Inter-linkages between BRICS and U.S.[1]

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ABSTRACT

We examine the inter-linkages of the BRICS nations with the U.S. The data consists of growth rates of the Coincident Index for the U.S. and BRICS (viz. Brazil, Russia, India, China and South Africa) nations from January 1995 till July 2017 which are collected from the Economic Cycle Research Institute, New York. To begin with, we estimate the time-varying conditional correlations among the nations using the Dynamic Conditional Correlation model (Engle, 2002). Subsequently, we estimate a dynamic panel data model (Arellano-Bond) to discern whether recent business cycle recessions in the U.S. (which are defined using dates given by ECRI) have been synonymous with a significant reduction in the correlation with BRICS. Our results indicate that there is a significant spike in correlations between BRICS and U.S. during the Great Recession of 2008-09. However, we do not find any evidence of a significant change in the correlations during the U.S. recession of 2001-02. Thereafter, we analyse correlations of BRICS with the U.S. at the individual country level. To do that, we first utilize the Bai and Perron (2003) technique to identify endogenous structural breaks in the correlations and identify the sub-periods for our analysis. We then study the correlation breakdowns based on the sub-periods defined above. Our results indicate that there is no significant evidence in favour of 'decoupling' of BRICS from the U.S. Finally, we conclude that there is some evidence in favour of the 'recoupling' of BRICS economies with the U.S. during the Great Recession.

Keywords: Decoupling Hypothesis; BRICS; US; DCC-GARCH; Bai and Perron; Arellano-Bond.

JEL Classification: C24; F44; G01.

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1. INTRODUCTION

Since the 1980s, there has been a dramatic rise in trade and financial transactions across nations. Post the liberalization, privatization and globalization of most EMEs during the 1990s, there has a growing interest in their inter-linkages with the Advanced economies. This has been synonymous with inter-dependencies both in trade and finance in economies around the world. The period since has also been marked by several widespread crises such as the Asian Crisis, the Russian Financial Crisis, the Argentinian Economic Crisis, Dot-com Bubble Burst, Turkish Economic Crisis, Uruguay Banking Crisis, Global Financial Crisis and Eurozone Sovereign Debt Crisis among others. The evolving dynamics among EMEs which are growing at a faster pace and the Advanced economies witnessing a dampening growth begs the question, is the growth in EMEs decoupled with that in the developed countries? If not, then what is the nature of the inter-linkages across the EMEs and the Advanced nations.

In fact, a 'decoupling' hypothesis was proposed in the context of the Chinese and Indian economies' stellar performance depicted by their high growth rates, despite several global shocks during the early 2000s. The economies seem to have been insulated from the growth slowdowns that occurred in the developed countries during the 2003-07 time period (which is also known as the Great Moderation). In addition, such a hypothesis could also be applied in part to other EMEs like Brazil, Russia and South Africa. The hypothesis asserts that growth in the EMEs is independent of or "decoupled" with that in the developed economies in view of the robust domestic demand conditions which enable them to sustain the growth momentum. With the aim of safeguarding themselves from global shocks, EMEs undertook various policy measures such as building reserve assets, monitoring net government debt and reducing foreign currency exposure. It was claimed that business cycle dynamics in EMEs are not closely linked to developed country business cycles. However, a debate on the 'decoupling' hypothesis was ignited in the aftermath of the U.S. Financial crisis of 2008-09 which triggered the Great Recession in several economies of the world.

The paper by Gore (2010) reasons that the Great Recession marks the end of the global development cycle that started in the 1950s. He argues that contradictions in the global development trajectory are at the heart of the recession which was precipitated by misdirected incentives, promotion of exotic and complex instruments and slackness in the regulation of the financial sector. Using cross-country regressions, the study by Giannone *et al.* (2011) finds that higher the adoption of policies aimed at liberalization of credit markets in an economy, lower the country's resilience to the recent recession during 2008-09. The study by Ball (2014)

attempts to quantify the long-term impact of the global recession on the output of 23 economies using the potential output pre-and post-crisis and concludes that the average size-weighted loss is 8.4%. Reinhart and Rogoff (2014) have shown that despite the recovery following the Great Recession, only two of twelve countries in their sample could attain pre-crisis levels of per capita Gross Domestic Product (GDP). In fact in some of the cases, the 2007-09 crisis was much more severe than the Great Depression of the 1930s.

The business cycle literature suggests that strong economic inter-linkages in the form of trade and financial links should lead to convergence of business cycle fluctuations across economies. It is notable that even in the absence of significant trade dependencies, contagion and spillovers across international financial markets would play a crucial role in explaining, for example, the widespread Global Financial Crisis of 2008-09. Devereux and Yetman (2010) develop a model to study the transmission of shocks internationally which abstracts from the importance of trade linkages and focuses instead on the role played by financial markets. It assumes that there are shared portfolio holdings among leverage-constrained investors. Further, in a scenario with binding leverage constraints along with portfolio diversification by these investors, there would be transmission of shocks *via* the financial channel that results in a positive co-movement of business cycles across countries. A similar channel of transmission of crises is also discussed in Davis (2014). Therefore, increasing integration of global financial markets is also likely to result in inter-linkages across growth of EME and developed economies.

We find that the existing evidence on the synchronization of EME and Advanced economies is mixed. Papers such as Fidrmuc and Korhonen (2010), Genc *et al.* (2010), Jayaram *et al.* (2009), Kose *et al.* (2012), Leduc and Spiegel (2013), Nachane and Dubey (2013), and Yeyati and Williams (2012) find evidence of decoupling while others such as Antonakakis (2012), Antonakakis and Badinger (2012), He and Liao (2012), Kim *et al.* (2011), and Wälti (2012) conclude that there has been recoupling. Tsionas *et al.* (2016) find that the EU 17 countries are vulnerable to the transmission of shocks from BRICs. The paper by Samake and Yang (2014) finds that there are significant spillovers from BRICS to low-income countries. These papers indicate the growing importance of the BRICS economies as a group. The paper by Dua and Tuteja (2016) shows that the Chinese and Indian stock markets witnessed contagion during the U.S. financial crisis of 2008-09. Therefore, these countries may have been susceptible to closer inter-linkages with the U.S. post the crisis.

Brazil, Russia, India, China and South Africa (BRICS) nations account for 25% of the world's land, 40% of the world's labour force and together account for a GDP of close to 18 trillion dollars. According to World Economic Outlook (2016), they are projected to grow from 28% to 33% of global GDP (in PPP terms) by 2020. This is notwithstanding the growing influence of these nations, both in terms of soft power and hard power, in the world. From Panel A of Table 1, we can infer that the Chinese and Indian economies have been growing at a fast pace of close to 10% in the time period prior to the Eurozone crisis. The Intra-BRICS trade matrix (Panel B) suggests that the economies have most significant trade links with China. Panel C indicates that they have been recipients of significant Foreign Direct Investment flows. It is notable that between 2000 and 2015, Brazil's Bovespa Index rose by 210%, Russia's RTS Index by 336%, India's Nifty Index by 572%, China's Shanghai Composite Index by 71% and South Africa's Johannesburg FTSE Stock Index by 267% respectively. China alone accounts for 14 per cent of world exports according to UNCTAD. The earlier literature while focusing on the issue contemplates the possibility of slowdowns being triggered in emerging economies due to spillovers from developed country cycles. It precludes the scenario that a slowdown in the Chinese and other emerging nations could lead to a slowdown world over. Despite the unfavourable global environment, the economies are expected to grow at about 5 per cent per annum. Therefore, it is interesting to analyse the changing relationship among these countries and the U.S.

