2006) suggest a simple frequency domain fix to this problem which is derived from Equation 7 and the second term of that equation

$$w_{\left(\frac{t}{n}\right)}(\lambda_s) = \frac{-1}{\sqrt{n}}\left(\frac{e^{i\lambda_s}}{1-e^{i\lambda_s}}\right)$$

as in Corbae *et al*. (2002).

Therefore, it is clear from the second term of Equation 7 that the leakage from the low frequency can be removed by de-trending in the frequency domain, leaving an asymptotically unbiased estimate of the first term in Equation 7, $\frac{1}{1-e^{i\lambda_s}} w_{\upsilon}(\lambda_s)$, over the nonzero frequencies. Overall, the CO filtering approach has superior statistical properties and much lower mean-squared error than the time domain-based filters such as BK and HP filters. Igan *et al*. (2011) use the CO filter to describe characteristics and co-movement of cycles in house prices, residential investment, credit, interest rates and real activity in advanced economies over 25 years.

Measuring co-movements

The classical correlation is the most common measure of co-movement between time series. However, it fails to capture any dynamics in the co-movement. Croux *et al.* (2001) propose dynamic correlation as a measure of co-movement of time series, which requires the decomposition of all the correlations between the two series into co-movement at different frequencies. This is a more convenient way than using the traditional indices (Croux *et al.*, 2001). Dynamic correlation also measures the degree to which the cyclical components of the two series are synchronized at a given frequency. The coherence charts the strength of correlation between any two economic time series, while the phase charts the lead and lag relationships. Therefore, the measure of dynamic correlation, coherence and phase angle are used to assess the structure of the co-movements among the cyclical components of SA and the BRIC countries at different frequencies, including the lead and lag relationships.

Consider x and y to be stationary zero-mean real stochastic processes and $S(\lambda)$ be the spectral density matrix of the covariance matrices at frequency $-\pi \leq \lambda \leq \pi$. The coherence between the two series x and y is defined by

$$\rho_{xy}(\lambda) = \frac{S_{xy}(\lambda)}{\sqrt{S_x(\lambda)S_y(\lambda)}} \tag{8}$$

where $\rho_{xy}(\lambda)$ is the coherency, $S_x(\lambda)$ and $S_y(\lambda)$ are the spectrum of x and y, respectively, and $S_{xy}(\lambda)$ is the cross-spectrum between x and y. Equation 8 measures the correlation between the complex representation of x_t and y_t at a frequency λ.

However, this index is not real since the cross-spectrum has an imaginary part. To obtain more convenient measure of co-movement, the squared coherency $\rho^2_{xy}(\lambda)$ is generally preferred in the literature. It can be interpreted as the contribution of the frequency λ to the squared correlation coefficient and defined as

$$\rho^2_{xy}(\lambda) = \frac{|S_{xy}(\lambda)|^2}{S_x(\lambda)S_y(\lambda)} \tag{9}$$

Nevertheless, this index is invariant with respect to a shift in the time process. Croux *et al*. (2001) suggest taking the real part of the coherency to avoid this limitative feature, which is called the dynamic correlation,

$$\phi_{xy}(\lambda) = \frac{C_{xy}(\lambda)}{\sqrt{S_x(\lambda)S_y(\lambda)}} \quad \text{for } 0 \leq \lambda \leq \pi \tag{10}$$

where $C_{xy}(\lambda)$ = real $S_{xy}(\lambda)$ is the co-spectrum between x and y. It measures the correlation between the real movements of x_t and y_t. The dynamic correlation, which lies between –1 and 1, has the advantage of being real and dependent upon a shift in the time process (Croux *et al.*, 2001).

The phase angle between x and y helps to identify the lead and lag relationship and is defined by

$$\theta_{xy}(\lambda) = \tan^{-1}(q_{xy}|S_{xy}) \tag{11}$$

where q_{xy} is the quadrature spectrum. The phase angle converges in distribution to a normal random variable only when $\theta_{xy}(\lambda) \neq 0$. It is possible to create confidence intervals for the lead and lag relations between the two processes once the coherence is significant.

III. Data and Estimation

The discussion covers large data set which contain 63, 50, 59, 61, 67 and 7 macroeconomic time series for Brazil, China, India, Russia, SA and the US, respectively. The data set includes indicators of real, nominal and financial variables, such as real GDP, consumption, investment, consumer prices, interest rates, exchange rates, monetary aggregates, international portfolio and direct investment flows and international trade. The US variables have been included because of the country's dominance and significance in the global business cycle, given the large size of its economy. The data set comprises a total of 307 (N = 307) quarterly variables, ranging from 1995Q2 to 2009Q4 which implies 58 time dimension (T = 58). The reason for the choice of this time span is the availability of data. The variables and their transformations are listed in more detail in Table 1. The data series are obtained from IMF's International Financial Statistics (IFS), the OECD and the GVAR Toolbox1.0 databases (http://www-cfap.jbs.cam.ac.uk/research/gvartoolbox/index.html).

The series are subject to the following primary steps. First and where appropriate, series are seasonally adjusted using X12 filter. Second, all series are transformed into logarithms, except those in percentages and those having negative values. Third, due to power problems of the traditional ADF tests for unit roots, we use more powerful Dickey–Fuller generalized least squares (DF-GLS) test of Elliott *et al*. (1996) to assess the degree of integration of all data series. We also apply stationarity test proposed by Kwiatkowski *et al*. (1992), hereafter the KPSS, where the uncertainty exists about the unit root. The KPSS test differs from the other unit root tests in which the data series are assumed to be trend-stationary and uses different null hypothesis of stationarity as opposed to nonstationary. All nonstationary series are made stationary through differencing. All series are standardized to have a mean of zero and a variance of one. We then first use the CO filter to estimate business cycles, second study the co-movement and lead–lag relationships between cycles and finally use the dynamic factor model to extract common dynamic factors to measure the degree of co-movement of cycles.

Estimating the number of factors

To determine the number of factors empirically, a number of methods have recently been developed, particularly by Bai and Ng (2002), Stock and Watson (2005), Hallin and Liska (2007), Bai and Ng (2007) and Alessi *et al.* (2010).

Bai and Ng, hereafter BN, (2002) suggest six criteria for determining the number factors. All six criteria seek the number of static factors that minimizes the mean-squared distance between observed data and part estimated by static principal components. The mean-squared distance is computed for all the possible number of static factors, r, up to $r_{\max} = \min\{N; T\}$. The BN criterion can be used to consistently estimate the number of factors where the cross-section dimension, N, and the length of the observed series, T, both go to infinity. The traditional AIC and the Bayesian information criterion (BIC), common in time series, fail because they rely on the assumption of $T \gg N$. Bai and Ng (2002) generalizes the C_p criteria of Mallows (1973) and obtain the Panel C_p (PC_p). In addition, they propose another class of criteria similar to the AIC and the BIC, but they use the logarithmic transformation of the error variance and obtained panel information criteria (IC_p).[5] Both principal components (PC_p) and information criteria (IC_p) estimate the number of factors consistently.

However, it has been observed that the BN criterion highly depends on the maximum number of static factors, $r_{\max}$, (Forni *et al*., 2009). Sometimes they do not reach a minimum values and hence making it impossible to determine the number of factors to include. Recently, Alessi *et al*. hereafter ABC, (2010) propose a similar approach, based on Hallin and Liska (2007) criterion, which improves the standard BN procedure for determining the number of static factors. The procedure of ABC criterion for selecting the number of static factors mainly focuses on the behaviour of the variance, S_c, of the estimated number of factors for both N and T for all the values up to infinity. We first implement the BN test and then apply the ABC test to 307 data sets.

