Exchange Rate and Oil Price Pass-through in the Emerging Market Economies

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ABSTRACT

This study provides a macroeconomic analysis of the exchange rate and oil price pass-through (EROPPT) in the emerging market economies with a focus on the BRICS and Nigerian economies. The econometrics tools used in the analysis are based on the linear and nonlinear methods. The first part of the study revisits the Exchange Rate Pass-Through (ERPT) to inflation in Nigeria and South Africa by incorporating structural breaks and using time series data from 1986Q1-2016Q4. Based on the Maki cointegration test and a flexible estimation approach of the Autoregressive Distributed Lag (ARDL) model, our empirical evidence suggests that the long- and short-run ERPT to inflation is complete for Nigeria while for South Africa, it is incomplete in both long run and short run. This result indicates that prices are stickier in South Africa compared to Nigeria. The comparison between Nigeria and South Africa confirms the role of inflation targeting and Central Bank credibility on the ERPT. The results divulge further that output growth in Nigeria increases inflation in the long run while it is anti-inflationary in the short run. For South Africa, the effect of output growth is negatively insignificant. In addition, the long-run effect of oil price is negative and significant for Nigeria, while for South Africa the short-run effect of oil price is positive and significant.

The second part investigates not only the question of whether there is exchange rate and oil price pass-through (EROPPT) but also the extent to which the pass-through is asymmetric or state dependent in the BRICS countries. Using monthly data and the nonlinear Vector Smooth Transition Autoregressive (VSTAR) model, we find evidence of period specific pass-through between the upper and lower regime periods,

governed by the selected transition variables. We also find asymmetric pass-through in all the countries with strong evidence of higher pass-through when the size of the shocks to the transition variable moves the system above a threshold level. The result further divulges that output growth asymmetrically reacts to the shocks. The implication of these findings is that the pass-through is strongly affected by the state of the economy.

The third part focuses on the pass-through of exchange rate and oil price in BRICS countries through the analysis of Diebold and Yilmaz (2012) spillover index and rolling-window. Using the monthly frequency time series data, our results provide the following novelties: (i) There is strong evidence of directional spillover in all the countries; (ii) the total spillover is low, with Brazil (India) having the highest (lowest). This suggests that a greater percent of shocks is explained by idiosyncratic shocks; (iii) the net spillover of oil price (output growth) is positive (negative) for all the countries, indicating that oil price (output growth) contributes to the forecast error variance decomposition of other variables more (less) than it receives from other variables. In addition, the net spillover of exchange rate is positive only for Russia and China while consumer price index is positive only for Brazil and China; (iv) the historical events and crises interrupt the extent of spillover in all the countries; (v) even though the spillover exhibits significant bursts, there is no clear-cut evidence of trends.

In the final part, we investigates the exchange rate and oil price pass-through (EROPPT) in BRICS Countries. The main objective is to determine whether changes in exchange rate and oil price of different magnitudes have disproportionate pass-through effects. To this end, we extend the Diebold-Yilmaz (DY) spillover index to incorporate nonlinearity based on a Vector Smooth Transition Autoregressive

(VSTAR) model. This approach allows for a smooth period-specific and regime-dependent DY spillover indexes, governed by the selected transition variable. The results provide evidence of significant differences between the upper and lower regimes of the period-specific and regime-dependent EROPPT. The results further suggest that the total pass-through in the regime-dependent model is higher compared to when the linear Vector Autoregressive (VAR) assumption is imposed. These findings, therefore, provide insights for policymakers to properly manage macroeconomics with a sound monetary policy.

Generally, the findings of this thesis provide insights for policymakers to properly manage macroeconomic variables with a sound monetary policy in order to reduce the pass-through of exchange rate and oil price in the emerging market economies.

Keywords: Exchange Rate Pass-Through; Oil price pass-through; EROPPT; Regime-dependent pass-through; Period-specific pass-through; Maki Cointegration test; ARDL model; VSTAR model; Diebold-Yilmaz spillover index; Rolling window analysis; GIRF; FEVD; BRICS Countries; Nigeria

ÖZ

Bu çalışma, BRICS ve Nijerya ekonomilerine odaklanarak, gelişmekte olan piyasa ekonomilerindeki döviz kuru ve petrol fiyatı geçişinin (EROPPT) makroekonomik bir analizini sunmaktadır. Analizde kullanılan ekonometri araçları doğrusal ve doğrusal olmayan yöntemlere dayanmaktadır. Çalışmanın ilk kısmı, Döviz Kuru Geçişini (ERPT) Nijerya ve Güney Afrika'daki enflasyona yapısal kırılmalar ekleyerek, 1986-2016 çeyreklik zaman serisi boyutunda incelemiştir. Maki eşbütünleşme testine ve Otoregresif Dağıtılmış Gecikme Modeli (ARDL) modelinin esnek bir kestirim yaklaşımına dayanarak, ampirik bulgularımız Nijerya için uzun ve kısa vadeli ERPT'nin tamamlanmış olduğunu gösterirken Güney Afrika için uzun ve kısa vadeli ERPT'nin tamamlanmamış olduğunu göstermektedir. Bu sonuç, Güney Afrika'da fiyatların Nijerya'ya göre daha katı olduğunu göstermektedir.

Nijerya ve Güney Afrika arasındaki karşılaştırma ERPT'de enflasyon hedeflemesinin ve Merkez Bankası'nın güvenilirliğinin rolünü doğrulamaktadır. Sonuçlar, üretim artışının uzun vadede ve kısa vadede Nijerya'daki enflasyondaki değişiklikleri dikkate almasına rağmen, uzun vadede ve kısa vadede, üretim artışının etkisinin Güney Afrika için negatif ve istatiksel olarak anlamsız olduğunu göstermektedir. Ayrıca, Nijerya'da petrol fiyatlarının enflasyon üzerindeki uzun vadeli etkisi negatif ve istatiksel olarak anlamlı olmakla birlikte, Güney Afrika'da petrol fiyatlarının enflasyon üzerindeki kısa vadeli etkisi pozitif ve istatiksel olarak anlamlıdır.

İkinci bölüm sadece döviz kuru ve petrol fiyat geçişi olup olmadığı (EROPPT) sorununu değil, aynı zamanda geçişin BRICS ülkelerinde asimetrik ya da devlete bağlı

olup olmadığını da incelemektedir. Aylık verileri ve doğrusal olmayan Vektör Düzgün Geçişli Otoregresif (VSTAR) modelini kullanarak, seçilen geçiş değişkenleri tarafından yönetilen üst ve alt rejim dönemleri arasındaki döneme özgü geçiş kanıtları bulunmuştur. Ayrıca, tüm ülkelerde, geçiş değişkenine giden şokların büyüklüğü sistemi bir eşik seviyenin üzerine getirdiğinde yüksek geçiş oranına dair güçlü kanıtlar bulunan tüm ülkelerde de asimetrik geçiş etkisinin olduğunu bulunmuştur. Sonuç, çıktı büyümesinin şoklara asimetrik tepki verdiğini ortaya çıkarmaktadır. Bu bulguların anlamı, geçişin ekonominin durumundan güçlü bir şekilde etkilenmesidir.

Üçüncü bölüm, BRICS ülkelerindeki döviz kuru ve petrol fiyatlarının Diebold ve Yılmaz (2012) yayılma endeksi ve yuvarlanma penceresi analizleri yoluyla aktarılmasına odaklanmaktadır. Aylık frekans süresi serisi verilerini kullanarak, sonuçlarımız aşağıdaki yenilikleri sunar: (i) Bütün ülkelerde güçlü bir yayılma kanıtı olduğu bulunmuştur; (ii) toplam yayılma düşükken, Brezilya (Hindistan) ise en yüksek olanıdır (en düşük olanı). Bu, şokların daha büyük bir yüzdesinin kendine özgü şoklarla açıklandığını gösteriyor; (iii) Petrol fiyatlarındaki net artış (üretim artışı) tüm ülkeler için pozitif (negatif) olup, petrol fiyatının (üretim artışı) tahmin edilen hata farkının diğer değişkenlerden daha az (daha az) diğer değişkenlerin ayrışmasına katkıda bulunduğunu göstermektedir. Ayrıca, döviz kurundaki net artış yalnızca Rusya ve Çin için, tüketici fiyat endeksi ise sadece Brezilya ve Çin için pozitif bulunmuştur; (iv) tarihsel olaylar ve krizler, tüm ülkelerde yayılma oranını engellemektedir; (v) yayılma önemli patlamaları gösterse de eğilimlerin açık bir kanıtı yoktur.

Son bölümde, BRICS ülkelerindeki döviz kuru ve petrol fiyatı geçişi (EROPPT) araştırılmaktadır. Temel amaç, döviz kurundaki ve farklı büyüklüklerdeki petrol fiyatlarındaki değişikliklerin orantısız geçiş etkilerinin olup olmadığını belirlemektir.

Bu amaçla, Diebold-Yılmaz (DY) yayılma endeksini, Vektör Düzgün Geçişli Otoregresif (VSTAR) modeline dayalı doğrusal olmayanlığı birleştirmek için genişlettik. Bu yaklaşım, seçilen geçiş değişkeni tarafından yönetilen düzgün bir döneme özgü ve rejime bağlı DY yayılma endekslerine izin vermektedir. Sonuçlar, döneme özgü ve rejime bağlı EROPPT'nin üst ve alt rejimleri arasında önemli farklılıklar olduğuna dair kanıtlar sunmaktadır. Sonuçlar ayrıca, rejime bağlı modeldeki toplam geçişin, doğrusal Vektör Otoregresif (VAR) varsayımının uygulanmasına kıyasla daha yüksek olduğunu göstermektedir.

Genel olarak, bu tezin bulguları, döviz kurunun ve petrol fiyatının geçişini azaltmak için politika yapıcıların makroekonomik değişkenleri sağlam bir para politikası ile uygun şekilde yönetebilmeleri için iç görü sağlar.

Anahtar Kelimeler: Döviz Kuru Geçişi; Petrol fiyatı geçişi; EROPPT; Rejime bağlı geçiş; Döneme özgü geçiş; Maki Eşbütünleşme testi; ARDL modeli; VSTAR modeli; Diebold-Yılmaz yayılma indeksi; Rolling pencere analizi; GIRF; F-EVD; BRICS Ülkeleri; Nijerya

DEDICATION

To my Late Father, MR. ONUCHE USMAN

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
ADF Test	Augumented Dickey-Fuller Test
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag
BRICS	Brazil, Russia, India, China and South Africa
CBN	Central Bank of Nigeria
CPI	Consumer Price Index
DY	Diebold and Yilmaz
Δ	Difference operator
EIA	Energy Information Administration
ERPT	Exchange Rate Pass-through
EROPPT	Exchange Rate and Oil Price Pass-through
FEVDs	Forecast Error Variance Decompositions
F-Test	Fisher-Test
F-test (F_{RAO})	Rao's version of Fisher-test
GDP	Gross Domestic Product
GIRF	Generalized Impulse Response Function
IPI	Industrial Production Index
LOOP	Law of One Price
LM Test	Lagrange Multiplier Test
Ln or log	Natural logarithm
LR Test	Likelihood Ratio Test
NEER	Nominal Effective Exchange Rate

OECD	Organization for Economic Cooperation and Development
OIL	Oil Price
OPPT	Oil price pass-through
PP	Phillips-Perron test
PPP	Purchasing Power Parity
SARB	South African Reserve Bank
SIC	Schwarz Bayesian Information Criterion
TVAR	Threshold Vector Autoregression
UECM	Unrestricted Error Correction Model
USD	United States Dollar
VAR	Vector Autoregression
VECM	Vector Error Correction Model
VSTAR	Vector Smooth Transition Autoregression
WDI	Word Development Index

Chapter 1

INTRODUCTION

1.1 Background and Motivation of the Study

The responsiveness of domestic prices to exchange rate and oil price movements otherwise known as pass-through has attracted policy attention of the government over the years, particularly after the demise of Bretton Woods' system of adjustable peg of 1971 following a crash in the US dollars and the oil price shocks of 1973 and 1979. Theoretically and empirically, the changes in exchange rate and oil price affect the level of inflation, unemployment, and output growth especially when the country has a floating exchange rate system (See Compa *et al.* 2004; Karoro *et al.* 2009; Ajmi *et al.* 2015; Lariau *et al.* 2016; Balcilar *et al.* 2017, 2018; Kabundi and Mbelu, 2018; Usman and Musa, 2018).

Essentially, the theoretical underpinning pass-through evolves from the theory of the Purchasing Power Parity (PPP) vis-à-vis the Law of One Price (LOOP), which categorically submits that the tradable goods and services will sell for the same price in different markets or countries once the prices are expressed using the same unit of currency. This theory, therefore, assumes that the pass-through is usually complete or full i.e. one-to-one response of exchange rate and oil price movements on prices. However, if this theory fails to hold, it means that the changes in exchange rate and oil price are not fully reflected in domestic prices; hence, the pass-through is incomplete or partial. By and large, the existing literature has identified certain factors, which can generate incomplete pass-through. These factors boil down to the menu cost of price adjustment, pricing-to-market, trade hysteresis, degree of competition as well as the stance of monetary policy rules (Goldberg and Knetter, 1997; Xu and Bernhofen, 1999; Choudhri and Hakura, 2003; Compa *et al.* 2004; Ihrig *et al.* 2006; Junttila and Korhonen 2012).

There are two main transmission channels of exchange rate and oil price pass-through: the direct and indirect channels. The direct channel refers to the extent to which an increase or decrease in domestic currency and oil price affect the costs of imported goods and production inputs. For example, if exchange rate depreciates or oil price rises, import of finished goods and production inputs become more expensive. This causes the cost of production to rise and consequently increases the consumer price index. On the other hand, the indirect channel occurs through aggregate domestic demand and wages. For example, if exchange rate depreciates or oil price rises, there will be high domestic demand for substitute goods. If the economy operates at a high level of capacity utilization, it exerts upward pressure on the prices of substitute goods and exports, which consequently result to high consumer prices. In particular, the depreciation of exchange rate increases the demand for exports of goods. The consequences of the rise in export demand can be analyzed in two-fold: firstly, the substitute goods and exports will turn out to be more expensive; and secondly, the demand for labour and wages will rise, thereby increasing consumer price index.

Furthermore, there is growing evidence that the pass-through of exchange rate and oil price is an asymmetric phenomenon. In other words, domestic prices possibly react asymmetrically to the shocks in exchange rate and oil price especially when prices exhibit downward rigidities and quantities exhibit upward rigidities (Pollard and Coughlin, 2004; Delatte and Lopez-Villavicencio, 2012; Baharumshah *et al.* 2017a,c; Usman and Elsalih, 2018). Indeed, if there is asymmetry in the pass-through channels, it implies that the responsiveness of prices to the direction and the size of exchange rate and oil price shocks are not linear or symmetric. Consequently, the assumption of linearity in the pass-through becomes unrealistic and misleading. More so, another strand of nonlinearity in the pass-through provides evidence that the elasticity of pass-through is dependent on the economically relevant regimes (See Correa and Minella, 2010; Junttila and Korhonen, 2012; Busiere, 2012; Shintani *et al.* 2013; Ben Cheikh and Lonhichi, 2016; Kilic, 2016). The theoretical literature supporting this kind of asymmetric effect boils down to pricing-to-market, menu cost of price adjustments, monetary policy stance etc.

The empirical evidence of exchange rate pass-through and oil price pass-through started coming to the limelight in early 1970s with a significant number of studies concentrating on the developed and advanced economies, leaving a missing gap for the developing and emerging market economies. However, a large body of literature on pass-through has come to the limelight in the emerging market economies particularly during the new millennium (See McCarthy, 2000; Chen, 2009; Correa and Minella, 2010; Kataranova, 2010; Yanamandra, 2015; Asghar and Naveed, 2015; Bouvet *et al.* 2017; Sek, 2017; Balcilar *et al.* 2018a, b). These studies have provided interesting accounts of the pass-through of exchange rate and oil price both in country-specific and cross-country settings. While empirical evidence on the pass-through has burgeoned, some numbers of issues remain contentious, such as whether the changes in policy direction of exchange rate and trade policy towards liberal economic policies exert pressure on the pass-through channels. It is in view of this that the general objective of this thesis is to investigate the exchange rate and oil price pass-through (EROPPT) in the emerging market economies with a focus on Brazil, Russia, India, China, and South Africa countries (henceforth BRICS countries) and Nigeria. The choice of the BRICS and Nigeria is informed by the shift in policy directions of exchange rate and trade towards market-based economic policies. This policy shift has however demonstrated a significant increase in the share of BRICS countries in the total world trade volume. As documented by Enerdata (2015), the total share of BRICS countries in the volume of world trade is USD 7.7 trillion, which accounts for 18% of the total world trade. This amount is about 70.5% higher than the total of USD 4.4 trillion in 2008. In Nigeria, the statistic show that the balance of trade has been positive over the years. It reaches its pick in 2012 with about USD 63.7 billion. Theoretically, as the economies become more connected globally with floating exchange rate system, one would expect such economies to be vulnerable to the effects of exchange rate and oil price fluctuations. This could impede the primary objective of the Central Bank in attaining low inflation levels and price stability. Therefore, BRICS countries as the fast-growing economic hub in the emerging market economies and Nigeria as the largest Africa’s economy, investigating the EROPPT for these countries is essential for the following reasons: (i) it determines the path of external adjustments in these countries. (ii) it is a requisite for the proper conduct of monetary policy since the monetary authorities can influence only the domestic component of price formation; and (iii) it determines the level of international transmission of shocks to these countries. In testing the pass-through of exchange rate and oil price in this thesis, our analysis switches from first stage of pass-through, which is concerned with the pass-through of exchange rate and oil price to import prices to the second stage, which focuses on the pass-through to inflation following the changes in exchange rate and oil price.

To achieve the general objective stated above, the thesis is split into the following chapters. Chapter 1 is a general introduction. Chapter 2 revisits the exchange rate pass-through (ERPT) to two largest economies in Africa (Nigeria and South Africa) by incorporating structural breaks based on the Maki cointegration test and a flexible estimation approach of the Autoregressive Distributed Lag (ARDL) model. The major contribution of this chapter is not only incorporating the structural breaks and their effects but also incorporating oil price and output growth into a standard doctrine of the Purchasing Power Parity (PPP), an offshoot of the Law of One Price (LOOP) to revisit the extent of the ERPT in Nigeria and South Africa. In addition, the chapter offers evidence as to whether the Central Bank credibility and inflation targeting dampen the pass-through effect.

In Chapter 3, we extend the pass-through of exchange rate and oil price to incorporate nonlinearity by investigating not only the question of whether there is exchange rate and oil price pass-through (EROPPT) but also the extent to which the pass-through is asymmetric or state dependent in the BRICS countries using the nonlinear Vector Smooth Transition Autoregressive (VSTAR) model. The chapter therefore contributes to the literature by departing from the previous studies, which concentrate mostly on the direction of the change in exchange rate and consider whether the pass-through of exchange rate and oil price is affected by the state of the economy. The theoretical argument here is that the behaviors of firms are strategically guided by the market share objective, which perhaps creates a difficult environment to fully pass-through the changes in exchange rate and oil price to domestic prices. If the size of the change in exchange rate and oil price is less than a certain threshold (small) and the cost required to change price is huge, then the firms may prefer to absorb the change in exchange rate and oil price and leave their prices unchanged, leading to zero pass-through. For a better understanding of the dynamics of asymmetric EROPPT, in this chapter, we explore a bootstrap approach where generalized impulse responses, which are history, shocks, and composition dependent, are obtained with 1000 bootstrap repetitions. This is because there is no clear-cut analytical point formula to forecast nonlinear multivariate VAR models as outlined in Hubrich and Teräsvirta (2013) and Balcilar *et al.* (2016; 2018b) .

In Chapter 4, we investigate the pass-through of exchange rate and oil price in the BRICS countries through the analysis of Diebold and Yilmaz (2012) spillover index and rolling-window. The novelties of this chapter are numerous. Firstly, the emphasis is placed on the pass-through (spillovers) of exchange rate and oil price to not only inflation but to all other variables captured in the model estimation. Secondly, three categories of spillover indexes are revealed, namely: directional spillovers; total spillovers, and net spillovers. Thirdly, the rolling window approach is explored in order to analyze the effects of historical events, crises, as well as other factors that characterize the channels of the pass-through.

In Chapter 5, the main objective is to determine whether changes in exchange rate and oil price of different magnitudes have disproportionate pass-through effects in the BRICS Countries. To this end, we extend the Diebold-Yilmaz (DY) spillover index to incorporate nonlinearity based on the VSTAR model. This approach allows for a smooth period-specific and regime-dependent DY spillover indexes, governed by the selected transition variable between the upper and lower regimes. Chapter 6 contains a summary of all the chapters and policy implications of the findings.

It is, therefore, hopeful that the findings of this thesis will provide policy implications, which will serve as the basis for the government, policymakers and monetary authorities to properly time current account adjustments, achieve monetary policy objective of low level and stable prices, as well as dampen the international transmission of shocks to these economies.

Chapter 2

REVISITING THE EXCHANGE RATE PASS-THROUGH TO INFLATION IN AFRICA'S TWO LARGEST ECONOMIES: NIGERIA AND SOUTH AFRICA

2.1 Introduction

The issue of exchange rate pass-through (ERPT) to inflation has triggered the recent upsurge of interest in international finance and macroeconomics especially in the small open economies. As economies become more globally connected, one would expect a change in exchange rate to be transmitted to domestic prices. Theoretically, the ERPT to inflation is equal to one (i.e. complete or full pass-through). However, the empirical evidence that abounds from the scholarly works reveal that the pass-through of the exchange rate is incomplete or partial, especially in the short- to medium-term (Mann 1986; Dornbusch, 1987; Marston, 1990). These studies mostly focused on the advanced and developed countries, leaving a missing gap for the developing countries, particularly in Africa. Given that almost entire economies in African continent are considerably driven by commodity prices, which have recently witnessed more fluctuations,[1] coupled with a significant change in exchange rate and trade policy

[1] The Central Bank of Nigeria reports that crude oil has accounted for 88.6% of total government revenue and 95% of export earnings in 2006. In South Africa, the Reserve Bank reports in 2016 that the mining industry makes up about 60% of the country's exports, and eight of the 10 largest individual export categories are commodities.

towards market-based economic policies, these economies have become more susceptible to the effects of the exchange rate movements on domestic prices. This has an adverse effect on the primary role of the Central Bank in achieving low and stable prices (Poloamina *et al.* 2009; Karoro *et al.* 2009; Balcilar and Usman, 2018).

In the recent years, a large body of empirical research has estimated the ERPT to import and consumer prices in African countries. These studies include Kiptui *et al.* (2005) for Kenya; Frimpong (2010), Amoah and Aziakpono (2017) for Ghana; Arabi (2015), Baharumshah *et al.* (2017a) for Sudan; Carvalho *et al.* (2012) for Angola; Bhundia (2002), Karoro *et al.* (2009), Aron *et al.* (2014), Jooste and Jhaveri (2014) for South Africa; and Aliyu *et al.* (2009), Omisakin (2009), Usman and Musa (2018) for Nigeria. Despite the rapid increase of literature on the ERPT, a number of issues still need to be addressed. One of these issues is whether the central bank credibility and inflation targeting policy dampen the channel of ERPT to inflation. In addition, whether the effects of structural breaks apparently ignored in most studies are possessive of influencing the integrating properties of the variables and their long-run relations. Generally, structural breaks have consequences on the performance of a standard or conventional unit root and cointegration test. When these tests are applied in the presence of structural breaks, their performance may be very poor, leading to spurious outcomes (See Gregory *et al.* 1996).

In this study, we focus on Nigeria and South Africa. These countries are the largest economies in the African continent based on the size of their gross domestic product (GDP) (WDI, 2015; AfDB, 2018). The countries (Nigeria and South Africa) have been witnessing large fluctuations in their bilateral exchange rate. The nominal effective exchange rate in Nigeria between 1985 and 1989 dropped significantly by an average of 41 percent on annually basis. In addition, the average depreciation of the official exchange rate was roughly 71 percent annually. Worst still is that of the parallel exchange rate market which depreciated by an average of 114 percent between 1986 and 1993. This further depreciated by 61.8 percent between 2016 and 2018 due to the plummeting of oil prices. The implication for these developments is the rising of the consumer price index (CPI) in Nigeria. Between 1985 and 1989, the CPI increased by 78 percent; this rose to about 300% in 1988 compared to the previous year. The recent reports by the Central Bank of Nigeria (CBN, 2018) show that the Nigerian inflation remains double-digit number at an average of 11.44 percent in 2018. Turning to South Africa, Sachais (2015) notes that since 2012, the South African rand has depreciated against US dollars by about 57 percent. More so, between January 2015 and January 2016, the rand has weakened by roughly 40% percent against US dollar. In 2000 and 2001 in particular, the nominal effective exchange rate depreciated by 17.4 percent and 34.4 percent. These fluctuations have a significant effect on domestic prices. For example, a relatively stable bilateral exchange rate of rand in 1990s manifests in the decline of an average inflation rate from 19.2 percent in 1986 to 9.8 percent in 1993. This also contributes to a decline of inflation from its high rate of 15.3 percent in 1991 to a low level of single-digit number since 1993 except in 2008, which stood at 11.5 percent.

Even though Nigeria and South Africa have similarities such as having volatile exchange rate markets and significant fluctuations in the inflation rates, significant differences exist between the two countries in terms of macroeconomic policymaking and monetary policy in particular. As an explanation to existence of ERPT, Taylor's

(2000) hypothesis that the responsiveness of inflation to exchange rate changes depends positively on the inflation rate has found empirical support in the literature. Gagnon and Ihrig (2004) find significant evidence that exchange rate pass through and inflation variability are positively linked for a number of advanced economies. Choudhri and Hakura (2006) obtain evidence showing that the positive link between inflation and ERPT exits for emerging markets and it is stronger than the links exists for the advanced economies.

Recently, Dovern *et al*. (2012), Carrière-Swallow *et al*. (2016), and Kabundi and Mlachila (2018) obtain statistical evidence that monetary policy environment and central bank credibility are also related to the ERPT. The evidence shows that central bank credibility and improvements in monetary policy framework establish anchors that reduce ERPT. Moreover, Aleem and Lahiani (2014) and Kabundi and Mlachila (2018) show that adaptation of inflation targeting regimes reduced the ERPT in a number of countries. The South African Reserve Bank (SARB) adopted a complete inflation targeting regime in February 2002. Kabundi and Mlachila (2018) argue that the SARB's strong track record of independence, which was established in the constitution in the mid-1990s, significantly increased its credibility as a monetary authority. The empirical evidence in Kabundi and Mlachila (2018) and Dube (2016) indicate that the credibility of monetary policy and inflation targeting regime reduced ERPT in South Africa. On the other hand, the Central Bank of Nigeria (CBN) did not yet adopted a complete inflation targeting regime and only recently accepted it as a principle. The CBN's commitment to the inflation targeting regime is yet to be seen. Additionally, unlike the SARB, there is no evidence supporting the credibility of monetary policy framework of the CBN (Bada *et al*. 2016; Ewurum *et al*. 2017). Thus, by comparing the ERPT in Nigeria and South Africa, our paper sheds light on whether central bank credibility and inflation targeting dampen the ERPT channels.

The main objective of this paper is to revisit the ERPT to inflation in Nigeria and South Africa over the period of 1986Q1 to 2016Q4. This period coincides with the era of market-based policies and inflation targeting regime of the CBN and the SARB. Therefore, the contributions of this paper to the literature are in several ways: First, we revisit the ERPT to inflation for two largest economies in Africa to ascertain the dynamic short-run and long-run pass-through coefficients during the period of market-based exchange rate and trade policies. Second, we incorporate oil price and output growth into a standard doctrine of the Purchasing Power Parity (PPP), an offshoot of the Law of One Price (LOOP) to revisit the extent of the ERPT to inflation for Nigeria and South Africa. Third, on the empirical issue, we take different approach in modelling ERPT by controlling for the effects of structural breaks. Fourth, the structural breaks identified are included in the model estimations to assess their effects on inflation in the long run. Fifth, our results offer evidence on whether central bank credibility and inflation targeting reduce ERPT.

Among the striking findings of this paper is that the ERPT for Nigeria is complete in the long run and incomplete in the short run while it is incomplete both in the short run and long run for South Africa. We find ERPT in Nigeria is higher both in the short run and long run compared to South Africa. This result suggests the price stickiness in South Africa compared to Nigeria. The oil price has opposite effects in Nigeria and South Africa. The long-run parameter estimates have a number of important implications. Increasing oil prices reduces domestic prices in Nigeria by improving balance of payments, employment, and output growth since Nigeria is a net oil exporter. Opposite, but statistically insignificant effects are observed in South Africa. The output growth in Nigeria is demand driven and, thus, inflationary while it is, although insignificant, anti-inflationary in South Africa. Our results, therefore, imply that central bank credibility and strong commitment to inflation targeting reduces ERPT both in the long run and short run.

The rest of the paper is structured as follows: Section 2.2 reviews both the theoretical and empirical literature. Section 2.3 discusses the data and methodology of the paper, which includes the description of the data, stationarity and nonstationarity tests and Maki's cointegration test as well as unrestricted error correction model derived from the autoregressive distributed lag (ARDL) bounds testing cointegration model. Section 2.4 provides the empirical results and discussion and section 2.5 contains the concluding remarks and policy implications based on the findings of this paper.

2.2 Theoretical Framework and Empirical Literature

The theoretical framework for the ERPT evolves from the theory of the Purchasing Power Parity (PPP), an offshoot of Law of One Price (LOOP) which states clearly that at equilibrium, the market prices of tradable goods and services are the same in different countries if their prices are measured in the same unit of currency. The main force of this theory is the perfect competitive arbitrage activities, which propels the exchange rate to adjust seemingly to the equilibrium level where the PPP holds. Therefore, following Rogoff (1996), the theory of the PPP, with the assumptions of no existence of transportation costs, tariffs, imperfect competition and other trade barriers is specified as:

$$P_{i,t} = ER_t \times P^*_{i,t} \quad (1)$$

where, $P_{i,t}$ is the domestic price for good i in period t, $P^{*}_{i,t}$is the foreign price for good i in period t, and ER_t is the nominal exchange rate in period *t*. Remarkably, equation (1) is the absolute form of the PPP, which is the generalization of the law of one price. It, therefore, demonstrates that given the same unit of currency, a basket of goods will cost the same in any country. Thus;

$$ER_t = \frac{P_{i,t}}{P^{*}_{i,t}} \qquad (2)$$

where, $P_{i,t}$, $P^{*}_{i,t}$ and ER_t remain as previously defined. The exchange rate between two currencies is equal to the ratio of price levels in these countries. However, as suggested by the empirical literature, the ERPT is partial and incomplete particularly in the short run. This means that the PPP and/or LOOP does not hold either in absolute or relative version.[2] This breakdown of the PPP or LOOP is based on the nominal price stickiness arising from the weak competitive arbitrage activities, which has remained the central debates between New Keynesian and New Classical economists (Rogoff 1996).

Given that Nigeria is the largest net oil exporting country in Africa and South Africa as a net oil importing country in Africa, we assume that oil price has a significant impact on their consumer price inflation. The implication of this assumption is that an increase in oil price could lead to an increase in import bills (input costs) of the net oil importing country, which adversely affect production, employment, and inflation. In contrast, this could improve the balance of payments of the net oil exporting country. Furthermore, following the dynamics described in the framework for the Phillip's

[2] Relative PPP suggests that a change in the price level is related to a change in the exchange rate. Hence, an economy with a relatively higher inflation rate tends to experience a depreciation of the currency.

Curve, output growth is essential in determining the short-run and long-run ERPT to inflation.

While there is growing interest in analyzing the extent of the ERPT at country-specific and panel settings particularly in the open economies, the results from the several studies have provided mixed pass-through elasticities in the short run and long run. Clearly, the focus of the early studies on ERPT is centered on estimating the size of pass-through to domestic prices. The results abound in the literature show that the ERPT is incomplete (See Menon, 1994 and 1995; Kenny and McGettigan, 1996; Corsetti and Pesenti, 2001; Gagnon and Ihrig, 2004). In the recent times, several studies have argued that the size of the pass-through has significantly declined especially in the industrialized countries. For example, in a study by Otani *et al.* (2003), it is revealed that within the Japanese economy, there is a huge decline in the pass-through for imports. This decline is mainly accounted by the global falling of inflation and the promotion of intra-firm imports. In the same vein, Marazzi *et al.* (2005) report a significant decline in the ERPT to aggregate imports for United States. Most notably, the result shows that the pass-through falls from 65% in 1980s to somewhat 12% by the end of a decade in 2004. This result, therefore, echoes the earlier finding by Mann (1986). More so, Campa and Goldberg (2005) in their study document a similar finding that the 1990s decline in the ERPT of the Organization for Economic Cooperation and Development (OECD) countries is largely caused by the changing commodity composition of trade rather than inflationary environment.