Against this backdrop, we attempt to investigate the inter-linkages between the economies of Brazil, Russia, India, China and South Africa (also known as BRICS economies) and the U.S. Our specific objectives are to evaluate the impact of U.S. recessions on the synchronization with the BRICS economies, to appraise the impact of the global financial crisis on the inter-linkages across BRICS and U.S., and to investigate the 'decoupling' vs. 'recoupling' of BRICS and U.S. nations.

The empirical strategy employed in the paper is as follows. We first estimate the dynamic conditional correlation across the BRIC and U.S. economies using a DCC-GARCH model (Engle, 2002). Subsequently, we utilize the recession dates for the U.S. economy given by ECRI, New York and utilize a dynamic panel data model (Arellano and Bond, 1991) to discern the impact of U.S. recessions on the conditional correlations across BRICS and U.S. Since, we do not know the exact location of the breaks in the conditional correlations, we use the Bai and Perron (2003) algorithm to detect endogenous multiple structural breaks in the conditional correlations across BRICS and U.S. We then define regimes or sub-periods for the

analysis. We study the behaviour of conditional correlations across the regimes as well as test for changes in causality in order to test for/infer periods of decoupling as well as recoupling. The data consists of smoothed growth rates of the Coincident Index for BRICS and U.S. and has been sourced from the Economic Cycle Research Institute, New York.

An overview of the existing literature suggests that there is scarce evidence on the issue. The present study, therefore, contributes to the existing literature on inter-linkages across EME and developed economies. To the best of our knowledge, there is no existing study which investigates the issue from the perspective of the BRICS nations and we attempt to fill this gap.

The rest of the paper is organized as follows: Section 2 succinctly reviews the previous empirical literature on synchronization of EME and developed economies. The methodology is are presented in the Section 3. The data and empirical strategy utilized in the paper have been expounded in Section 4. The empirical results are reported and discussed in Section 5. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

There is a huge literature on the synchronization of business cycles. Further, several studies have focused on the decoupling/ recoupling of EME business cycles with those of developed nations. We succinctly review some of the recent literature on the synchronization of cycles across developing and developed countries especially in the context of the recent crises in U.S. and Eurozone.

The paper by Antonakakis (2012) studies the pattern of synchronization among the G7 countries during the U.S. recessions since 1870s. The study concludes that there was a exceptionally high level of synchronization during the recession of 2007-09. A study by Antonakakis and Badinger (2012) focuses on the international business cycle interdependence for a set of 27 countries since 1870s. They find that the Advanced countries are net transmitters of cycle shocks and the Great Recession of 2008-09 is marked with exceptionally large business cycle spillovers. The paper by Banerji and Dua (2010) investigates the synchronization of recessions in major developed and emerging economies during the global recession (post the U.S. recession of 2007-09) and conclude that unlike other economies the two Emerging Market Economies (EMEs) *viz.* China and India did not undergo a recession but only a milder slowdown. Fidrmuc and Korhonen (2010) find evidence in favour of the decoupling hypothesis when they study synchronization across Chinese, Indian and OECD

business cycles. However, they too concede that the global financial crisis has had a significant impact on the nature of linkages across the economies. Fidrmuc *et al.* (2014) study the business cycle co-movement between China and G7 economies and find that the synchronization is different at business cycle frequency. Genc *et al.* (2010) show that the GCC countries have decoupled from the U.S. He and Liao (2012) observe that the Asian economies have become more integrated due to stronger linkages within the region than with the G7 countries overtime. Jayaram *et al.* (2009) discuss the decoupling of the Indian economy with the industrialized countries and conclude that the Indian economy is closely linked with the developed countries. Kose *et al.* (2012) investigate the global business cycle interdependence among EME and industrial countries and find that while there is convergence within the group, there is decoupling across the two groups. Leduc and Spiegel (2013) find a decline in the co-dependence of Asian and U.S. economies during the recovery from the global financial crisis. Nachane and Dubey (2013) discover that there has been both trend and cyclical decoupling of the EMEs from the developed world. Pascha and Yoon (2011) examine the decoupling of East Asia and find evidence of decoupling during upturns and recoupling during downturns. Kim *et al.* (2011) investigate the decoupling hypothesis for emerging Asian nations and find that there has been increasing integration overtime. Wälti (2012) concludes that the interdependence among EME and Advanced countries has become stronger overtime and that there has been no decoupling. Yeyati and Williams (2012) show that there has been decoupling of EME business cycles with the Advanced economies along with a financial recoupling across the two groups.

Some of the studies that investigate the impact of the global financial crisis of 2008-09 include Gore (2010), Giannone *et al.* (2011), Ball (2014) and Reinhart and Rogoff (2014). The paper by Gore (2010) reasons that the Great Recession marks the end of the global development cycle that started in the 1950s. He argues that contradictions in the global development trajectory are at the heart of the recession which was precipitated by misdirected incentives, promotion of exotic and complex instruments and slackness in the regulation of the financial sector. Using cross-country regressions, the study by Giannone *et al.* (2011) finds that higher the adoption of policies aimed at liberalization of credit markets in an economy, lower the country's resilience to the recent recession during 2008-09. The study by Ball (2014) attempts to quantify the long-term impact of the global recession on the output of 23 economies using the potential output pre-and post-crisis and concludes that the average size-weighted loss is 8.4%. Reinhart and Rogoff (2014) have shown that despite the recovery following the Great Recession, only two of twelve countries in their sample could attain pre-crisis levels of per

capita Gross Domestic Product (GDP). In fact in some of the cases, the 2007-09 crisis was much more severe than the Great Depression of the 1930s.

An important paper which examines the decoupling vs. recoupling of EME and developed country financial markets is Dooley and Hutchison (2009). They evaluate the popular notion of decoupling vs. recoupling of EMEs in the face of the U.S. subprime crisis. They evaluate the hypothesis by investigating the issue of financial market linkages in the context of CDS spreads and equity markets. They find that the EME markets were decoupled with the U.S. economy till mid-2008. However, after the news of the Lehman collapse in fall of 2008, the EME markets reacted sharply to the deteriorating state of affairs in the U.S. economy signalling a recoupling of the markets.

Therefore, we can conclude that the existing evidence on the synchronization of EME and Advanced economies is mixed. Papers such as Fidrmuc and Korhonen (2010), Genc *et al.* (2010), Jayaram *et al.* (2009), Kose *et al.* (2012), Leduc and Spiegel (2013), Nachane and Dubey (2013), and Yeyati and Williams (2012) find evidence of decoupling while others such as Antonakakis (2012), Antonakakis and Badinger (2012), He and Liao (2012), Kim *et al.* (2011), and Wälti (2012) conclude that there has been recoupling. There is no existing study which investigates the issue from the perspective of the BRICS nations and we attempt to fill this gap.