Table 2 presents the estimated number of factors and cumulated variance share by 10 principal components based on the BN test. The dimension of r is 4 according to PC_{p1} and PC_{p2} criteria and 6 based on PC_{p3} criteria, while the criteria IC_{p1}, IC_{p2} and IC_{p3} suggest two, one and three factors, respectively. We choose three factors, $r = 3$, following the IC_{p3} criteria. The first reason is that the IC_p criteria are more robust than PC_p (Bai and Ng, 2002). Another reason is that if the numbers of common factors are overestimated, the estimated results are still consistent, unlike when the common factors are underestimated (Stock and Watson, 2002b). Finally, if we look at the cumulative variance shares of common component, which present the variance share explained by the first principal components, the three factors combined to explain 25% of the total variance (Table 2). Thereafter, the variance share explained by the additional factor is less than the 5% benchmark.

Figures 1 and 2 display the IC_2 and PC_2 tests of ABC approach, respectively, and show how the IC_2 and PC_2 criterion works. The solid line provides the suggested number of factors, $r^{*T}_{r;N}$, as the constant, c, increases. When different subsamples of the data set are considered, the solid line provides a measure of instability of $r^{*T}_{r;N}$. On the other hand, a plateau of the dashed line, S_c, means that the suggested number of factors is stable across different values of c. Hence, the smallest value of c has to be chosen where both a plateau of the dashed line and a zero of the solid line occur. The main difference between the

[5] See Bai and Ng (2002) for more technical details of all six information criteria.

Table 1. Macroeconomic series

No	Country	Variable	Log	Stationarity	Treatment
1	Brazil	Monetary aggregate (M1) sa	l	1	5
2	Brazil	Monetary aggregate (M2) sa	l	1	5
3	Brazil	Monetary aggregate (M3)	l	1	5
4	Brazil	Monetary aggregate (M4)	l	1	5
5	Brazil	National currency per SDR	l	1	5
6	Brazil	National currency per US dollar sa	l	1	5
7	Brazil	NEER from ins (index)	l	1	5
8	Brazil	REER sa	l	1	5
9	Brazil	Gold in million ounces	l	1	5
10	Brazil	Holdings of SDRs	l	0	4
11	Brazil	Total reserves minus gold	l	1	5
12	Brazil	Money market rate	nl	1	2
13	Brazil	Savings deposits	nl	1	2
14	Brazil	Time deposits	nl	1	2
15	Brazil	Share prices (index)	l	1	5
16	Brazil	PPI/WPI (index) sa	l	1	5
17	Brazil	National CPI (index) sa	l	1	5
18	Brazil	CPI food and beverages (index) sa	l	1	5
19	Brazil	Industrial production (index) sa	l	1	5
20	Brazil	Production of crude petroleum (index)	l	1	5
21	Brazil	Production in total mining (index)	l	1	5
22	Brazil	Production in total manufacturing (index) sa	l	1	5
23	Brazil	Production of total construction (index) sa	l	1	5
24	Brazil	Exports (flow) sa	l	1	5
25	Brazil	Imports (flow) sa	l	1	5
26	Brazil	Volume export incl coffee (index) sa	l	0	4
27	Brazil	Volume of imports (index) sa	l	0	4
28	Brazil	Export unit values/export prices (index) sa	l	1	5
29	Brazil	Import unit values/import prices (index)	l	1	5
30	Brazil	Services: credit (flow) sa	l	1	5
31	Brazil	Services: debit (flow) sa	nl	1	2
32	Brazil	Income: credit (flow)	l	0	5
33	Brazil	Income: debit (flow) sa	nl	1	2
34	Brazil	Current transfers: credit (flow)	l	1	5
35	Brazil	Current transfers: debit (flow) sa	nl	1	2
36	Brazil	Capital account: credit (flow)	l	1	5
37	Brazil	Capital account: debit (flow)	nl	0	1
38	Brazil	Direct investment abroad	nl	0	1
39	Brazil	Direct invest. in rep. economy	l	0	4
40	Brazil	Portfolio investment assets (flow)	nl	1	2
41	Brazil	Portfolio investment liabilities (flow)	nl	0	1
42	Brazil	Other investment assets (flow)	nl	0	1
43	Brazil	Other investment liabilities (flow)	nl	0	1
44	Brazil	PI equity securities assets (flow)	nl	0	1
45	Brazil	PI debt securities assets (flow)	nl	0	1
46	Brazil	PI equity securities liabilities (flow)	nl	0	1
47	Brazil	PI debt securities liabilities (flow)	nl	0	1
48	Brazil	PI banks assets (flow)	nl	0	1
49	Brazil	OI other sectors assets (flow)	nl	0	1
50	Brazil	OI mon auth liabilities (flow)	nl	0	1
51	Brazil	OI banks liabilities (flow)	nl	0	1
52	Brazil	OI other sectors liabilities (flow)	nl	0	1
53	Brazil	Net errors and omissions (flow)	nl	0	1
54	Brazil	Reserve assets (flow)	nl	0	1
55	Brazil	Government consumption expend. (flow) sa	l	1	5
56	Brazil	Gross fixed capital formation (flow) sa	l	1	5
57	Brazil	Changes in inventories (flow)	nl	0	1
58	Brazil	Household cons. expenditure (flow)	l	1	5
59	Brazil	Net primary income from abroad (flow) sa	nl	1	2
60	Brazil	Gross national income (flow) sa	l	1	5
61	Brazil	GDP deflator (index) sa	l	0	4
62	Brazil	GDP vol. (index) sa	l	1	5

(*continued*)

Table 1. Continued

No	Country	Variable	Log	Stationarity	Treatment
63	Brazil	Short-term interest rates	nl	1	2
64	Russia	National currency per SDR sa	l	1	5
65	Russia	National currency per US dollar	l	1	5
66	Russia	NEER from ins (index)	l	1	5
67	Russia	REER based on rel. CPI (index) sa	l	1	5
68	Russia	Gold in million ounces (stock)	l	1	5
69	Russia	Gold (stock) sa	l	1	5
70	Russia	Holdings of SDRs (stock)	nl	1	2
71	Russia	Reserve position in the fund (US dollars)	l	1	5
72	Russia	Reserve position in the fund (SDRs)	l	1	5
73	Russia	Total reserves minus gold (stock) sa	l	1	5
74	Russia	Money market rate (per cent per annum)	l	1	5
75	Russia	Deposit rate (per cent per annum) sa	l	1	5
76	Russia	Lending rate (per cent per annum)	l	1	5
77	Russia	Refinancing rate (per cent per annum)	l	1	5
78	Russia	PPI per cent change over previous period	nl	1	2
79	Russia	Consumer price index (index) sa	l	1	5
80	Russia	Consumer prices: services (index)	l	1	5
81	Russia	Consumer prices: food (index) sa	l	1	5
82	Russia	Industrial production (index) sa	l	1	5
83	Russia	Production of crude petroleum (index) sa	l	1	5
84	Russia	Production of coal (units, tonnes mln) sa	l	0	4
85	Russia	Production of gas (units, mş bln) sa	l	0	4
86	Russia	Unemployment (number of persons) sa	l	1	5
87	Russia	Employment (index)	l	1	5
88	Russia	Exports (flow) sa	l	1	5
89	Russia	Imports (flow)	l	1	5
90	Russia	Services: credit (flow)	l	1	5
91	Russia	Services: debit (flow) sa	nl	1	2
92	Russia	Income: credit (flow)	nl	1	2
93	Russia	Income: debit (flow)	nl	1	2
94	Russia	Current transfers: credit (flow) sa	l	1	5
95	Russia	Current transfers: debit (flow) sa	nl	1	2
96	Russia	Capital account: credit (flow)	l	0	4
97	Russia	Capital account: debit (flow)	nl	0	1
98	Russia	Direct investment abroad (FDI outward)	nl	1	2
99	Russia	Direct invest. in rep. economy (FDI inward)	nl	1	2
100	Russia	Portfolio investment assets (flow)	nl	0	1
101	Russia	Portfolio investment liabilities (flow)	nl	0	1
102	Russia	Other investment assets (flow)	nl	0	1
103	Russia	Other investment liabilities (flow)	nl	1	1
104	Russia	PI equity securities assets (flow)	nl	0	1
105	Russia	PI debt securities assets (flow)	nl	0	1
106	Russia	PI equity securities liabilities (flow)	nl	0	1
107	Russia	PI debt securities liabilities (flow)	nl	0	1
108	Russia	OI gen govt assets (flow)	nl	0	1
109	Russia	OI banks assets (flow)	nl	1	2
110	Russia	OI other sectors assets (flow)	nl	0	1
111	Russia	OI mon auth liabilities (flow)	nl	0	1
112	Russia	OI gen govt liabilities (flow)	nl	0	1
113	Russia	OI banks liabilities (flow)	nl	0	1
114	Russia	OI other sectors liabilities (flow)	nl	0	1
115	Russia	Net errors and omissions (flow)	nl	0	1
116	Russia	Reserve assets (flow)	nl	0	1
117	Russia	Government consumption expenditure (flow)	l	1	5
118	Russia	Private final consumption expenditure sa	l	1	5
119	Russia	Gross fixed capital formation (flow)	l	1	5
120	Russia	Changes in inventories (flow)	nl	1	2
121	Russia	Household cons. expenditure (flow) sa	l	1	5
122	Russia	GDP, production based (flow) sa	l	1	5
123	Russia	Statistical discrepancy (flow)	nl	0	1
124	Russia	GDP vol. (index) sa	l	1	5