In cross-sectional setting, Pollard and Coughlin (2004) use data for 30 industries to estimate the pass-through of the exchange rate to US import prices. The result, however, provide a strong evidence that the reaction of these industries to changes in the exchange rate is incomplete. Cunningham *et al.* (2017) examine the time variation in the exchange rate pass-through to import prices in 24 advanced countries over the period 1995–2001. The finding suggests that the pass-through is heterogeneous and incomplete across the countries. Using a quarterly data between 2000 and 2014 for the 7 economies in the Southeast Europe, Kurtovic *et al.* (2018) demonstrate that the pass-through of the exchange rate to import prices is incomplete. This finding, in totality refutes the claim that the size of the pass-through has reduced over time. The result of the study further divulges that the pass-through in the transitional countries is higher than in the developed countries. More so, in Hungarian economy, Hajnal *et al.* (2015) investigate the ERPT into consumer prices. The result carefully discloses that the size of the ERPT varies over time. The size before the crisis stands at 0.3% while after the crisis, the size falls between 0.1 and 0.2%.

Furthermore, there has been a significant amount of literature that relates a significant decline in the extent of the ERPT to domestic prices particularly in the industrialized countries to high degree of competitiveness and low as we as stable inflation environment (See Taylor, 2000; Bailliu and Fujii, 2004; Campa and Goldberg, 2005; Choudhri and Hakura, 2006; Junttila and Korhonen, 2012). More so, McCarthy (2000) uses impulse responses and variance decomposition within the framework of VAR to estimate the ERPT for the economies of industrialized countries. The results divulge that disinflationary effect identified by the study is attributed to external factors, which occurs during the past couple of years. However, this conclusion remains unchanged during the post-1982 period. Choudhri and Hakura (2006) using a dataset for 71 countries over the period 1979-2000, find that the pass-through is related to the average inflation rate across these countries. On the contrary, Campa and Linda (2002) investigate the ERPT to import prices for 25 OECD countries over the period 1975 to 1999 with quarterly data. The empirical results indicate that the periods of high rate of inflation and high volatility of exchange rate have a weak correlation with high ERPT. In most recently, Ben Cheikh and Louhichi (2016) use a large panel of 63 countries over the period of 1992 to 2012 in order to revisit the association of inflation environment and ERPT. Their finding indicates a strong evidence of a positive relationship between inflation environment and the ERPT. This finding affirms the earlier study by Taylor (2000).

In Nigeria, the research on the ERPT has received much attention, particularly in the new millennium. For example, Aliyu *et al.* (2009) and Oyinlola and Egwaikhide (2011) examine the extent of the ERPT to import and consumer prices in Nigeria based on the Johansen cointegration and vector error correction model (VECM). The results indicate the existence of a long-run relationship between exchange rate and domestic prices but that the pass-through elasticity is incomplete in the two studies. In contrast, Omisakin (2009) reports no evidence to support the pass-through of the exchange rate to inflation and growth in Nigeria, both in the short run and long run. This finding is not entirely supported in by Poloamina *et al.* (2009) who reveal that in the long run, there is no evidence of the ERPT to import prices but in the short run, the ERPT is complete, i.e. a 1% depreciation in the exchange rate would lead to a 1% increase in import prices. Adding to the empirical literature, Usman and Musa (2018) in their recent study posit that exchange rate, import prices, and trade openness index are the major determinants of consumer price inflation in the long run, while in the short-run, the effect of import price is diminished.

In the case of South Africa, the pass-through elasticities documented by the early studies are very high. However, there is a growing evidence that the pass-through has significantly declined in the recent times due to relatively low and stable inflation rate (Aron *et al.* 2014; Jooste and Jhaveri 2014). Bhundia (2002) finds that the pass-through elasticity to producer price inflation in South Africa is approximately 72% after eight quarters. Similarly, SARB (2002) examines the first stage of the ERPT in South Africa based on Johansen cointegration and vector error-correction model. Using a monthly data for the period 1980-2001, the result shows that the pass-through of the exchange rate to import prices is about 78% in the long run. However, Ocran (2010) using monthly data between the period 2000M1 to 2009M5, finds that the pass-through of the exchange rate to CPI is approximately 13% and 20% to producer prices in South Africa. Using a sample based on the individual goods and services between 1990 and 2008 for South Africa, Parsley (2012) finds a low degree of pass-through to consumer good prices. Comparing to the pass-through estimates of consumer good prices and services, it is somewhat higher for services while that of the pass-through to imports is the highest with roughly 60%. Conversely, Aron *et al.* (2014) examine the ERPT to monthly import price index in South Africa during the period 1980-2009. Using Johansen's procedures, which controls for domestic and foreign costs, the result suggests an incomplete pass-through with slower pass-through during inflation targeting. Adding to the ERPT literature for the case of South Africa, Mjanja (2018) found on the basis of panel techniques that the pass-through in South Africa is comparable to the pass-through experience of emerging market and developing economies.

Conclusively, following the above literature we have reviewed, it is pertinent to state that even though the existing literature on ERPT is significantly large, most of the studies focused on examining the ERPT without considering the effects of structural breaks in both the short run and long run. More so, the fact that these countries are inflation targetters, the knowledge of the short-run and long-run pass-through coefficients could inform the monetary authorities of the stickiness of price which is essential for the conduct of monetary policy.

2.3 Data and Methodology

2.3.1 Data Description

This study uses quarterly frequency data from 1986Q1 to 2016Q4 for Nigeria and South Africa. The choice of the period selected is informed by the rapid movements undertaken by the Central Bank of Nigeria and South African Reserve Bank to allow the exchange rate and trade policy to be guided by market-oriented principles and the inflation targeting monetary policy introduced in 2007 for Nigeria and 2000 for South Africa. These make the study of the ERPT more interesting in these countries. The economic variables used for the study consumer prices, exchange rate, output, and energy. Following Ghosh and Rajan (2009) and Balcilar and Usman (2018), an exchange rate is measured as the nominal effective exchange rate (NEER)[3] for two major reasons. First, NEER is a wider measurement of the exchange rate, and second, it tends to produce a robust result because of its variations. The output is measured as gross domestic product (GDP) (constant 2010 US$) and energy prices is measured by the international Brent crude oil spot price in US$ per barrel. The CPI and GDP series

[3] The NEER is defined as the value of a basket of foreign currencies per unit of domestic currency, hence its increase represents appreciation.

are seasonally adjusted. The quarterly frequency data for CPI and NEER are obtained from the database of the International Financial Statistics (IFS). The annual data for GDP is obtained from the World Bank – World Development Indicators (WDI) and then converted to quarterly frequency data by the use of linear interpolation since the variable is not available on a quarterly basis. The quarterly data on Brent crude oil spot price is obtained from the Datastream database. All the variables are expressed in natural logarithms.

2.3.2 Unit Root Test

To check the integrating properties of the variables, we apply a unit root test developed by Zivot and Andrews (1992) which allows for the possibility of a single structural break. The test is performed based on the following model specifications: Model 1 includes a break only in the intercept, Model 2 includes a break only in the trend, and Model 3 includes a break in both intercept and trend. This test has a null hypothesis of a unit root in the presence of a single structural break. The Zivot and Andrews unit root test has 15% trimming region from both ends of the sample.

2.3.3 Maki Cointegration Tests with Multiple Structural Breaks

As widely documented in the econometrics literature, the economic and financial series usually exhibit structural breaks over time. This may render the results of the standard or conventional cointegration tests such as Engle and Granger (1987), Johansen (1988) unreliable and misleading (See Gregory *et al.* 1996; Gregory and Hansen.1996). Therefore, in this article, we address this problem by making use of the Maki cointegration tests with multiple breaks, which provides efficient and robust procedures for testing the long-run relations between the variables in the presence of structural breaks. To perform this cointegration test, four regression models proposed by Maki (2012) with all the variables integrated of order one, I(1), are:

Model 1: $$Z_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' y_t + v_t \quad (3)$$

Model 2: $$Z_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' y_t + \sum_{i=1}^{k} \beta_i y_t D_{i,t} + v_t \quad (4)$$

Model 3: $$Z_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \beta' y_t + \sum_{i=1}^{k} \beta_i y_t D_{i,t} + v_t \quad (5)$$

Model 3: $$Z_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t D_{i,t} + \beta' y_t + \sum_{i=1}^{k} \beta_i y_t D_{i,t} + v_t \quad (6)$$

Where $D_{i,t}$ is the dummy variable, $D_{i,t} = 1$ if $t > T_{Bi}$, and 0 if otherwise. T_{Bi} represents the breakpoints in the series over the time. v_t denotes error term. The null hypothesis of no cointegration is tested against the alternative hypothesis of cointegration among the variables. Eq. 3 indicates a model with the level shifts i.e. break in intercept and no trend. Eq. 4 shows a model with regime-shifts i.e. with a break in intercept and coefficients but no trend. Eq. 5 includes a trend in addition to Eq. 4, that is, a model with a break in intercept and coefficients, and with a trend. Finally, Eq. 6 includes a model with a break in intercept, coefficient, and trend.

2.3.4 Model Specification

The short-run and long-run estimates are obtained using a dynamic unrestricted error correction model (UECM), which is derived from the Autoregressive Distributed Lag (ARDL) approach proposed by Pesaran *et al.* (2001). The ARDL model is given as:

$$\mathrm{lncpi}_t = \gamma_0 + \sum_{i=1}^{q} \gamma_i \,\mathrm{lncpi}_{t-i} + \sum_{i=0}^{k_1} \lambda_{1,i}\,\mathrm{lnneer}_{t-i} + \sum_{i=0}^{k_2} \lambda_{2,i}\,\mathrm{lngdp}_{t-i} + \sum_{i=0}^{k_3} \lambda_{3,i}\,\mathrm{lnoilpr}_{t-i} + \varepsilon_t \qquad (7)$$

where lncpi, lnneer, lngdp, and lnoilpr are the natural logarithm of CPI, nominal effective exchange rate, output represented by the GDP, and energy prices captured by the oil price. ε_t denotes zero mean white noise process with variance σ^2, $\varepsilon_t \sim \mathrm{iid}(0, \sigma^2)$. If lncpi, lnneer, lngenp, and lnoilpr are cointegrated they maintain a levels relationship specified with long-run parameters. In this case, they can be represented with an error-correction model (ECM). The long-run parameters can be obtained by estimating the following regression:

$$\mathrm{lncpi}_t = \psi_0 + \psi_1 \mathrm{lnneer}_t + \psi_2 \mathrm{lngdp}_t + \psi_3 \mathrm{lnoilpr}_t + \sum_{i=1}^{q} \phi_i \,\Delta\mathrm{lncpi}_{t-i} + \sum_{i=1}^{k_1-1} \alpha_{1,i}\,\Delta\mathrm{lnneer}_{t-i} + \sum_{i=1}^{k_2-1} \alpha_{2,i}\,\Delta\mathrm{lngdp}_{t-i} + \sum_{i=1}^{k_3-1} \alpha_{3,i}\,\Delta\mathrm{lnoilpr}_{t-i} + \varepsilon_t \qquad (8)$$

where Δ is the first difference operator defined generically as $\Delta x_t = x_t - x_{t-1}$. The long-run coefficients can be obtained as $\beta_i = \psi_i / (1 - \sum_{j=1}^{q} \phi_j)$, $i = 1,2,3$. As all variables are in the natural logarithms the long-run parameters are equal to long-run elasticities. The usual error-correction (EC) term can be obtained as $ec_t = \mathrm{lncpi}_t - \beta_1 \mathrm{lnneer}_t - \beta_2 \mathrm{lngdp}_t - \beta_3 \mathrm{lnoilpr}_t$. The parameters β_1, β_2, and β_3 are the long-run estimates of the ERPT, long-run output effect, and long-run oil price effect on CPI. Furthermore, the PPP doctrine reviewed in Section 2 of this paper assumes that the ERPT to prices is usually complete especially in the long run, implying that $\beta_1 = -1$. As shown by the previous studies, the prices may not adjust immediately to the long run equilibrium path if there is a change in the exchange rate as well as other variables that determine prices. Therefore, to capture the adjustment speed of the reversion from short run to long run equilibrium, we use the following conditional ECM:

$$\begin{aligned} \Delta \mathrm{lncpi}_t = \mu + \sum_{i=1}^{q} \rho_i \, \Delta \mathrm{lncpi}_{t-i} + \sum_{i=0}^{k_1} \theta_{1,i} \, \Delta \mathrm{lnneer}_{t-i} + \sum_{i=0}^{k_2} \theta_{2,i} \, \Delta \mathrm{lngdp}_{t-i} \\ + \sum_{i=0}^{k_3} \theta_{3,i} \, \Delta \mathrm{lnoilpr}_{t-1} + \delta \mathrm{ec}_{t-1} + \varepsilon_t \end{aligned} \quad (9)$$

where ec_t is the error correction term, obtained from the Eq. 9 and δ is the coefficient that measures the speed of adjustment to the equilibrium. The parameters ρ_i, $\theta_{1,i}$, $\theta_{2,i}$, and $\theta_{3,i}$ are the short-run coefficients representing the inflation inertia, short-run ERPT, short-run output effect, and short-run oil price effect, respectively. For the short-run ERPT, we only consider the effect of the first period.

We identify the structural breakpoints using approach of Maki (2012) and perform cointegration tests in Table 6 through the dummy variables in order to assess their long-run effects on price determination. To determine the whether the pass-through is complete or incomplete; we conduct a Wald test (coefficient restrictions) with a null hypothesis $\theta_{1,0} = -1$ in the short run and $\beta_1 = -1$ in the long run. If the calculated Wald test value exceeds the critical value, determined by *F*-statistic or *t*-statistic, the null hypothesis of complete pass-through will, therefore, be rejected. The rejection of the null hypothesis simply implies that the pass-through is partial or incomplete.

2.4 Empirical Results and Discussion

2.4.1 Visual Properties of the Data

The first step in this section is to examine the visual properties of the time series by determining the time plots of the macroeconomic variables in the model estimation for the possible existence of drift, trend, seasonality and structural breaks. The time plots of the variables as reported in Figures 1 and 2, suggest sudden breaks in each of the variables. These breaks are more conspicuous in NEER and oil price. The major reason for the breaks is the adoption of the market-based policies and the various interventions by the government to stabilize domestic currency (Ojo, 2003).

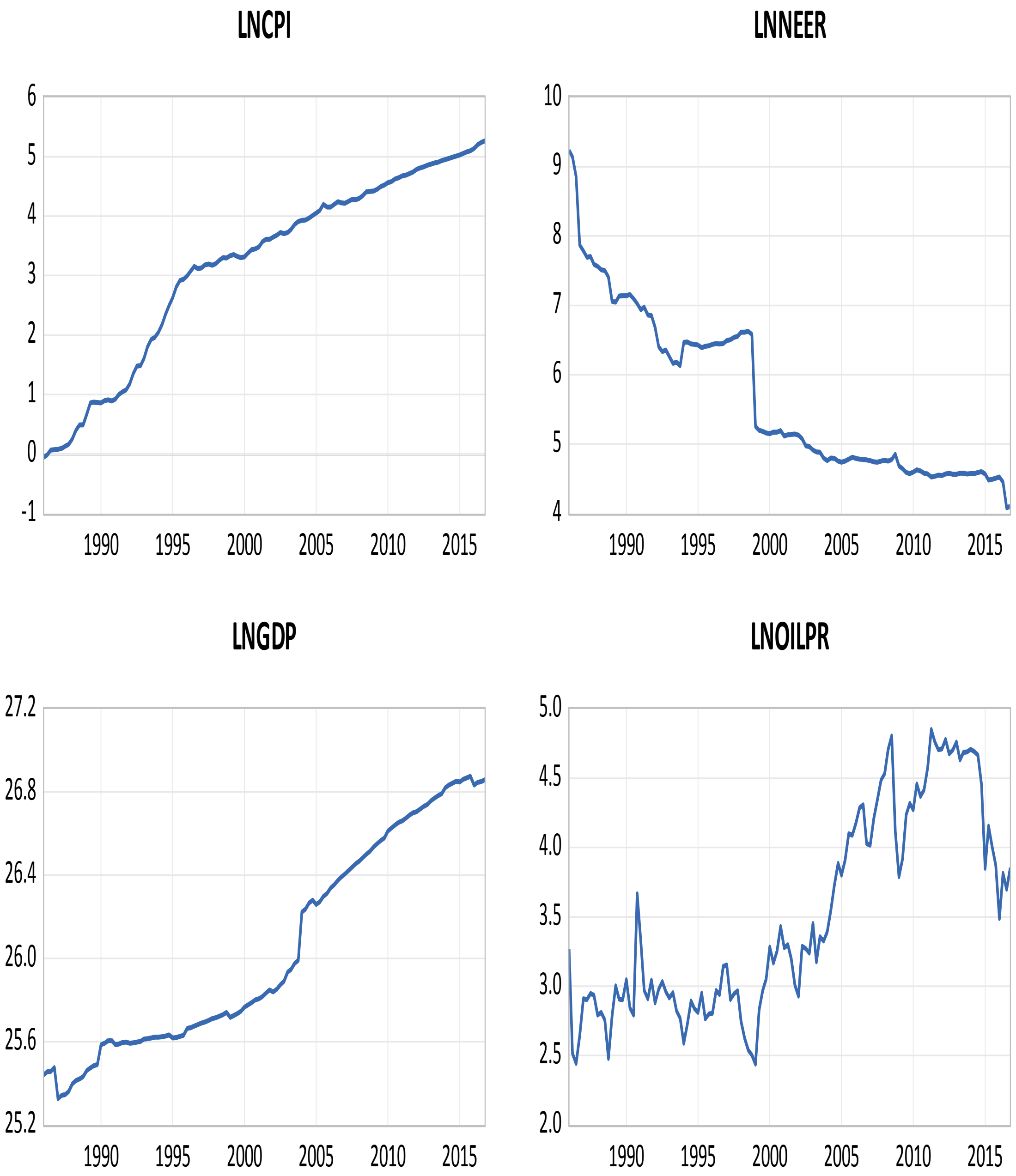

Figure 1: Time series plots of the CPI, NEER, GDP and crude oil price series (in logs) for Nigeria

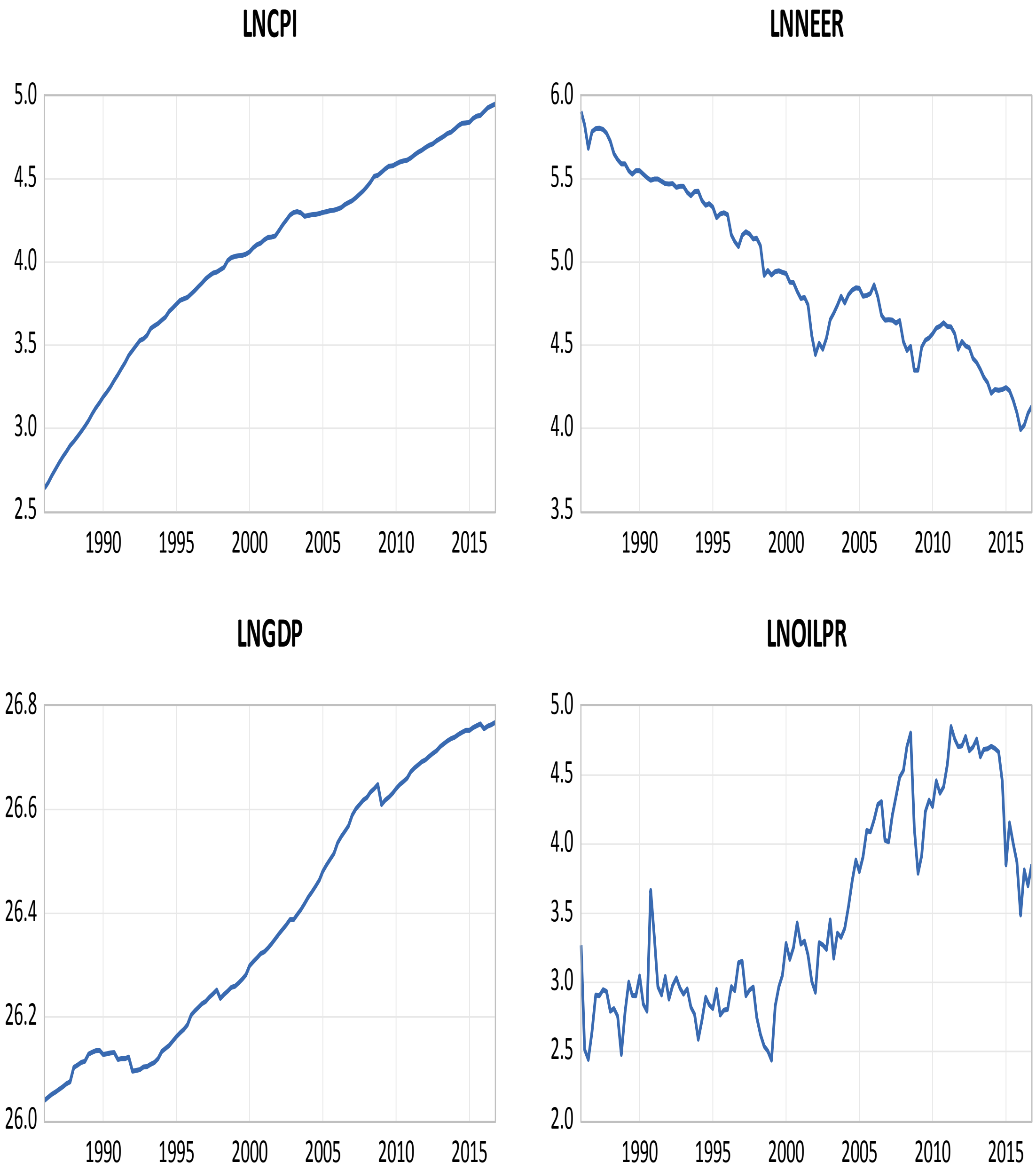

Figure 2: Time series plots of the CPI, NEER, GDP and crude oil price series (in logs) for South Africa

2.4.2 Results of Unit Root Test

Table 1 shows the result of Zivot-Andrews unit root test, which accommodates one structural breakpoint. The result indicates that the natural logarithms of CPI, NEER, GDP and oil price (OILPR) are not stationary in their levels. These variables are all stationary after their first differences have been taken, i.e. the null hypothesis of unit root with one structural break is not rejected. The nonrejection of the null hypothesis implies that the variables are integrated of order one, I(1).

2.4.3 Results of Cointegration Tests

Table 2 presents the results of the cointegration tests proposed by Maki (2012) with multiple structural breaks estimated using the GAUSS software.[4] This test determines whether there exists a cointegrating vector based on Eq. 6. The result of the test shows that at 1% level of significance, the null hypothesis of no cointegration is rejected in all the cointegrating models for Nigeria while for South Africa, all models are statistically significant except Model 2, which includes a break in intercept and coefficients and no trend. In general, our results shows cointegration for Nigeria all four cases and cointegration for South Africa for three cases. This, therefore, confirms that long-run relationship is present among inflation, NEER, output growth and oil price for Nigeria and South Africa in the presence of structural breaks. The structural breaks identified in the model with regime shifts and trend (Model 4) for Nigeria are 1987Q2, 1990Q3, 1992Q2, 1994Q1, and 1998Q4 while for South Africa are 1993Q4, 2002Q1; 2003Q3, 2005Q3, and 2008Q for South Africa. The breakpoints in Nigeria are attributed to the effects of structural adjustment program as well as other policies introduced by the government such as the rolling window plans of early 1990s to stabilize the value of Naira. For South Africa, the break points can be attributed mainly to political stability after the first multiracial democratic elections in 1994. Furthermore, the robustness of the results of the cointegration test by Maki (2012) is checked by applying the ARDL bounds testing approach by Pesaran *et al.* (2001). The

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[4] The results of the Maki cointegration tests reported in this paper are from Model 4. A comprehensive result will be made available upon request from the authors.

result as reported in Table 3 shows that the test statistic exceeds the critical value at 5% level of significance for the two countries. This confirms that the earlier result is robust and consistent.

Table 1: Results of Zivot-Andrews Unit Root Test

	Zivot-Andrews Test at Level			Zivot-Andrews Test at First Difference			
Variable	Model A	Model B	Model C	Model A	Model A	Model A	Order of Integration
Nigeria							
LNCPI	-3.775	-3.025	-3.611	-8.917***	-6.783***	-7.766***	I(1)
Breakpoint	2003:Q2	2005:Q2	2006:Q4	2005:Q4	2014:Q1	2005:Q4	
Lag length	(1)	(2)	(1)	(1)	(2)	(2)	
LNNEER	-3.673	-3.963	-4.159	-6.496***	-6.334***	-5.631***	I(1)
Breakpoint	2014:Q1	2013:Q4	2009:Q2	2005:Q4	2013:Q4	2007Q3	
Lag length	(1)	(2)	(1)	(2)	(2)	(1)	
LNGDP	-3.525	-3.396	-4.402	-8.487***	-8.224***	-6.052***	I(1)
Breakpoint	2004:Q1	2007:Q3	2004:Q1	2003:Q1	2004:Q2	2005:Q1	
Lag length	(1)	(4)	(1)	(1)	(1)	(4)	
LNGDP	-2.604	-3.537	-3.578	-8.971***	-8.859***	-8.996***	I(1)
Breakpoint	2014:Q1	2012:Q4	2011:Q1	2004:Q1	2011:Q2	2010:Q1	
Lag length	(1)	(2)	(1)	(2)	(2)	(1)	
Critical values							
1 Percent	-5.34	-4.80	-5.57	-5.34	-4.80	-5.57	
5 Percent	-4.93	-4.42	-5.08	-4.93	-4.42	-5.08	
10 Percent	-4.58	-4.11	-4.82	-4.58	-4.11	-4.82	

	Zivot-Andrews Test at Level			Zivot-Andrews Test at First Difference			
Variable	Model A	Model B	Model C	Model A	Model A	Model A	Order of Cointegration
South Africa							
LNCPI	-3.758	-3.986	-4.667	-6.885***	-6.729***	-6.792***	I (1)
Breakpoint	2003:Q1	1991:Q4	2003:Q3	2006:Q3	2003:Q4	2006:Q3	
Lag length	(1)	(3)	(4)	(4)	(2)	(1)	
LNNEER	-4.169	-3.477	-4.329	-9.677***	-5.599***	-8.836***	I (1)
Breakpoint	2006:Q3	2001:Q1	2003:Q1	2002:Q2	2003:Q4	2002:Q2	
Lag length	(4)	(2)	(1)	(4)	(2)	(1)	
LNGDP	-3.800	-2.600	-3.163	-5.788***	-5.633***	-5.239***	I (1)
Breakpoint	2004:Q1	1991:Q3	2009Q:2	2008:Q2	2005:Q4	1992:Q2	
Lag length	(4)	(2)	(2)	(2)	(4)	(4)	
LNOILPR	-2.604	-3.537	-3.578	-8.971***	-8.859***	-8.996***	I (1)
Breakpoint	2014:Q1	2012:Q4	2011:Q1	2004:Q1	2011:Q2	2010:Q1	
Lag length	(1)	(2)	(1)	(2)	(2)	(1)	
Critical values							
1 Percent	-5.34	-4.80	-5.57	-5.34	-4.80	-5.57	
5 Percent	-4.93	-4.42	-5.08	-4.93	-4.42	-5.08	
10 Percent	-4.58	-4.11	-4.82	-4.58	-4.11	-4.82	

Notes: ***, ** and * denote that the null hypothesis is rejected at the 1% level. Model A is a model with intercept, Model B is a model with trend and Model C is a model with intercept and trend.

Table 2: The Results of Maki Cointegration Tests

Models	Test Statistics (Critical Values)	Breakpoints
Nigeria		
Model with Level Shifts (Model 1)	-11.331*** (-6.555; -6.038; -5.773)	1998Q4; 2001Q1; 2002Q4; 2004Q3; 2015Q2
Model with Level Shifts and Trend (Model 2)	-9.488*** (-6.784; -6.250; -5.976)	2006Q1; 2008Q4; 2011Q1; 2013Q1; 2015Q2
Model with Regime Shifts (Model 3)	-10.866*** (-8.673; -8.110; -7.796)	1991Q4; 2004Q1; 2005Q3; 2007Q1; 2009Q1
Model with Regime Shifts and Trend (Model 4)	-10.866*** (-8.673; -8.110; -7.796)	1987Q2; 1990Q3; 1992Q2; 1994Q1; 1998Q4
South Africa		
Model with Level Shifts (Model 1)	-6.117** (-6.555; -6.038; -5.773)	1989Q4; 1991Q4; 1994Q3; 2005Q4; 2009Q1
Model with Level Shifts and Trend (Model 2)	-5.611 (-6.555; -6.038; -5.773)	1988Q4; 1991Q3; 1993Q3; 2011Q3; 2013Q3
Model with Regime Shifts (Model 3)	-7.913* (-8.673; -8.110; -7.796)	1989Q3; 1991Q4; 1993Q3; 2003Q1; 2009Q1
Model with Regime Shifts and Trend (Model 4)	-8.601* (-9.428; -8.800; -8.508)	1993Q4; 2002Q1; 2003Q3; 2005Q3; 2008Q2

Notes: The numbers in the parentheses are the critical values at 1%, 5% and 10% as provided in Table 1 of Maki (2012). ***, **, and * indicate that the test statistic value lies above the Maki’s critical value at 1%, 5%, and 10% significance level, respectively, with the trimming parameter of 0.05.

Table 3: Results of Cointegration using Bounds Testing Approach

Countries	F-Statistic	5% Lower Bound	5% Upper Bound	Conclusion
Nigeria	5.202**	3.23	4.35	Cointegrated
South Africa	5.637**	3.23	4.35	Cointegrated

Notes: ** denotes that the null hypothesis of no cointegration is rejected at 5% level of significance for Nigeria and South Africa, and the critical value is determined where $k = 3$ independent variables with unrestricted intercept and no trend. The maximum lag order is 4 and optimal lag order is selected by the Akaike Information Criterion (AIC), which is 3 for Nigeria and 2 for South Africa.

2.4.4 Results of the ARDL for Long-run and Short-run Coefficients

The long- and short-run analyses of the ERPT are reported in Table 4 and Table 5 for Nigeria and South Africa after cointegration evidence has been established. As specified by economic theory, an increase in the NEER (appreciation) implies that exports turn out to be more expensive and imports relatively cheaper, resulting in the loss of trade competitiveness by domestic country. In this context, an increase in the NEER simply signifies appreciation of domestic currency and a fall in the NEER implies a depreciation of domestic currency. Therefore, from the empirical results, the coefficient of the NEER in the long-run for Nigeria (See Table 4) is negative, almost unit inelastic and statistically significant at 1% significance level ($\beta_1 = -0.950, p < 0.01$). This means that a 1% appreciation in the NEER causes inflation to decrease by approximately 0.95%. However, the coefficient of the NEER in the long-run for South Africa (See Table 5) is negative, inelastic, and statistically significant at 1% ($\beta_1 = -0.633, p < 0.01$). By implication, a 1% appreciation in the NEER would lead to 0.63% decrease in inflation. Furthermore, to determine whether the pass-through is complete or not, we apply a WALD test (coefficient restrictions) with the null hypothesis of complete pass-through, i.e. $\beta_1 = -1$. The result for Nigeria indicates that an *F*-statistic of 0.035 and *t*-statistic of 0.188 both do not reject the null hypothesis of complete pass-through even at 10% level of significance. Similarly, for South Africa, an *F*-statistic is 4.798 and the *t*-statistic is -2.190. These values reject the null hypothesis of complete pass-through at the 5% level. The nonrejection of the null hypothesis in the two test statistics implies a strong evidence that the ERPT in the long-run is complete for Nigeria, while rejection implies that is long-run ERPT is incomplete for South Africa. In other words, prices are stickier in South Africa compared to Nigeria. The deviations from the long-run equilibrium of the ERPT is revised by the speed of about 11.9% and 1.2% quarterly for Nigeria and South Africa, respectively. This finding remarkably conforms the finding that prices are quite stick in South Africa. Overall, the long-run estimates indicate that the monetary authority credibility and inflation targeting reduce ERPT by establishing strong nominal anchors. Thus, our results are complimentary to the results of Dovern *et al*. (2012), Aleem and Lahiani (2014), Carrière-Swallow *et al*. (2016), Dube (2016), and Kabundi and Mlachila (2018).

The finding for Nigeria is in contrast with the recent study by Bada *et al.* (2016) who report that the long-run pass-through elasticities from the baseline and alternative models are 0.24% and 0.30% respectively in Nigeria. Our findings also fail to align with Omisakin (2009) and Lariau *et al.* (2016) who all claim that there is no evidence of pass-through in the long run for Nigeria. More importantly, our results on South Africa confirm the proposition that the size of the pass-through has significantly declined along the price chains as suggested by Ocran (2010), Jooste and Jhaveri (2014), Dube (2016), and Kabundi and Mlachila (2018) for South Africa in the long run.

The empirical findings in the long run also show that output growth measure and oil price account significantly for the inflation in Nigeria. A 1% increase in output growth causes inflation to increase by approximately 1.09% and a 1% increase in oil price reduces inflation by 0.84%. Whereas in South Africa, there is no significant evidence to support that a change in output growth and oil price would lead to a change in inflation in the long run. Therefore, this finding suggests that, while other factors remain constant, exchange rate is the major source of inflation in South Africa in the long run. The finding for Nigeria echoes the result of Baharumshah *et al.* (2017a) that a 10% increase in output growth leads to 18% increase in the inflation for Sudan. Furthermore, the result of oil price for Nigeria concurs with the previous studies by Aliyu *et al.* (2009) and Bada *et al.* (2016). They both report that in the long-run oil price negatively affect domestic prices in Nigeria, while in the case of South Africa the result is consistent with Baharumshah *et al.* (2017a) who find that oil price shocks are insignificant in explaining the variations in inflation for Sudan. This finding contradicts Balcilar *et al.* (2017) that oil price has influence on the real output of South Africa being a net oil importer.