3. METHODOLOGY

This section explains the methods that have been utilized in the paper to derive the results. In this regard, we follow a step by step approach and begin with a DCC-GARCH model, followed by a dynamic panel data model, then we use the Bai and Perron algorithm and finally, the Ordinary Least Squares (with robust standard errors) methodology.

3.1 Dynamic Conditional Correlation Model (Engle, 2002)

We utilize the multivariate DCC-GARCH model proposed by Engle (2002) to estimate the dynamic conditional correlations across the economies. The model accounts for heteroscedasticity and guarantees parsimony (Chiang *et al.*, 2007). We include an AR(1) term to correct for possible autocorrelation in the model. Upon estimation of the conditional correlation coefficient series, we utilize the same to analyse the regime shifts resulting from the U.S. recessions as well as test for decoupling vs. recoupling. The estimated equation for the DCC-GARCH (1,1) model is

$$y_t = \gamma_0 + \gamma_1 y_{t-1} + \varepsilon_t \quad (1)$$

where $y_t = (r_{1t}, r_{2t})'$ are the growth rates in the economies; $\mathcal{F}_{t-1} = \{\varepsilon_{t-1}, \varepsilon_{t-2}, \dots\}$ is the set of past information on the error $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$, $\varepsilon_t | \mathcal{F}_{t-1} \sim N(0, \Sigma_{t|t-1})$ where N denotes the Gaussian distribution and $\Sigma_{t|t-1}$ is the conditional covariance matrix. The multivariate DCC-GARCH model is estimated for the pairs of BRICS and U.S. economies.

The model estimates the conditional covariance matrix in two steps. In the first step, a univariate GARCH model is specified for the conditional variances. Subsequently, given the conditional variances obtained in the first step, the conditional correlation matrix is computed by imposing the assumption that it would be positive definite at all points of time. In Bollerslev (1990)'s Constant Conditional Correlation (CCC) formulation, the conditional correlation matrix is assumed to be constant and the conditional covariances are constructed by taking the product of the conditional correlations and the respective conditional standard deviations.

$$\Sigma_{t|t-1} = D_t R_t D_t = (\rho_{ij} \sqrt{\sigma_{ii,t} \sigma_{jj,t}}) \quad (2)$$

where $D_t = diag(\sigma_{1t|t-1}, \dots, \sigma_{Nt|t-1})$ is the $N \times N$ diagonal matrix containing time-dependent standard deviations on the diagonal, $\sigma_{ii,t}$ are the conditional variances each of which is estimated as a univariate GARCH model, $R = \rho_{ij}$ is an $N \times N$ constant, symmetric and positive definite matrix of the conditional correlation coefficients ρ_{ij} with $\rho_{ii} = 1, \forall i$.

However, in the case of financial time series, the assumption of constant conditional correlation seems implausible. The Dynamic Conditional Correlation (DCC) model proposed allows the matrix R to be time-dependent. The DCC model (Engle, 2002) is defined as follows

$$\Sigma_{t|t-1} = D_t R_t D_t \quad (3)$$

with D_t defined as above and R_t is now a time-varying matrix defined as

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1} \quad (4)$$

R_t is the $N \times N$ conditional correlation matrix with the diagonal terms as one and the off-diagonal terms less than one in absolute value, and $Q_t = (q_{ij,t})$ is the $N \times N$ symmetric positive definite matrix of v_t (v_t is the standardized innovation vector with elements $v_{it} = \varepsilon_{it}/\sigma_{it}$) such that

$$Q_t = (1 - \alpha - \beta)S + \alpha(v_{t-1} v_{t-1}') + \beta Q_{t-1} \quad (5)$$

where $S = E(v_t v_t')$ is the $N \times N$ unconditional correlation matrix of the standardized residuals v_t, the scalar parameters α and β are such that $0 \leq \alpha, \beta \leq 1$ and $\alpha + \beta \leq 1$. These restrictions guarantee that the estimated matrix R_t is positive definite. Therefore, the $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}$ with $i, j = 1,2$, $i \neq j$ and is the correlation estimator which is positive definite.

The DCC model[3] can be estimated consistently using a two-step procedure to maximize the log-likelihood function. Let θ_1 denote the parameters in D_t and θ_2 be the parameters in R_t then the log-likelihood function LL_t can be written as-

$$LL_t(\theta_1, \theta_2) = \left[-\frac{1}{2}\sum_{t=1}^{T}(Nlog(2\pi) + log|D_t|^2 + v_t' D_t^{-2} v_t)\right] + \left[-\frac{1}{2}\sum_{t=1}^{T}(\log|R_t| + v_t' R_t^{-1} v_t - v_t' v_t)\right] \quad (6)$$

So, the log likelihood function can be written as a sum of the mean and volatility component, and the correlation component (Engle, 2002). In the first part of the above equation, volatility is calculated by adding up the individual GARCH likelihoods and is maximized in the first stage of estimation over the parameters θ_1 in D_t. Once the parameters in the first stage are obtained, in the second stage maximization of the correlation part of the likelihood function is undertaken to get the estimated correlation coefficients.

3.2 Dynamic Panel Data Model (Arellano-Bond)

We test that the international business cycle correlation is higher and indicates synchronization or recoupling during the U.S. recessions using a dynamic panel data model which is similar to the specification given in Antonakakis (2012). The dynamic panel regression has the following form

$$\hat{\rho}_{ij,k,t} = \pi_1 + \pi_2 Trend + \pi_3 rec_t + \epsilon_{ij,k,t} \quad (7)$$

where k denotes the pair of economies, $Trend$ is the linear trend and rec_t is the dummy denoting U.S. recessions[4] which is equal to 1 if the U.S. economy is in a recession in month t and zero otherwise. The model is estimated using the Arellano-Bond (1991) GMM estimation technique.

3.3 Bai and Perron Method

The Bai and Perron (2003) procedure detects endogenous multiple structural breaks in the dynamic conditional correlations among BRIC and U.S. derived from the DCC-GARCH

[3] The paper by Tse and Tsui (2002) examines performance of varying-correlation multivariate GARCH models (similar to DCC-GARCH according to Bauwens *et al.*, 2006) in small-samples and find the bias and mean squared error to be small in samples of 500 observations or more.

[4] There are two recessions during this period which are from March, 2001 to November, 2001 and from December, 2007 to June, 2009 respectively.

model described in Section 3.1. The break dates are unknown and are, therefore, selected endogenously. We consider a minimum span of 40 months between two breaks and utilize a BIC criterion to select the structural breaks in the data. We include a constant as the regressor in the equation for the time-varying conditional correlations[5]. The Bai and Perron model is as follows

$$\rho_{ij,t} = \omega_{1l} + u_t; t = T_{l-1} + 1, \ \dots, T_l, for\ l = 1, \dots, 5 \quad (8)$$

The maximum number of breaks is 5. The LWZ statistic and sequential F tests reject the null of no breaks.