(*continued*)

Table 1. Continued

No	Country	Variable	Log	Stationarity	Treatment
125	India	Monetary aggregate (M1) sa	l	1	5
126	India	Monetary aggregate (M3) sa	l	1	5
127	India	Demand deposits (stock) sa	l	1	5
128	India	Time deposits (stock) sa	l	1	5
129	India	Credit from reserve bank (stock)	nl	0	1
130	India	National currency per SDR, sa	l	1	5
131	India	National currency per US dollar, sa	l	1	5
132	India	Gold ac.to national valuation (stock) sa	l	1	5
133	India	Holdings of SDRs	l	0	4
134	India	Reserve position in the fund (US dollars)	l	1	5
135	India	Reserve position in the fund (SDRs)	l	1	5
136	India	Total reserves minus gold (US dollars) sa	l	1	5
137	India	Lending rate (per cent per annum)	nl	1	2
138	India	Share prices (index)	l	1	5
139	India	Wholesale prices: total (index) sa	l	1	5
140	India	PPI/WPI (index) sa	l	0	4
141	India	Consumer prices: all items (index) sa	l	1	5
142	India	Industrial production (index) sa	l	1	5
143	India	Production in total mining (index) sa	l	1	5
144	India	Production in total manufacturing (index) sa	l	1	5
145	India	Production of electricity (index) sa	l	1	5
146	India	Goods exports: f.o.b. (flow) sa	l	1	5
147	India	Goods imports: f.o.b (flow)	nl	1	2
148	India	Services: credit (flow)	l	0	4
149	India	Services: debit (flow)	nl	1	2
150	India	Income: credit (flow)	l	0	4
151	India	Income: debit (flow)	nl	1	2
152	India	Current transfers: credit (flow) sa	l	0	4
153	India	Current transfers: debit (flow)	nl	0	1
154	India	Direct investment abroad (FDI outward)	nl	1	2
155	India	Dir. invest. in rep. economy (FDI inward)	l	0	4
156	India	Portfolio investment liabilities (flow)	nl	0	1
157	India	Other investment assets (flow)	nl	0	1
158	India	Other investment liabilities (flow)	nl	0	1
159	India	PI equity securities liabilities (flow)	nl	0	1
160	India	OI gen govt assets (flow)	nl	0	1
161	India	OI banks assets (flow)	nl	0	1
162	India	OI other sectors assets (flow)	nl	0	1
163	India	OI mon auth liabilities (flow)	nl	0	1
164	India	OI gen govt liabilities (flow)	nl	0	1
165	India	OI banks liabilities (flow)	nl	0	1
166	India	OI other sectors liabilities (flow)	nl	0	1
167	India	Net errors and omissions (flow)	nl	0	1
168	India	Reserve assets (flow)	nl	0	1
169	India	Foreign assets (stock) sa	l	1	5
170	India	Foreign liabilities (stock) sa	l	1	5
171	India	Claims on government (stock)	l	1	5
172	India	Claims on comm and coop banks	nl	0	1
173	India	Claims on ofis (stock)	l	0	4
174	India	Currency outside banks (stock) sa	l	1	5
175	India	Reserve money (stock) sa	l	1	5
176	India	Government deposits (stock)	l	1	5
177	India	Claims on private sector (stock) sa	l	1	5
178	India	Domestic credit (stock) sa	l	1	5
179	India	Money (stock) sa	l	1	5
180	India	Quasi-money (stock) sa	l	1	5
181	India	GDP vol. (index, 2005 = 100)	l	1	5
182	India	Short-term interest rates	nl	1	2
183	India	Equity price (index)	l	1	5
184	China	Monetary aggregate (M1) sa	l	1	5
185	China	Monetary aggregate (M2)	l	1	5
186	China	Reserves (claims on pbc, stock) sa	l	1	5

(*continued*)

Table 1. Continued

No	Country	Variable	Log	Stationarity	Treatment
187	China	Demand deposits (stock) sa	l	1	5
188	China	Savings deposits (stock)	l	1	5
189	China	Time deposits (stock) sa	l	1	5
190	China	Bonds (stock)	l	1	5
191	China	Restricted deposits	l	0	4
192	China	Credit from monetary authorities	l	1	5
193	China	NEER from ins (index) sa	l	1	5
194	China	REER sa	l	1	5
195	China	National currency per SDR sa	l	1	5
196	China	National currency per US dollar	l	1	5
197	China	Gold ac.to national valuation (stock)	l	1	5
198	China	Holdings of SDRs (US dollars)	l	1	5
199	China	Reserve position in the fund (US dollars)	l	1	5
200	China	Reserve position in the fund (SDRs)	l	1	5
201	China	Total reserves minus gold (stock) sa	l	1	5
202	China	Monetary auth.: other assets (stock)	l	1	5
203	China	Banking insts. assets (stock)	l	1	5
204	China	Banking insts. liabilities (stock)	l	1	5
205	China	SDR reserve assets	l	1	5
206	China	Share prices (index)	l	1	5
207	China	CPI per cent change	nl	1	2
208	China	Consumer prices: all items (index) sa	l	1	5
209	China	Consumer prices: food (index) sa	l	1	5
210	China	Industrial production (index)	l	1	5
211	China	Production of cement sa	l	1	5
212	China	Exports (flow) sa	l	1	5
213	China	Imports (flow) sa	l	1	5
214	China	Foreign assets (stock)	l	1	5
215	China	Foreign liabilities (stock)	l	1	5
216	China	Direct investment abroad (FDI outward)	nl	1	2
217	China	Direct invest. in rep. economy (FDI inward)	l	1	5
218	China	Claims on cent. government (stock)	l	1	5
219	China	Claims on other sectors (stock)	nl	1	2
220	China	Claims on deposit money banks (stock) sa	l	1	5
221	China	Currency outside banks (stock) sa	l	1	5
222	China	Reserve money (stock) sa	l	1	5
223	China	Central govt deposits (stock)	l	1	5
224	China	Capital accounts (stock)	l	1	5
225	China	Claims on other sectors (stock) sa	l	1	5
226	China	Domestic credit (stock) sa	l	1	5
227	China	Money (stock) sa	l	0	4
228	China	Quasi-money (stock) sa	l	1	5
229	China	Bonds (stock)	l	1	5
230	China	Restricted deposits	l	0	4
231	China	Capital accounts (stock)	l	1	5
232	China	GDP vol. (index)	l	1	5
233	China	Short-term interest rates	nl	1	2
234	South Africa	Monetary aggregate (M1) sa	l	1	5
235	South Africa	Monetary aggregate (M2) sa	l	1	5
236	South Africa	Monetary aggregate (M3) sa	l	1	5
237	South Africa	NEER from ins (index)	l	1	5
238	South Africa	REER based on rel. cpi (index)	l	1	5
239	South Africa	National currency per SDR	l	1	5
240	South Africa	National currency per US dollar	l	1	5
241	South Africa	Gold in million ounces (stock)	l	0	4
242	South Africa	Gold ac. to national valuation (stock) sa	l	1	5
243	South Africa	Holdings of SDRs (stock)	l	1	5
245	South Africa	Reserve position in the fund (SDRs)	l	1	5
246	South Africa	Total reserves minus gold (stock)	l	1	5
247	South Africa	Money market rate (per cent)	nl	1	2
248	South Africa	Treasury bill rate (per cent)	nl	1	2
249	South Africa	Deposit rate (per cent)	nl	1	2
250	South Africa	Lending rate (per cent)	nl	1	2