Table 4: Long-run and Short-run Coefficients for Nigeria

Dependent Variable = $\Delta lncpi_t$				
	Variables	Coefficient	t-Statistic	*p*-value
	Constant	0.306***	5.839	0.000
	$\Delta lncpi_{t-1}$	0.260***	3.328	0.001
	$\Delta lncpi_{t-2}$	-0.338***	-4.484	0.000
	$\Delta lnneer_t$	-0.182***	-6.605	0.000
	$\Delta lnneer_{t-1}$	-0.008	-0.397	0.692
	$\Delta lnneer_{t-2}$	0.049**	2.422	0.017
	$\Delta lngdp_t$	-0.157	-1.358	0.178
	$\Delta lngdp_{t-1}$	-0.191*	-1.709	0.091
	$\Delta lngdp_{t-2}$	-0.080	-0.752	0.454
	$\Delta lnoilpr_t$	-0.023	-1.347	0.181
	$\Delta lnoilpr_{t-1}$	-0.026	-1.598	0.113
	$\Delta lnoilpr_{t-2}$	-0.025	-1.568	0.120
	ngd1	0.030	0.945	0.347
	ngd2	-0.054***	-3.253	0.002
	ngd3	0.026	1.369	0.174
	ngd4	0.144***	5.196	0.000
	ngd5	-0.222***	-8.173	0.000
	ec_{t-1}	-0.119***	-7.695	0.000
Long-run Parameters				
	Lneer	-0.950***	-3.558	0.001
	Lngdp	1.086*	1.848	0.068
	Lnoilpr	-0.838**	-2.619	0.010
Residual Diagnostics		**Statistic**	***p*-value**	
ARCH Test Heteroscedastic [1]		1.707	0.194	
B-G Serial LM Test [7]		1.762	0.107	
Ramsey RESET Test [1]		1.541	0.127	
Jarque-Bera Normality Test		22.936	0.000	

Note: ***, ** and * denote significance at 1%, 5%, and 10% significance level, respectively.

Finally, the result of the dummy variables included in the long-run estimations to capture the effects of structural breaks on inflation indicates that for Nigeria the coefficient of ngd4 is positive and statistically significant at 5% level, ngd2 and ngd5 are negative and statistically significant at 5%, while ngd1 and ngd2 are positive and statistically insignificant. This implies that both the shocks – both positive and negative ones have effects on inflation in Nigeria. For South Africa, the coefficients of these dummies are statistically insignificant for sad1 and sad5, while significant at 5% level and positive for sad2 and sad4, and negative for sad3.

Table 5: Long-run and Short-run Coefficients for South Africa

Dependent Variable = $\Delta lncpi_t$				
	Variables	Coefficient	t-Statistic	P-value
	Constant	-0.188**	-2.308	0.023
	$\Delta lncpi_{t-1}$	0.276***	3.330	0.001
	$\Delta lnneer_t$	-0.049***	-3.756	0.000
	$\Delta lnneer_{t-1}$	-0.032**	-2.594	0.011
	$\Delta lngdp_t$	-0.151	-1.617	0.109
	$\Delta lngdp_{t-1}$	-0.157	-1.564	0.121
	$\Delta lnoilpr_t$	0.014***	4.079	0.000
	$\Delta lnoilpr_{t-1}$	0.000	-0.075	0.940
	sad1	-0.004	-1.035	0.303
	sad2	0.011***	3.445	0.001
	sad3	-0.017***	-4.167	0.000
	sad4	0.007**	2.190	0.031
	sad5	0.002	0.645	0.520
	ec_{t-1}	-0.012**	-2.566	0.012
Long-run Parameters				
	Lneer	-0.633***	-3.774	0.000
	Lngdp	-0.207	-0.366	0.715
	Lnoilpr	0.215	1.482	0.141
Residual Diagnostics		**Statistic**	**P-value**	
ARCH Test Heteroscedasticity [1]		0.728	0.395	
B-G Serial LM Test [7]		0.412	0.663	
Ramsey RESET Test [1]		1.404	0.163	
Jarque-Bera Normality Test		2.380	0.304	

Note: ***, ** and * denote significance at 1%, 5%, and 10% significance level, respectively.

The results of the residual-based diagnostic tests show that the null hypothesis of ARCH conditional heteroscedasticity test at [1] lag and Breusch-Godfrey LM test for serial correlation at lag [7] and [2] for Nigeria and South Africa cannot be rejected. This implies that the models we have estimated have no conditional heteroscedasticity and serial correlation problems. To test for the normal distribution of the series, we apply the Jarque-Bera test. The result shows that the null hypothesis of a normal distribution is rejected for Nigeria while for South Africa the null hypothesis cannot be rejected. Finally, the functional form of the model is checked using the Ramsey RESET test at lag [1] for both countries. The result, therefore, fails to reject the null hypothesis, which implies stability of our models.

Tables 4 and Table 5 report the results of the short-run analysis of the ERPT. The result for Nigeria shows that the coefficient of the NEER is negative, inelastic and statistically significant at 1% significance level ($\theta_{1,0} = -0.182, p < 0.01$). This implies that a 1% appreciation in the NEER would lead to approximately 0.18% decrease in inflation in the short-run. For South Africa, the coefficient of the NEER is inelastic, negative and statistically significant, easily passing a significance test at 1% significance level ($\theta_{1,0} = -0.049, p < 0.01$). This result implies that a 1% appreciation in the NEER would lead to 0.05% decrease in inflation in the short-run. Therefore, to test whether the pass-through in the short-run is complete or incomplete, we use a WALD statistic with the null hypothesis $\theta_{1,0} = -1$. The result for Nigeria indicates that the *F*-statistic is 1382.608 and *t*-statistic is 37.183. For South Africa, the *F*-statistic is 6619.452 and *t*-statistic is 81.360. These results unequivocally reject the null hypothesis of complete short-run pass-through at 1% level of significance. In other words, our finding provides strong evidence that the ERPT in the short-run is incomplete for both Nigeria and South Africa. However, the size and magnitude of the pass-through is 3.7 times higher in Nigeria compared to South Africa. For this reason, the results concur with the existing studies such as Essien (2005) and Adeyemi and Samuel (2013) for Nigeria and Ocran (2010) and Aron *et al.* (2014) for South Africa who submit that the pass-through in the short-run is incomplete. Therefore, our results concur with Devereux and Yetman (2010) who linked the short-term low pass-through to rigidity in price. More so, studies such as Taylor (2000), Bailliu and Fujii (2004), Junttila and Korhonen (2012), Aron *et al.* (2014) also attribute the declining pass-through along the price chains to persistent and low inflation environment.

Furthermore, our short-run empirical results reveal that, while the coefficient of output growth is negative and significantly affecting inflation, the effect of oil price movements on inflation is negative and statistically insignificant for Nigeria. In particular, a 1% increase in output growth decreases inflation by 0.191%, implying an anti-inflationary output growth, and a 1% increase in oil price decreases inflation by 0.023%–but statistically insignificant. However, in South Africa, a 1% increase in output growth reduces inflation by 0.151%, implying an anti-inflationary output growth. However, this effect is not statistically significant. Our results also indicate that the effect of oil price on inflation is positive–a 1% increase in oil price transmits a 0.014% inflation. Comparing with the previous findings, our result on the relationship between inflation and output growth disagrees with Baharumshah *et al.* (2017a) who report that output growth is attributed to Sudanese high inflation. In the case of oil price, the result for South Africa is consistent with Ajmi *et al.* (2015) who find no cointegration between oil price and price level in South Africa but report further that a positive and negative oil price shock leads to positive price level shock with negative shock having a stronger impact.

2.5 Concluding Remarks and Policy Implications

In this paper, ERPT to inflation is revisited for Nigeria and South Africa over the period 1986Q1 to 2016Q4. In order to suppress the problem of low predicting power of the unit root test in the presence of structural breaks, we applied the Zivot-Andrews nonstationarity test. The results of the test showed that all the variables are integrated of order one, I(1). We proceeded to establish a cointegration among variables using the recently proposed cointegration test by Maki (2012), which considers multiple structural breaks. This result revealed the existence of valid long-run interactions among the variables. The robustness of this result is checked through the bounds testing approach.

Therefore, the empirical results find that the long-run pass-through is complete in Nigeria while it is incomplete in South Africa. On the basis of the short run, we find a result of incomplete ERPT in both countries. In overall, these results indicate that prices are much stickier in South Africa than in Nigeria. More so, while an increase in output growth increases inflation for Nigeria in long run, we find that the contribution of output growth to inflation in South African economy is insignificant. More so, an increase in oil price accounts for a decline in inflation in Nigeria in the long run, but in South Africa, the effect of oil price is positive and significant only in the short run. Another interesting result found is that the structural breaks identified for the countries have significant effects in both countries. Additionally, the deviation from the long-run equilibrium is reversed back more quickly in Nigeria than in South Africa. Our results indicate that credible monetary policy framework and inflation targeting reduces ERPT by creating nominal anchors for inflation expectations and interest rate, which is confirmed by the much lower ERPT finding for South Africa both in the short run and long run.

Based on these findings, to reduce the ERPT to inflation in Nigeria and South Africa, we suggest the need for the governments and policymakers to pursue policies that will boost domestic production of goods and services and lessen the rate of imports in these countries. To this end, supply-side policies that promote competitions and efficiency such as deregulation and privatization, low-income tax rate to enhance heavy investments as well as education and training to improve skills and labor productivity are required. Furthermore, we suggest the intervention of the government especially in more critical areas to overcome market failure. These policies would strengthen domestic currency and reduce the effect of exchange rate shocks on domestic prices. By implication, the government goal of a single-digit price and its stability as well as correcting the current account path would be achieved. For Nigeria, the commitment of the CBN to inflation targeting and improvements in the credibility of the monetary policy framework will help reduce the ERPT.

Chapter 3

TESTING THE ASYMMETRIC EFFECTS OF EXCHANGE RATE AND OIL PRICE PASS-THROUGH IN BRICS COUNTRIES: DOES THE STATE OF THE ECONOMY MATTER?

3.1 Introduction

One of the central issues within the framework of the new open economy macroeconomic models is the pass-through of exchange rate and oil price. This is largely rekindled by two main factors: firstly, the persistent and high volatilities in terms of exchange rates between countries following the collapse of the Bretton Wood's system of adjustable peg in the 1970s and secondly, the severe impact of oil shocks, resulting from the perpetual crisis that has been erupting the Middle East since 1970s. Essentially, these factors have demonstrated an increased risk of achieving the monetary policy goal of price stability, especially in the developing and emerging markets economies during the periods of greater economic liberalization policies. (See McCarthy 2000; Compa *et al.* 2004; Gagnon and Ihrig 2004; Usman and Musa 2018).

There has been flourishing empirical literature on exchange rate and oil price pass-through (EROPPT) over the years and a great deal of it seeks to estimate the EROPPT to inflation using the linear models. The outcomes of the studies almost entirely suggest that the pass-through is incomplete and as such dampening along the price chains. In other words, the responsiveness of prices to exchange rate and oil price variations is not full or complete, particularly in the short to medium term. The major explanations given in the literature include the presence of the menu cost adjustment price, pricing-to-market, trade hysteresis, degree of market competition, and the stance of monetary policy (See Taylor 2000; Choudhri and Hakura 2003; Bailliu and Fujii 2004; Ihrig *et al.* 2006; Atkeson and Burstein 2008; Junttila and Korhonen 2012; Kilic 2016).

Even though the literature on pass-through has increased particularly in the new millennium, many studies assume that the direction and the size of the shocks in exchange rate and oil price do not matter for pass-through. However, this assumption has been challenged by the recent literature that domestic prices may possibly react asymmetrically to the shocks in exchange rate and oil price especially when domestic prices are strictly downward sloping and quantities are upward sloping (Delatte and Lopez-Villavicencio 2012; Baharumshah *et al.* 2017a; Usman and Elsalih 2018). The objective of this paper is to investigate not only the question of whether there is evidence of nonlinear EROPPT in the bloc of Brazil, Russia, India, China and South Africa (henceforth BRICS Countries). If the EROPPT is nonlinear, not only the pass through is asymmetric but also the sign and size of the shocks matter. The choice of the BRICS countries is motivated by large changes in exchange rates and trade policies towards market-based economic policies. These changes, however, demonstrate a significant increase in the share of BRICS countries to the total volume of the world trade. As shown by Enerdata (2015), the total share of BRICS in the total volume of world trade is USD 7.7 trillion, which accounts for about 18%. This statistic is about 70.5% higher than the total of USD 4.4 trillion in 2008. The worrisome implication of the increase in trade when exchange rate is allowed to float freely is the exposure of these economies to the effects of exchange rate and oil price volatilities. Therefore, investigating the dynamics of pass-through of exchange rate and oil price are essential for the proper management of macroeconomic policies and a sound understanding of the process of price determination, which is a key issue in monetary policymaking.

Theoretically, the behaviours of the exporting firms are strategically guided by the market share objectives, which perhaps creates a difficult environment to fully pass-through the changes in exchange rate and oil price to domestic prices. If the size of the change in exchange rate and oil price is less than a certain threshold (small) and the changes in price are costly, the firms may prefer to absorb it and leave their prices unchanged, leading to zero pass-through. There are two main reasons to support this argument. First, it allows exporting firms to gain and maintain market share and secondly, the cost required to change prices (price adjustment cost or menu cost) exceeds the revenues that the exporting firms generate from price adjustment. Furthermore, if the size of the change in exchange rate is more than a certain threshold (large), the exporting firm would adjust their exporting price in such a way that their mark-ups will absorb a certain change and pass-through some change into export prices, leading to incomplete pass-through. Finally, if import prices are set in the currency of an exporting country, a small or large shock does not change the prices received by the domestic firms hence EROPPT is complete. Although if import price is set in the currency of an importing country, the pass-through tends to be stronger when the shock is somewhat large than when the shock is somewhat small (See Dornbusch 1987; Baldwin 1988; Pollard and Coughlin 2004).

While studies on the asymmetric exchange rate pass-through (ERPT) abound for developed and developing economies, there are only a small number of studies focusing on the responses of the prices to the change in exchange rate and oil price in different state or regime of the economy. Such regime dependent ERTP can be represented by a nonlinear model, such as the VSTAR. In a VSTAR model, responses are asymmetric, implying they are period specific (history matters) and both the sign and size of shocks alter responses. For example, Aron *et al*. (2014) analyze the ERPT to monthly price index in South Africa for the period of 1980-2009 and report that ERPT is higher during a small appreciation of rand. This result is contrary to Karoro *et al.* (2009) who find that the pass-through during a depreciation is higher than an appreciation in South Africa. Similarly, a study by Jooste and Jhaveri (2014) affirm that a decline in the pass-through in South Africa is attributed to a low and stable inflation environment. This group of findings in South Africa is congenial to Pollard and Coughlin (2004), Junttila and Korhonen (2012), Shintani *et al.* (2013), Ben Chiekh and Louhichi (2016), Kilic (2016), Jimenez-Rodriguez *et al.* (2016) and Soon *et al.* (2017). In China, Apergis (2015) finds asymmetric evidence of the ERPT to poverty with the period of depreciation of the Chinese currency having a stronger pass-through impact than when Chinese currency appreciates. In addition, Bouvet *et al.* (2017) find evidence that the pass-through of the exchange rate to Chinese exports is almostcomplete between 2000 and 2006 on the basis of firm-level data. In the case of Russia, Kataranova (2010) indicates that consumer prices react to the depreciation of home currency than appreciation. This finding is, however, contrary to Ponomarev *et al*. (2016) who show that the depreciation of domestic currency causes prices to rise but the appreciation of it does not lead to a fall in prices. In Brazil, Albuquerque and Portugal (2005) apply the time-varying parameters to investigate the ERPT to inflation during the period of 1980-2002. This finding discloses a significant reduction in the pass-through estimation during the era of post-floating of exchange rate. Similarly, Correa and Minella (2010) investigate on the basis of Phillips curve, whether the short run pass-through of exchange rate in Brazil is affected by the business cycle, exchange rate volatility and the direction of exchange rate. Among the findings discovered is that the short run pass-through is stronger during the periods of the high growth of the economy and low volatility of exchange rate. More so, Macera and Divino (2015) demonstrate that deterioration of trade following the long-run effect of the variable shocks during an appreciation of the exchange rate offset the effect of import tariffs in Brazil. Furthermore, in the case of India, Yanamandra (2015) provides that import prices at the aggregated level are slightly different with evidence of more than complete pass-through in the short run and even higher in the long run. This finding also shows evidence of nonlinearity in the ERPT in terms of the direction and the size of the changes in the exchange rate.

While there is a growing interest in the literature of oil price-inflation nexus, several studies abound for developed countries leaving a missing gap for the developing and emerging economies. Hooker (2002) using the framework of Phillips curve, discovers that oil price shock directly contributes to core inflation before 1980, and after which the pass-through becomes dampened and sometimes zero in the US. This decline is largely attributed to the proper implementation of monetary policy, flexible labor markets and lower intensity of energy use by the industries. De Gregorio *et al.* (2007) report that oil price pass-through (OPPT) to consumer prices for the sample of thirty-seven industrialized and emerging countries for the past thirty years has drastically reduced compared to the pass-through in the 1970s and 1980s. More so, Valcarcel and

Wohar (2013) find that the effect of oil prices on inflation and economic activity has dropped substantially in the advanced countries. On the contrary, Baharumshah *et al.* (2017b) show that the OPPT to domestic inflation is revived during the period of post-inflation in Mexico.

Furthermore, Asghar and Naveed (2015) examine the long-run OPPT to inflation in Pakistan and provide evidence of positive interaction between oil price and inflation as well as establish a one-way causality, running from oil prices to inflation and again from oil price to exchange rate. This finding is perhaps related to Sek (2017) who divulges that oil price is connected to high output growth in Malaysia through an increase in import and production prices. Therefore, a sector with high oil-intensiveness tends to experience a larger pass-through of oil prices. Furthermore, a study by Balcilar *et al.* (2017) reveal that real output growth under the low growth episode can be adequately predicted by the oil price shocks in South Africa business cycles; however low output growth episode is smaller compared to the high output growth episode. In the same development, Kpodar and Abdallah (2017) document that the positive shocks of oil price is more effective on retail gasoline prices in the 162 countries. Finally, Balcilar *et al.* (2018a) explicitly disclose that oil price and inflation are related, with the positive shock in oil price having a stronger effect on inflation compared to the negative shock of the same size. Balcilar and Usman (2018) examine both ERPT and OPPT for BRICS countries using Diebold and Yilmaz (2009) spillover index methodology. They find strong evidence of directional spillover in all the countries, but the results are somewhat heterogenous across the countries. Our study differs from Balcilar and Usman (2018) in two important ways. Balcilar and Usman (2018) use a linear VAR model and spillover indexes to asses ERPT and OPPT. Our study considers nonlinearity and focuses on state dependence. We also use bootstrap based impulse functions as the main analysis tool to assess the pass-through dynamics, which has advantages over the analysis based on asymptotic results.

Despite a burgeoned empirical evidence on pass-through, some numbers of issues remain contentious, such as whether the changes in policy directions of exchange rate and trade policy towards liberal economic policies exert pressure on the pass-through channels. In addition, the extant literature mostly focused on the pass-through of exchange rate changes to import prices, which is known as the first stage of pass-through. In testing for pass-through in this paper, our analysis switches from first stage pass-through to the second stage, which focuses on the pass-through to inflation following changes in exchange rate and oil price. Therefore, our study contributes to the existing literature based on the following aspects: First, we investigate whether there is evidence of nonlinearity in the EROPPT for the BRICS countries and further investigate whether the asymmetry of the shocks to exchange rate and oil price matter for EROPPT in these countries, an aspect that has received less attention in the literature. Second, our paper uses a country-specific analysis based on time series. Even though the BRICS countries are considered as a bloc of the fast-growing economic hub of the emerging markets in the past two decades (See IMF, 2011), it is obvious that the country-specific analysis will shed more light on the dynamics of asymmetric EROPPT and provide better outcomes due to the heterogeneous nature of pass-through estimates in these countries. Third, methodologically, the paper applies the VSTAR model, which allows for the smooth transition of the economy from one particular regime periods to another regime periods, governed by the selected transition variables. Fourth, for a better understanding of the dynamics of asymmetric

EROPPT, we explore a bootstrap approach where the generalized impulse responses based on history, shocks, and composition dependent are obtained with 1000 bootstrap repetitions since there is no clear-cut analytical formula to obtain the impulses of VSTAR models.

The main findings of this paper are as follows: there is evidence of period specific pass-through between the upper and lower regime periods, governed by the selected transition variables. The findings also suggest an asymmetric pass-through in all the countries with strong evidence of higher pass-through when the size of the shocks to the transition variable moves the system above a threshold level. The result further discloses that output growth asymmetrically reacts to the shocks. The implication of these findings is that the pass-through is strongly affected by the states of the economy.

The remainder of the paper is organized as follows: Section 3.2 discusses the data and the preliminary analysis of the data. Section 3.3 contains the discussion of the econometric methodologies explored. Section 3.4 discloses the results and discussions while section 3.5 makes conclusions of the paper.

3.2 Data and Preliminary Analysis

We use monthly frequency data for the BRICS countries in this paper. Specifically, the data for Brazil and India spans from 1986M01-2018M04, China and South Africa span from 1990M01-2018M04, and for Russia, the data ranges from 1995M01-2018M04. These periods selected for each country are influenced by the availability of data. The consumer price index (CPI), exchange rate, and oil price are the main variables of interest. However, output growth is added as a control variable. The CPI is measured in terms of the seasonally adjusted CPI, exchange rate is measured as the nominal broad effective exchange rate (NEER) and output growth is measured in terms of the seasonally adjusted industrial production index (IPI).[5] For crude oil price (OIL), we collect the spot price of oil in USD per barrel and multiply it by the nominal exchange rate of each country to obtain the crude oil price in terms of local currency. The data on CPI is obtained from the database of the International Financial Statistics (IFS) database of the International Monetary Fund (IMF). The data on NEER and IPI are sourced from the Thomson Reuters DataStream while data on crude oil price (in USD) is obtained from the US Energy Information Administration (EIA, 2018). Following Balcilar *et al*. (2017; 2018b), we convert the series into their natural logarithms to ensure the stability of the variance.

Before we estimate the model, it is required that the variables must be stationary. The results of the stationarity properties of the variables based on the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests divulge that all the series are only stationary in their first differences, I(1) (see Balcilar and Usman 2018). Therefore, our analyses are based on the log-growth rate in percent, which is expressed as $\log(y_t/y_{t-1}) \cdot 100$, where y_t is the level variable, and y_{t-1} is the one-lag value of the level variable. One of the advantages of using variables at the first difference is that it makes the VAR model stable if the variables are possibly nonstationary (see Lütkepohl 2005).

Table 6 discloses the descriptive statistics of the monthly frequency data on CPI, IPI, NEER, and OIL variables for the BRICS countries. Panel A unveils the statistical

[5] Due to insufficient data on industrial production index in the case of South Africa, the manufacturing production index (MPI) is used to measure output growth.

characteristics of the variables expressed in their natural logarithms while Panel B divulges the statistical characteristics of the variables in their log-differences (log growth rate). The total number of observations in the case of Brazil and India is 388 and 387 for log-level and log-difference. For China and South Africa, it is 340 and 339 while Russia is 280 and 279 respectively. Following the result in Panel A, the largest and smallest mean for NEER and CPI is found in Brazil with the values of 7.67 for log level and 1.02 for log-difference. Pertaining to Panel B, the largest and lowest mean is found to be CPI and IPI with the values of 5.59 for log-level and -5.17 for log-difference. Furthermore, we find that in Russia, India, China, and South Africa, oil price is found to have the largest mean as divulged in Panels A and B respectively. The largest variability is found to be oil price for Brazil, followed by Russia, South Africa, India, and China. This volatility is more conspicuous in their log-differences (Panel B) across the BRICS countries. The skewness of the variables discloses that some of the variables captured in this study are skewed to the right (positively skewed) and others are skewed to the left (negatively skewed). In addition, the variables exhibit positive kurtosis in both panels leading to leptokurtic distribution. Consequently, we reject the null hypothesis of normal distribution at a 1% level of significance for all the countries. This perhaps implies that the distribution of the variables grossly departs from normality path in the BRICS countries. The non-normality of all series implies that nonlinear VAR models such as the STVAR we consider represent the time series properties of the data better than the linear alternatives.

Figures. 3 to 7 disclose the time series plots of OIL, CPI, NEER, and IPI based on their log-levels. Figures 3 illustrates the time plots for Brazil, which show that OIL and IPI exhibit upward movement up to 1995, after which they become relatively constant.

This, therefore, implies co-movement between OIL and IPI. The case of NEER slopes downward until it settles down in 1995, suggesting depreciation of currency while CPI shows evidence of upward random movement with fluctuations over the years. Figures 4, 5, and 7 divulge the time plots of Russia, India, and South Africa. The figures exhibit similar characteristics in these countries. The OIL and CPI demonstrate profoundly an upward movement with evidence of time-trend. On the other hand, the NEER and IPI show evidence of fluctuations, which are apparently more noticeable in IPI. As we can easily see, the NEER slopes downward while IPI slopes upward until the recent drop in the prices of the international crude oil erupted in 2014. This perhaps affects the output growth significantly in these countries. Finally, the case of China in Figure 6 shows evidence of large fluctuations and structural breaks in all the variables, but no clear-cut evidence of time trends is noticeable. The figure further reveals several spikes in the CPI.

Table 6: Descriptive Statistics

Country	Variable	Obs.	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	J-B	Prob.
Brazil	*Panel A: Log levels*										
	LCPI	388	1.018997	4.075663	5.070877	-16.57065	6.396228	-1.691848	4.378926	215.8384	0.000000
	LIPI	388	4.360285	4.340856	4.661645	3.854554	0.171673	-0.053943	1.940456	18.33742	0.000104
	LNEER	388	7.669047	4.579227	24.15897	3.989513	6.045022	1.680257	4.300968	209.9333	0.000000
	LOILPRICE	388	1.029656	4.217415	5.526531	-16.65770	6.514840	-1.616267	4.168795	191.0150	0.000000
	Panel B: Log growth rate (%)										
	CPI	387	5.592126	0.618144	60.09785	-0.511013	10.22331	2.265599	8.301609	784.3009	0.000000
	IPI	387	0.088113	0.014175	25.04676	-28.65762	3.830480	-0.203315	15.53172	2535.002	0.000000
	NEER	387	-5.171851	-0.991641	23.24798	-48.75259	10.78120	-1.581341	5.248093	242.7857	0.000000
	OILPRICE	387	5.567258	3.911372	59.28725	-33.03097	13.61654	0.791329	4.517514	77.52346	0.000000
Russia	*Panel A: Log levels*										
	LCPI	280	3.994640	4.218929	5.145201	1.426907	0.951375	-0.855137	2.711300	35.09782	0.000000
	LIPI	280	4.478483	4.529146	4.774316	4.041075	0.220185	-0.343405	1.569245	29.38564	0.000000
	LNEER	280	4.781331	4.682733	6.000754	3.983573	0.493661	1.227443	3.707925	76.15559	0.000000
	LOILPRICE	280	6.994150	7.416477	8.320565	4.279885	1.186111	-1.073785	2.860546	54.03423	0.000000
	Panel B: Log growth rate (%)										
	CPI	279	1.332722	0.796805	32.51945	-0.541475	2.431510	8.427774	100.4034	113594.1	0.000000
	IPI	279	0.148411	0.278738	36.87810	-36.37963	3.916431	0.121407	56.82635	33681.52	0.000000
	NEER	279	-0.706954	-0.110797	12.84716	-75.22282	5.555069	-8.961018	118.0875	157708.5	0.000000
	OILPRICE	279	1.448272	1.415102	81.86996	-26.96859	9.186072	2.147879	23.31527	5012.278	0.000000
India	*Panel A: Log levels*										
	LCPI	388	4.026699	4.053521	5.124215	2.788211	0.666429	-0.096055	1.975092	17.57872	0.000152
	LIPI	388	3.958581	3.895726	4.972909	2.913711	0.583388	0.007951	1.695562	27.51264	0.000001
	LNEER	388	4.807077	4.754699	5.790924	4.259280	0.364154	0.836282	3.081124	45.33218	0.000000
	LOILPRICE	388	7.157390	7.196706	8.867119	4.984887	1.027749	-0.191852	1.822644	24.78992	0.000004

	Panel B: Log growth rate (%)										
	CPI	387	0.596989	0.621764	4.473589	-4.207775	0.866835	-0.328521	6.519883	206.7432	0.000000
	IPI	387	0.528334	0.467177	20.19156	-11.33461	2.624107	0.881922	14.31522	2114.719	0.000000
	NEER	387	-0.380438	-0.263247	6.334198	-19.31782	1.989631	-3.991808	38.19138	20997.51	0.000000
	OILPRICE	387	0.710185	1.231999	40.94007	-41.07009	8.864054	-0.349374	5.910145	144.4348	0.000000
China	*Panel A: Log levels*										
	LCPI	340	4.644574	4.627910	4.849684	4.582925	0.052615	2.027565	7.027911	462.7988	0.000000
	LIPI	340	4.719602	4.718006	4.868343	4.385381	0.047909	-0.682358	9.265864	582.5829	0.000000
	LNEER	340	4.583393	4.586730	4.881276	4.211068	0.154223	-0.353737	2.610152	9.243750	0.009834
	LOILPRICE	340	5.696524	5.615523	6.951132	4.476394	0.644509	0.140261	1.672392	26.08417	0.000002
	Panel B: Log growth rate (%)										
	CPI	339	-0.007157	0.000000	2.245092	-2.607971	0.700642	-0.109977	4.171660	20.07399	0.000044
	IPI	339	0.085124	0.024691	24.82882	-23.85232	3.724733	0.022520	17.63733	3026.329	0.000000
	NEER	339	-0.018894	0.135452	5.899195	-39.70609	2.499935	-11.81161	188.7983	495491.7	0.000000
	OILPRICE	339	0.315347	1.147736	39.15444	-33.18515	8.502249	-0.313888	5.155114	71.17049	0.000000
S/Africa	*Panel A: Log levels*										
	LCPI	340	4.240805	4.293636	5.020643	3.176699	0.484056	-0.299998	2.173486	14.77755	0.000618
	LIPI	340	4.491540	4.505920	4.705532	4.176192	0.118836	-0.535070	2.226985	24.68897	0.000004
	LNEER	340	4.782962	4.760198	5.590149	3.945015	0.438962	0.149618	2.001726	15.38632	0.000456
	LOILPRICE	340	5.513011	5.631227	7.022546	3.793362	1.006921	-0.227718	1.554696	32.53128	0.000000
	Panel B: Log growth rate (%)										
	CPI	339	0.543936	0.478470	2.666847	-1.141886	0.499469	0.594338	4.194314	40.10560	0.000000
	IPI	339	0.079609	-0.018259	9.690183	-9.609447	2.329628	-0.057542	5.561979	92.89985	0.000000
	NEER	339	-0.416090	-0.303963	8.894686	-17.64327	2.986058	-1.146915	8.462187	495.7471	0.000000
	OILPRICE	339	0.780077	0.967010	38.57859	-41.74234	8.738280	-0.350976	5.382956	87.16842	0.000000

Notes: The table summarizes descriptive statistics, which contains the sample mean, median, maximum, minimum, standard deviation, skewness, kurtosis, Jarque–Bera test statistic, and the p-value of the Jarque–Bera test statistic. The variables used include CPI, IPI, NEER and Oil price in the national currency of each of the BRICS countries. Panel A summarizes the log levels and Panel B summarizes the log growth rate (%)