3.4 Correlation Breakdowns

In the next step, we consider the approach for inferring the direction of coupling across the economies. We test for a significant increase or decrease in conditional correlation across the economies during the various phases defined using Bai and Perron (2003) procedure above.

$$\hat{\rho}_{ij,t} = \delta_0 + \delta_1 D_{1k} + \delta_2 D_{2k} + \delta_3 D_{3k} + \delta_4 D_{4k} + \delta_5 D_{5k} + \vartheta_t \quad (9)$$

where $\hat{\rho}_{ij,t}$ is the pairwise TVCC coefficient between economy *i* and economy *j*; *i* and *j* denote the BRICS and US respectively, and δ_0 is the intercept term. A positive and significant coefficient $\delta_i, i = 1, \dots, 5$ indicates a significant rise in the conditional correlation during the sub-period vis-à-vis the stable period and is termed 'recoupling'. A negative and significant coefficient would imply a divergence (or fall) in the dynamic conditional correlation among the economies during the sub-period in comparison to the normal time period and is dubbed 'decoupling'. An insignificant coefficient during the crises coupled with a significant coefficient in tranquil times is indicative of ''inter-linkages' or synchronization among the economies. The estimation framework, therefore, allows us to test for the existence of decoupling (and recoupling) or inter-linkages across economies where in a significant rise (fall) in correlation is taken to be signal of the heightened (diminished) co-movement across the economies during the period under study. We utilize the ordinary least squares (OLS) with robust standard errors for estimation of the model.

[5] This is because we want to focus on the changes in the level of the conditional correlations across the growth rates.

4. EMPIRICAL STRATEGY AND DATA

This section describes the data and empirical strategy used in the study.

4.1 Data

The Economic Cycle Research Institute (ECRI), New York provides data on the coincident index[6] of economic activity and the corresponding growth rates for 22 major economies of the world. In order to examine the inter-linkages across the EME and advanced nations, we collect monthly data on the growth rate of the coincident index of economic activity from ECRI. We analyse the data for the countries of Brazil, Russia, India, China, South Africa and U.S. over the period January, 1995 to July, 2017. We also utilize recession dates for the U.S. which are sourced from the website of ECRI.

Table 2 provides the summary statistics for the growth rates of the Coincident Index for BRICS as well as U.S. According to Panel A, the average growth rate of economic activity is highest for China followed by India. Brazil is the slowest growing economy amongst the BRICS. Russia has the most volatile growth trajectory, followed closely by India. Panel B presents the unconditional correlations for the economies. Russia and South Africa are most closely related to the rest of the BRICS. U.S. is closest linked to the South African economy.

According to latest data collected from the National Bureau of Economic Research (NBER, 2012) and the Economic Cycle Research Institute (ECRI, 2016a), for the period under study two recessions in the U.S. ensued from March, 2001 to November, 2001 and from December, 2007 to June, 2009. These are utilized to define the appropriate dummy variables for the U.S. recessions. It is notable that this includes the sub-period of the global financial crisis which occurred from September, 2008 till June, 2009 (as per the timeline provided by the Federal Reserve Bank of St. Louis on its website).

The results from the unit root tests are presented in Table 3. The null hypothesis for DF-GLS is non-stationarity and it is rejected at 1% for all the cases. On the other hand, the null hypothesis for KPSS is stationarity and we again find all the growth rates to be stationary.

[6] The coincident index comprises indicators that measure current economic performance such as measures of output, income, employment and sales, which help to date peaks and troughs of business cycles. It is a broad measure of the level of economic activity at the aggregate level and is more suitable for analyses since it depicts that the business cycle is a consensus of cycles across sectors of the economy which have a tendency to undergo similar fluctuations.

From Figure 1 Panel A, we find that the GDP growth rate in the U.S. is negative during the recessions of 2001 as well as 2008-09. The growth process seems to be stabilizing thereafter albeit at a low level. Panel B shows the growth rates for the Brazilian economy and we see that the economy has been contracting post 2014-15. In Panel C, we show the growth rates for the Russian economy which has been showing signs of recovery post the negative growth rates during 2014-15. On the other hand, the Indian economy (Panel D) has been growing steadily although slowly since 2013 (when it had suffered as a consequence of the Eurozone crisis). Interestingly, the Chinese economy (Panel E) has posted high growth rates during the period of study but seems to have slowed down considerably in the recent period. Finally, in Panel F South Africa has lost the growth momentum post the global financial crisis of 2008-09.

4.2 Empirical Strategy

The empirical estimation consists of the following steps. First, we test for the stationarity of the stock market returns using the DF-GLS (Dickey-Fuller Generalized Least Squares, Elliott *et al.*, 1996) and the KPSS (Kwiatkowski *et al.*, 1992) tests and conclude that all the series are stationary. The results are given in Tables 2 and 3. Second, we estimate the time-varying conditional correlation between U.S. and BRICS economies using the DCC-GARCH model proposed by Engle (2002). Thereafter, we utilize the dynamic panel data model to estimate the impact of U.S. recessions on the correlations among the BRICS and U.S. growth rates. Next, we use the Bai and Perron (2003) test[7] to detect structural breaks in the conditional correlation coefficients across the economies and define regimes for each of the pairs. In the next step, we test for a significant increase or decrease in conditional correlation across the pairs during the various phases defined using Bai and Perron (2003) procedure above. We utilize the ordinary least squares (OLS) with robust standard errors for estimation of the model.

5. RESULTS

This section discusses the results of the empirical estimation. To begin with, we obtain the time varying conditional correlation coefficients of the BRICS with the U.S. This is followed by the results from the panel data model which are estimated using the Arellano-Bond GMM method. We then go on to discern the sub-periods for each of the conditional correlation pairs of BRICS-U.S. by applying the Bai and Perron algorithm. Finally, we test the hypotheses

[7] Bai and Perron (2003) methodology endogenously detects structural breaks in a time series.

regarding the nature of inter-dependence between BRICS and U.S. using the sub-periods defined on the basis of the above step.

5.1 DCC-GARCH Results

In order to estimate the time-varying conditional correlation for the BRICS and U.S. economies, we employ the DCC-GARCH model. The results of the model are given in Table 4. We find that there are significant multivariate ARCH effects which cannot be captured by the constant conditional correlation GARCH model. The AR(1) terms are significant and the DCC parameters indicate large persistence effects.

Figure 2 Panels A-E depict the conditional correlations obtained by the model above. From Panel A for Brazil-U.S., we see a huge spike in the correlation coefficients post the Lehman collapse in September 2008. The correlations die down overtime and seem to return to the usual levels post 2011. The conditional correlations for Russia-U.S. also show a similar pattern and spike towards the end of 2008. They come down to the pre-crisis average level after 2012. In Panel C for India-U.S., we see a huge spike around the beginning of 2009 but the impact of crisis shocks dies down fairly quickly by the end of year. The conditional correlations for China-U.S. varying a lot over the period of study. It is notable that they do not rise immediately post the crisis and have remained fairly volatile ever since. Finally, the pair for South Africa-U.S. also witnesses a sharp rise in correlations in the aftermath of the crisis and they return to the mean level by 2012. The graphical analysis seems to suggest that the impact of the U.S. financial crisis was across the board. However, China and India have reacted differently from Brazil, Russia and South Africa in the face of the crisis.