(*continued*)

Table 1. Continued

No	Country	Variable	Log	Stationarity	Treatment
251	South Africa	Discount rate (per cent)	nl	0	1
252	South Africa	Government bond yield (per cent) sa	nl	1	2
253	South Africa	Share prices: indust and comm (index)	l	1	5
254	South Africa	Share prices: gold mining (index)	l	1	5
255	South Africa	Share prices: all shares (index) sa	l	1	5
256	South Africa	PPI/WPI (index) sa	l	0	4
257	South Africa	Consumer price index (index) sa	l	1	5
258	South Africa	Manufacturing production (index) sa	l	1	5
259	South Africa	Gold production (index) sa	l	1	5
260	South Africa	Mining production (index) sa	l	1	5
261	South Africa	Gold output (net) (flow) sa	l	0	4
262	South Africa	Goods exports: f.o.b. (flow) sa	l	1	5
263	South Africa	Goods imports: f.o.b (flow)	nl	1	2
264	South Africa	Services: credit (flow) sa	l	1	5
265	South Africa	Services: debit (flow) sa	nl	1	2
266	South Africa	Income: credit (flow)	l	1	5
267	South Africa	Income: debit (flow)	nl	0	1
268	South Africa	Current transfers: credit (flow)	l	1	5
269	South Africa	Current transfers: debit (flow)	nl	1	2
270	South Africa	Capital account: credit (flow) sa	l	1	5
271	South Africa	Capital account: debit (flow)	nl	0	1
272	South Africa	Direct investment abroad (FDI outward)	nl	0	1
273	South Africa	Direct investment in rep. economy (FDI inward)	nl	0	1
274	South Africa	Portfolio investment assets (flow)	nl	0	1
276	South Africa	Other investment assets (flow)	nl	0	1
277	South Africa	Other investment liabilities (flow)	nl	0	1
278	South Africa	PI equity securities assets (flow)	nl	0	1
279	South Africa	PI debt securities assets (flow)	nl	0	1
280	South Africa	PI equity securities liabilities (flow)	nl	0	1
281	South Africa	PI debt securities liabilities (flow)	nl	0	1
282	South Africa	OI mon auth assets (flow)	nl	0	1
283	South Africa	OI gen govt assets (flow)	nl	0	1
284	South Africa	OI banks assets (flow)	nl	0	1
285	South Africa	OI mon auth liabilities (flow)	nl	0	1
286	South Africa	OI gen govt liabilities (flow)	nl	0	1
287	South Africa	OI banks liabilities (flow)	nl	0	1
288	South Africa	Net errors and omissions (flow)	nl	0	1
289	South Africa	Reserve assets (flow)	nl	0	1
290	South Africa	Private final consumption expenditure (index) sa	l	1	5
291	South Africa	Government consumption expend. sa	l	1	5
292	South Africa	Gross fixed capital formation sa	l	1	5
293	South Africa	Changes in inventories sa	nl	1	2
294	South Africa	Household cons. expenditure sa	l	1	5
295	South Africa	Net primary income from abroad sa	nl	0	1
296	South Africa	Gross national income sa	l	1	5
297	South Africa	GDP deflator (index, 2005 = 100) sa	l	1	5
298	South Africa	GDP vol. (index, 2005 = 100) sa	l	1	5
299	South Africa	Consumption of fixed capital sa	l	1	5
300	South Africa	Short-term interest rates (per cent)	nl	1	2
301	United States	Broad money (M3) (index) sa	l	1	5
302	United States	S and P industrials (index) sa	l	1	5
303	United States	CPI all items (index, 2005 = 100) sa	l	1	5
304	United States	GDP deflator (index, 2005 = 100) sa	l	0	4
305	United States	GDP vol. (index, 2005 = 100) sa	l	1	5
306	United States	Short-term interest rates (per cent)	nl	0	2
307	United States	Nominal equity price index sa	l	1	5

Notes: The transformation codes (treatment) are as follows: 1 indicates no transformation (level); 2 indicates first difference; 4 indicates log arithm (log-level); 5 indicates first difference of logarithm (log-first difference). sa denotes seasonally adjusted series; l stands for logarithm; nl indicates the level of the data; 0—integrated of order zero; 1 denotes the first difference of the series NEER, Nominal Effective Exchange Rate; REER, Real Effective Exchange Rate; PPI, Producer Price Index; WPI, Wholesale Price Index; CPI, Consumer Price Index; PI, Portfolio Investment; OI, Other Investment; GDP, Gross Domestic Product; Vol., Volume; Govt, Government; SDR, Special Drawing Unit; Incl, Including; Cons, Consumption; Ac, Accumulation; Insts, Institutions.

Table 2. The BN test for selecting the number of factors

r	*PCp1*	*PCp2*	*PCp3*	*ICp1*	*ICp2*	*ICp3*	Cumulated variance share
1	0.8982	0.8999	0.8933	−0.0735	−0.0699*	−0.0832	0.13
2	0.8725	0.8761	0.8628	−0.0735*	−0.0664	−0.0929	0.19
3	0.8583	0.8636	0.8437	−0.0648	−0.0541	−0.0940*	0.25
4	0.8532*	0.8604*	0.8338	−0.0479	−0.0337	−0.0869	0.29
5	0.8535	0.8624	0.8291	−0.0272	−0.0094	−0.0758	0.33
6	0.8560	0.8667	0.8268*	−0.0062	0.0151	−0.0646	0.37
7	0.8627	0.8751	0.8286	0.0182	0.0430	−0.0500	0.40
8	0.8712	0.8854	0.8322	0.0428	0.0712	−0.0350	0.43
9	0.8824	0.8984	0.8386	0.0694	0.1014	−0.0182	0.46
10	0.8952	0.9130	0.8465	0.0964	0.1319	−0.0009	0.49

Note: * represents the ideal number of factors.

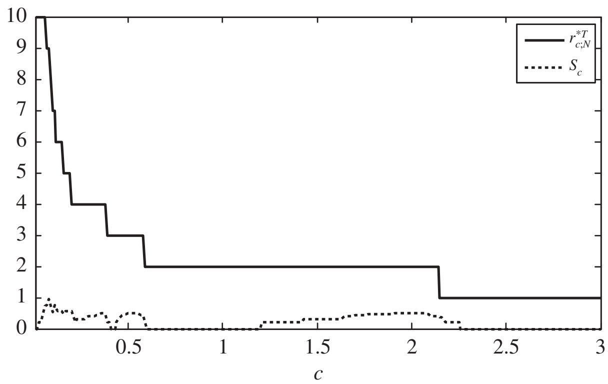

Fig. 1. The ABC estimated number of factors, PC_2 test

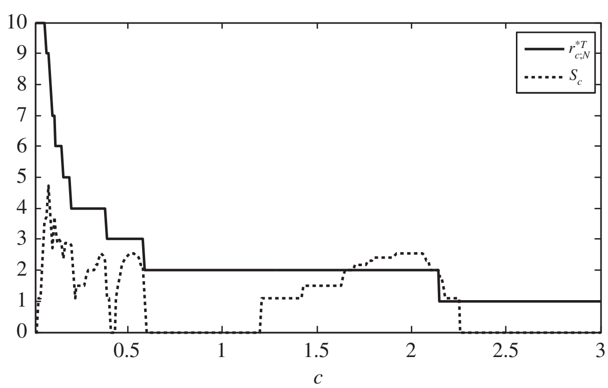

Fig. 2. The ABC estimated number of factors, IC_2 test

traditional *IC* criteria by Bai and Ng (2002) implicitly consider only the case $c = 1$. Therefore, the choice of the optimal number of common factors is done based on IC_2 and PC_2 tests of ABC approach. Since there is no formal method to select the upper bound and size of subsamples, we choose $c = 3$ for the upper bound such that the number of factors is not zero and the subsamples of 230 ($3/4 \times N$). We find four static factors based on the IC_2 and PC_2 tests. However, we opted for three factors here as the results do not change by using three or four factors.