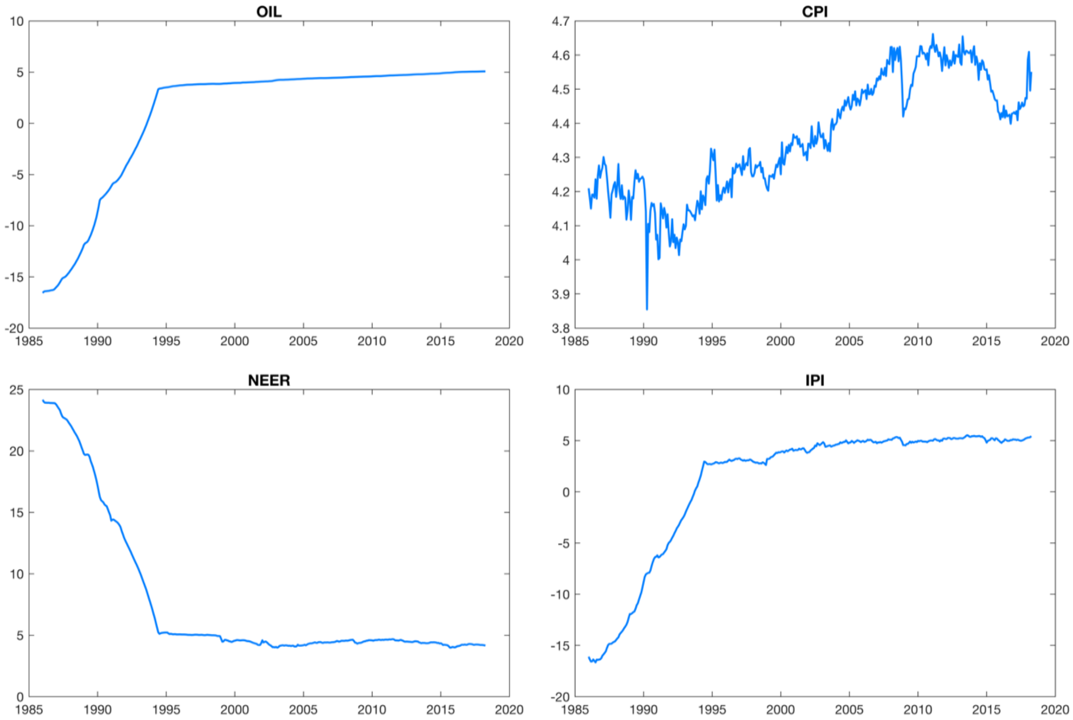

Figure 3: Time series plot of data in levels for Brazil

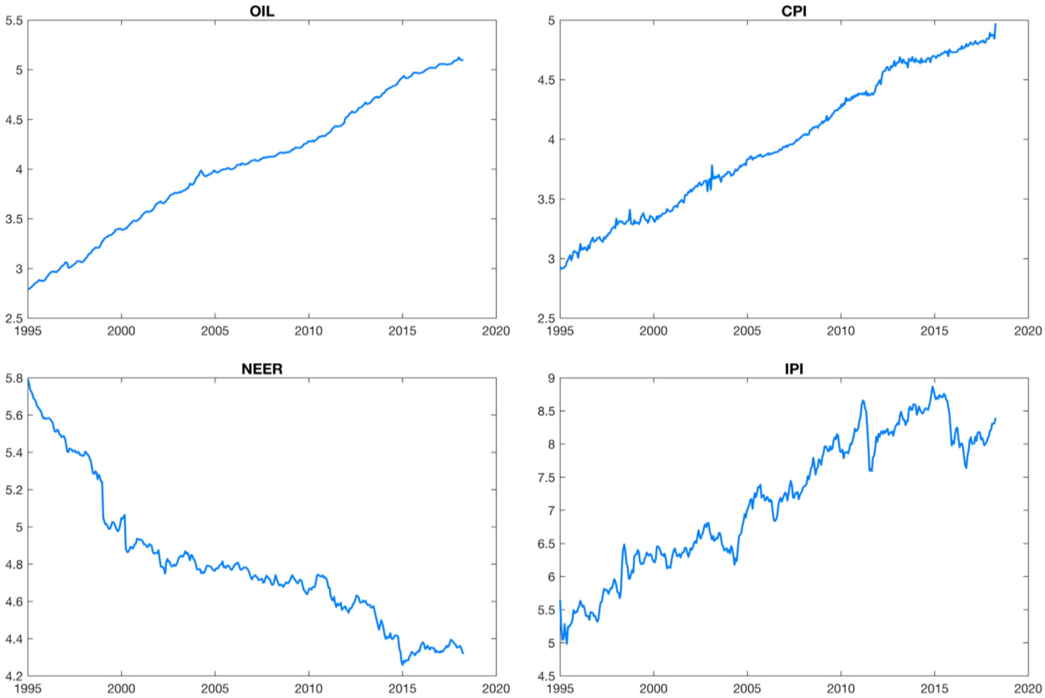

Figure 4: Time series plot of data in levels for Russia

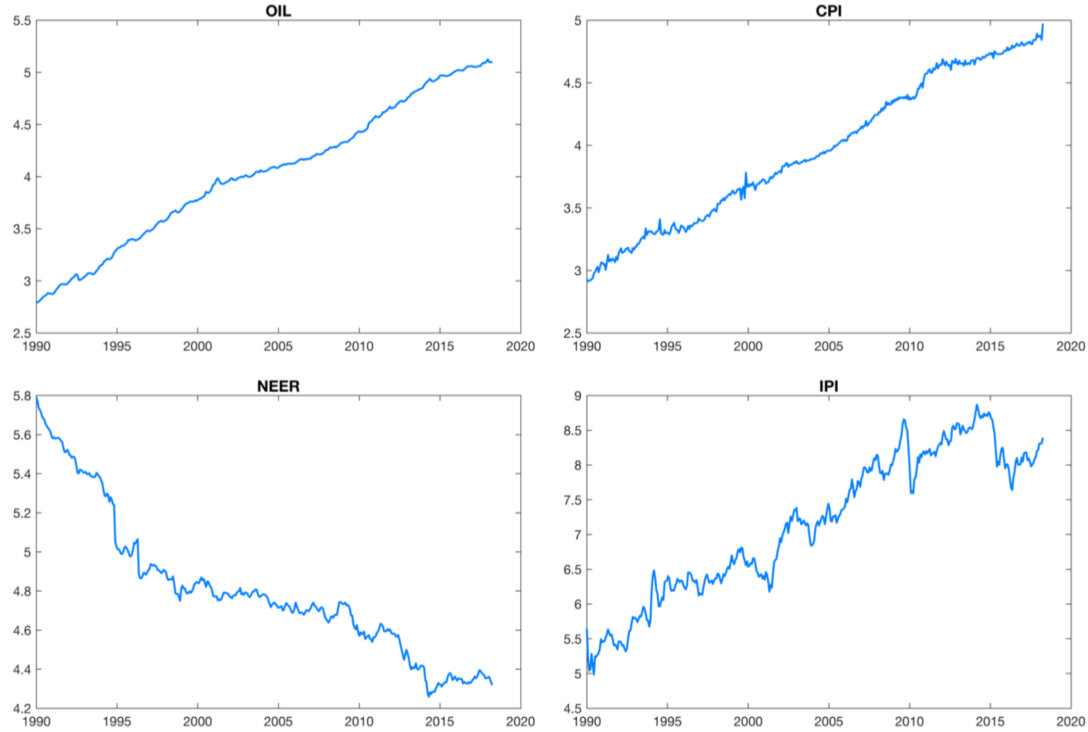

Figure 5: Time series plot of data in levels for India

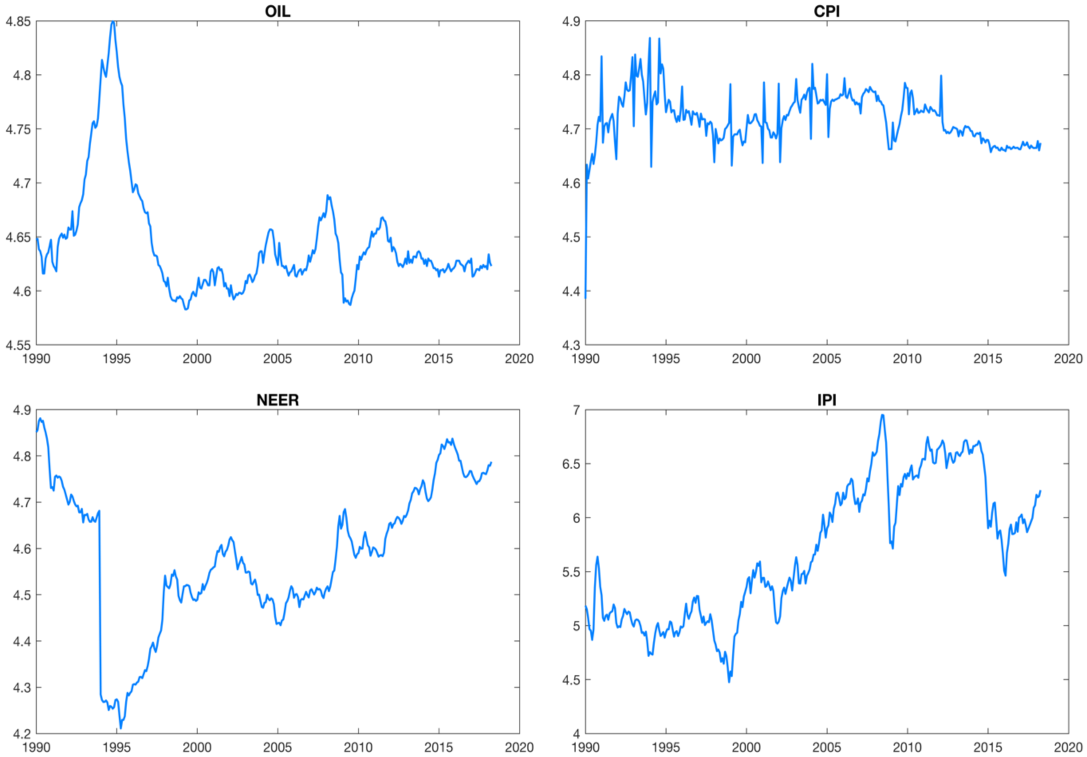

Figure 6: Time series plot of data in levels for China

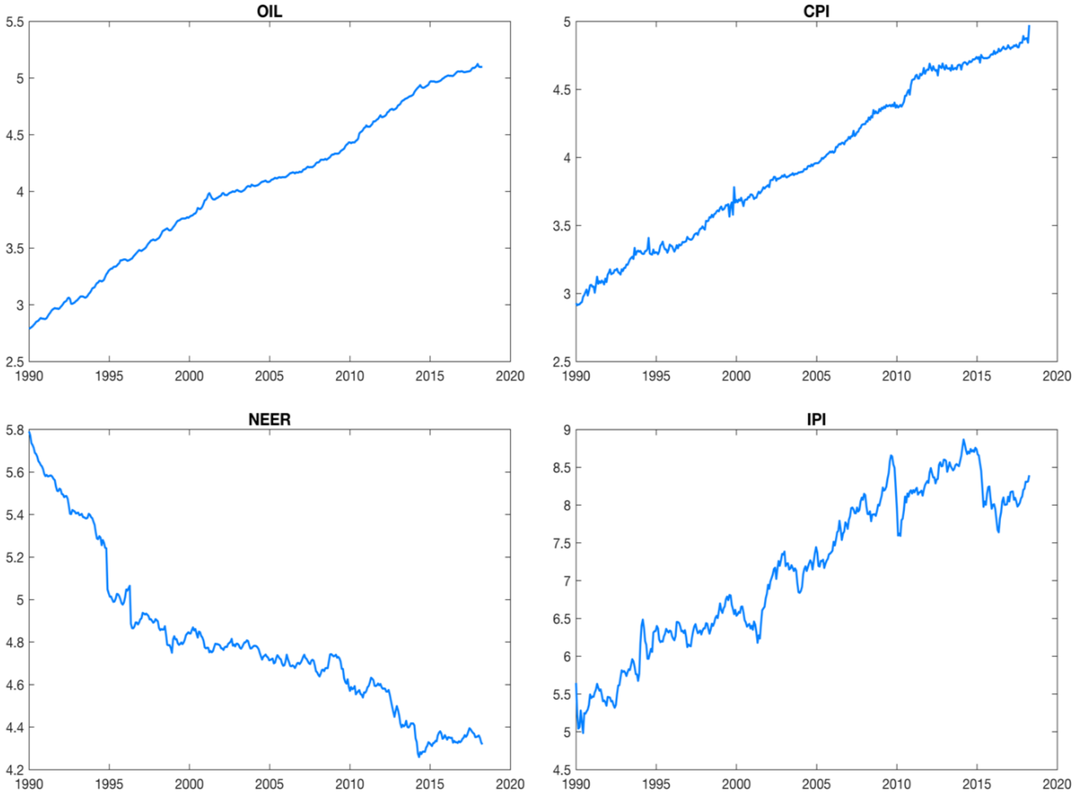

Figure 7: Time series plot of data in levels for South Africa

3.3 Econometric Methodology

This section presents our strategy to investigate an asymmetric EROPPT to inflation in the countries of BRICS. This strategy is based on the VSTAR model, which allows for an economically relevant smooth transition from one particular regime periods to another regime periods, governed by the selected transition variable. Therefore, following Anderson and Vahid (1998), Weise (1999), Camacho (2004), Auerbach and Gorodnichenko (2012), Teräsvirta and Yang (2014), and Balcilar *et al*. (2016, 2018b), among others, who extended the smooth transition autoregressive threshold models to a multi-equation setting based on the single-equation introduced by Teräsvirta and Anderson (1992), our STVAR model is specified as:

$$Y_t = \mu^1 + \sum_{i=1}^{p} \Phi_i^1 Y_{t-1} + \left(\mu^2 + \sum_{i=1}^{p} \Phi_i^2 Y_{t-1}\right) F(z_t; \gamma; c) + \epsilon_t \tag{10}$$

where $Y_t = (Y_{1t}, Y_{2t}, \ldots, Y_{Nt})'$. Indeed, the number of variables, N is 4 hence, Y_{1t} is ΔOIL_t, Y_{2t} is ΔNEER_t, Y_{3t} is ΔCPI_t and Y_{4t} is ΔIPI_t. Notes that $\Delta x_t = x_t - x_{t-1}$ with x_t representing OIL, NEER, CPI, and IPI are oil price, nominal effective exchange rate, consumer price index and industrial production index in natural logarithms.[6] The scalar transition function, $F(z_t; \gamma, c)$ is bounded between zero (lower regime) and one (upper regime). These two extreme values correspond to the lower regime periods and upper regime periods respectively.

In this study, we assume that the transition function is a logistic function, expressed as:

$$F(z_t; \gamma, c) = [1 + \exp\{-\gamma(z_t - c)\}]^{-1} \tag{11}$$

where γ represents the smoothness (adjustment speed), which determines whether the transition between lower regime periods and upper regime periods is sharp or smooth; $c\ is$ the threshold, and z_t is the state or transition variable, which is selected as $z_t = Y_{it-d}$, where i denotes OIL, NEER, CPI, and IPI and d is the delay. As the smoothness parameter approaches infinity, the transition function is reduced to the indicator function; hence, the model becomes a threshold VAR (TVAR) advanced by Tong (1983).[7] However, if the smoothness parameter approaches zero, the transition function converges to a constant, and hence the model becomes linear, as the nonlinear part is redundant. The time index $t = 1,2,3, \ldots, N$, upper regime periods are $t_u \in$

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[6] Note that other vectors and matrices are defined analogously.

[7] The indicator function, $I(z_t)$ is captured by 1 if $z_t > c$ and 0 if $z_t < c$.

$\{t_{u1}, t_{u2}, \dots, t_{uN_u}\}$, $N_u < N$, such that for each t_{ui}, $i = 1,2, \dots, N_u$, $z_t > c$, i.e. $t_u = t|z_t > c$. Analogously, lower regime periods are defined as the set $t_l \in \{t_{l1}, t_{l2}, \dots, t_{lN_l}\}$ such that $t_l = t|z_{t-d} < c$. Note that $N_u + N_l = N$.

As well established in the literature, testing for linearity before fitting a nonlinear model is the first step in building nonlinear models. To this end, we first perform *F* version of the linearity test and the Likelihood Ratio (LR) linearity test using the 1-st, 2-nd and 3-rd order Taylor expansions as described in Teräsvirta and Yang (2014), to solve the problem of identification under linearity. We test the null hypothesis of $H_0: \gamma = 0$ i.e. linearity against the alternative $H_1: \gamma > 0$ i.e. nonlinear (VSTAR) model. The LM linearity test can be carried out equation by equation by excluding all the nonlinear parameters in the equation as described by Teräsvirta and Anderson (1992) and Weise (1999). To perform this test, we follow a three-step procedure, which includes the following:

The first one is to consider each restricted regression of *k*-variable linear VAR with *p* lags model in Equation (12) and obtain residuals $\hat{u}_{it}$ with the sum of squared residuals clearly define as $SSR_0 = \sum \hat{u}_{it}^2$.

$$Y_{it} = \beta_{i0} + \sum_{j=1}^{pN} \beta_{ij} W_{jt} + u_{it} \tag{12}$$

In the second step, we run the unrestricted regression that appears in Equation (12) and obtain residuals $\hat{v}_{it}$ with the sum of squared residuals define as $SSR_1 = \sum v_{it}^2$.

$$u_{it} = \alpha_{i0} + \sum_{j=1}^{pN} \alpha_{ij} W_{jt} + \sum_{j=1}^{pN} \delta_i z_t W_{jt} + v_{it} \tag{13}$$

Finally, we, therefore, compute the LM test statistics from the results obtained in Equations (12) and (13) as:

$$LM = \frac{T(SSR_0 \times SSR_1)}{SSR_0} \sim \chi^2(pN) \tag{14}$$

where T denotes the number of observations. More so, the LR linearity test for excluding all nonlinear parameters in all the equations is performed to assess the linearity based on the whole system as described in Weise (1999). To compute the asymptotically distributed LR test statistic given as $LR = T\{\log|\Omega_0| - \log|\Omega_1|\} \sim \chi(pN^2)$, where $\Omega_0 = \sum \hat{u}_t \hat{u}_t' / T$ and $\Omega_1 = \sum \hat{v}_t \hat{v}_t' / T$ are the estimated variance-covariance matrices of the residuals based on the restricted and unrestricted regressions in equations (12) and (13). The decisions for both F and LR linearity tests are based on the bootstrapped p-values obtained with 1000 bootstrap repetitions. This helps to circumvent bias and imprecise inferences using asymptotic p-value due to nonstandard distributional and finite sample problems.

In addition to the F and LR linearity tests, we apply the system linearity test proposed by Rao (1973), which uses the Rao's version of the F-test (F_{RAO}) for the exclusion of the nonlinear parameters in all the equations. The test is computed as follows:

$$F_{RAO}(k) = \left(\frac{1 - \Lambda^{\frac{1}{s}}}{\Lambda^{\frac{1}{s}}} \right) \frac{\delta s - \frac{1}{2}(Nk - 2)}{Nw} \tag{15}$$

where $\Lambda = |\widehat{\Omega}_1| / |\widehat{\Omega}_0|$, represents the Wilk's Lambda, $w = k(pN + 1)$, $s^2 = (N^2 w^2 - 4)/w^2 + N^2 - 5)$, $\delta = T - (1 + pN) - \frac{1}{2}(N + w + 1)$, k is order of the Taylor expansion, and the F_{RAO}-statistic is approximately distributed as $F\left(Nw, \delta s - \frac{1}{2}(Nk - 2)\right)$ under the null hypothesis. The decision rule in respect of this test is similar to F and LR linearity tests.

3.4 Results and Discussion

3.4.1 Linearity Tests

The first stage in this section is the presentation of the first-round linearity tests. Tables 7(a)-(e) present the results of the *F* and *LR* linearity tests based on a standard 4-dimensional VAR model using transition variables for each equation based on the a priori selection as indicated in Balcilar *et al.* (2016). The F_{RAO} tests are given Tables 8(a)-(e). The lag order is chosen by the Schwarz Information Criterion (SBC) and 1 for all countries. The results based on the bootstrapped *p*-values with 1000 repetitions provide substantial evidence to reject the null hypothesis of a linear VAR in favor of a nonlinear VAR (VSTAR) model in each of the equations and the system as a whole. We select the transition variable based on the minimum *p*-value and majority of the rejection of linearity for each of the dependent variables using the results presented in Tables 7(a)-(e). Therefore, on the basis of these results, ΔOIL_{t-1} is selected as the transition variables (z_t) for Brazil and Russia, ΔIPI_{t-1} is selected for China and India, while ΔNEER_{t-1} is selected for South Africa.

Table 7(a): Linearity Tests for Brazil

		State Variable			
Hypothesis: Statistics	Equation	OIL_{t-1}	CPI_{t-1}	$NEER_{t-1}$	IPI_{t-1}
H_{01}: F	OIL	0.222	9.443	6.645	5.288
H_{01}: F	CPI	3.315	45.173***	18.296***	24.864***
H_{01}: F	NEER	2.079*	8.379***	7.448***	9.675***
H_{01}: F	IPI	1.270+	14.996***	9.094***	13.475***
H_{02}: F	OIL	3.474	2.493***	2.878***	0.795***
H_{02}: F	CPI	1.604**	15.636*	19.129*	6.934
H_{02}: F	NEER	3.497	1.200***	17.685***	3.750***
H_{02}: F	IPI	1.869**	9.362	8.785***	4.140**
H_{03}: F	OIL	1.187	1.868***	0.464***	1.394**
H_{03}: F	CPI	15.623	15.948	13.245	0.228
H_{03}: F	NEER	3.804***	3.743***	1.922***	4.844
H_{03}: F	IPI	3.232**	1.421**	3.595	2.472***
H_{01}: LR	System	30.990*	194.520	118.010**	141.078*
H_{02}: LR	System	83.209*	75.653***	82.236***	36.320***
H_{03}: LR	System	83.209***	75.653***	82.236***	36.320**

Table 7(b): Linearity Tests for Russia

		State Variable			
Hypothesis: Statistics	Equation	OIL_{t-1}	CPI_{t-1}	$NEER_{t-1}$	IPI_{t-1}
H_{01}: F	OIL	3.261	3.732	2.384	1.577
H_{01}: F	CPI	17.962*	20.099**	20.045+	9.700
H_{01}: F	NEER	5.806***	6.122***	6.051***	2.722***
H_{01}: F	IPI	8.302***	0.807***	14.585***	19.242*
H_{02}: F	OIL	3.042***	2.238	1.088***	5.051***
H_{02}: F	CPI	5.637*	0.420+	2.737	3.143***
H_{02}: F	NEER	5.687***	1.480	3.300*	4.172*
H_{02}: F	IPI	3.126***	1.351	4.108*	1.764**
H_{03}: F	OIL	2.800*	1.740	0.726**	0.800
H_{03}: F	CPI	4.432*	11.221	1.867	1.276
H_{03}: F	NEER	6.119**	9.258***	3.067	1.252
H_{03}: F	IPI	4.501***	0.437***	0.507*	0.944
H_{01}: LR	System	131.262**	103.346	155.340	134.293
H_{02}: LR	System	43.630***	54.952***	19.017***	18.669***
H_{03}: LR	System	43.630***	54.952***	19.017	18.669

Table 7(c): Linearity Tests for India

		State Variable			
Hypothesis: Statistics	Equation	OIL_{t-1}	CPI_{t-1}	$NEER_{t-1}$	IPI_{t-1}
H_{01}: F	OIL	2.741	0.222	2.156	0.913
H_{01}: F	CPI	0.745*	0.987	1.250^{+}	0.536
H_{01}: F	NEER	11.128	1.518	1.076	4.585
H_{01}: F	IPI	2.027***	0.686	1.325	1.920**
H_{02}: F	OIL	1.517^{+}	0.273	0.468	0.880
H_{02}: F	CPI	1.231	7.642	0.791	1.362
H_{02}: F	NEER	11.152	0.427***	1.199	1.797
H_{02}: F	IPI	0.803***	1.761	0.809	6.156
H_{03}: F	OIL	2.221	0.535	0.797	0.415***
H_{03}: F	CPI	1.493^{+}	4.417	0.974	2.672
H_{03}: F	NEER	9.210	1.428**	0.741	1.152*
H_{03}: F	IPI	1.762***	0.908	0.587	12.192
H_{01}: LR	System	63.557	13.895	22.415	33.254***
H_{02}: LR	System	55.188***	29.200	12.790	64.612**
H_{03}: LR	System	55.188***	29.200*	12.790	64.612***

Table 7(d): Linearity Tests for China

		State Variable			
Hypothesis: Statistics	Equation	OIL_{t-1}	CPI_{t-1}	$NEER_{t-1}$	IPI_{t-1}
H_{01}: F	OIL	1.938	0.555	1.931	0.523
H_{01}: F	CPI	0.745	0.337	0.163	0.687
H_{01}: F	NEER	12.066	13.994	2.290	6.501
H_{01}: F	IPI	6.150***	9.354***	10.057^{+}	10.054***
H_{02}: F	OIL	2.873***	1.305***	4.406***	2.476***
H_{02}: F	CPI	0.267*	2.385	1.221**	3.008*
H_{02}: F	NEER	0.333	14.031^{+}	0.486	6.276*
H_{02}: F	IPI	0.643	3.079***	2.660	3.074***
H_{03}: F	OIL	0.460	4.014*	1.808*	3.385*
H_{03}: F	CPI	2.975	1.990**	2.073	2.310**
H_{03}: F	NEER	7.004*	9.027^{+}	2.422^{+}	4.518^{+}
H_{03}: F	IPI	4.416***	0.176***	4.780*	6.752**
H_{01}: LR	System	75.920**	86.243	51.859***	61.691***
H_{02}: LR	System	53.989***	53.459***	42.493***	65.184***
H_{03}: LR	System	53.989***	53.459***	42.493***	65.184***

Table 7(e): Linearity Tests for South Africa

Hypothesis: Statistics	Equation	*State Variable*			
		OIL_{t-1}	CPI_{t-1}	$NEER_{t-1}$	IPI_{t-1}
H_{01}: *F*	OIL	1.832	1.609	0.940	0.435
H_{01}: *F*	CPI	0.571	1.300	0.335	0.334
H_{01}: *F*	NEER	0.912	0.820	2.149	0.890
H_{01}: *F*	IPI	2.391	1.463	1.852^{+}	3.651
H_{02}: *F*	OIL	2.410^{+}	0.727	1.948	0.683^{**}
H_{02}: *F*	CPI	0.818^{*}	5.824	0.800	0.634
H_{02}: *F*	NEER	1.199	0.669^{***}	0.905	0.275
H_{02}: *F*	IPI	0.983	0.589	0.416	1.967
H_{03}: *F*	OIL	2.125	0.331	0.496	1.550^{+}
H_{03}: *F*	CPI	1.615^{+}	0.423	2.602	0.977
H_{03}: *F*	NEER	0.644	0.132	0.858^{*}	1.024
H_{03}: *F*	IPI	0.879	0.571	4.219	1.046
H_{01}: *LR*	System	22.692	20.208	20.642^{**}	20.413
H_{02}: *LR*	System	19.076	6.390	31.796	16.896
H_{03}: *LR*	System	19.076	6.390	31.796^{*}	16.896

Note: $^{+}$, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

3.4.2 VSTAR Estimations

We estimate the multivariate unrestricted VSTAR model using nonlinear least squares, which is based on equation (10). The results of the estimations are divulged in Tables 8(a)-(e) where the lower regime periods and upper regime periods correspond to the pass-through estimates determined by the conditions $z_t \leq c$ and $z_t > c$, respectively. The estimates of the speed of adjustment and the threshold parameters are reported for each country with their corresponding p-values. Particularly, the estimates of the speed of adjustment parameters γ show the existence of a smooth transition between the upper and lower regimes with Brazil having the largest estimate, followed by Russia, India, China, and South Africa. However, it is evident in all countries that γ is larger than zero and statistically significant in Brazil and China.[8] In addition, the estimate of

[8] As noted by van Dijk (2002) the smoothness parameter is difficult the estimate and its estimation precision is low. Thus, statistical tests on the smoothness parameter should are not reliable.

the threshold parameter c, is positive and significantly higher than zero in all the countries, indicating an asymmetric EROPPT for all the countries investigated. However, the fact that the adjustment speed estimates are distantly higher than zero in all the countries suggest the existence of the low-cost of price adjustment, which encourages firms to easily adjust their prices to small and large changes in exchange rate and oil prices. This result is contrary to the theoretical conjecture described in Pollard and Coughlin (2004) that a small shock to exchange rate is likely to be absorbed within the firms' mark-up margins because of the high cost of price adjustment (menu cost). In overall, the possibility of adjusting prices to a small and large shock to exchange rate and oil price is higher in Brazil, followed by in China, India, South Africa, and Russia.

The coefficient estimates of the VSTAR models for all the countries as disclosed in Tables 8(a)-(e) show the responses of the CPI, IPI, NEER, and OIL to the shocks in NEER and OIL in these countries. The results based on the model estimations show that the variables respond positively and negatively to the shocks in all the equations with evidence of asymmetry, which is possibly determined by the dynamic interactions among the investigated variables both in the upper and lower regime periods. These results could be traceable to exchange rate and oil price volatilities. This finding is similar to Balcilar *et al.* (2016) who depicted that the responses to shocks in the logistic STVARs dynamically interact and co-move in the lower regime, corresponding to the period of financial tightening and financial volatility and the upper regime periods, which corresponds to the stable and loose financial conditions' periods.

Furthermore, we perform equation by equation F-linearity, the system LR linearity, and the system F_{RAO} linearity tests in the models using the selected transition variables for each country investigated. These tests are different from the *F* and LR tests in Tables 7(a)-(e) since they test the null hypothesis that coefficients on the estimated variable $F(z_t; \hat{\gamma}, \hat{c})$ are jointly zero.[9] The results of *F* statistic indicate that with the exception of Brazil, there is no evidence to reject the null hypothesis of linearity in all the remaining countries when we used OIL as transition variables. However, the results of the system linearity test (i.e. LR and Rao's *F*-test) apparently provide strong evidence congenial to nonlinearity in all the equations with ΔOIL_{t-1} as a transition variable for Brazil and Russia, ΔIPI_{t-1} for India and China as well as ΔNEER_{t-1} for South Africa. This suggests that the shocks to each of the variables have asymmetric effects. In other words, the shocks to NEER and OIL have asymmetric pass-through effects in BRICS countries.[10]

[9] Following Balcilar *et al.* (2016), the *F*-tests applied are based on the Wald statistics with the heteroscedasticity-consistent matrix proposed by White (1980). Inferences are taken based on the bootstrapped *p*-values.

[10] The selection of transition variables, z_t for each of the equations is based on the LM_3 test for linearity, LR test and Rao F test for exclusion of the nonlinear part.