5.2 Panel Data Estimation

Table 5 presents the estimation results for the panel data model. On one hand, we find that the impact of the U.S. recession of 2001 is insignificant. While on the other hand, the U.S. recession of 2008-09 is significant. Its impact is positive and significant at 10% level. This indicates that the conditional correlations among BRICS-U.S. growth rates increased during the Great Recession. However, in view of the weak evidence we now attempt to test for decoupling vs. recoupling by studying the same at a more micro or individual country level.

5.3 Bai and Perron Algorithm

We now identify the sub-periods for each of the conditional correlation pairs of BRICS-U.S. for the analysis at the country-level. To do that, we do not impose any a priori knowledge about the time periods of decoupling or recoupling. We apply the Bai and Perron (2003) algorithm which provides us the endogenous break dates in the conditional correlations obtained from the DCC-GARCH model. The results are given in Table 6. We obtain 4 breaks for Brazil, Russia, China and South Africa, and one break for India. The corresponding sub-periods for analysis have been defined in the last column of the Table as well. It is interesting to note that there is a break in the conditional correlations for each of the countries around 2007-08.

5.4 Correlation Breakdowns

The sub-periods defined above are utilized to study the conditional correlations overtime. The dummies corresponding to the sub-periods are created and used for the analysis.

It is notable that the average conditional correlations for the BRICS with the U.S. are positive and significant barring the Chinese economy. Therefore, we conclude that the growth rates of the Chinese economy are not closed linked with that in the U.S. economy during the stable period prior to 2007. The average conditional correlations during the stable period are highest for the growth rates of South Africa and U.S. followed by Russia-U.S. In the recent period captured by the last dummy variable, both the economies have witnessed a significant rise in the correlation with the U.S. economy.

We find that Russia and South Africa do witness a fall in conditional correlations with the U.S. around early 2000 but similar evidence for the rest of the countries is not found. Further, the quantitative analysis confirms the results of the graphical analysis as the impact of the period corresponding to the Great Recession is significant at 1% level for Brazil, Russia and South Africa but not for China and India. These results are not surprising and similar results have been found by Dua and Banerji (2010) and Dua and Tuteja (2017) as well.

We conduct robustness checks for our work by defining the dependent variables in such a way that they are no longer restricted to vary between -1 and +1. This strategy has been borrowed from the paper by Antonakakis (2012). We find that our results remain the same despite this redefinition.

6. CONCLUSIONS

We study the pattern of synchronization among the BRICS nations and the U.S. economy. Specifically, we intend to examine the trends in co-movement of BRICS and U.S. growth rates. The data for the study consists of smoothed growth rates of the Coincident Index for BRICS and U.S. sourced from ECRI, New York. To do that we estimate a DCC-GARCH model which provides us with the time-varying conditional correlation coefficients across the economies.

We subsequently evaluate the impact of U.S. recessions on the synchronization between BRICS and U.S. economies. We obtain the recession dates for the U.S. from ECRI (which are corroborated with NBER). There have been two recessions in the U.S. during the period of study. These are the dot-com bubble burst of 2001 and the global recession in 2008-09. Therefore, we test for the impact of these recessions on the synchronization of BRICS and U.S. cycles by using a dynamic panel data model which is estimated using the Arellano-Bond procedure. Our results indicate that the recession of 2001 did not lead to a significant change in the conditional correlations between BRICS and U.S. economies.

We then study the conditional correlations by country pair and seek to test for the decoupling vs. recoupling of BRICS and U.S. To undertake this analysis, we need to know the exact locations of the break dates for conditional correlations across the economies. However, since the regimes are not known a priori, we use the Bai and Perron (2003) algorithm to detect multiple endogenous structural breaks in the conditional correlations across BRICS and U.S.

Upon obtaining the break dates, we use these to define the regimes for the testing exercise performed in the next step. We employ OLS with robust standard errors to infer whether there has been any decoupling across the economies. We do not find any significant evidence of a change in correlations post the Asian crisis of 1998 till the global financial crisis of 2008-09. However, there is significant evidence which suggests that the economies were indeed ‘recoupled’ in the aftermath of the Global Financial crisis of 2008-09.

Therefore, we do not find any evidence in favour of the ‘decoupling’ hypothesis. In view of the results on synchronization of BRICS growth rate cycles with those in the U.S., we may generalize to say that the EMEs continue to be vulnerable to shocks emanating from the developed world. While studies such as Karolyi (2004) emphasize the role of appropriate national level policies as a response to common shocks especially regulation of the domestic financial sector, supervision by the central bank and improvement of risk management

practices[8]. However, the 'recoupling' of EMEs with the U.S. seems to suggest that policies at the domestic level may not be adequate to contain the risks to the growth process in the emerging and developing countries. One possibility is the recourse to policy coordination and the setting up of the BRICS bank along with policy dialogues to encourage intra-BRICS trade may be a step in the right direction.

[8] In the context of the market for credit risk, the paper by Breitenfeller and Wagner (2010) advises that regulation is a partial solution which needs to be supplemented by better risk management.

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TABLES

Table 1: BRICS Economies

Panel A: Profile of BRICS (2005-2011)

	Rog of GDP p.a.	Infl Rate p.a.	Public Debt (% of GDP)	Fiscal Surplus/ Deficit (% of GDP)	Current Account Surplus/ Deficit (bn USD)	Forex Reserves (bn USD)
Brazil	4	5.3	64.9	-2.6	-52.5	350.4
Russia	4.2	10.3	12	1.6	98.8	453.9
India	8.1	8.1	67	-9	-51.8	271.3
China	11	3.1	25.8	-1.2	201.7	3202.8
South Africa	3.5	6.1	38.8	-4.6	-13.7	42.6

Panel B: Intra-BRICS Trade Matrix

	Brazil	Russia	India	China	South Africa	Total
Brazil	-	7%	10%	80%	3%	100%
Russia	7%	-	8%	85%	0%	100%
India	9%	6%	-	72%	13%	100%
China	30%	28%	26%	-	16%	100%
South Africa	7%	1%	20%	72%	-	100%

Panel C: BRICS FDI Inflows, Outflows (in % to World) and Net to World (USD) in 2010

Country	Inward	Outward	Net FDI
Brazil	3.9	0.9	36.9
Russia	8.5	5.1	37.7
India	2	1.1	10
China	3.3	3.9	-10.5
South Africa	0.1	0	1.1
BRICS compared to World	17.8	11.1	75.3

Source: World Development Indicators (Various Issues)

Table 2: Descriptive Statistics

Panel A: Summary Statistics

	y^{BR}	y^{RU}	y^{IN}	y^{CH}	y^{SA}	y^{US}
Mean	1.97	2.85	5.83	10.08	2.30	2.14
Std. Dev	5.01	5.74	5.57	3.64	2.75	2.71
Skewness	-0.32	-0.45	0.11	0.28	-0.73	-2.16
Kurtosis	2.78	2.96	3.06	2.20	5.26	8.79
Maximum	14.37	16.66	25.05	19.04	10.00	5.73
Minimum	-11.13	-14.55	-9.64	2.94	-8.04	-9.74
ARCH LM (5) Test	168.8***	106.3***	70.7***	56.1***	37.9***	253.6***

Panel B: Unconditional Correlations

	y^{BR}	y^{RU}	y^{IN}	y^{CH}	y^{SA}	y^{US}
y^{BR}	1.00					
y^{RU}	0.50	1.00				
y^{IN}	0.36	0.50	1.00			
y^{CH}	0.34	0.37	0.20	1.00		
y^{SA}	0.51	0.59	0.53	0.28	1.00	
y^{US}	0.14	0.24	0.18	-0.19	0.49	1.00

Note: y^{BR}, y^{RU}, y^{IN}, y^{CH}, y^{SA} and y^{US} denote the growth rates for Brazil, Russia, India, China, South Africa and U.S. respectively.