IV. Empirical Results

Analysis of co-movements

This section examines the degree of co-movement between the cyclical components of real GDP output across SA and the BRIC countries using the CO filter. The CO filter is chosen in preference to others, such as HP and BK filters, because it overcomes some of the shortcomings of those filters. All GDP data have been seasonally adjusted and spans the period 1995Q1 to 2009Q4 for Russia, due to data availability, and 1979Q2 to 2009Q4 for all the other BRICS countries.

As pair correlations of cyclical components of real output examine the degree of business cycle co-movements, we present the evolution of these co-movements between SA and each of the BRIC countries in Fig. 3. We observe that there are some distinct periods of co-movement between SA and Brazil. For instance, from 1983 to the end of 1987, Brazil experienced an upward trend while SA experienced an only modest upward and downward cycle movement. The major difference between the two cycles is apparent in the 1980s where the Brazil's cycle is more volatile than the SA cycle. The cyclical component between the two countries started co-moving from end of 1980s and became more synchronized over time. A closer inspection reveals that SA is lagging Brazil in the 1980s. But, the two cycles become contemporaneous in the 1990s.

Like Brazil, we also observe different periods of co-movement between SA and China. Particularly, the major difference between SA's and China's business cycles is the expansion in the late 1981 in SA at a time when the China's cycle was contracting. During the downturn of 1984 to 1988, the SA contraction was deeper. Between 1989 and 1990, the China's cycle contracted much more than the SA.

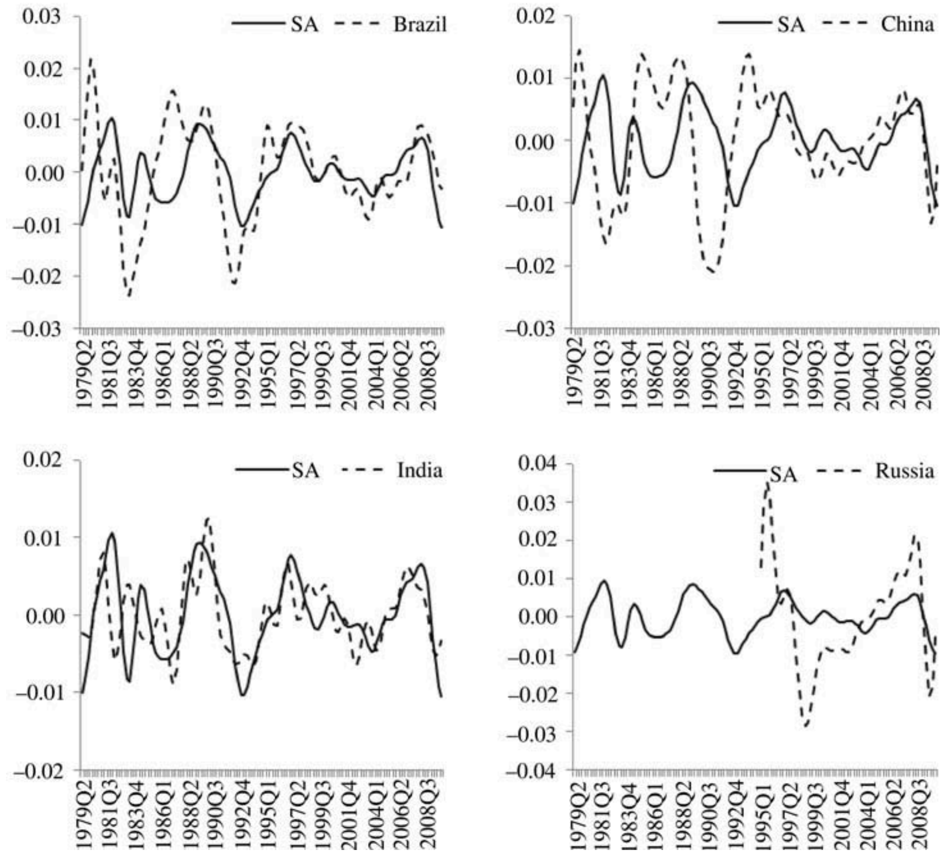

Fig. 3. Co-movement between countries
Note: The values on *x*-axis are in a percentages.

A similar pattern of co-movement between the two cycles is displayed after 1997. The SA business cycle synchronization with the Chinese shows a declining trend from 1997Q1 to 2003Q4. Afterward, it displays an increasing trend up to the second quarter of 2008 and a downward trend over the 2008Q2–2009Q2 period. Overall, China is leading SA prior to the 1980s and the large part of 1990s. The two cycles become contemporaneous from 1995 onward. Like Brazil, the China's cycle is more volatile than SA's cycle in the 1980s. This finding is in line with the conventional wisdom, as it is often assumed that the foreign business cycle leads the SA business cycle via an increase in SA exports (Barr and Kantor, 2002).

To a larger extent, SA is contemporaneous with India. The two cycles are contemporaneous since the 1980s and they also exhibit the same volatility, both in the 1980s and in the 1990s. The correlation of cycles between the two countries is strong, albeit with some distinct periods of co-movements. The correlation of SA's and India's business cycles suggests strong co-movement between the two countries' cycle.

The Russia's and SA's cycles are moving together, but Russia is more volatile than SA. For instance, both increased in 1995, but Russia experienced a rapid expansion than SA. Russia and SA both were in recession during Asian crisis, but Russian recession was deeper than SA. Early in 1998, they started to move beyond the recessionary phase, and after recovering, Russia's cycle reaches a maximum of 2% in 2006, while SA's cycle reaches a maximum of 1% only. The cyclical correlation between the two countries has consistently exhibited some co-movements since 2003Q4. The synchronization of cycles between SA and Russia shows an increasing trend up to 2008Q1, and afterward a declining trend.

In general, the correlation analysis suggests that the synchronization of the SA's cycle with the BRIC countries has increased, especially after 1995. Hence, these positive output correlations might be attributed to the integration of SA into the global economy right after the new political dispensation of 1994. In addition, it seems that, in recent times, emerging market economies tend to display similar cycles. These findings are in line with the work of Kabundi (2009) and Kabundi and Loots (2007, 2010) who find strong evidence of synchronization between SA and the US business cycles, co-movement of the business cycle between SA and the SADC countries and co-movement between the SA and the German business cycle, mainly following integration of SA into the global economy. A closer look reveals that volatility in the SA business cycle decreased significantly since 1994. The business cycle volatility in the SA economy is more stable than the BRIC countries, except for India.

Dynamic correlations

The pair correlation of cyclical components of the real GDP output in SA and the BRIC countries is enough to indicate whether or not they are co-moving. However, it is not possible to explain the strength of such co-movements, lead–lag and the evolution of relationships. We, therefore, use the coherence, the phase and the dynamic correlation. Mostly, countries display the same pattern in the cyclical period where they seem to be concurrently affected by common shocks. If shocks are transmitted from one country to another through, for example, international trade, then the co-movements are observed in different periods. Hence, in this instance, one cycle tends to lead the other since the transmission mechanism takes some time.

Three components of the aggregate correlation between SA and the BRICs are examined. First, the long-run co-movements belong to the low frequency band which corresponds to cycles with a period longer than 8 years or from 32 quarters to infinity, $(0, \pi/16)$. Second, the traditional business cycles belong to the high frequency band, $(\pi/16, \pi/3)$, which corresponds to cycles with a period between 1.5 and 8 years or between 6 and 32 quarters. Finally, the short-run co-movements are defined by frequencies $(\pi/3, \pi)$ or periodicities between the second and sixth quarters.