Table 8(a): Estimates of VSTAR Models for Brazil

Parameter	System	*Equation* OIL	CPI	NEER	IPI
c	22.340***				
	(1.805)				
γ	22.628**				
	(8.203)				
μ_i^1		0.339	0.004	0.317	0.216
		(0.602)	(0.186)	(0.302)	(0.208)
$\phi_{1,OIL}^1$		0.137*	0.031	-0.080*	0.040+
		(0.064)	(0.020)	(0.032)	(0.022)
$\phi_{1,CPI}^1$		1.050***	1.001***	-0.798***	0.099+
		(0.146)	(0.045)	(0.073)	(0.050)
$\phi_{1,NEER}^1$		0.228+	-0.018	0.123*	0.120**
		(0.119)	(0.037)	(0.060)	(0.041)
$\phi_{1,IPI}^1$		0.184	0.107*	0.036	-0.400***
		(0.141)	(0.044)	(0.071)	(0.049)
μ_i^2		0.561	-4.879*	-1.384	0.630
		(6.194)	(1.918)	(3.105)	(2.135)
$\phi_{1,OIL}^1$		0.168	0.203**	-0.124	0.050
		(0.205)	(0.064)	(0.103)	(0.071)
$\phi_{1,CPI}^1$		-0.318	-0.349***	0.469**	-0.309**
		(0.290)	(0.090)	(0.145)	(0.100)
$\phi_{1,NEER}^1$		-0.018	-0.165	0.218	-0.131
		(0.353)	(0.109)	(0.177)	(0.122)
$\phi_{1,IPI}^1$		1.559**	0.743***	-0.710**	0.492**
		(0.478)	(0.148)	(0.240)	(0.165)
F linearity test		3.625**	12.894***	6.727***	6.068***
		(0.000)	(0.000)	(0.000)	(0.000)
LR linearity test	75.463***				
F_{RAO} linearity test	3.876***				

Note: +, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

Table 8(b): Estimates of VSTAR Models for Russia

		Equation			
Parameter	System	OIL	CPI	NEER	IPI
c	1.370				
	(390.240)				
γ	15.000				
	(3415.923)				
μ_i^1		1.609	-0.032	-0.134	0.300
		(1.349)	(0.304)	(0.783)	(0.485)
$\phi_{1,OIL}^1$		0.303^{+}	-0.016	0.008	0.118*
		(0.154)	(0.035)	(0.090)	(0.056)
$\phi_{1,CPI}^1$		0.165	0.901***	0.163	0.296
		(0.596)	(0.135)	(0.346)	(0.215)
$\phi_{1,NEER}^1$		-0.249	-0.057	0.538***	-0.020
		(0.230)	(0.052)	(0.133)	(0.083)
$\phi_{1,IPI}^1$		0.082	0.009	0.102	-0.056
		(0.204)	(0.046)	(0.118)	(0.073)
μ_i^2		-1.157	0.712	-0.274	-0.349
		(2.136)	(0.482)	(1.240)	(0.769)
$\phi_{1,OIL}^1$		-0.102	0.010	-0.119	-0.026
		(0.223)	(0.050)	(0.129)	(0.080)
$\phi_{1,CPI}^1$		0.278	-0.260	0.035	-0.620*
		(0.857)	(0.193)	(0.497)	(0.308)
$\phi_{1,NEER}^1$		0.607^{+}	0.213**	-0.321	-0.028
		(0.355)	(0.080)	(0.206)	(0.128)
$\phi_{1,IPI}^1$		-0.061	-0.057	-0.083	-0.719***
		(0.295)	(0.067)	(0.171)	(0.106)
F linearity test		1.411	7.878***	2.245^{+}	12.832***
		(0.000)	(0.000)	(0.000)	(0.000)
LR linearity test	107.304***				
F_{RAO} linearity test	5.674***				

Note: $^{+}$, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

Table 8(c): Estimates of VSTAR Models for India

		Equation			
Parameter	System	OIL	CPI	NEER	IPI
c	2.514***				
	(0.163)				
γ	11.900				
	(120.475)				
μ_i^1		0.843	0.419***	-0.017	0.645***
		(0.621)	(0.048)	(0.134)	(0.172)
$\phi_{1,OIL}^1$		0.279***	-0.002	-0.018	-0.005
		(0.053)	(0.004)	(0.011)	(0.015)
$\phi_{1,CPI}^1$		-0.227	0.245***	-0.359*	0.090
		(0.704)	(0.055)	(0.152)	(0.195)
$\phi_{1,NEER}^1$		0.057	-0.010	0.166***	-0.085
		(0.229)	(0.018)	(0.049)	(0.063)
$\phi_{1,IPI}^1$		0.009	-0.031	0.050	-0.506***
		(0.250)	(0.019)	(0.054)	(0.069)
μ_i^2		1.353	0.459+	-1.010	-0.313
		(3.007)	(0.234)	(0.650)	(0.833)
$\phi_{1,OIL}^1$		-0.344*	0.025*	-0.223***	0.042
		(0.158)	(0.012)	(0.034)	(0.044)
$\phi_{1,CPI}^1$		-1.067	-0.035	0.145	1.148*
		(1.899)	(0.148)	(0.411)	(0.526)
$\phi_{1,NEER}^1$		-1.226	0.089	-0.367*	0.098
		(0.855)	(0.066)	(0.185)	(0.237)
$\phi_{1,IPI}^1$		-0.179	-0.034	0.128	-0.038
		(0.497)	(0.039)	(0.107)	(0.138)
F linearity test		1.151	2.287+	6.837***	1.899
		(0.000)	(0.000)	(0.000)	(0.000)
LR linearity test	48.505***				
F_{RAO} linearity test	2.464***				

Note: +, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

Table 8(d): Estimates of VSTAR Models for China

Parameter	System	OIL	CPI	NEER	IPI
		Equation			
c	5.066***				
	(1.117)				
γ	7.774*				
	(2.523)				
μ_i^1		0.162	-0.013	0.049	0.182
		(0.463)	(0.037)	(0.108)	(0.159)
$\phi_{1,OIL}^1$		0.282***	0.003	-0.009	0.021
		(0.055)	(0.004)	(0.013)	(0.019)
$\phi_{1,CPI}^1$		0.706	0.264***	-0.194	0.233
		(0.721)	(0.058)	(0.168)	(0.248)
$\phi_{1,NEER}^1$		-0.614+	-0.046	0.418***	-0.196
		(0.367)	(0.030)	(0.085)	(0.126)
$\phi_{1,IPI}^1$		-0.294+	0.047***	-0.001	-0.400***
		(0.171)	(0.014)	(0.040)	(0.059)
μ_i^2		7.579	1.366**	-12.146***	-3.710*
		(5.319)	(0.429)	(1.237)	(1.831)
$\phi_{1,OIL}^1$		0.059	-0.040+	0.586***	0.029
		(0.298)	(0.024)	(0.069)	(0.103)
$\phi_{1,CPI}^1$		0.158	-0.051	-3.426***	2.599***
		(2.247)	(0.181)	(0.523)	(0.774)
$\phi_{1,NEER}^1$		2.008+	0.080	-1.383***	1.826***
		(1.032)	(0.083)	(0.240)	(0.355)
$\phi_{1,IPI}^1$		-0.390	-0.123**	0.790***	0.334*
		(0.476)	(0.038)	(0.111)	(0.164)
F linearity test		1.629	3.294*	33.525***	13.042***
		(0.000)	(0.000)	(0.000)	(0.000)
LR linearity test	166.770***				
F_{RAO} linearity test	8.974***				

Note: +, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

Table 8(e): Estimates of VSTAR Models for South Africa

		Equation			
Parameter	System	OIL	CPI	NEER	IPI
c	1.383				
	(1.208)				
γ	4.244				
	(2.416)				
μ_i^1		2.632*	0.284***	-0.578	0.080
		(1.155)	(0.047)	(0.387)	(0.279)
$\phi_{1,OIL}^1$		0.159*	0.005^{+}	-0.010	0.031^{+}
		(0.068)	(0.003)	(0.023)	(0.016)
$\phi_{1,CPI}^1$		-1.341	0.564***	-0.100	-0.693*
		(1.386)	(0.056)	(0.465)	(0.335)
$\phi_{1,NEER}^1$		0.484^{+}	-0.005	0.157^{+}	-0.056
		(0.252)	(0.010)	(0.085)	(0.061)
$\phi_{1,IPI}^1$		-0.115	0.009	0.005	-0.396***
		(0.257)	(0.010)	(0.086)	(0.062)
μ_i^2		-6.030	-0.235	-0.050	1.967*
		(3.712)	(0.150)	(1.246)	(0.896)
$\phi_{1,OIL}^1$		-0.013	0.001	0.000	-0.042
		(0.173)	(0.007)	(0.058)	(0.042)
$\phi_{1,CPI}^1$		-1.004	-0.085	1.707	0.870
		(3.114)	(0.126)	(1.045)	(0.752)
$\phi_{1,NEER}^1$		1.042	0.027	0.124	-0.424*
		(0.728)	(0.029)	(0.244)	(0.176)
$\phi_{1,IPI}^1$		1.083	0.002	-0.101	-0.158
		(0.717)	(0.029)	(0.240)	(0.173)
F linearity test		1.571	1.335	1.916	2.458*
		(0.000)	(0.000)	(0.000)	(0.000)
LR linearity test	28.648*				
F_{RAO} linearity test	1.446^{+}				

Note: $^{+}$, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

3.4.3 Generalized Impulse Response Functions (GIRFs)

The coefficient estimates based on the VSTAR model may not make much meaningful interpretation rather than exposing the shape and position of the speed of adjustment and threshold parameters. To properly understand the dynamic behaviors of the variables and make more meaningful and insightful interpretations, most studies used impulse response functions (IRFs) as suggested by Sim (1980). In the nonlinear literature, there is no clear-cut analytical point formula to construct nonlinear IRFs because the impulse responses and the size of the shocks are not proportional, neither do they independent of the "history". To address this problem, the generalized impulse responses (GIRFs) are proposed by Koop *et al.* (1996), which can be based on bootstrap or Monte Carlo method. The bootstrap based GIRF method is used by Weise (1999) and recently used by Rahman and Serletis (2010), Balcilar *et al.* (2016; 2018b).

According to Weise (1999), unlike the linear IRFs, which assume that the shocks are invariant to "history" (i.e. the starting value), the nonlinear IRFs assume that the shocks are based on a specific "history". In other words, the "history" of the variables is considered as a random variable. Likewise, the effects of shocks in the future are inconsequential or rather considered insignificant in the linear IRFs; whereas for nonlinear IRFs, "the future shocks are drawn from some distribution and their effects averaged out over a large number of draws" (Weise, 1999:105). Furthermore, the linear IRFs do not vary with the size and magnitude of the shocks, whereas in the nonlinear IRFs the responses to shocks are notably determined by their sizes and magnitudes.

Specifically, to compute the multivariate GIRFs, we assume that Y_t denotes a random vector, v_t represents the shock that causes GIRF, and ω_{t-1} is the history of the variables "starting values" Hence,

$$\varphi_Y\left(n, v_{t,} w_{t-1}\right) = E\left[Y_{t+n} \middle| v_{t,} \omega_{t-1}\right] - E[Y_{t+n}|\omega_{t-1}],\ n = 0, 1, 2,3, \dots \qquad (16)$$

where φ_Y represents the GIRFs of Y_t, n denotes the forecast horizon while $E[\cdot]$denotes the expectations operator. GIRFs of the STVAR model are history dependent, thus, we evaluate the GIRFs by taking distinct sets as the history. The upper regime period GIRFs are obtained by randomly drawing the history ω_{t-1} from the set $t_u \in \{t_{u1}, t_{u2}, \dots, t_{uN_u}\}$. Analogously, we obtain the lower regime GIRFs with random histories ω_{t-1} drawn from the set $t_l \in \{t_{l1}, t_{l2}, \dots, t_{lN_l}\}$. The results of the GIRFs are divulged in Figures 8 to 17.[11] We set the size of the shock v_t to one standard deviation the shocked variable. As all variables are in log first differences the NEER shock represents a one standard deviation appreciation while the OIL shock represents a one standard deviation increase in the price of oil in the local currency unit. Thus, responses also in growth rate terms. The results as already mentioned are obtained with 1000 bootstrap repetitions and 95% confidence interval. The responses of the variables are computed for 25-month forecast horizon for Brazil while for Russia, India, China, and South Africa, the responses are computed based on the period of 10-month forecast horizon. These periods are sufficient to evaluate the responses of the variables to the shocks in NEER and OIL in the BRICS countries.

3.4.3.1 Responses to NEER Shocks

As reported in Figures 8 to 17, we track the pass-through of NEER shocks to OIL, CPI, NEER, and IPI to NEER and OIL shocks in the BRICS countries in both the upper regime periods and the lower regime periods. Specifically, figures 8 to 12 analyze the pass-through of NEER shocks to all the variables in our models including own-shocks while figures 13 to 17 present the pass-through of OIL shocks to all the variables including own-shocks. In figures 8(a)-(h) the pass-through of the shocks in NEER to OIL, CPI and IPI is divulged for Brazil. The pass-through to OIL, CPI and IPI is negative in the upper regime periods. This pass-through is statistically significant for OIL and CPI, and dampens gradually and smoothly until it stabilizes to the steady state (equilibrium) after twenty months. In the case of IPI, the pass-through is not

[11] For the purpose of this study, the "regime specific" impulse responses obtained with 1000 bootstrap repetitions, go with the "period specific" term.

significant for the first three months, after which it becomes significant and decreasing smoothly after the first month until it becomes neutral in the fifteen months. More so, the pass-through of own-shock (innovation) is positively significant and dampening to its equilibrium value after twenty months. In the lower regime periods, the pass-through to OIL, CPI, and IPI is negative and insignificant, while the pass-through of own-shocks is positive and significant. The pass-through gradually stabilizes to the steady state after ten months for all the variables. As can be seen further, the pass-through declines instantaneously in the first month, after which the pass-through becomes smooth and slow in all the variables. The smoothness in the pass-through indicates some delays on the pass-through channels in stabilizing to its equilibrium value. This delay is influenced by the stance of monetary policy and Central Bank credibility, which is the major argument in the recent pass-through literature (Aleem and Lahiani, 2014; Dube, 2016; Kabundi and Mlachila, 2018). Furthermore, comparing the size of the pass-through between the two regime periods, our results suggest a higher pass-through in the upper regime periods to the lower regime periods for all the variables.

The pass-through of the NEER shocks to all the variables in Russia is reported in Figures 9(a)-(h). In the upper regime periods, the pass-through to OIL and IPI is positive within the first month. This crosses to negative where they begin to rise instantaneously in the first month and reduce sharply in the second month until the pass-through is stabilized in the fourth and second month horizons respectively. The pass-through of own-shocks is positive and significant up to the second month after which it becomes neutral. Also, the pass-through to CPI is negative and insignificant. It therefore becomes positive in the first month, after which it turns significant until it stabilizes to its equilibrium in the second month. In the lower regime periods, the pass-through to OIL, NEER, and IPI is positive. In the case of OIL, the pass-through is not statistically significant while for IPI, it is statistically significant up to the second month. Finally, the pass-through to CPI is negative and insignificant; this gradually declines and becomes neutral after second month. Following these results, it can be seen that with the exception of the pass-through to OIL which is smooth and slow, the pass-through is high-pitched for Russia. Although there is noticeable difference in terms of the size of the pass-through between the states. The general conclusion is that the pass-through is stronger in the upper regime periods for Russia.

Figures 10(a)-(h) shows that the pass-through of NEER shock to OIL and NEER is positive in India in the upper regime periods. Although the pass-through to OIL is not noticeable in the first month; however, between the second and third months, the pass-through is positive and insignificant. The pass-through of own shock is positively significant and dampening until it stabilizes to its steady state in the second month. The pass-through to CPI is negative and significant up to the third month, after which it becomes stable. With respect to IPI, the pass-through is initially positive in the first month and later turns negative. However, after the end of the first month, the pass-through to IPI begins to dampen until it becomes stable in the second month. Furthermore, in the lower regime periods, our results demonstrate that the pass-through of NEER to OIL is negative and significant as well as larger compared to the upper regime periods. This remains negative and subsequently stabilizes to its equilibrium value after the fourth month. Concerning the pass-through to CPI, the results provide a positive pass-through initially, and later hits negative within the first month. This pass-through is larger and significant between the first and second months, and hence stabilizes to its equilibrium state in the third month horizon. More so, the pass-through to NEER is positive and significant up to the second month, after which it dampens continuously until its effect becomes neutral after the second month. Finally, the pass-through to IPI is positive in the first month but becomes negative after the first month, and sharply moves towards its steady state in the second month. Furthermore, there is evidence that the pass-through transition for all the variables including own-shocks is instantaneous and the size seems to be only larger in the upper regime periods for NEER and IPI.

The results documented in Figures 11(a)-(h) are pass-through of NEER shocks in China. In the upper regime periods, the pass-through to OIL and IPI is initially negative and become positive but insignificant in the first month. By the end of the first month, it decreases until it becomes stable in the second month. The pass-through to CPI is negative and significant in the first month; this dampens to its equilibrium value in the second month. Lastly, the pass-through to NEER is positive and continue to dampen until it becomes neutral at the end of the first month. This situation of the pass-through is different from the pass-through recorded in the lower regime periods. According to the results, the pass-through of NEER shock to own-variable is positive and hence reaches its steady-state value in the second month. The pass-through to OIL and CPI is negative and significant in the first month. This gradually declines until it becomes neutral in the third month horizon. More so, the pass-through to IPI is negative and significant. It eventually becomes positive after the first month and hence moves to its equilibrium state in the second month horizon. In addition, our results provide that the pass-through transition to its equilibrium value between the states is sharp in all cases both in the upper and lower regime periods except the pass-through to CPI at the lower regime periods, which is characterized by smoothness and slowness.

Finally, figures 12(a)-(h) present the pass-through of NEER shocks for South Africa. In the upper regime periods, the results divulge that the pas-through to OIL, IPI and NEER is positive and only significant in the case of OIL and NEER while it is negative to CPI. The pass-through becomes neutral after the third month for OIL, first month for CPI and second month for IPI. However, the results record that the pass-through to own-variable is positively significant and falling gradually until its impact is extinguished prior to the second month. Likewise, in the lower regime periods, the evidence shows that NEER shocks negatively and significantly pass-through to OIL from first to the second months. For CPI, the pass-through is initially negative, and then crosses to the positive region in the first month. This pass-through stabilizes to its equilibrium value in the second month. The pass-through of own-shocks and IPI is positive. However, for own-shocks, the pass-through continues to decline until it becomes neutral after the first month. In the case of IPI, our evidence provides that the pass-through turns positive within the first month horizon and subsequently drops until it is stabled in the second month horizon. Furthermore, the pass-through transition from the shocks in NEER is apparently instantaneous for South Africa. Also, the size of the pass-through is higher in the upper regime periods compared to the lower regime periods.

3.4.3.2 Responses to Oil Price Shocks

Similar to the discussions in 4.3.1, the pass-through of OIL shocks to CPI, NEER, IPI and own-variable in the BRICS countries is disclosed both in the upper regime periods and in the lower regime periods. Figures 13(a)-(h) for Brazil indicate that pass-through of OIL shocks to OIL, CPI and IPI is positive and significant within the first month horizon and dampens instantaneously until it becomes negative, after which it gradually stabilizes to its equilibrium value in the tenth month. In the case of CPI, the pass-through becomes significant after the second month and continues to decline smoothly and slowly until it stabilizes to its equilibrium value in twelve months. More so, the pass-through to own-variable is initially negative and significant. It sharply becomes positive and significant within the same month and consequently declines smoothly and slowly until it becomes stable after 15 months. In the lower regime periods, the results provide a positive and significant pass-through of OIL shock to own-variable, CPI and IPI, while the pass-through to NEER is negative and significant until the second month. Furthermore, the results provide evidence of sharp pass-through transition within the first month between the states. In addition, the size of the pass-through is higher in the upper regime periods when the shocks to the transition variable apparently shift the system above the threshold level.

The pass-through of the shocks in OIL with respect to Russia is displayed in figures 14(a)-(h). In the upper regime periods, the pass-through to OIL, NEER, and IPI is positive and significant, while to CPI is negative and significant. The pass-through becomes neutral after the second month for all the variables except in the case of IPI where it becomes neutral after the first month. In the lower regime periods, the results provide that the pass-through to OIL, NEER, and IPI remains positive and significant. While the pass-through hits its steady state after the first month in the case of OIL to own shocks, the pass-through to NEER and IPI hit negative and subsequently stabilizes to the equilibrium value after the second month. However, the pass-through to NEER and IPI is only significant between the first and second months. More so, the pass-through transition is sharp among the variables. Between first and second month in the upper regime periods, the pass-through to OIL, CPI and NEER is smoother and slower, indicating some delays in stabilizing to the equilibrium values. Comparing the size of the pass-through transition between the states, we find that it is higher in the upper regime periods than in the lower regime periods.

Furthermore, the pass-through of OIL shocks with respect to India are disclosed in figures 15(a)-(h). In the upper regime periods, the pass-through to OIL itself and CPI is positively and negatively significant and sharp up to the second month, after which the pass-through of the shocks becomes stable. In the case of CPI, the pass-through becomes smoother after the end of the first month until it reaches the equilibrium value. Similarly, the pass-through to NEER and IPI is negative. The pass-through is statistically significant up to the second month for NEER and that of IPI is insignificant after the first month. Whereas, in the lower regime periods, we find evidence that the pass-through to OIL and CPI is positive and negative as well as statistically significant. The pass-through sharply dampen to the steady-state value after the second month. For NEER and IPI, the pass-through is negative and positive; although not statistically significant in the case of NEER. The results further suggest that there is perhaps evidence of a sharp pass-through in India. There is also evidence based on the results that the size of the pass-through transition is higher in the upper regime periods compared to the lower regime periods.

Figures 16(a)-(h) presents the pass-through of the shocks in OIL in China. Based on the results of the upper regime periods, we find a positive and significant pass-through to OIL, CPI and IPI in the first two months. While the pass-through to OIL and CPI sharply dampens in the first month, in the second month, we find evidence of slow and smooth decrease until it gets to the steady state. For IPI, it quickly and drastically declines to its equilibrium value after the first month. More so, the pass-through to NEER is negative, sharp and significant up to the end of the first month after which it becomes neutral. In the lower regime periods, the pass-through to the OIL, CPI, and IPI is positive, and statistically significant in the first month. The impact is sharp and become neutral after the first month. For NEER, the pass-through is negative and significant in the first month. This pass-through continues to dampen smoothly and gradually until it becomes stable after the second month. Furthermore, the results suggest that the pass-through transition in China is mostly instantaneous in nature except in the case of pass-through to NEER in the lower regime where it is smoother and slower.

In South Africa, the results of the pass-through of OIL shocks are displayed in figures 17(a)-(h). In the upper regime periods, the OIL shocks positively and significantly pass-through to itself. The pass-through of NEER and IPI is positive and significant while the pass-through to CPI is negative and statistically significant in the first month. The results further suggest that the pass-through converge to the equilibrium value sharply after the second month in the cases of OIL and CPI. However, for NEER, the pass-through declines and hits negative after the first month and then sharply decreases to the equilibrium in the second month. For IPI, the pass-through becomes neutral after the first month. Furthermore, in the lower regime periods, the pass-through to itself is positive and significant. Equally, the pass-through to NEER and IPI is positive and significant in the first month. The pass-through converges to the stable state after the second month. In the case of the pass-through to CPI, we find it to be negative and significant. The results show that the pass-through sharply approaches the steady state after the second month. In the case of pass-through to CPI, we find a delay after the end of the first month. Similarly, in the lower regime periods for the pass-through to OIL itself, and to NEER, there is a delay in the second month until it gradually stabilizes to its equilibrium state.