Table 3: Unit Root Tests

Panel A: DF-GLS Test (Constant and Trend)
H_0: Non stationarity

Variable	DF-GLS Statistic	DF-GLS: Inference
y^{BR}	-61.23462 ***	I (0)
y^{RU}	-14.98770***	I (0)
y^{IN}	-11.84314***	I (0)
y^{CH}	-25.28961***	I (0)
y^{SA}	-30.80911***	I (0)
y^{US}	-64.57981***	I (0)
Critical Values		
10%	-2.570000	
5%	-2.890000	
1%	-3.480000	

Panel B: KPSS Test (Constant and Trend)

H_0: Stationarity

Variable	KPSS Statistic	KPSS: Inference
y^{BR}	0.084554	I (0)
y^{RU}	0.038057	I (0)
y^{IN}	0.062375	I (0)
y^{CH}	0.102471	I (0)
y^{SA}	0.082318	I (0)
y^{US}	0.061182	I (0)
Critical Values		
10%	0.119000	
5%	0.146000	
1%	0.216000	

Note: y^{BR}, y^{RU}, y^{IN}, y^{CH}, y^{SA} and y^{US} denote the growth rates for Brazil, Russia, India, China, South Africa and U.S. respectively.

Table 4: Estimates of DCC-GARCH Model

Preliminary Tests	
Test	**Statistic**
Multivariate ARCH Effects	3599.65***
CCC-GARCH	36.78***

Market	**Returns Equation**			**Variance Equation**			
y^{BR}	γ_0	γ_1	γ_2	c	a	b	Persistence
y^{RU}	0.0004***	-0.0727***	0.0560*	9.35E-07***	0.0525***	0.9315***	0.9840
y^{IN}	0.0004***	0.0144	0.2861***	1.09E-06***	0.0706***	0.9132***	0.9838
y^{CH}	0.0004***	0.0142	0.2150***	5.89E-07***	0.0854***	0.9014***	0.9868
y^{SA}	0.0001	0.0070	0.1167***	5.67E-07***	0.0634***	0.9242***	0.9876
y^{US}	0.0003***	-0.0796***	-	2.27E-07***	0.0704***	0.9215***	0.9919
Multivariate DCC Equation							
DCC 1	0.0071***						
DCC 2	0.9910***						

Note: $y^{BR}, y^{RU}, y^{IN}, y^{CH}, y^{SA}$ and y^{US} denote the growth rates for Brazil, Russia, India, China, South Africa and U.S. respectively.

Table 5: Dynamic Panel Data Model (Arellano-Bond) Business Cycle Synchronization

		Number of Observations: 1330
		Number of Groups: 5
Variable	**Coefficient**	**p-value**
Constant	0.0412326***	0.000
Trend	-0.0000249	0.701
Lagged Term	0.7694546***	0.000
Recession 2001	0.0024553	0.801
Recession 2008-09	0.0163173*	0.096

Table 6: Bai and Perron (2003) Pair-wise Regimes (BIC with min span 40 and constant)

Correlation	**Number of Breaks**	**Dates Selected**	**Regimes Defined**
rho^{BUS}	4	1999:10	1995:01-1999:09
		2003:05	1999:10-2003:04
		2008:09	2003:05-2008:08
		2012:01	2008:09-2011:12
			2012:01-2017:07
rho^{RUS}	4	1998:06	1995:01-1998:05
		2004:06	1998:06-2004:05
		2008:06	2004:06-2008:05
		2011:10	2008:06-2011:09
			2011:10-2017:07
rho^{IUS}	3	1998:08	1995:01-1998:07
		2004:06	1998:08-2004:05
		2008:06	2004:06-2008:05
		2011:10	2008:06-2011:09
			2011:10-2017:07
rho^{CUS}	4	2007:02	1995:01-2007:01
		2007:11	2007:02-2007:10
		2008:10	2007:11-2008:09
		2011:11	2008:10-2011:10
			2011:11-2017:07
rho^{SUS}	4	1999:10	1995:01-1999:09
		2003:07	1999:10-2003:06
		2008:09	2003:07-2008:08
		2012:01	2008:09-2011:12
			2012:01-2017:07

Table 7: Correlation Breakdowns (OLS with robust standard errors)

Panel A: Brazil-U.S.

Constant	DB1	DB2	DB3	DB4	Trend
0.129***	0.046***	0.038	0.144***	0.062	-0.000*

Panel B: Russia-U.S.

Constant	DR1	DR2	DR3	DR4	Trend
0.248***	-0.001	-0.056***	0.195***	0.074*	-0.000***

Panel C: India-U.S.

Constant	DI1	DI2	DI3	Trend
0.154***	0.023**	0.000	0.047	-0.000

Panel D: China-U.S.

Constant	DC1	DC2	DC3	DC4	Trend
-0.192***	0.313***	0.119**	-0.098	0.061	0.001***

Panel E: South Africa-U.S.

Constant	DS1	DS2	DS3	DS4	Trend
0.409***	-0.185***	0.072*	0.555***	0.320***	-0.002***

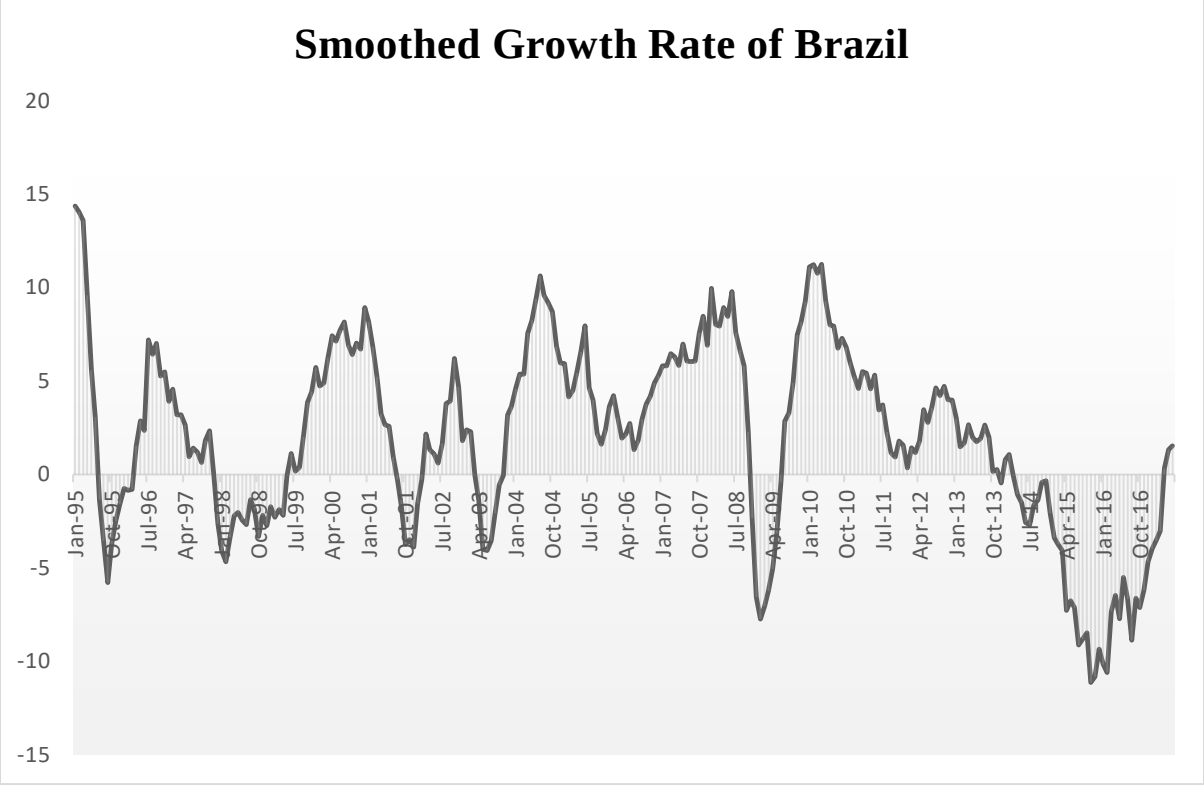
Note: Inclusion of an AR(1) term in the specification does not change the main results. The dummies correspond to the periods shown in Table 6 above. ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