First, the coherence between the cycles of SA and BRICs is measured. The coherence is the frequency domain analogous to the correlation of determination, the R-square, which measures the strength of the cyclical components of output and provides valuable information about the importance of the co-movement of the two time series. According to this measure, higher output correlation between countries implies a higher degree of business cycle synchronization. It can be interpreted as the squared linear correlation coefficient for each frequency

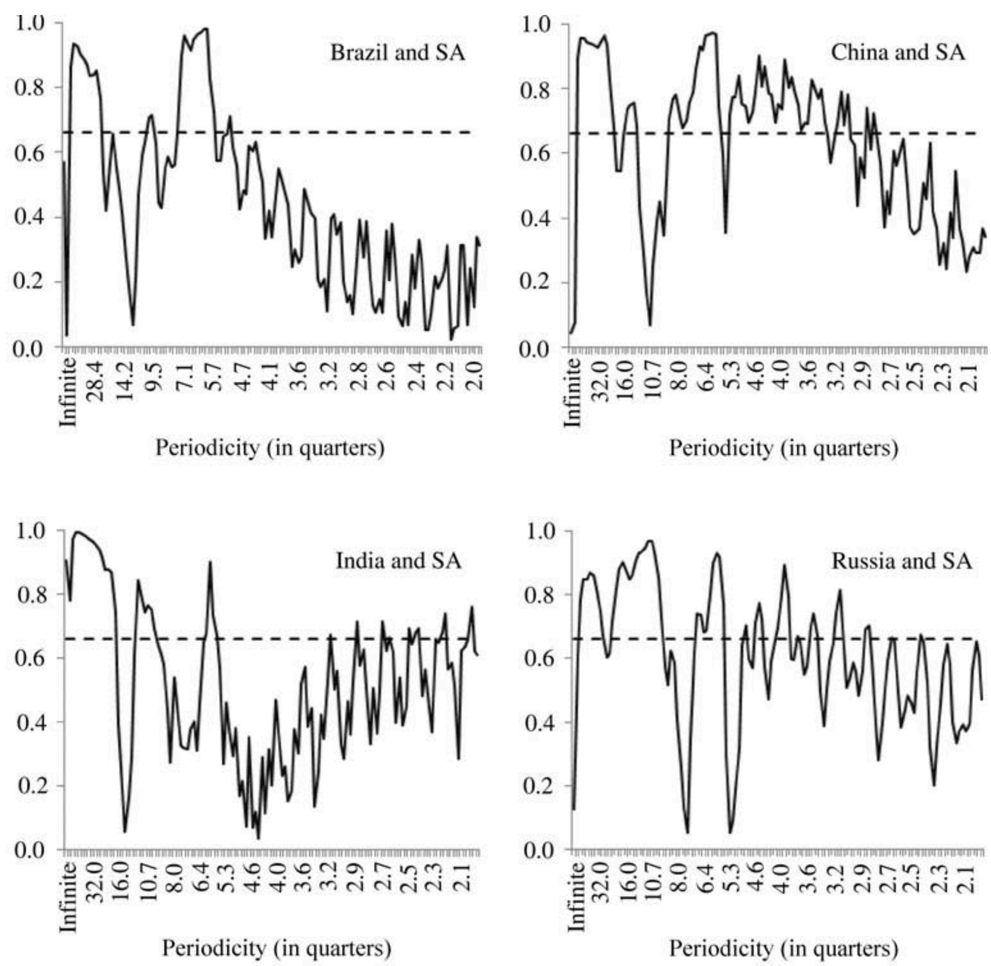

Fig. 4. Coherence between countries

of the spectra of two series. Its coefficient varies between 0 and 1. The coherence between SA and each of the BRIC countries successfully charts the strength of their correlation.

Figure 4 shows that the correlation of cycles between Brazil and SA is insignificant over the long run, but becomes significant and strong over the cyclical period. It reaches a maximum of 98% between eight after six quarters. Over the short run, the relationship between SA and Brazil is generally weak and insignificant. The relationship between China and SA is weak and insignificant over the long run (Fig. 4). Similar to Brazil, their relationship becomes strong and significant over the cyclical period, reaching a maximum of 97%. Over the short horizon, the relationship between SA and China is significant and strong in periodicities ranging between third and fifth quarters. But it is insignificant in frequencies of less than a year. Unlike the previous cases, Fig. 4 shows that India and SA has significant and strong correlation over the long-run period, with a maximum of 99%. This pattern is evident in Fig. 3, where the two cycles tend to move contemporaneously and they exhibit the same volatility. The significant and strong relationship that exists between the two countries is consistent over the cyclical period with a maximum of 90%. But, the relationship between SA and India is weak and insignificant over the short run. Like in the case of Brazil and China, SA and Russia depicts a very weak and insignificant relationship over the long run. Nevertheless, the relationship becomes strong and significant over the cyclical period attaining a maximum of 97%. In addition, the two cycles seem to co-move even in the short term, there seems with the highest correlation coefficient of 93%. However, this picture can be misleading in the sense that the Russian cycle is only available after 1992.

Second, the phase between the cycles of SA and the BRICs is measured. With respect to phase shift between the co-movement of output cycle across countries, if x is the output cycle of country i, and y of country j, we say that the x series leads the output cycle by q quarters if $corr\,(x, y)$ peak at x_{t-q} with $q \geq 0$ and the x series lags the output cycle by q quarters if $corr\,(x, y)$ peak at x_{t+q} with $q \geq 0$. The results, presented in Fig. 5, suggest that Brazil, China and Russia lead SA over the long run, and not over

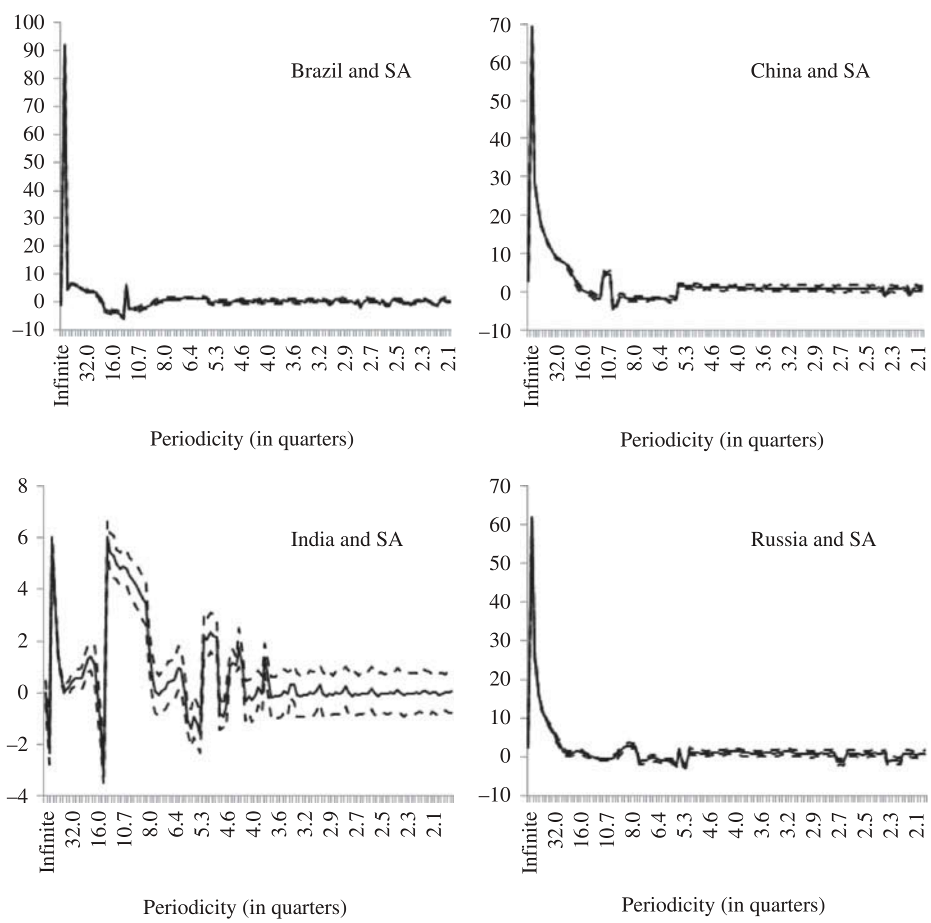

Fig. 5. Phase between countries
Note: Dashed lines are 95% significance levels.

the cyclical and short-run periods. The phase angle scores the highest value of 90%, 70% and 60% for Brazil, China and Russia, respectively. Conversely, the phase angle between India and SA gives evidence of contemporaneous relationship over time. The highest value is only 6%, which is too low compared to the other BRIC countries. These results are in line with the picture depicted in Fig. 3. Overall, the results suggest that the SA's cycle tends to lag cycles of the BRIC countries over the long run, except for India.