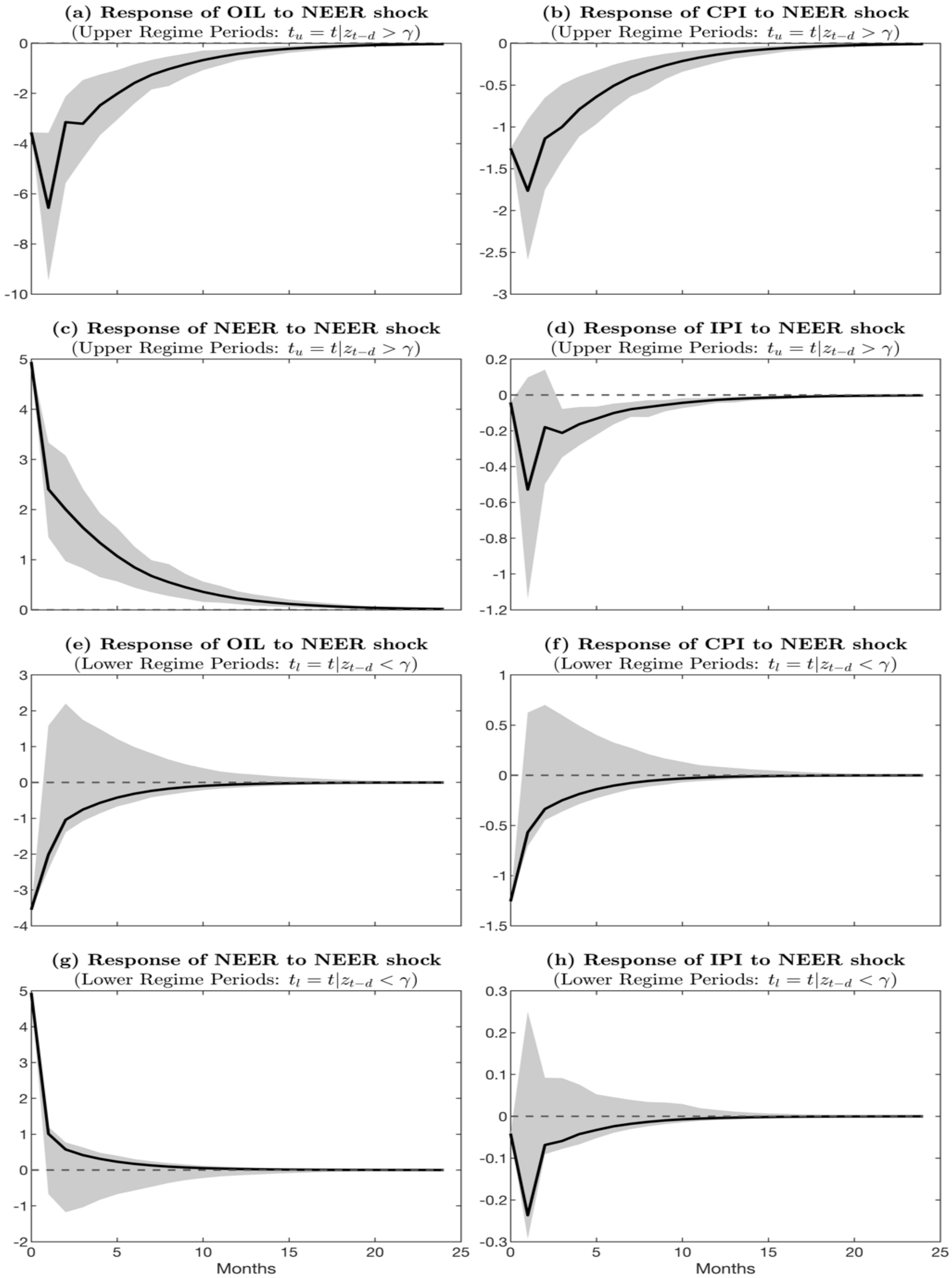

Figure 8: Responses to exchange rate shocks for Brazil

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

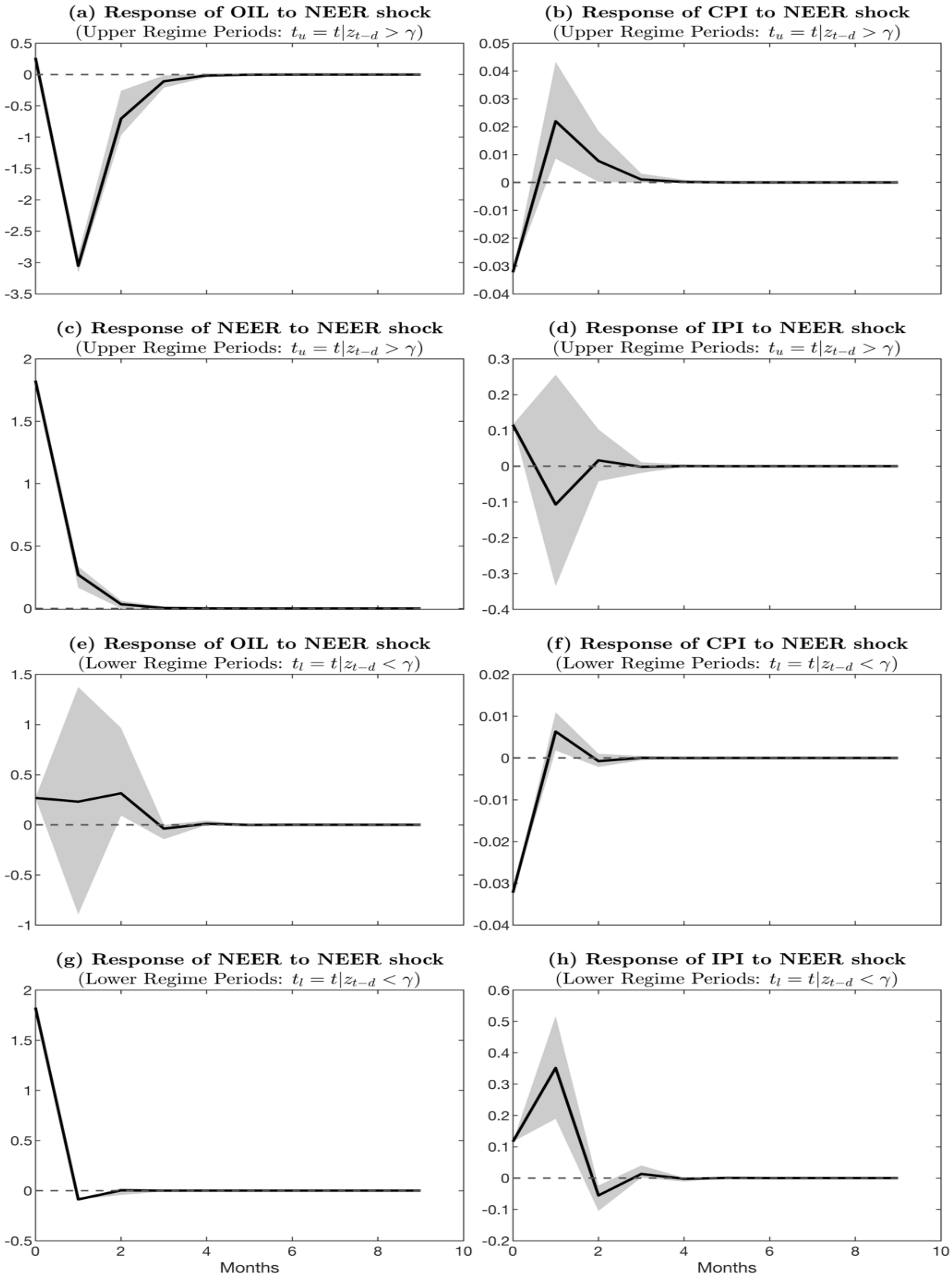

Figure 9: Responses to exchange rate shocks for Russia

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

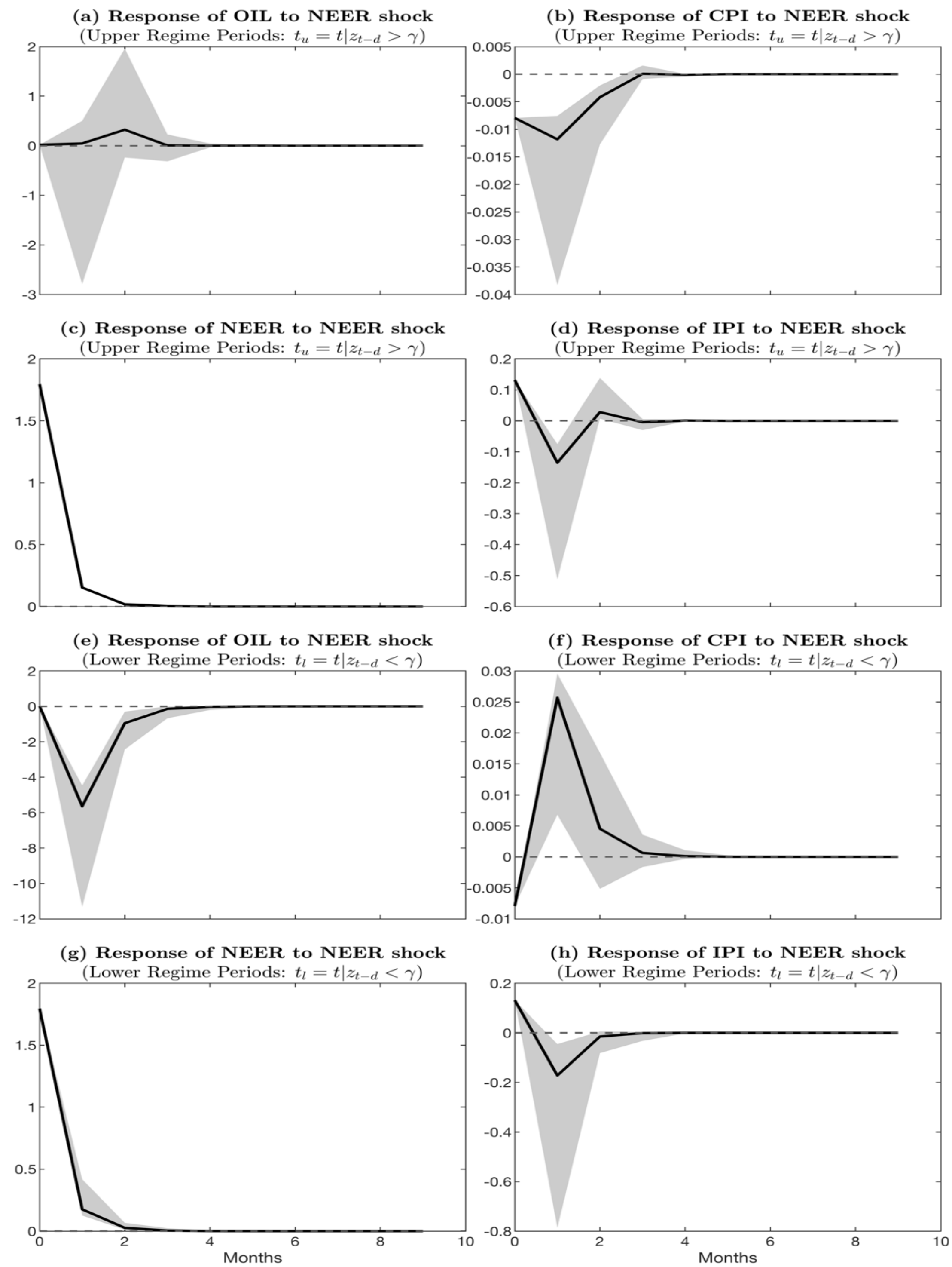

Figure 10: Responses to exchange rate shocks for India

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

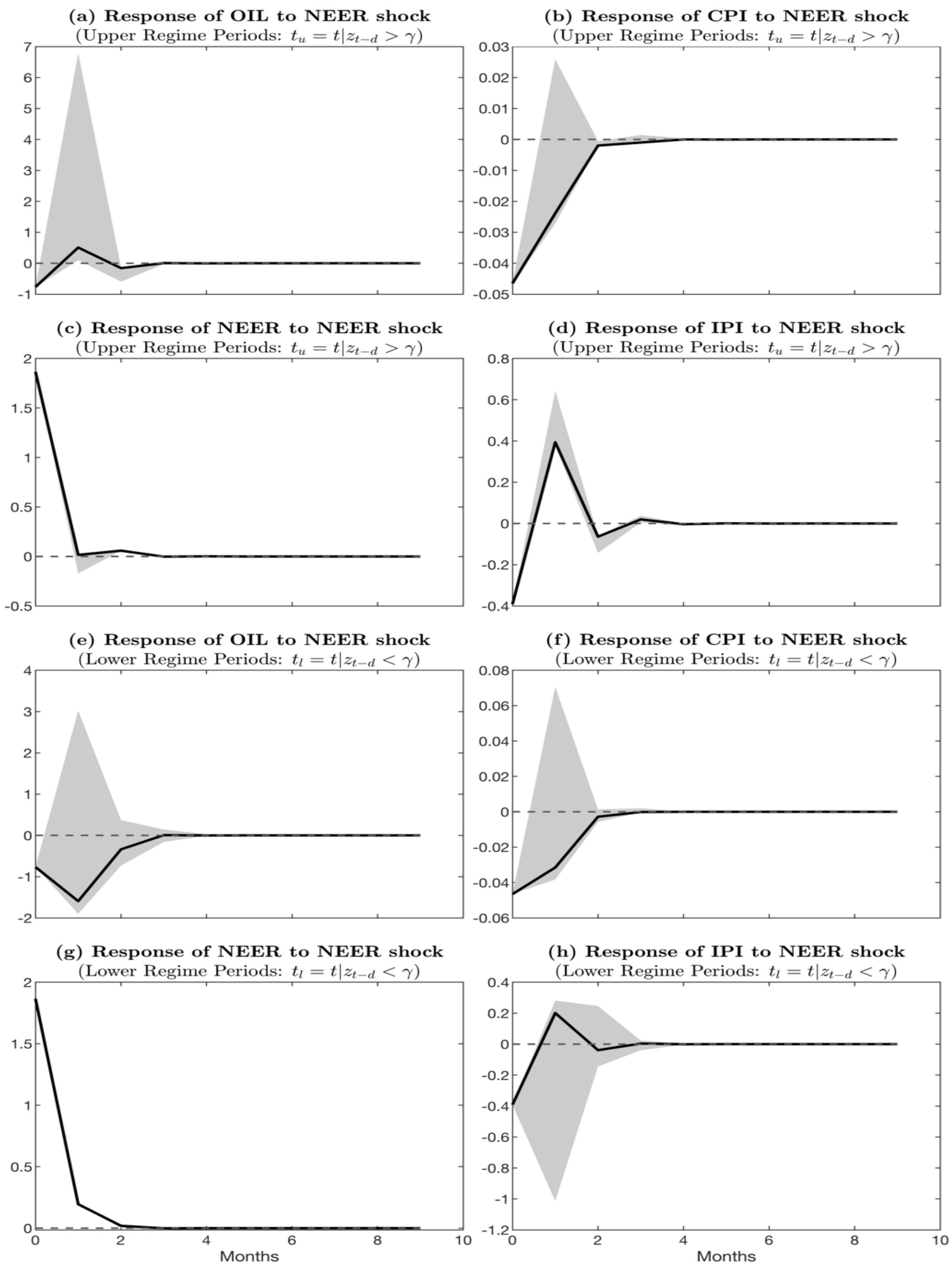

Figure 11: Responses to exchange rate shocks for China

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

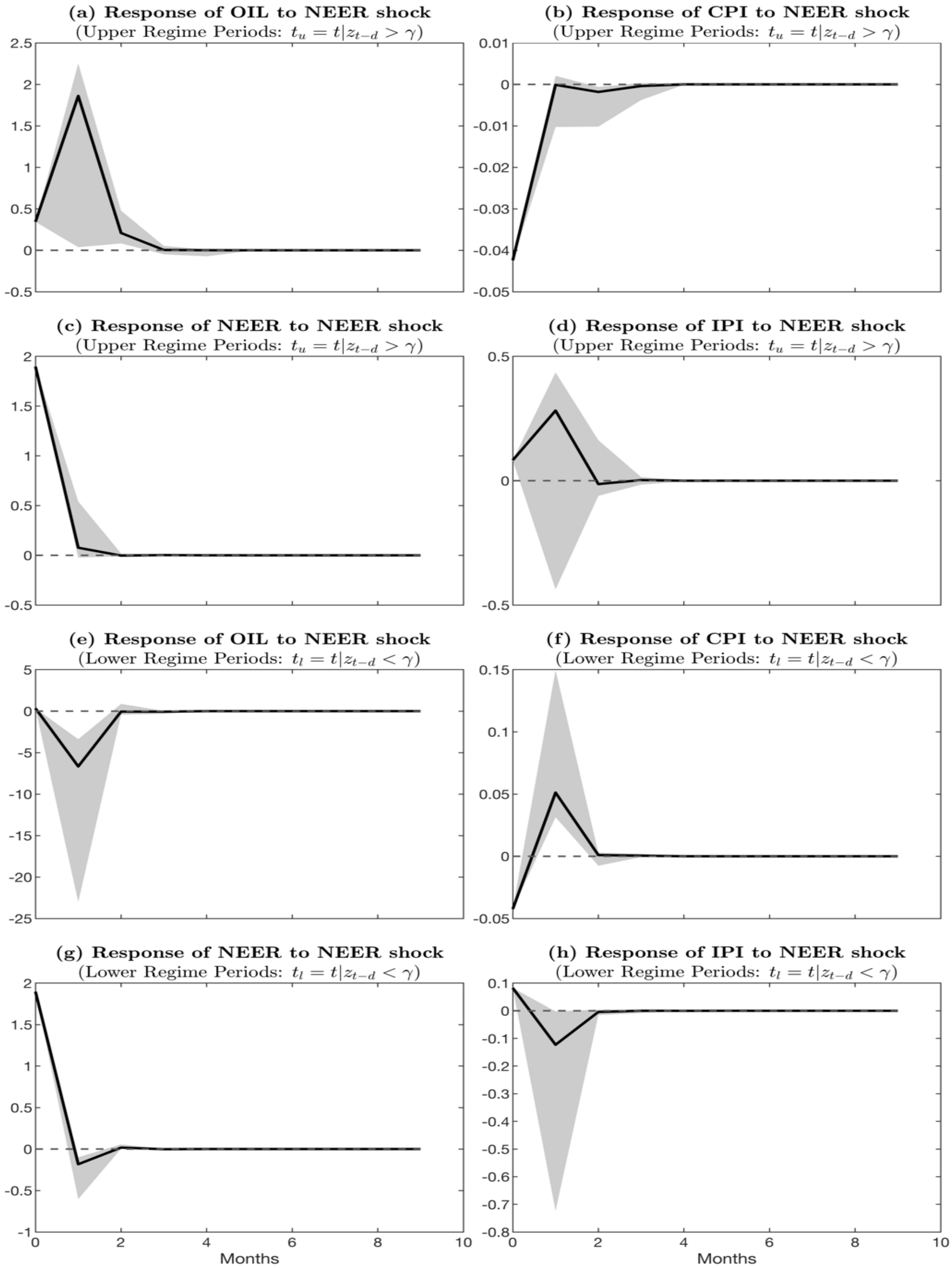

Figure 12: Responses to exchange rate shocks for South Africa

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

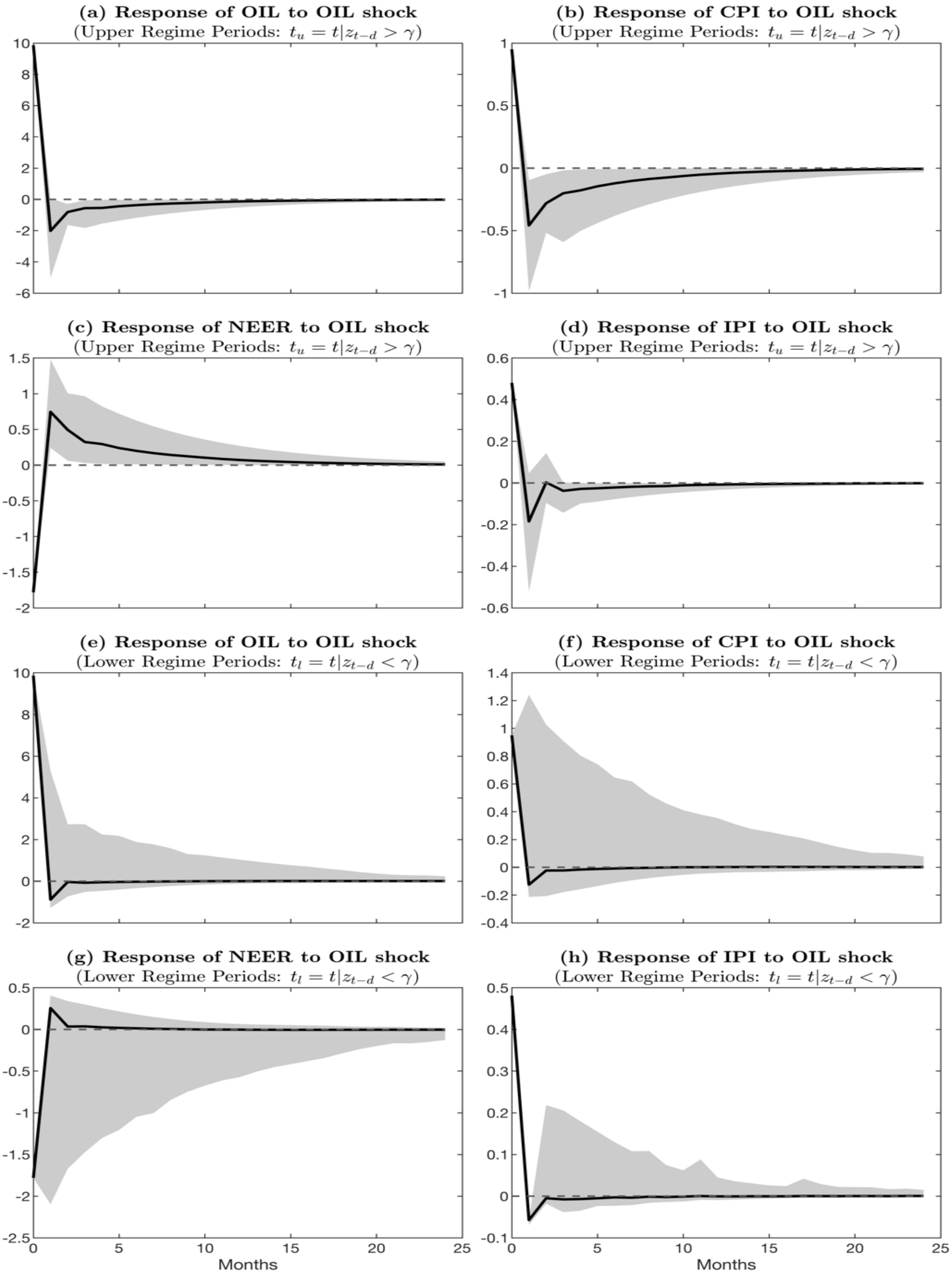

Figure 13: Responses to oil shocks for Brazil

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray are denotes the 95% confidence region.

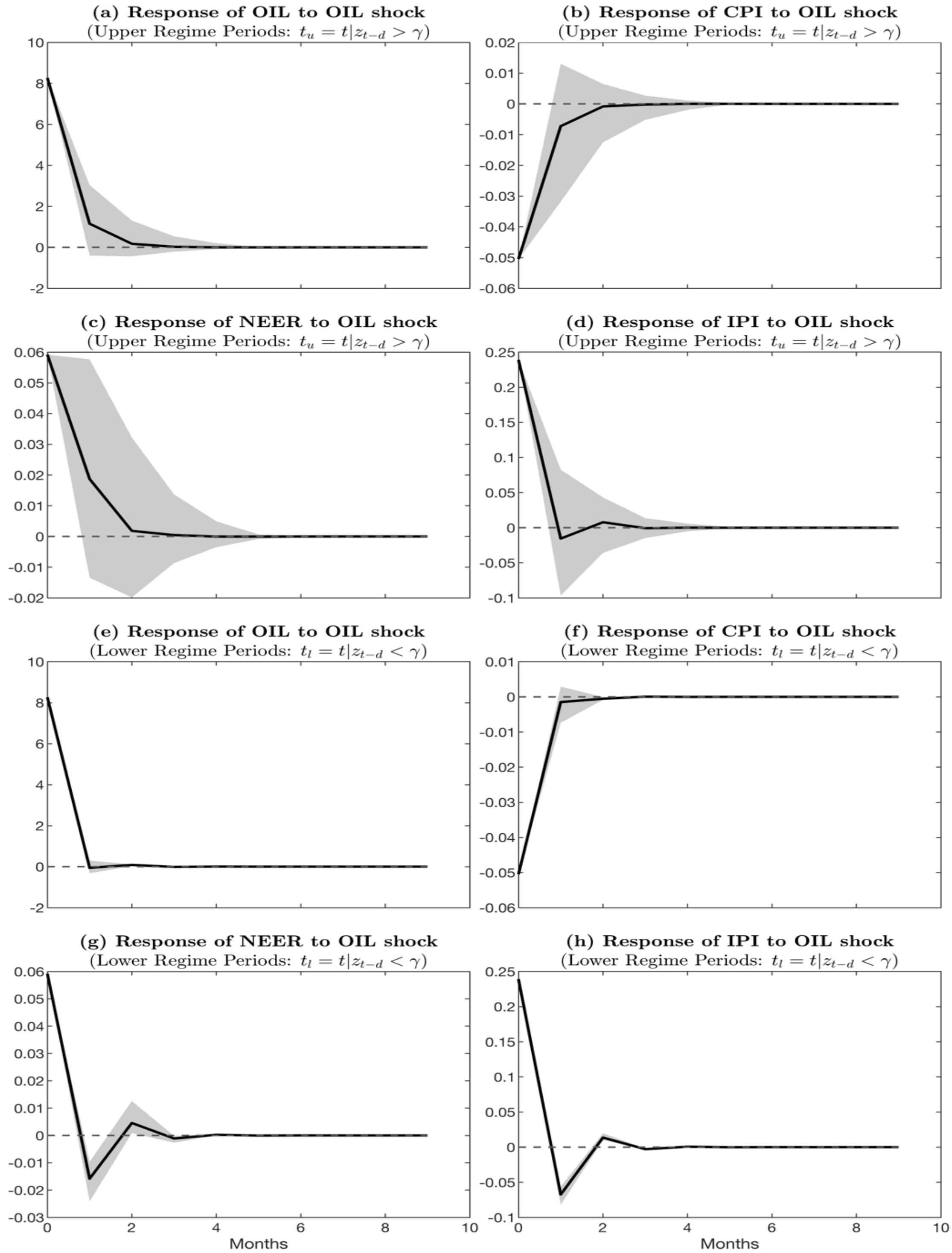

Figure 14: Responses to oil shocks for Russia

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

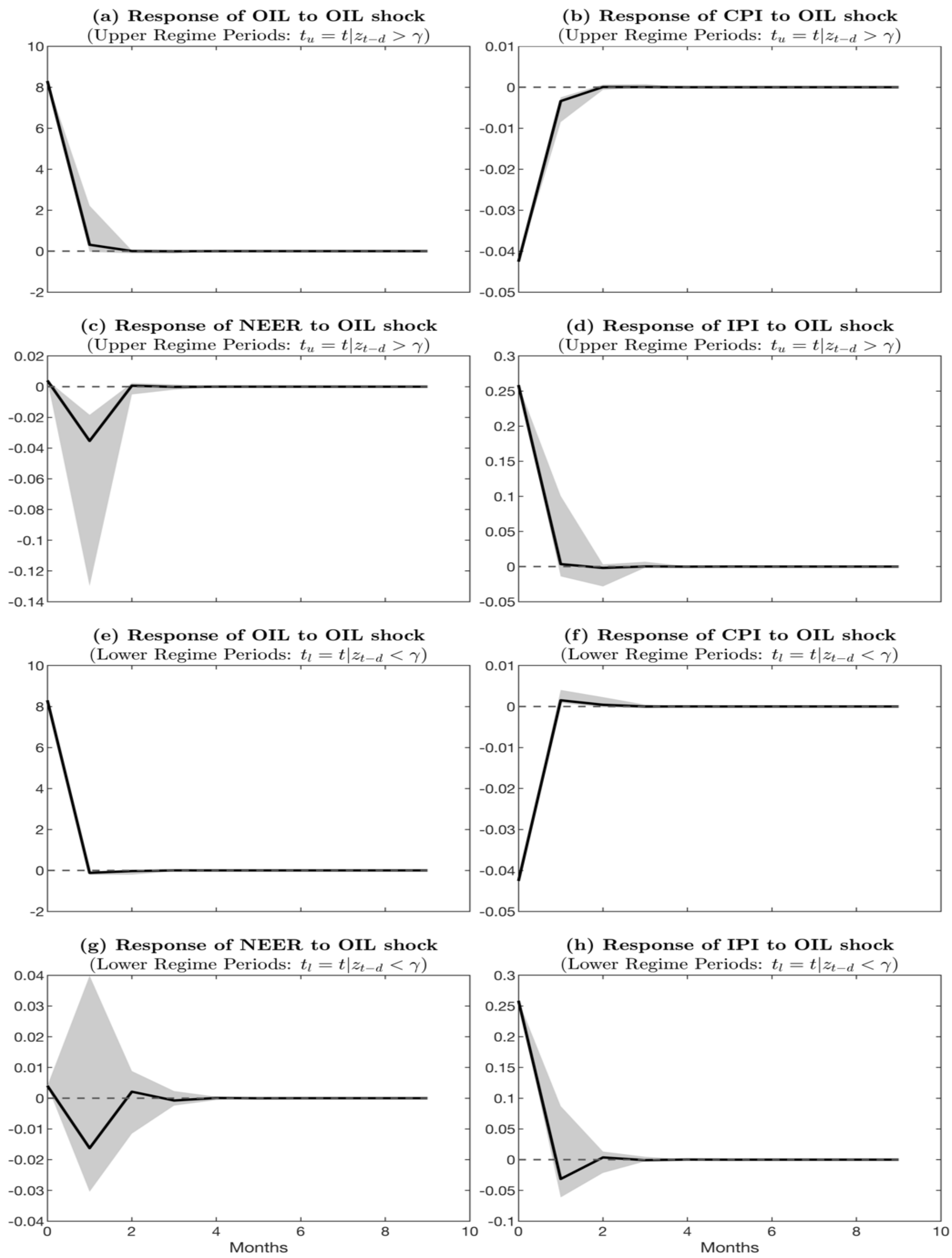

Figure 15: Responses to oil shocks for India

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

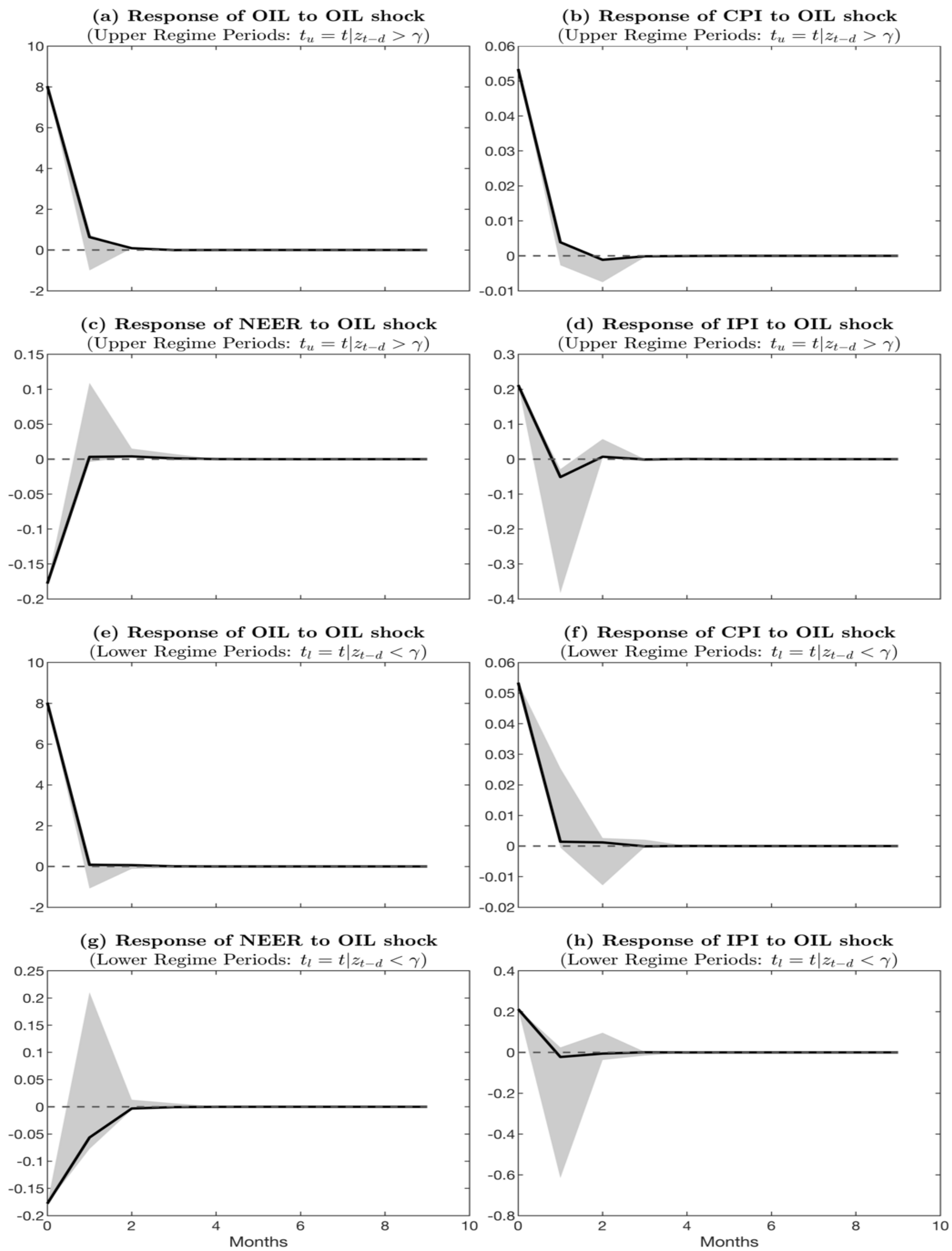

Figure 16: Responses to oil shocks for China

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

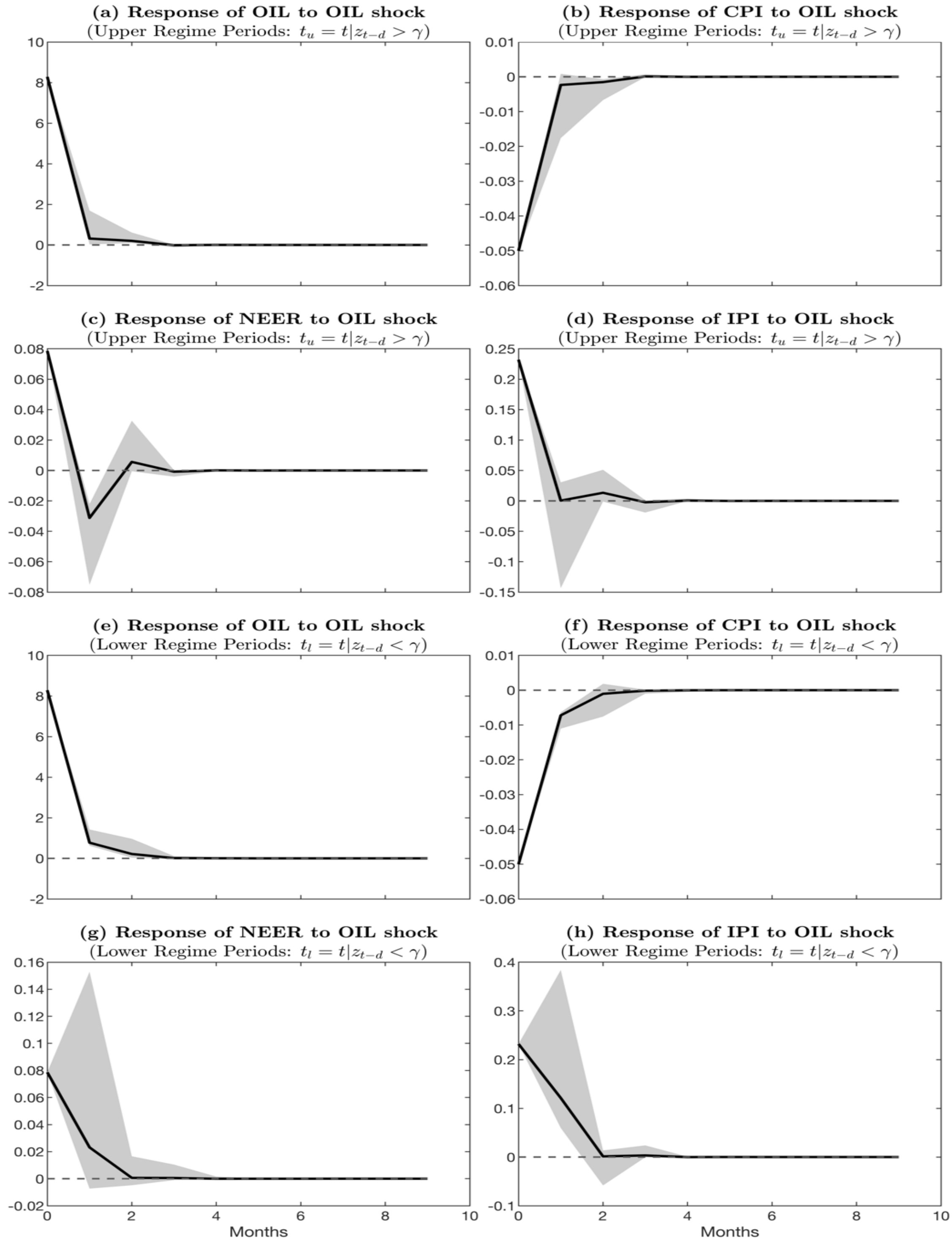

Figure 17: Responses to oil shocks for South Africa

Note: Generalized impulse responses are obtained with 1000 bootstrap repetitions. Gray denotes the 95% confidence region.

3.5 Conclusion

Several studies have come to the limelight in the literature of asymmetric EROPPT in recent times. However, a common limitation of the literature is that many of these studies focus mostly on the direction of the pass-through and the role of inflation volatility in the channel of pass-through without giving due consideration to whether the state of the economy in exchange rate and oil price matter for pass-through. This leaves a missing gap in the literature. This paper, therefore, investigates not only the question of the asymmetric EROPPT to inflation but also to investigate the extent to which the size of the shocks to exchange rate and oil price affect such asymmetric relationship in the BRICS countries. To achieve this objective, we apply the nonlinear VSTAR model, which allows a smooth transition, governed by the selected transition variables to determine the pass-through in the upper and lower regime periods.

The results of the linearity tests based on the LM, LR, and F_{RAO} versions of linearity tests indicate the presence of nonlinearity in all the equations in each of the country. The results based on the model estimations show that the variables asymmetrically respond to the shocks in all the equations in the upper and lower regime periods. To interpret the dynamics of the pass-through, we make use of the GIRFs, which we obtained with 1000 bootstrap repetitions. The results show evidence asymmetric and significant of EROPPT in the upper and lower regime periods. The results also divulge the presence of asymmetric pass-through in all the countries with strong evidence of higher pass-through when the size of the shocks crosses some threshold level. Furthermore, our results provide that output growth asymmetrically react to the large and small shocks to exchange rate and oil price differently. The implication for these results is that state of the economy matter for the EROPPT. Therefore, a sound macroeconomic management is required to reduce the pass-through effect especially when exchange rate and oil price fluctuations are above a certain threshold.

Chapter 4

EXCHANGE RATE AND OIL PRICE PASS-THROUGH IN BRICS COUNTRIES: EVIDENCE FROM THE SPILLOVER INDEX AND ROLLING-SAMPLE ANALYSIS

4.1 Introduction

The role of the exchange rate and oil price shocks on inflation and output growth has been a course of concern for the government and policy makers as well as economists over the years. This role has been rekindled following the disintegration of the system of adjustable peg in the early 1970s, which led to large fluctuations in the bilateral exchange rates of most countries, particularly the developing countries. Theoretically, an increase in the nominal exchange rate and oil price causes the cost of inputs to increase and hence increase the cost of production of goods and services. On the other hand, an increase in the nominal exchange rate and oil price creates inflationary pressure on the price level. Therefore, to curtail this pressure, the monetary authority has to increase interest rate, which consequently reduces investment and hence economic growth (Ghosh and Kanjilal, 2014; Misati *et al*. 2013).

While several studies examine the relationship between the exchange rate and inflation (See Dornbusch, 1987; Taylor, 2000; Bhundia, 2002; Bailliu and Fujii, 2004; Delatte and Lopez-Villavicencio, 2012; Kurtovic *et al*., 2018), others investigate the relationship between oil price and inflation[12] (See Chen, 2000; Kanjilal, 2014; Ajmi *et al*. 2015; Sek, 2017; Balcilar *et al*. 2017; Balcilar *et al*. 2018a). In the case of the relationship between exchange rate and inflation, a significant amount of studies suggests an incomplete pass-through with different pass-through sizes across the countries of the world. For example, Herzberg *et al*. (2003) applied the Smooth Transition Autoregressive (STAR) model to analyze the extent through which the UK import prices respond to shocks in the exchange rate. The finding shows that the pass-through is incomplete and probably explained by the combination of the sticky prices and pricing to market. Karoro *et al*. (2009) examined the exchange rate pass-through (ERPT) to import prices in South Africa, considering the role of asymmetries. The result reveals that the magnitude and speed of the ERPT to import prices in South Africa is incomplete but relatively high; however, the ERPT is higher in the periods of depreciation than appreciation of the rand. More so, Jiang and Kim (2013) used the structural VAR model to investigate the pass-through of the exchange rate to inflation in China with emphasis on the producer price index (PPI) and retail price index (RPP). The finding indicates that the pass through to the PPI and RPP are generally incomplete with PPI having the highest pass-through compared to RPP. The recent study by Kurtovic *et al*. (2018) reported that the pass-through of the exchange rate to import prices of seven countries in Southeast Europe is incomplete, and has not reduced over

[12] The relationship between exchange rate and inflation or oil price and inflation is known as exchange rate pass-athrough (ERPT) or oil price pass-through (OPPT). Therefore, ERPT is defined as the percentage change in domestic prices that is attributed to a change in the nominal exchange rate, while OPPT is defined as the percentage change in domestic prices that is attributed to a change in the oil price.

time. However, the pass-through in the transitional countries is higher than in the developed countries.

Turning to the pass-through of oil price to inflation, Chen (2009) investigated the pass-through of oil price into inflation for 19 industrialized countries with the aim of finding the main determinants of the decline in oil shocks on inflation. The result shows that monetary policy is more active in responding to inflation during appreciation of domestic currency. Ghosh and Kanjilal (2014) found that the effect of negative oil shocks in India is greater than the effect of positive shocks. Ajmi *et al*. (2015) using a novel asymmetric causality approach, provided evidence that causality runs from oil prices to price level in South Africa, while both positive and negative oil price shocks caused positive price level shocks, with negative shocks having more stronger effect. In addition, Balcilar *et al*. (2017) focused on the role of oil price shocks on the South African business cycles using quarterly data over the period 1960Q2 to 2013Q3. The finding indicates that oil price has a predictive power for real output growth under the low growth episode, but the low growth episode is shorter than the long growth episode. Adding a pinch of salt to the literature, Balcilar *et al*. (2018a) further investigated the dynamic relationship between the exchange rate and inflation in South Africa using a long period data spanning from 1922M01 to 2013M07. The finding shows that oil price has a positive relationship with inflation; however, the positive shocks have higher impact on inflation than the negative shock of the same magnitude.

Clearly, even though the literature on pass-through is quite large, most of the existing studies that investigated either the exchange rate-inflation nexus or oil price-inflation nexus, provided mixed results. Therefore, the main aim of this paper is to use the spillover index and rolling window approach recently proposed by Diebold and Yilmaz (2012) to reconsider the pass-through of the exchange rate and oil price in Brazil, Russia, India, China and South Africa countries (henceforth BRICS countries). We focus our analyses on the BRICS countries, being the fast-growing economic hub in the emerging markets for the past two decades (IMF, 2011).

The contributions of this paper to the bulk of literature are in several ways: First, on the scope of analysis, this is the first time, to the best of our knowledge, that the pass-through of the exchange rate and oil price is examined for BRICS countries using a time-series approach. Second, on the methodological basis, our paper uses a spillover index recently proposed by Diebold and Yilmaz (2009) and its extension by Diebold and Yilmaz (2012). This methodology uses a generalized vector autoregressive (VAR) framework, where the forecast-error variance decompositions are invariant to the variable ordering. Third, we apply the rolling window approach, which allows all the historical events, crises as well as other factors that characterize the behaviours of the spillovers to be analyzed. Fourth, unlike the previous studies, the gross shocks transmitted to a particular variable, and those received from all other variables as well as the net spillovers are considered in our results. Therefore, given the primary objective of the Central Bank in maintaining low and stable inflation, which is central to achieving the goal of strengthening the macroeconomic policy and building a resilience to external shocks in BRICS countries, it is important to understand the channels through which exchange rate and oil price movements are passed to inflation. To this extent, the findings of this paper will assist in timing the current account adjustments and the proper conduct of monetary policy (See McCarthy 2000; Krugman and Obstfeld, 2003).

The rest of the paper is structured as follows: section 4.2 describes the data employed and presents preliminary analysis as well as model used, which is based on the Diebold and Yilmaz (2012). Section 4.3 discusses the empirical results while section 4.4 concludes the paper.