FIGURES

Figure 1: Growth Rate Cycles

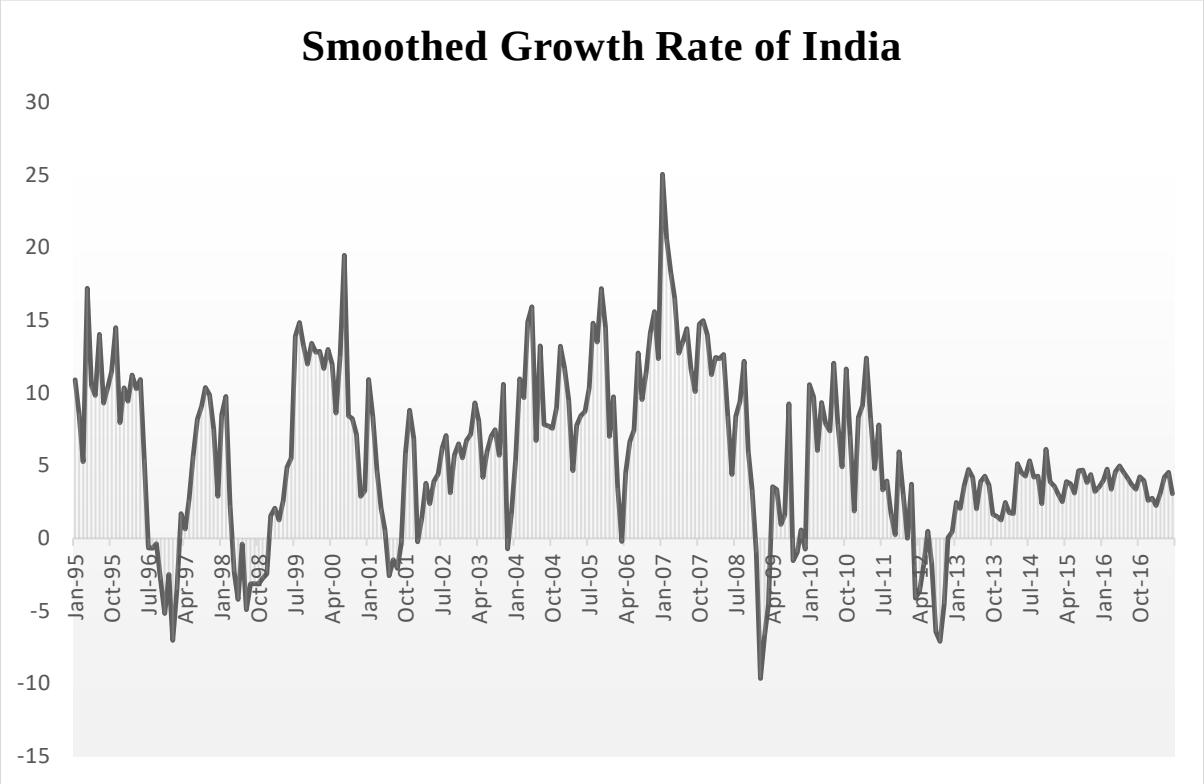
Panel A: U.S.