Finally, the dynamic correlation of business cycles between SA and the BRIC countries is measured. According to this measure, depicted in Fig. 6, the relationship between Brazil's and SA's cycles varies over time, attaining highest value at around 84% after 32 quarters. This shows that the two countries are highly correlated over the long run. Similarly, the two countries are also highly correlated over the cyclical period. By contrast, the dynamic correlation between the two countries takes the smallest values over the short run. The pattern that emerges in dynamic correlation between China and SA, and between Russia and SA shows that these two countries have close relationship with SA over the cyclical period. The dynamic correlation of cycles scores the highest values of 75% and 93% for China and Russia, respectively. However, the relationship is negative and weak over the long and short run. Importantly, India portrays different relationship when compared to other BRICS countries and has a strong correlation over time. The correlation coefficient takes the highest value (around 98%) over the long run. This points strong business linkages between India and SA.

In general, the dynamic correlation between SA and the BRIC countries vary across countries and over time. The pattern is remarkably different for India. India is the only country that has significant and strong correlation with SA cycle over the long and short run, and the cyclical period. Brazil, China and Russia are characterized by close relationships with SA over the business cycle period. Relatively strong trade ties between SA and the BRIC countries may explain some of the business cycle correlations over the cyclical period.

The interdependence between SA and the BRICs

The argument that SA is becoming increasingly more interdependent with the BRICs is supported by the variance share of common component depicted in Table 3.

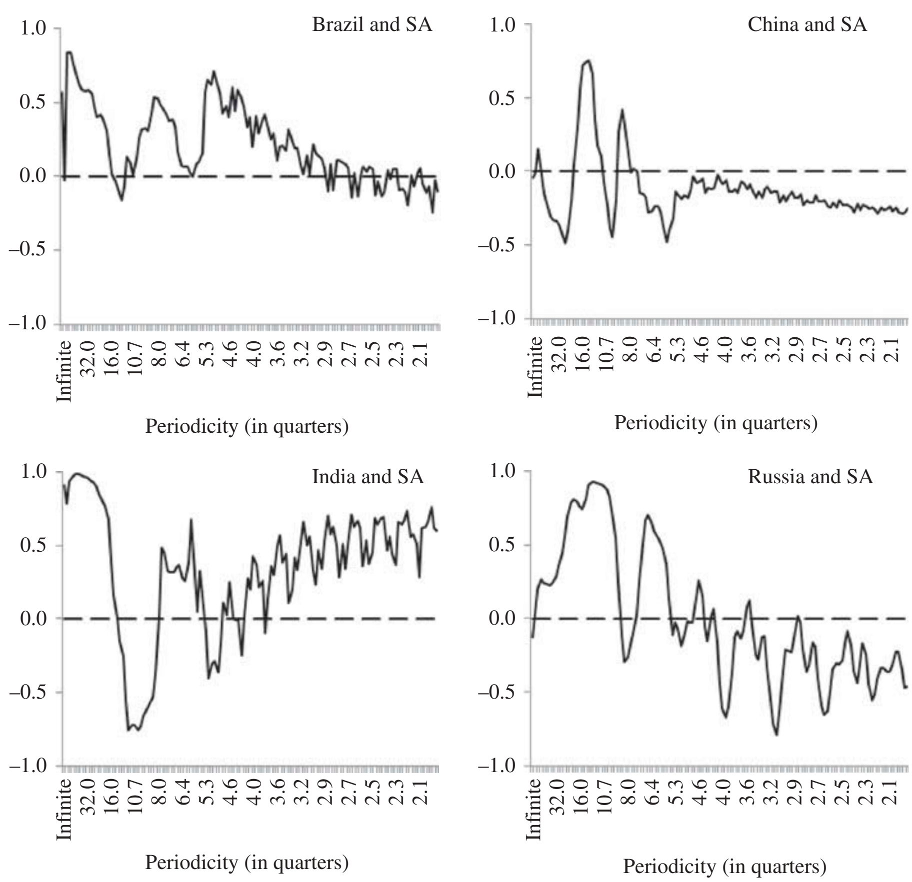

Fig. 6. Dynamic correlation across countries

Table 3. The variance share of the common components

Country	Variable	Variance share of common components
South Africa	Consumer price index	0.18
South Africa	Consumption of fixed capital	0.57
South Africa	FDI inward (flow)	0.13
South Africa	FDI outward (flow)	0.26
South Africa	GDP	0.68
South Africa	Exports	0.58
South Africa	Imports	0.63
South Africa	Gross fixed capital formation	0.66
South Africa	Household consumption expenditure	0.39
South Africa	Manufacturing production	0.52
South Africa	Monetary aggregate (M1)	0.17
South Africa	Monetary aggregate (M2)	0.27
South Africa	National currency per US dollar	0.51
South Africa	Portfolio investment assets	0.30
South Africa	Portfolio investment liabilities	0.37
South Africa	Private final consumption expenditure	0.60
South Africa	Real effective exchange rates	0.33
South Africa	Share prices	0.26
South Africa	Short-term interest rates	0.58

Note: Forecast horizon is 20 quarter and bootstrapping methods are used to construct 95% confidence intervals.

The results show that 68% of variation of SA GDP is explained by common factors, which suggests a close synchronization between SA and the BRIC countries. The shock from one country can somewhat be transmitted to other countries though international trade and capital flows, depending on relative size and the degree of openness (Canova and Dellas, 1991). Strong international trade and financial linkages lead to a high interdependence among countries. Using three dynamic factors, we obtain variance shares of the common components 63% for imports and 58% for exports. It means that trade linkages contribute more to co-movement of cycles of BRICS. Since most of real variables depict higher variance share of common components (66% for gross fixed capital formation, 60% for private consumption expenditure and 58% for manufacturing production), we can conclude that trade integration leads to synchronization of real variables across the bloc. Conversely, financial variables exhibit lower variance share of common components (33% for real exchange rate and 26% for share prices), which means financial markets of BRICS are less integrated. Hence, the co-movement of business cycles is mainly due trade integration instead of financial linkages. Moreover, since the common components explains 58% of the variation of short-term interest rate, it is possible that their monetary policies tend to be somewhat synchronized. It is therefore possible to examine the response of SA variables to monetary policy shocks from other BRICS countries, but this is beyond the scope of current study.

There is more evidence of trade linkages than financial linkages. Thus, more bilateral trade between SA and the BRICs constitute underlying forces behind co-movement of business cycles. Particularly, the Chinese and Indian demand for SA commodities has increased significantly over the last decade. The theoretical argument behind this is that the countries that have strong trade linkages have somewhat similar business cycles 17 (Frankel and Rose, 1998; Baxter and Kouparitsas, 2005). In addition to Kabundi (2009) and Kabundi and Loots (2010), who find evidence of integration between SA cycle and those of the US and Germany, and the current study finds evidence of integration of SA and the other BRICS countries. This finding points to the benefit of the strategy of diversification of trade adopted by SA most recently.