4.2 Data and Methodology

4.2.1 Data and Preliminary Analysis

In this study, we use monthly data to analyze the exchange rate and oil price pass-through to inflation in BRICS countries. The data spans from 1986M01 to 2018M04 for Brazil and India, 1990M01 to 2018M04 for China and South Africa and 1995M01 to 2018M04 for Russia.[13] The seasonally adjusted consumer price index (CPI) data is obtained from the International Financial Statistics database, while the exchange rate, which corresponds to the nominal broad effective exchange rate (NEER) and the measure of output growth, which corresponds to the seasonally adjusted industrial production index (IPI) are generated from Thomson Reuters DataStream[14]. Finally, the spot price for crude oil (in national currency) is extracted from the database of the U.S Energy Information Administration (EIA)[15]. The four variables in this study (CPI, IPI, NEER and Oil price) are expressed in their natural logarithms. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (see Appendix A) show that all series are

[13] The period covers for each of the countries is due to data availability.

[14] Note that for South Africa, manufacturing production index (MPI) is used to measure output growth due to data availability

[15] The spot price of crude oil in national currency is obtained by multiplying the nominal exchange rate (national currency per dollar) by the spot price for crude oil in US dollars.

nonstationary in levels but stationary in first difference. Therefore, all analysis are performed using log growth rates.

Therefore, to compute the log growth rate in percent of the log level variables, the following equation is applied:

$$\pi_t = \ln\left(\frac{y_t}{y_{t-1}}\right) \cdot 100 \tag{17}$$

where π_t denotes the log-growth rate of the variables, y_t is the log level variable, y_{t-1} is the previous value of the log level variable. The summary of the descriptive statistics of the CPI, IPI, NEER and oil price variables is displayed in Table 6 (See Chapter 3).

While Panel A of Table 6 shows the log levels, Panel B displays the log growth rate (%) of these variables. Based on the result of Panel A, we find that for Brazil, the NEER and CPI have the highest and lowest sample mean, while in Panel B, the highest and lowest sample mean are the CPI and IPI. For the rest of the countries, we find that oil price has the highest sample mean both in Panel A and Panel B respectively. The standard deviation of the variables shows that Brazil is the most volatile country compared to the rest of the countries. This volatility is more conspicuous in their growth rate in percent (Panel B) across BRICS countries with oil price having the highest volatility. The skewness of the variables shows that some of the variables are positively skewed, while others are negatively skewed. In addition to the pattern of their skewness, all the variables exhibit positive kurtosis in both panels with more evidence of positive excess kurtosis. Consequently, the null hypothesis of a normal distribution is rejected at one percent level of significance for all the countries. The rejection of the null hypothesis implies that the distribution of all the variables deviates from normality in the BRICS countries.

Figures 18 to 22 examine the time plots of the macroeconomic variables (inflation, exchange rate, oil price and output growth) for the possible existence of the drift, trend, and structural breaks. Specifically, Figure 18 presents the time plots for all the variables for Brazil. Based on this figure, the CPI shows an upward movement, which is peculiar to a time trend. The NEER shows a downward slope, which is peculiar to a negative trend. This series eventually settles down to a constant zero value since the early 1990s. This, therefore, implies that the series is constant as the time varies. Finally, the plots of the IPI and oil price show upward random movements with a time trend. These series are suspected to have sudden breaks.

Figure 19 shows the time plots of the variables for Russia. The CPI shows an upward movement with a time trend. The NEER exhibits structural breaks and eventually settles down at the constant zero value. The IPI and oil prices exhibit upward random movements with a time trend. Furthermore, the time plot of the variables for India is shown in Figure 20. Based on this figure, it is clear that the CPI and IPI variables slope upward with a time trend. The NEER has negative and downward movements with a time trend, while the time plot of the oil price indicates more than one breaks at various points.

In the case of China, Figure 21 shows that all the variables exhibit random movements with the evidence of structural breaks. Particularly, the plot of the IPI shows several breaks at several time points with no particular pattern of movements. The figure further shows a jump in the CPI and a sudden fall in the NEER in 1995. These are attributed to a significant change in the exchange rate policy in 1994. Finally, Figure 22 presents the time plots of the variables for South Africa. The CPI indicates an upward movement to a time trend. The NEER shows a downward slope, which is peculiar to a negative trend. The time plots of IPI and oil prices exhibit structural breaks, which are more noticeable in oil price.

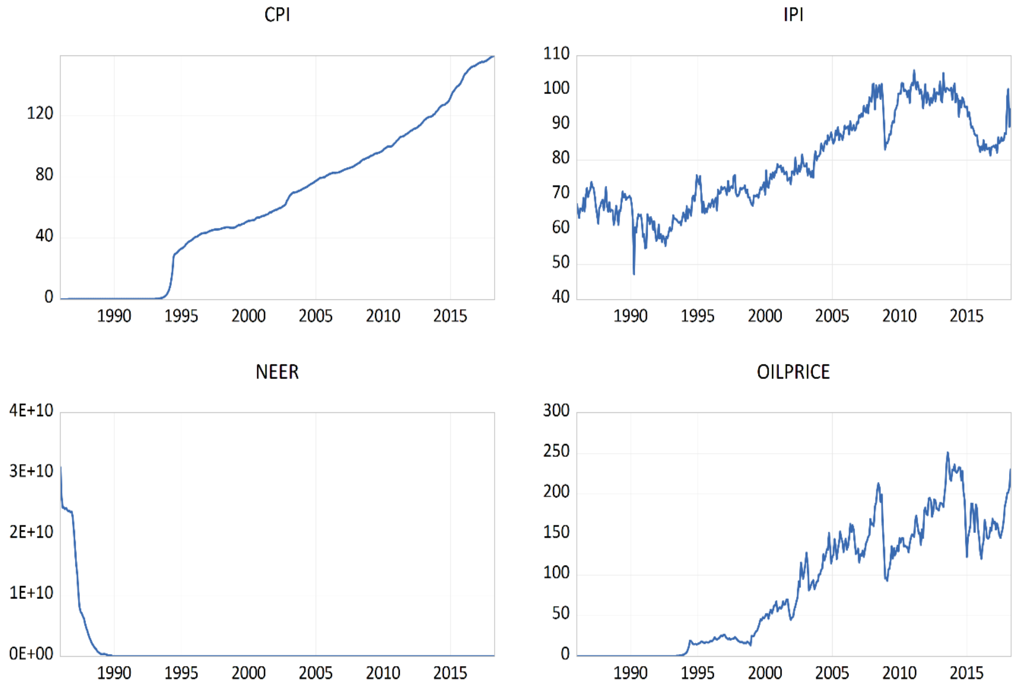

Figure 18: Time series plot of data in levels for Brazil

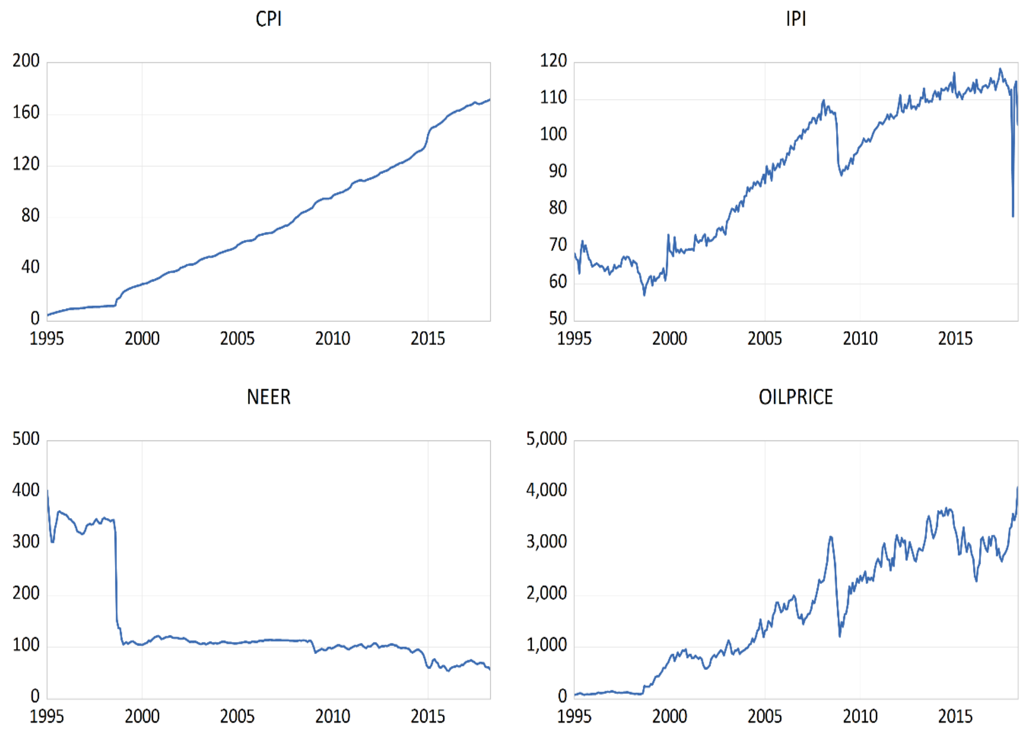

Figure 19: Time series plot of data in levels for Russia

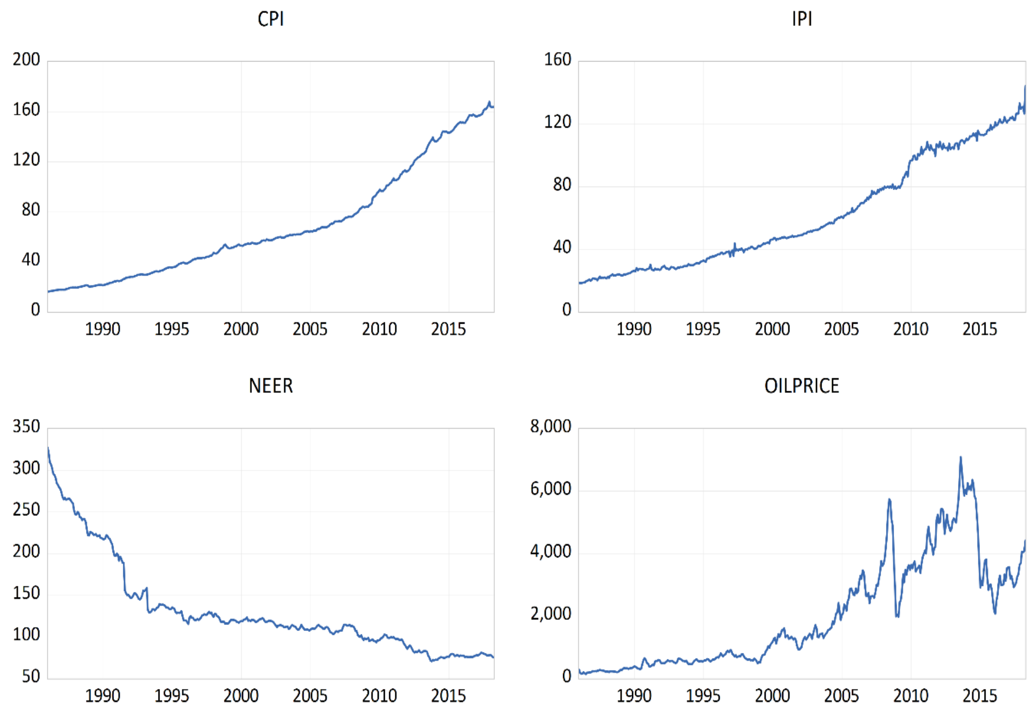

Figure 20: Time series plot of data in levels for India

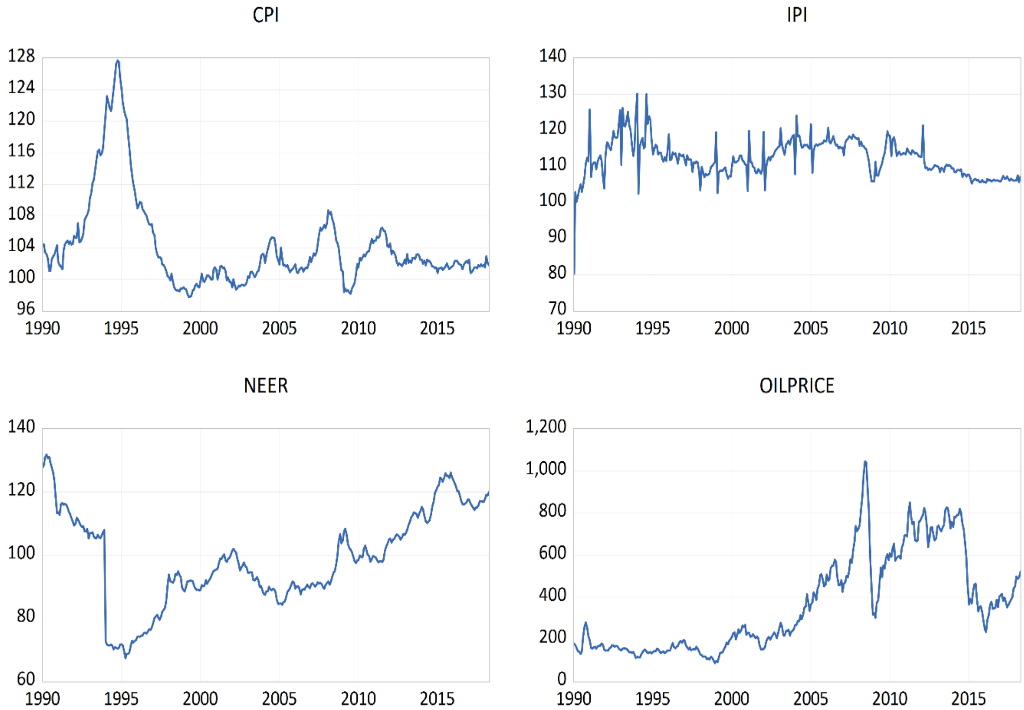

Figure 21: Time series plot of data in levels for China

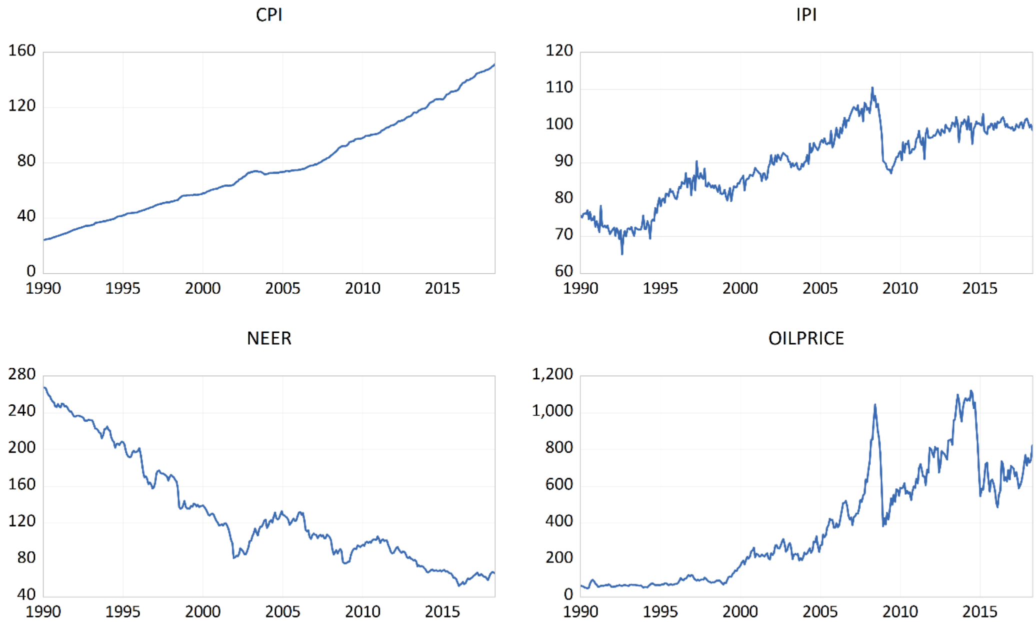

Figure 22: Time series plot of data in levels for South Africa

4.2.2 Diebold-Yilmaz (2012) Spillover Index

The spillover index developed by Diebold and Yilmaz (2012) is based on the framework of the generalized vector autoregressive (VAR) model proposed by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998) (henceforth KPPS). In this index, the forecast error variance decomposition is invariant to the ordering of variables (See Zhou *et al*. 2012; Antonakakis and Kizys, 2015; Salisu *et al*. 2018). Therefore, following the pioneering study of Diebold and Yilmaz (2009) and its extension by Diebold and Yilmaz (2012), we consider the general form of VAR(p) with covariance stationary N variables[16].

$$y_t = A_0 + \sum_{i=1}^{p} A_i y_{t-i} + \varepsilon_t \tag{18}$$

where N represents the number of variables, y_t is $(N \times 1)$ a vector of the dependent variables, A_i denotes the $N \times N$ matrix of the autoregressive coefficients, and ε_t is a zero mean white noise process with covariance matrix Σ, $\varepsilon_t \sim iid(0, \Sigma)$. Equation (18) can be written in terms of a moving average as follows:

$$y_t = \sum_{i=0}^{\infty} C_i \varepsilon_{t-i} \tag{19}$$

where the $(N \times N)$ coefficient matrices, C_i obey the recursion $C_i = A_1 C_{i-1} + A_2 C_{i-2} + \cdots + A_p C_{i-p}$. C_0 denotes the $(N \times N)$ identity matrix, where $A_i = 0$ for $i < 0$. Based on the generalized forecast error variance decomposition of the moving average in equation (19), we provide three main dimensions of the growth rate spillovers – directional, total and net spillovers. According to Diebold and Yilmaz

[16] See Lukepohl (2005) and Juselius (2006) for a detailed discussion on the VAR model.

(2012), "the own variance shares" are measured as the fractions of the H-step-ahead error variances in forecasting y_{it} for $i = 1,2,\dots,N$ and "cross variance shares" being the fractions of the H-step-ahead error variance in forecast y_{it} owing to the shocks to y_{jt}, for $j = 1,2,\dots,N$, such that $i \neq j$. Therefore, following Pesaran and Shin (1998), the KPPS H-step-ahead generalized forecast error variance decomposition is defined as:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=1}^{H-1} \left(e_i' C_h \Sigma e_j\right)^2}{\sum_{h=1}^{H-1} (e_i' C_h \Sigma C_h' e_i)}, \tag{20}$$

where Σ represents the variance matrix of the error vector ε_t, σ_{jj} denotes the standard deviation of error terms for j-th equation, e_i shows the selection vector with one as the i-th element, and 0 otherwise. It is clear that the sum of the own variance and cross variance shares contributions is not equal to unity under the generalized decomposition i.e. $\sum_{j=1}^{N} \Theta_{ij}^{g}(H) \neq 1$. Hence, we follow Deiebold and Yilmaz (2012) by normalizing each entry of the variance decomposition matrix by the sum of the row as:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{21}$$

$\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{K} \tilde{\theta}_{ij}^{g}(H) = N$. Therefore, the total growth rate spillover index can be constructed as follows:

$$S_T^{g}(H) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{n} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100 \tag{22}$$

where $S_T^{g}(H)$ denotes the total growth rate spillover. The index is applied to measure the average contributions of the spillover from the shocks across the variables of interest to the total forecast error variance decomposition. Furthermore, to compute the directional spillover, we focus on two main dimensions: the directional spillovers received by variable i from other variables j, and the directional spillovers transmitted by variable i to other variables j. Therefore, the former is computed as:

$$\mathrm{DS}_{\mathrm{i}\leftarrow\mathrm{j}}^{\mathrm{g}}(\mathrm{H})=\frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H})}{\sum_{\mathrm{i,j}=1}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H})}\times 100=\frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H})}{\mathrm{N}}\times 100 \tag{23}$$

and the latter is computed as:

$$\mathrm{DS}_{\mathrm{i}\rightarrow\mathrm{j}}^{\mathrm{g}}(\mathrm{H})=\frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ji}}^{\mathrm{g}}(\mathrm{H})}{\sum_{\mathrm{i,j}=1}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H})}\times 100=\frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{n}}\tilde{\theta}_{\mathrm{ji}}^{\mathrm{g}}(\mathrm{H})}{\mathrm{N}}\times 100 \tag{24}$$

Finally, to compute the net spillovers from variable i to all other variables j, we subtract equation (23) from equation (24) as:

$$\mathrm{NS}_{\mathrm{i}}^{\mathrm{g}}(\mathrm{H})=\mathrm{DS}_{\mathrm{i}\rightarrow\mathrm{j}}^{\mathrm{g}}(\mathrm{H})-\mathrm{DS}_{\mathrm{i}\leftarrow\mathrm{j}}^{\mathrm{g}}(\mathrm{H}) \tag{25}$$

where $\mathrm{NS}_{\mathrm{i}}^{\mathrm{g}}(\mathrm{H})$ is simply the net spillover, which is expressed as the difference between the gross shocks transmitted to and those received from all other variables.

4.3 Empirical Findings and Discussion

4.3.1 Analysis of Spillover Tables

This section contains the results of the directional, total and net spillovers constructed based on a generalized VAR framework of Diebold and Yilmz (2012). The spillover table for the growth rate (%) of the oil price, NEER, CPI and IPI in BRICS countries is reported in Tables 9 (a) – (e). The computation of this Table is based on the first order VAR with four variables. The Schwarz Information Criterion (SBC) is used in selecting the optimal lag length of the model, which is 1. The spillover analysis is performed using $H=12$-step ahead forecast error variance decomposition. The sum of the off-diagonal elements (column) gives "the contribution to others" which technically implies the total contribution of a variable under consideration to other variables' forecast error variance decomposition. Furthermore, the sum of the off-diagonal elements (row) offers "the contribution from others", which technically measures the overall contribution of shocks to other variables to the forecast error variance decomposition of a variable under consideration. With exception of the main diagonal elements, the individual elements found in each column capture the contribution of each variable to the forecast error variance decomposition of other variables. Similarly, the individual elements, except the main diagonal, measures the contributions of other variables to the forecast error variance of a particular variable. The total spillover index, which appears at the lower right-hand corner of Tables 9 (a) – (e), is computed as the sum of all elements in the (4×4) matrix excluding the sum of the diagonal elements.

Therefore, starting with Brazil, the result of the directional spillover, with exclusion of the main diagonal from others indicates that CPI terrifically has the largest contribution to the forecast error variance decomposition of the NEER. Specifically, the contribution of the CPI to the forecast error variance decomposition of the NEER is about 36.3%. This is distinctly followed by the OILPRICE with about 21.4% and IPI estimate at 7.3%. Similarly, the oil price has the largest contribution to the forecast error variance decomposition of the NEER. Particularly, the oil price explains about 28.5% to the forecast error variance decomposition of the NEER, followed by the CPI with about 26.8% and the least is the IPI with about 3.3%. The implication for this result is that the spillover between CPI and oil price is apparently bidirectional. Furthermore, the contribution from the other variables to the forecast error variance decomposition of the CPI is absolutely dominated by the OILPRICE estimated at

26.8%. This is followed by the NEER with 13.2% and the IPI with 1.5%. By contrast, the contribution of other variables to the forecast error variance decomposition of NEER is captured largely by CPI rather than OILPRICE. Finally, the IPI receives the lowest contribution from the other variables with CPI having the largest contribution estimated at 7.3%. This is followed by the oil price with about 3.3% and the NEER with just about 1.4%.

For Russia, the NEER and IPI are the only contributors to the forecast error variance decompositions of the oil price with as low as about 0.2% for each. The results further show that oil price has the largest contribution to the forecast error variance decompositions of the NEER and CPI than IPI. Specifically, the oil price explains about 23.7% and 21.7% of the forecast error variance decomposition of the CPI and NEER, respectively. Notably, even though the shocks in the CPI are not likely affecting the behaviours of the oil price, our results reveal that oil price explains about 23.7% to the forecast error variance decomposition of the CPI. In the case of India, our results suggest that only the CPI contributes to the forecast error variance decomposition of the oil price with as low as 0.1%. However, the contribution of the oil price to the forecast error variance decomposition of the CPI is estimated at 0.8%, which is larger than 0.1%. In addition, the oil price contributes as high as about 4.1% to the forecast error variance decomposition of the NEER and 1.1 in the case of the IPI.

The directional spillover for China indicates that CPI has the largest contribution to the forecast error variance decomposition of the IPI with about 6.6%. This is followed by the NEER with 4.0% and oil price with 0.5%. The largest contributor to the forecast error variance decomposition of the CPI is the NEER with about 4.0%, followed by IPI with 2.9% and last but not the least, the oil price with 1.5%. In contrast, like the CPI, the contribution of the other variables to the forecast error variance decomposition of the IPI is dominated by the NEER with about 12.7%, tracked by the CPI with 6.6% and 0.6% for the oil price. The lowest contribution from other variables is received by the oil price with CPI having dominance. Finally, in South Africa, the contribution to the forecast error variance decomposition of the CPI mainly comes from two variables – the NEER with about 3.3% and oil price with about 2.6%. The result also suggests that oil price has the largest contribution to the forecast error variance decomposition of the NEER as it explains about 5.2%. This is followed by the CPI with about 0.9%. Likewise, the contribution from the other variables to the forecast error variance decomposition of the IPI is dominated by the oil price. In other words, the forecast error variance decomposition of the IPI is influenced by the shocks to the oil price estimated at 1.0%. This is closely followed by the CPI with about 0.4% and NEER estimated at 0.3%. There is also evidence that oil price has about 2.6% to the forecast error variance decomposition of CPI.

The total spillover index as provided in the lower right-hand corner of Table 3 is estimated as the average of the spillover from other variables. The result reveals that the total spillover index is 34.5% for Brazil, 24.7% for Russia, 2.6% for India, 8.9% for China and 3.8% for South Africa. Apparently, these results imply that the forecast error variance decompositions are due to the spillovers among the variables captured in our study. The implication for the results is that the pass-through measured by the total spillovers is incomplete and very low in all the countries with Brazil having the highest. Our results, therefore, align with the hypothesis advanced by Taylor (2000) that the pass-through has significantly declined in the recent years owing to a stable and low inflation.

The result for Brazil suggests that CPI and oil price transmit the largest contributions to the forecast error variance decomposition to other variables with about 65.1% and 58.5%, respectively; whereas about 41.5% and 26.1% are received by the CPI and oil price from the other variables. By implication, the oil price and CPI contribute about 32.5% and 23.6% to the forecasting of other variables than they receive from other variables, hence they are referred to as "net transmitters or givers". The contributions of the rest of the variables to the forecast error variance decomposition of other variables are smaller than what they receive from other variables; hence their net spillovers are negative. For example, in Table 3, the NEER and IPI net spillovers are about -47.7% and -8.37%, respectively. In Russia, the net spillovers of the oil price and NEER are estimated at 47.6% and 21.9%, while those of the CPI and IPI are -59.1% and -10.3%, respectively. In the case of India, the net spillovers for the oil price and CPI are estimated at 5.8% and 1.9% and for the NEER and IPI are -5.9% and -1.8% respectively. Furthermore, the net spillovers for China are 2.3% for oil price, 10.8% for NEER, 2.6% for CPI and -15.8 for IPI. Finally, the results of the net spillovers in South Africa indicate that oil price is about 7.7%, NEER is about -1.4%, CPI is about -4.7% and IPI is estimated at -1.5%.

Table 9(a): Spillover Indexes for Brazil

	OILPRICE	NEER	CPI	IPI	From others
OILPRICE	**73.9**	3.5	21.4	1.2	26.1
NEER	28.5	**34.2**	36.3	1.0	65.8
CPI	26.8	13.2	**58.5**	1.5	41.5
IPI	3.3	1.4	7.3	**88.0**	12.0
Contr. to others	58.6	18.1	65.1	3.7	145.4
Contr. Incl. own	132.5	52.2	123.6	91.7	Total Spillover
Net Spillover	32.5	-47.7	23.6	-8.3	Index = 35.4%

Table 9(b): Spillover Indexes for Russia

	OILPRICE	NEER	CPI	IPI	From others
OILPRICE	**99.6**	0.2	0.0	0.2	0.4
NEER	21.7	**77.0**	1.2	0.1	23.0
CPI	23.7	41.0	**35.3**	0.0	64.7
IPI	2.6	3.7	4.4	**89.4**	10.6
Contr. to others	48.0	44.9	5.6	0.3	98.7
Contr. Incl. own	147.6	121.9	40.9	89.6	Total Spillover
Net Spillover	47.6	21.9	-59.1	-10.3	Index = 24.7%

Table 9(c): Spillover Indexes for India

	OILPRICE	NEER	CPI	IPI	From others
OILPRICE	**99.8**	0.0	0.1	0.0	0.2
NEER	4.1	**93.2**	2.6	0.1	6.8
CPI	0.8	0.3	**98.6**	0.3	1.4
IPI	1.1	0.6	0.5	**97.8**	2.2
Contr. to others	6.0	0.9	3.3	0.4	10.5
Contr. Incl. own	105.8	94.1	101.9	98.2	Total Spillover
Net Spillover	5.8	-5.9	1.9	-1.8	Index = 2.6%

Table 9(d): Spillover Indexes for China

	OILPRICE	NEER	CPI	IPI	From others
OILPRICE	**98.9**	0.1	0.5	0.4	1.1
NEER	1.2	**94.0**	4.0	0.8	6.0
CPI	1.5	4.0	**91.5**	2.9	8.5
IPI	0.6	12.7	6.6	**80.1**	19.9
Contr. to others	3.4	16.8	11.1	4.1	35.4
Contr. Incl. own	102.3	110.8	102.7	84.2	Total Spillover
Net Spillover	2.3	10.8	2.6	-15.8	Index = 8.9%

Table 9(e): Spillover Indexes for South Africa

	OILPRICE	NEER	CPI	IPI	From others
OILPRICE	**98.8**	1.0	0.0	0.2	1.2
NEER	5.2	**93.9**	0.9	0.0	6.1
CPI	2.6	3.3	**94.0**	0.1	6.0
IPI	1.0	0.3	0.4	**98.3**	1.7
Contr. to others	8.9	4.7	1.3	0.2	15.0
Contr. Incl. own	107.6	98.5	95.3	98.6	Total Spillover
Net Spillover	7.7	-1.4	-4.7	-1.5	Index = 3.8%

4.3.2 Rolling-Sample Analysis for Overall Spillovers Indexes

The full-sample spillover table and spillover index computed based on static analysis in the preceding section are not be able to adequately describe the numerous changes that occur during the period of the study. The reason is that, this spillover measure is based on the one-time estimation of a VAR model; hence, the parameters are fixed over the estimation period (Diebold and Yilmaz, 2012). To circumvent this shortcoming, we apply the rolling window approach, which captures all the historical events, crises as well as other factors that characterize the behaviours of the spillovers.

Figures 23(a) – (e) present the time-varying measure of the overall spillover indexes for the sample period using a 60-month (5 years) rolling samples with 12-step horizons for BRICS countries. This approach allows us to analyze how overall spillover changes over time in each country. Based on these figures, we observe large fluctuations in the overall spillover for BRICS countries. These fluctuations are more conspicuous in India, South Africa, and China. However, there is no straightforward evidence of trend movements among these countries. In addition, there is evidence of responsiveness of the overall spillover to historical events such as economic policies, crises etc. In Brazil, as presented in Figure 23(a), the overall spillover begins at a value slightly below 50% in the first window. This continues to fluctuate in the early 1980s, owing to various economic problems occasioned by a significant fall in the price of crude oil. Notably, the fluctuations in the overall spillover before the year 2000 plunged between 40% and 50%. However, from 1999 through 2018, the overall spillover declines with an evidence of low fluctuations between 10% and 20%. In 1995, there is a slight fall in the overall spillover, which is attributed to the “Plano Real” or Real Plan designed in 1994 to track the hyperinflationary process that ensued the economy of Brazil. This subsequently led to a managed peg or crawling peg system of the exchange rate. As noted by Alemán (2011), this policy is able to stabilize the economy as the overall spillover suddenly declines from above 40% to 10% between 1998 and 1999. Nevertheless, the effect of this policy is short-lived as a result of the Asia financial crisis of 1997 that erupted and spread to Brazil. In addition to this financial crisis is a fall in the price of oil to almost $10 per barrel in 1998 as well as the slowdown of commodity prices in 2001. These are all responsible for the sharp upward movement of the overall spillover in the late 2001. Furthermore, the upward movement of the overall spillover during 2005 to 2007 could be traceable to the effects of the dollar crisis in March 2005 that spread to several developing and developed countries, while the jump up of the overall spillover in 2008 coincides with the global financial crisis of 2007-2008 all the way to 2009. Finally, the shocks in the overall spillover in the late 2013 are traceable to the effects of the drop in the crude oil prices in the international market.

In Russia, the overall spillover indexes as graphically displayed in Figure 23(b) begins at a value slightly above 40%, and it is relatively stable in the first and second windows. This is as a result of an exchange rate corridor system introduced in 1995. The sharp decline in the overall spillover in 2004 is attributed to the introduction of a managed floating exchange rate in the late 2003. This marks a move from the system of an authorization-based to flow controls in Russia. More so, the shocks in the overall spillover in 2005 are traceable to two major incidents: first, a dual-currency basket introduced as an operational indicator for the exchange rate policy and second, the dollar crisis of March 2005, which affected most economies in the emerging and advanced countries. More so, the sharp spike in 2008 is occasioned by the global financial crisis of 2007-2008. Finally, the 2014 spike on the total spillover is owed to a significant fall in the crude oil price as well as a step taken towards a free floating of rubble by abolishing the dual currency soft peg on the 10th November 2014.