Panel B: Brazil



Panel C: Russia

Panel D: India



Panel E: China

Panel F: South Africa

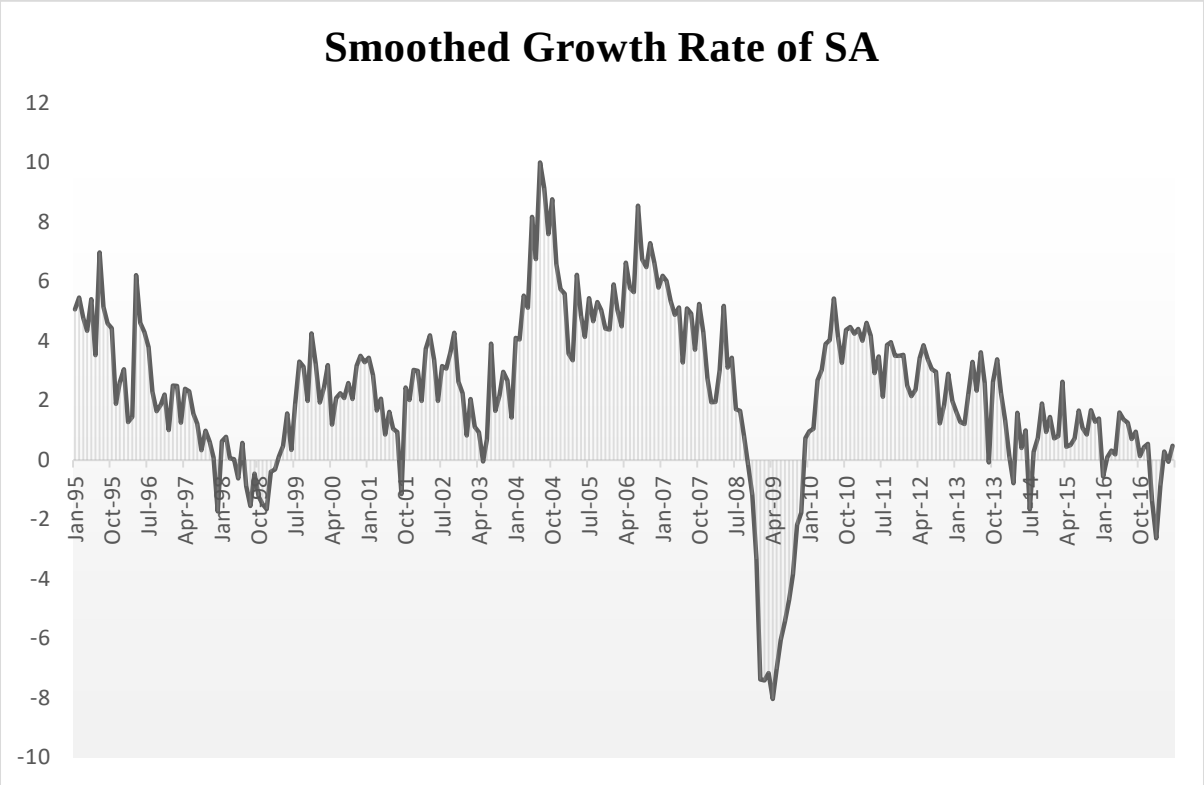
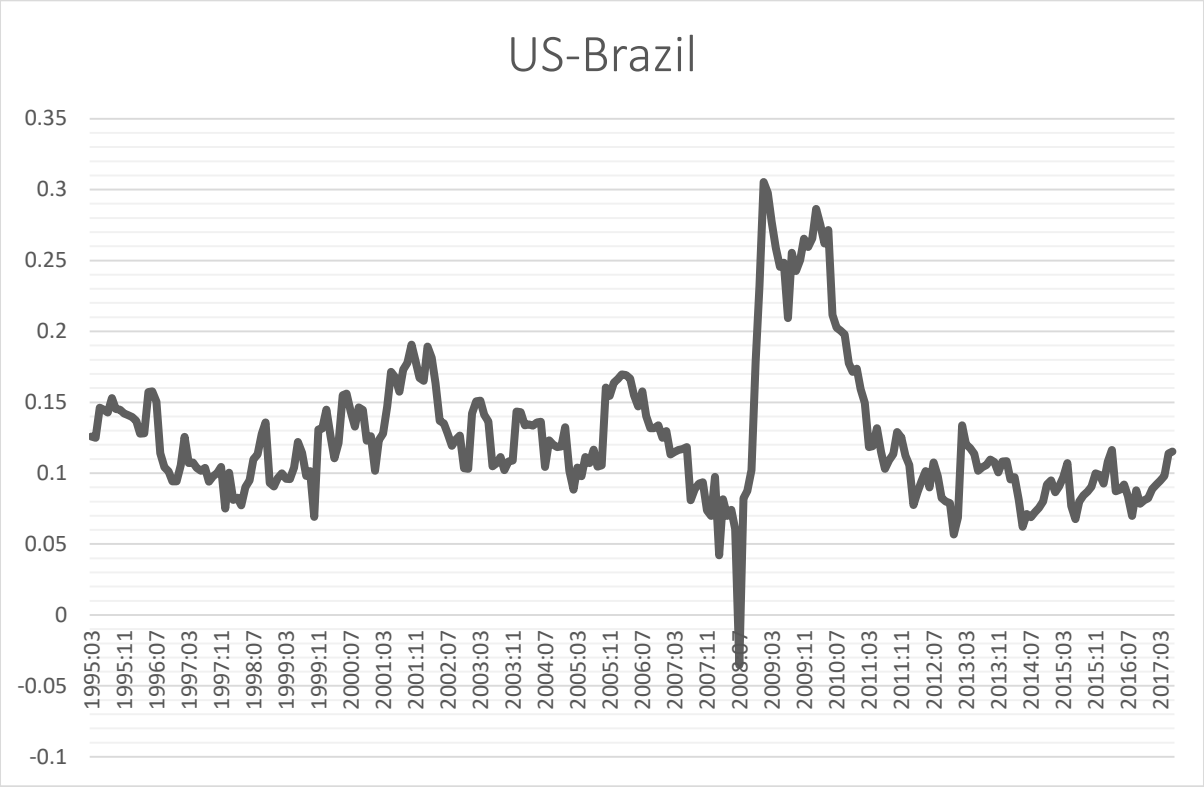


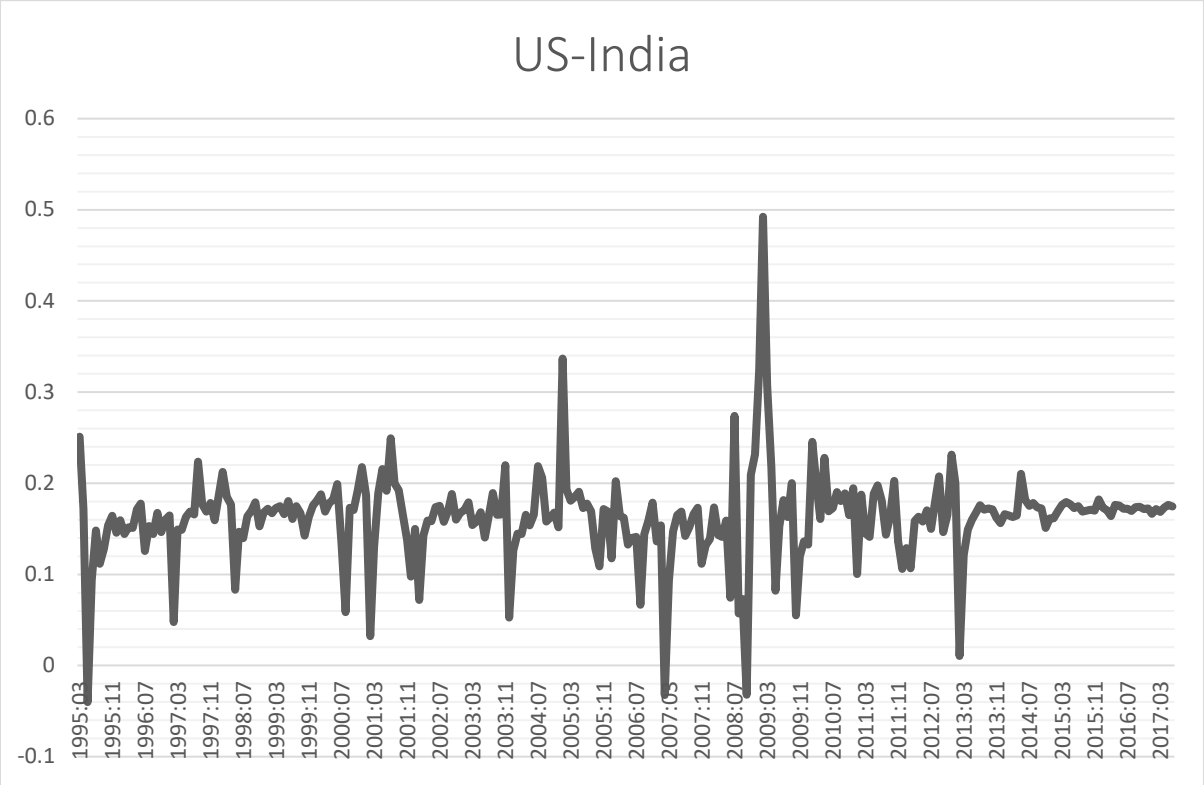
Figure 2: Estimated Conditional Correlations

Panel A: U.S.-Brazil



Panel B: U.S.-Russia

Panel C: U.S.-India



Panel D: U.S.-China

Panel E: U.S.-South Africa