Identification of common factors

Given that factors underlying co-movement are latent, they are mainly seen as black boxes and void of any economic interpretation. The question arises as to whether the common factors have their origins from or they are external but common to the bloc. To answer this question, we use marginal regressions of each of the 307 series on the common factors. The marginal R-squares are obtained and used as measure of predictability for each series. In addition, given that the factors are orthogonal, it should be relatively easy to identify them. Figures 7–9 show the estimated factors with the R-squares from different estimations on the y-axis.

Figure 7 plots the first factor which can be interpreted as a broad measure of real economic activity since it scores high values for real economic indicators. Specifically, this factor appears largely in Brazil's industrial production,

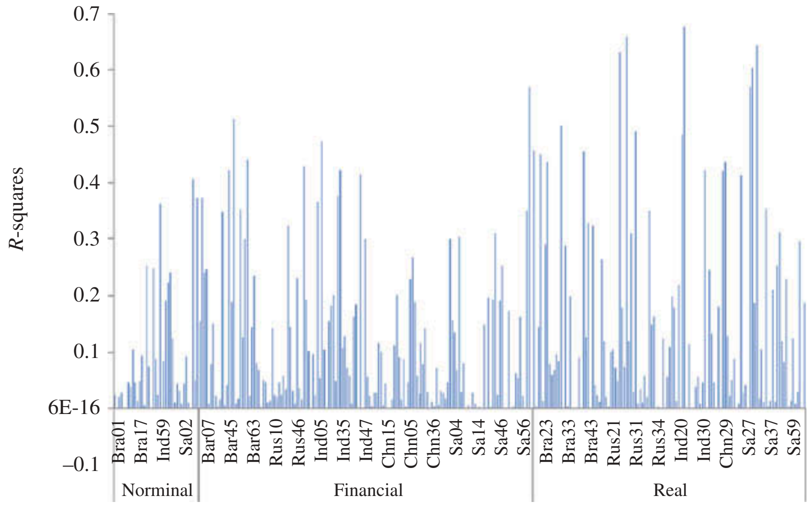

Fig. 7. Correlation between Factor 1 and each of the variables

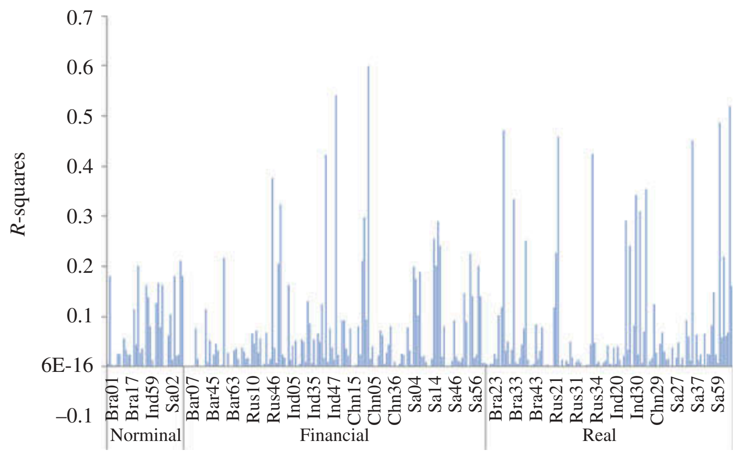

Fig. 8. Correlation between Factor 2 and each of the variables

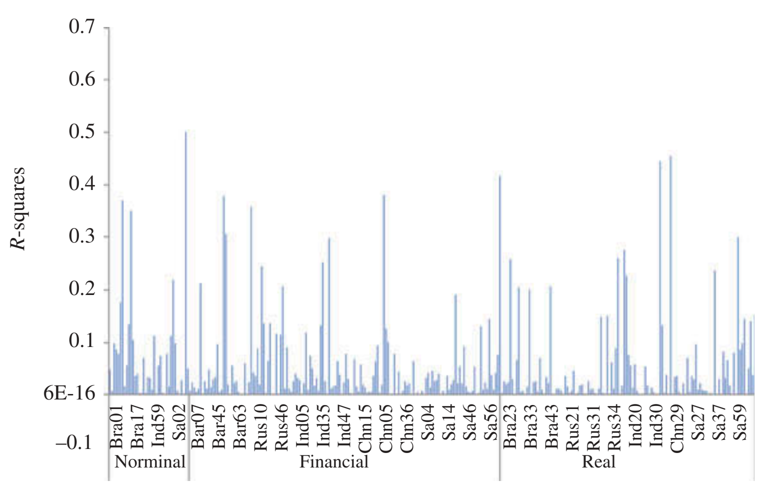

Fig. 9. Correlation between Factor 3 and each of the variables

manufacturing, imports and portfolio investments, SA's services, exports and imports, Russia's exports, services and current transfers as well as in both India's and China's exports. The largest values are observed on India's imports, Russia's exports and services as well as SA's services, exports and imports. Thus, this factor can be broadly interpreted as an index of production, exports and imports for the BRICS economies.

Figure 8 presents the second factor which is a combination of real and financial variables with correlations of around 60%. Specifically, this factor explains the variation of China's exchange rates, Brazil's imports, Russia's production of gas and SA's consumption of fixed capital.

Factor three in Fig. 9 can be broadly interpreted as a US factor as it explains most of the variation in the US nominal (GDP deflator) and financial variables (short-term interest rates). For the BRICS countries, this factor predicts changes in SA's and India's real variables, China's and Brazil's financial variables as well as Russia's nominal variables. However, the magnitude of R-squares of this factor on the BRICS variables is less than 50%. In general, the first two factors are clearly related to the BRICS variables and can be interpreted as BRICS factors, while factor three is a US factor.

In summary, synchronization of cycles is caused by two main channels. The first one is bilateral trade that empirical studies, such as those by Frankel and Rose (1998), Clark and van Wincoop (2001), Baxter and Koupiratsas (2005) and Imbs (2006), indicate that countries with higher levels of bilateral trade also have higher business cycle synchronization. The second one is the financial channel which also exploited in the literature. For instance, Imbs (2006) finds that more financially integrated countries are more synchronous and Kose *et al.* (2003) provide evidence that financially open developing economies have synchronized cycles with the group of 7 most advanced countries (G7). Based on our findings, it seems that trade linkages is the one causing synchronization of cycles across SA and the other BRICS countries. These results confirm the observations in paper of Çakır and Kabundi (2013), which show that China, India, Brazil and Russia ranked as SA's the first, the eighth, the seventeenth, and the fortieth largest trade partners in 2009, respectively.

V. Conclusions

Since SA's re-entry' into the global economy, which coincides with the new political dispensation, there is an increasing interest among the policymakers and academics to examining the extent to which the country is integrated with the rest of the world. This article presents a descriptive analysis of relationships of business cycles between SA and the BRIC countries for the period 1995Q2 to 2009Q4. The article focuses on co-movement and lead–lag relationship of these cycles across countries and over time, pointing to channels underlying these co-movements. Main findings can be summarized as follows. As a result of analysis, we find significant but different degrees of co-movement between SA and the BRIC countries. SA's commonalities are high with Brazil, China and India but low with Russia. In addition, Brazil, China and Russia lead SA only in the long run. It implies that shocks from these countries are more likely to be transmitted to SA. The pattern of dynamic correlation is remarkably different for India. Only India moves contemporaneously with SA over the long run, the cyclical and the short-run periods. Furthermore, trade linkages are the main factors underlying co-movement between SA and BRICs. Moreover, the US constitutes an additional source of co-movement of business cycles of SA and those of the other BRICS countries. Although positive correlation largely exists between SA and the BRIC countries, there are differences across countries and over time. Nearly all BRIC countries show positive and significant relationship over the business cycle, and their relationships are weak and insignificant, except for India, in the long- and short-run periods on the other.

Policymakers should understand the nature of linkages between SA and its BRIC partners. Given that South African integration with the BRIC increases over time, it can benefit from positive shocks from BRIC, but it is at the same vulnerable to negative shocks. A strong reliance on the BRIC as a bloc might be a risky strategy. Instead the country should aim at diversifying to a larger extent the pool of its trading partners.

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