In the case of India, the overall spillover indexes are presented in Figure 23(c). The figure shows that the fluctuation of the overall spillover is high in the first window. The overall spillover starts at a value little above 8% and rose to about 20% in 1995. The spike in 1991 has been traceable to the India crisis that arises from the budget deficit, and the subsequent upward movement and fluctuations in the overall spillover within the first window are attributed to episodes such as the European Exchange Rate Mechanism (ERM) crisis of 1992-1993, the 2000-2001 European Union and US recessions, and the 2002-2003 Iraq crisis. By the end of 1994, the overall spillover reaches its peak at 20% and subsequently witnesses a sharp decline in 1995, which could be attributed to the effects of two major policy shifts. First, the liberalized exchange rate management system is put in place in March 1992 and second, the dual exchange rate system (managed floating exchange rate), which replaced the liberalized exchange rate management system in March 1993. The increase in the overall spillover in 2005 is accounted for by the US dollar crisis in March 2005. This crisis pushes India and the rest of the emerging countries to consider the option of diversifying the central bank reserve away from the US dollar. Additionally, the upward movement and subsequent spike in the overall spillover during 2007-2008 is traceable to the global financial to two main factors: the rise in the intensity of the war with Pakistan and the effects of the global financial crisis. However, the overall spillover stays well below 8% after the end of the financial crisis until a significant fall in the crude oil prices jacked up overall spillover plot to 16% in 2014.

The overall spillover index for China is presented in figure 23(d). Based on this figure, we observe that the overall spillover plot starts at 16% and rises to its peak at 24% at the end of 1999. The increase in the overall spillover is mainly attributed to the Asia crisis of 1997, which mounted pressure of devaluation on the Chinese currency, and subsequently led to the financial crisis in China in the 1990s. The sharp downward slope of the overall spillover index in 1998 is traceable to the tight monetary policy adopted by the Chinese government in late 1997 to track the overheated economy. Furthermore, the European Union and US recessions of 2000-2001 are traceable to the upward movement, characterized by high fluctuations in the overall spillover index. However, the overall spillover plot gradually slopes downward due to the revaluation of the yuan on 21st July 2005 by 2.1% against the US Dollars. This ends the fixed exchange rate regime in China. By 2008, there is a sudden rise in the overall spillover index, which is attributed to the global financial crisis of 2007/2008. This upward movement reaches the peak of 24% in 2010. By and large, the overall spillover starts to exhibit downward sloping with high fluctuations in 2011. This is exacerbated by the Chinese stock market turbulence of 2015 and early 2016.

Finally, the overall spillover index for South Africa is presented in the graph marked as figure 23(e). The figure starts at a value somewhat above 8% and reaches the climax at 20% in 1998. The overall spillover index as observed is characterized by high fluctuations over the sample windows. The high fluctuations and upward movement of the overall spillover are traceable to the era of apartheid and episode of the first general elections that held between 26th and 29th April 1994. The jump up of the overall spillover index with the exhibition of high fluctuations, which started in 2001, is caused by the decline in world demand for South African exports. However, the high spike in the late 2007 and 2008 is significantly caused by the European Union debt crises of 2007-2010 and the global financial crisis that erupted the world's economy in 2008, while the upward sloping of the total spillover in 2014 is attributed to the effect of the crude oil price oscillations and volatilities. In total, a careful examination of the plot for the total spillover index indicates no straightforward evidence of trends; rather what it possesses is the occurrence of bursts over the sample windows.

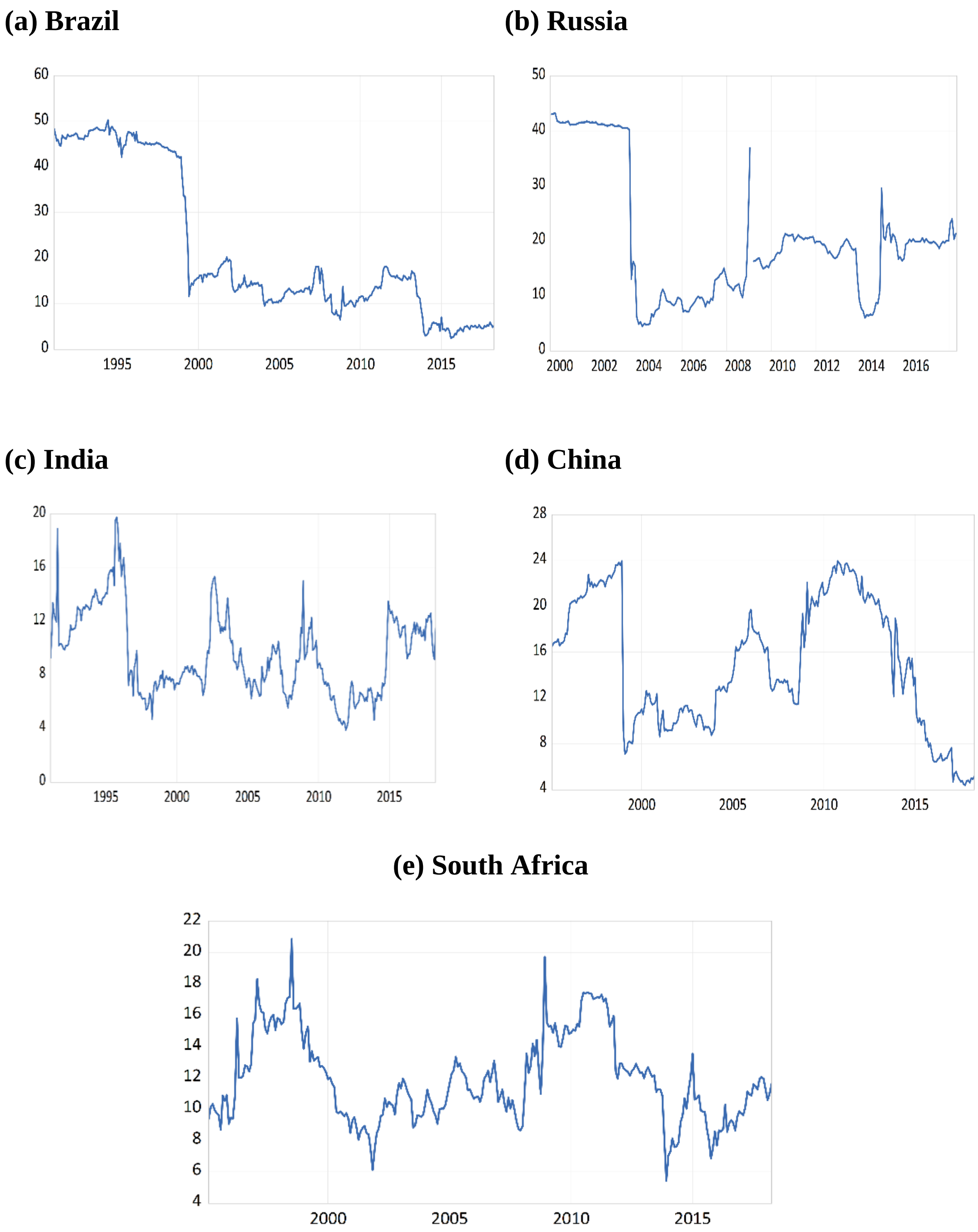

Figure 23: Overall spillover indexes for BRICS Countries

Note: Overall rolling spillover index is estimated with 60 months windows and 12 step horizons.

4.3.3 Rolling Spillover Estimates from NEER and Oil Price

In this subsection, we examine the bivariate rolling spillover estimates from the NEER and oil price for BRICS countries. The estimations are based on 60-month windows and 12-step horizons. Figure 24 presents the graphical estimates of the rolling spillovers from the NEER and oil price for Brazil. We observe that the spillover of the NEER to oil price and to the rest of the variables significantly witnessed up and down movements with no clear-cut trending movements. The spillover, however, declines in 1996 and sharply increases to its climax at 25% in 1998 due to hyperinflationary pressure, which surged to almost 5000 percent per year in the mid-1994. Furthermore, the spillover from the oil price to NEER and from the oil price to CPI is very high between 2000 and 2004. This is traceable to the high demand for oil due to the September 11, 2001 attack in the U.S. and the 2003 Iraq war. Additionally, the spillover of the oil price to IPI continues to slope upwards with evidence of fluctuations between 2000 and 2013. By 2014 the spillover sharply declines to about 4% from 28% in 2013. This could be traceable to a significant fall in the oil price.

The estimates of the rolling spillover from the NEER and oil prices for Russia are presented in Figure 25. The spillover from the NEER to oil price is characterized by constant fluctuations with no clear-cut evidence of a trend. The spillover spikes to its peak in 2008, indicating the effect of the global financial crisis. More so, we observe that the spillover from the NEER to CPI and from NEER to IPI exhibits fluctuations with a spike in 2015 owing to the introduction of a free-floating exchange rate of rubble on the 10th November 2014. Furthermore, we observe that spillover from the oil price to IPI exhibits more fluctuations than from oil price to NEER and/or to CPI. The result provides that the spillover from the oil price to NEER and from the oil price to CPI drastically declines from their peak at 60% to slightly above zero line in 2004. This is attributed to Iraq war in the late 2003, which led to the shortage of oil supply in the international oil market. Finally, the spillover from oil price to IPI slopes upward with a sharp decline in 2008 and 2014 due to the 2007–2008 strong demand for oil and the subsequent breakdown of oil prices in 2014.

The case of India as presented in Figure 26 reveals that the spillovers from both the NEER and oil price fluctuates randomly with no clear pattern of movements. We found that a spike occurs in 1991 on the spillover from the NEER to oil price, NEER to CPI and NEER to IPI. The NEER records no spillover to oil price between 1993 and 1996 owing to the efficacy of the liberalized exchange rate management system and managed floating exchange rate system introduced in 1992 and 1993. In addition, there is a sharp increase in the spillover in 1998. This is traceable to the effects of the Asia crisis in 1997. Furthermore, the spillover from the oil price to NEER, oil price to CPI and oil price to IPI reveals a spike in 1997, which is traceable to the East Asian crisis of 1997. We observe that the spillover randomly fluctuates and without any clear pattern of movement.

The rolling spillover results are presented in Figure 27 for China. For China, we observe that the spillover from the NEER to oil price, NEER to CPI and NEER to IPI fluctuates over the sample windows with evidence of spike particularly from the NEER to oil price in 2008 due to the global financial crisis. We observe further that there is no evidence to support the spillover from the NEER to oil price between 1996 and 1999. However, the spillover from the NEER to oil price is less than 2% before the year 2000 and not greater than 2% between 2005 and 2009. There is evidence that the spike on the spillover in 2009 is attributed to the global financial crisis of 2007/2008 and sudden decline in the spillover from the NEER to the oil price in 2014 is attributed to crude oil price oscillations and upheavals. In comparison, the spillover of the NEER to CPI witnesses more fluctuations than the spillover from the NEER to IPI. Regarding the spillover from oil price to NEER, oil price to CPI, and oil price to IPI, we observe evidence of a spike from the oil price to NEER in 2008 and 2014 owing to the global financial crisis and the oil price fluctuations. However, the spillover from oil price to NEER and oil price to CPI is higher after the global financial crisis, while in the case of oil price to IPI, the spillover increases after the event of 2008 and decline in oil price in 2014.

Finally, as presented in Figure 28 for South Africa, there is a spike in the spillover from the NEER to the oil price in 1995, 1999 and 2008 respectively. These spikes are attributed to the first and second presidential elections in South Africa after the era of apartheid. The spike in 2008 is caused by the global financial crisis. Between 2002 and 2009, the spillover of the NEER to oil price is very low, slightly above zero percent, owing to a significant decline in the South African exports. More so, the spillover of the NEER to CPI and NEER to IPI highly fluctuate over the sample windows with no evidence a trend. The only spike identified in the spillover occurs in 1999 from the NEER to CPI and a sharp decline in 2006 from the NEER to IPI. In the case of the spillover of the oil price to NEER, we observe an upward sloping from 1995 to its peak of 35% in 1998. This could be attributed to the Iraqi invasion of Kuwait in the 1990s and the subsequent 1991 Gulf war. There is evidence that the spillover of the oil price to NEER, oil price to CPI and oil price to IPI is characterized by high fluctuations with no clear pattern of the movement. This is due to the events such as the general elections of 1994 and 1999, the September 11, 2001 attack in the U.S, the 2003 Iraq war, Union debt crises of 2007-2010 and the global financial crisis of 2008, and the oil price fluctuations in 2014.

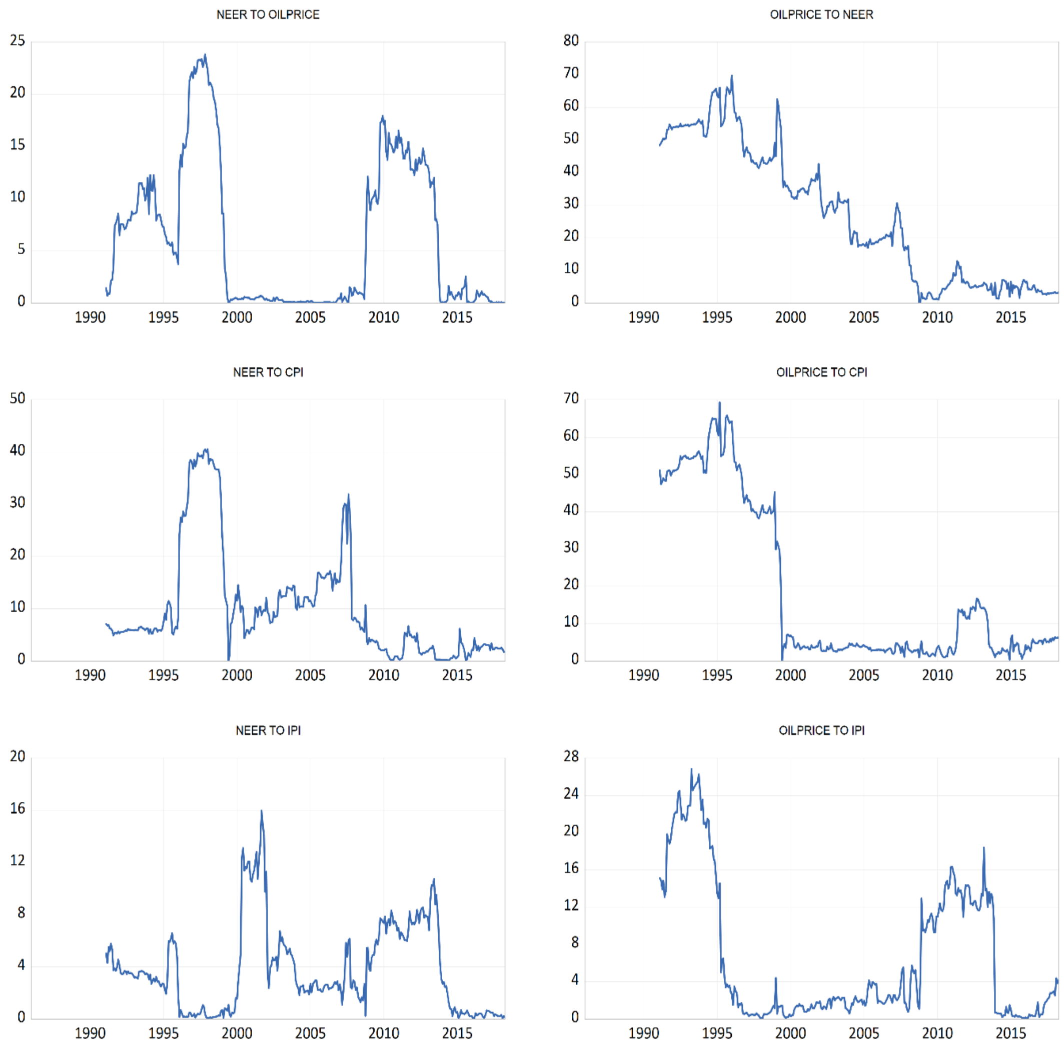

Figure 24: Rolling spillover estimates from nominal effective exchange rate and oil prices for Brazil

Note: Rolling spillover index is estimated with 60-month windows and 12-step horizons.

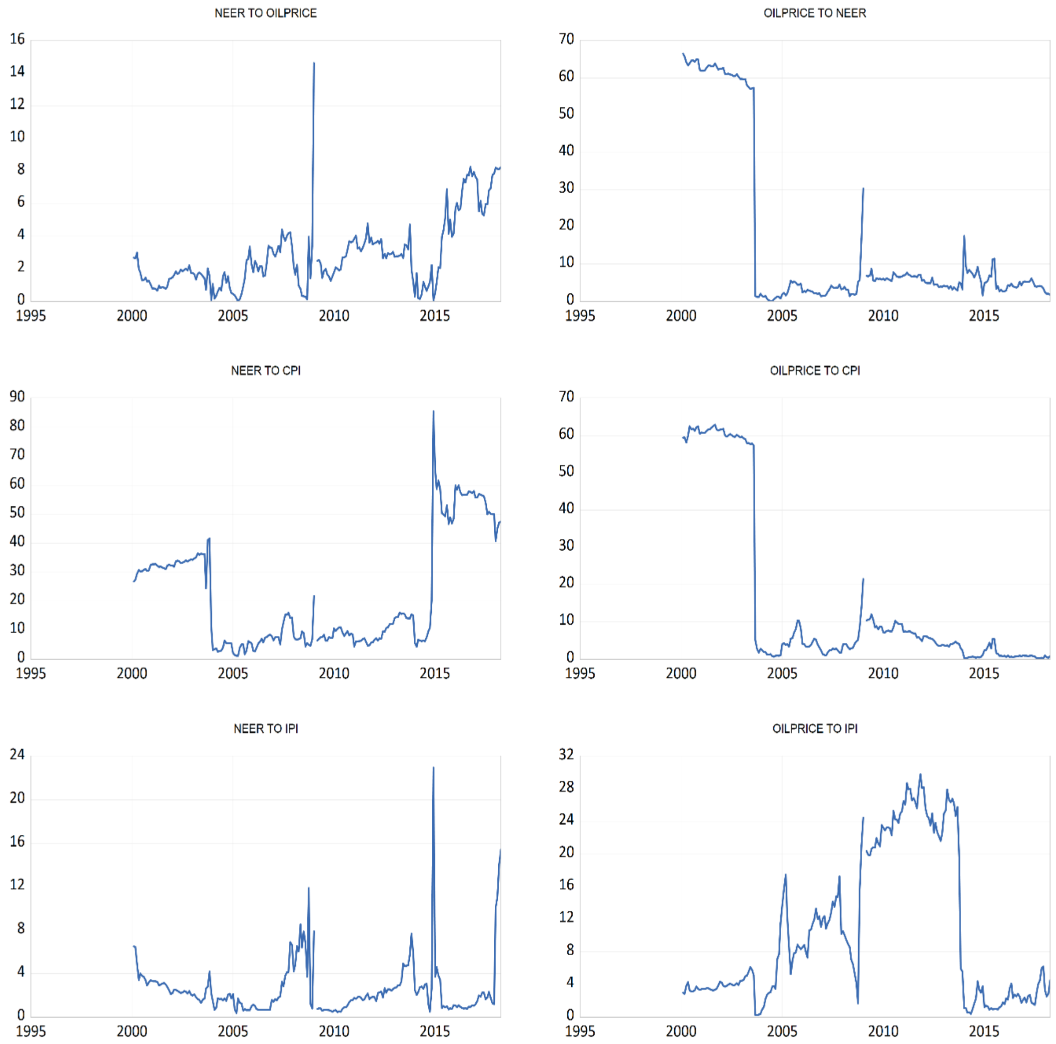

Figure 25: Rolling spillover estimates from nominal effective exchange rate and oil prices for Russia

Note: Rolling spillover index is estimated with 60-month windows and 12-step horizons.

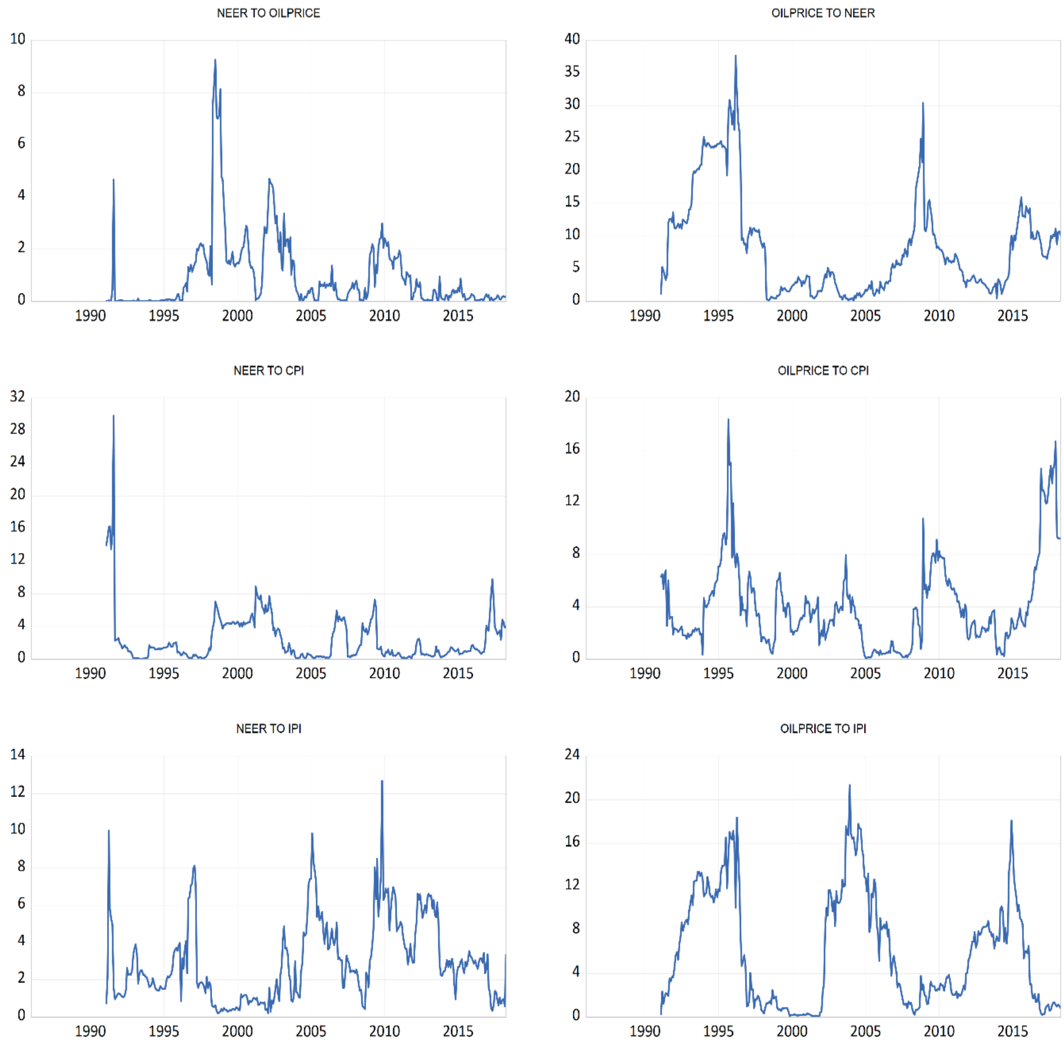

Figure 26: Rolling spillover estimates from nominal effective exchange rate and oil prices for India

Note: Rolling spillover index is estimated with 60-month windows and 12-step horizons.

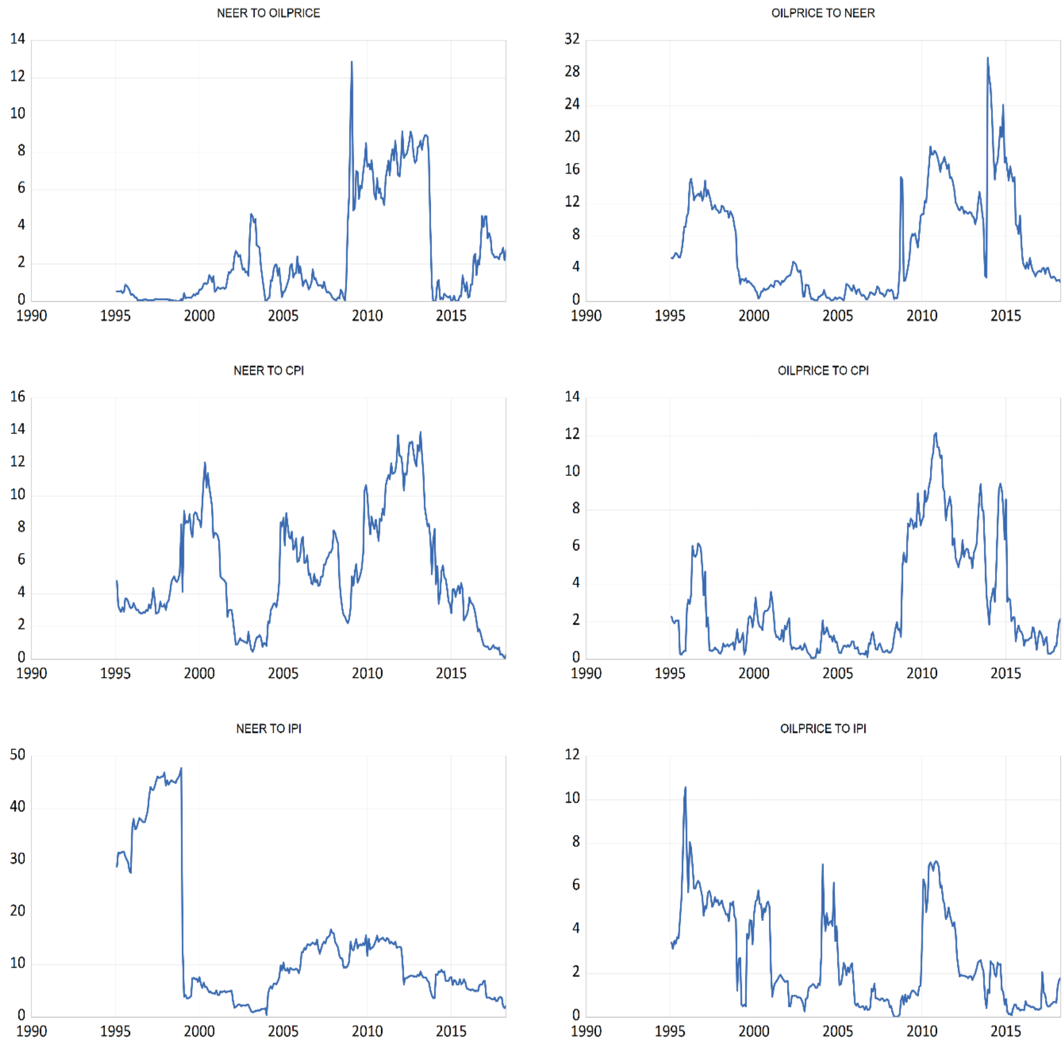

Figure 27: Rolling spillover estimates from nominal effective exchange rate and oil prices for China

Note: Rolling spillover index is estimated with 60-month windows and 12-step horizons.

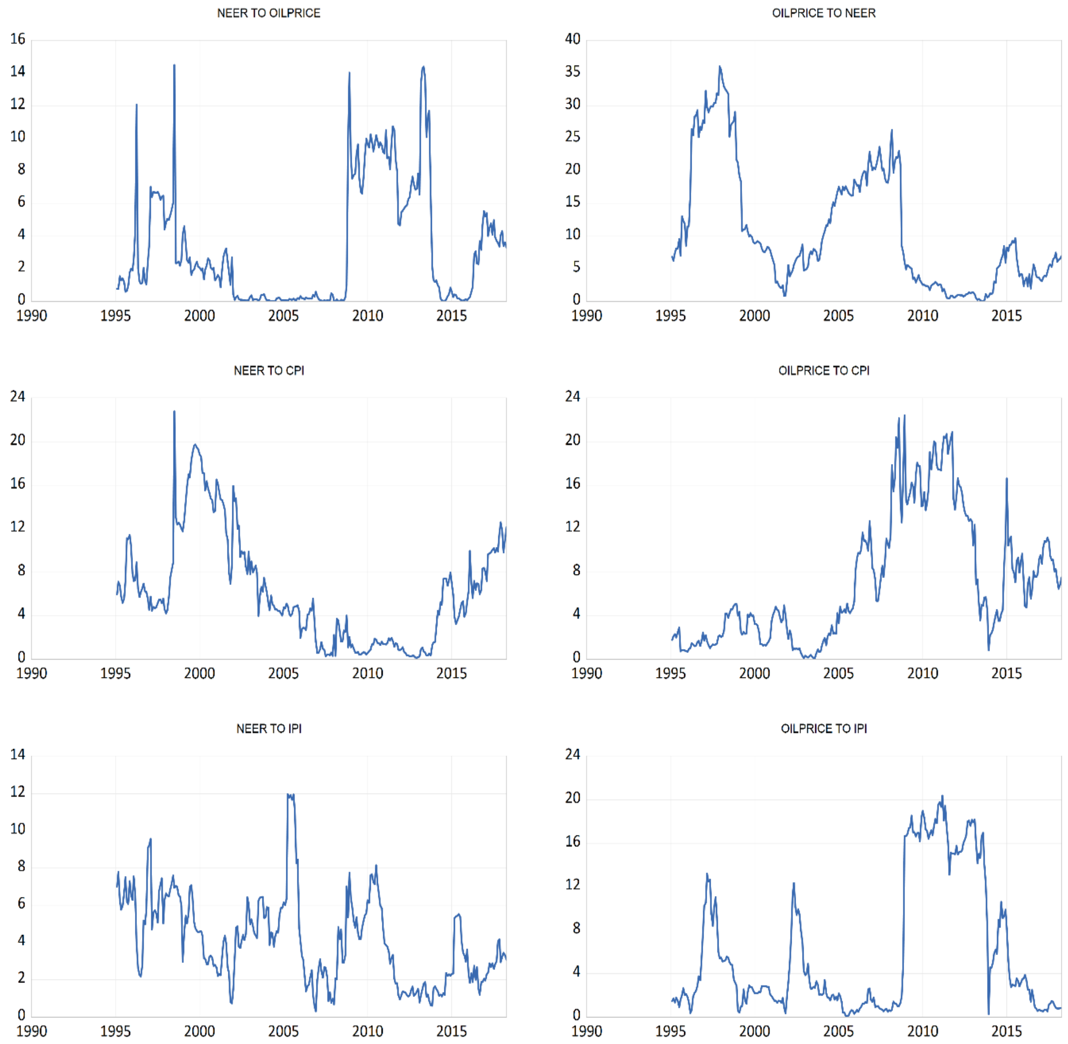

Figure 28: Rolling spillover estimates from nominal effective exchange rate and oil prices for South Africa

Note: Rolling spillover index is estimated with 60-month windows and 12-step horizons.

4.4 Conclusion and Policy Implications

In this study, we examined the pass-through of the exchange rate and oil price using the Diebold and Yilmaz (2012) connectedness index and rolling-sample approaches for the BRICS countries. Using the monthly frequency data, we computed the directional spillover, the total spillover and the net spillover indexes for the variables employed. The results showed that: (i) there is strong evidence of the directional spillovers in all the countries. (ii) the total spillover is low with Brazil having the highest and India having the lowest. This suggests that a larger percentage of shocks is explained by idiosyncratic shocks and (iii) the net spillover of oil price (output growth) is positive (negative) for all the countries, indicating that oil price (output growth) contributes to the forecast error variance decomposition of all other variables more(less) than what it receives from other variables. In the case of exchange rate, the net spillover effect is only positive for Russia and China while consumer price index is positive only for Brazil and China. In addition, we estimated the overall spillover indexes and the bivariate version of the spillover estimates from the NEER and oil price for all the countries through the rolling-spillover approach. The overall spillover enables us to identify how total spillover changes over time and the bivariate version of it tracks the time evolution of the spillover from the NEER and oil price to other variables in the model. The findings of the rolling-sample windows revealed that the spillovers in BRICS countries are interrupted by the structural changes over time. However, even though the spillover exhibits significant fluctuations, there is no clear-cut evidence of trends among the variables. Therefore, the findings of this paper have policy implications for the attainment of the recent monetary policy objectives of inflation targeting as well as low and stable prices. Finally, our paper suggests an extension of our analysis by introducing regime dependent Diebold and Yilmaz indices in the future research.

Chapter 5

MOVING OUT OF THE LINEAR RUT: A PERIOD-SPECIFIC AND REGIME-DEPENDENT EXCHANGE RATE AND OIL PRICE PASS-THROUGH IN BRICS COUNTRIES

5.1 Introduction

Generally, the central question of how the economy responds to changes in exchange rate and oil price has generated a large body of research in international finance and macroeconomics especially the period when exchange rates are allowed to float freely. This is largely because changes in exchange rate and oil price have direct implications on the cost of inputs and production, and hence price-cost margins of the firms. Theoretically, changes in exchange rate are invariably expected to fully reflect on domestic prices as encapsulated in the doctrine of Purchasing Power Parity (PPP).[17] Following the previous empirical studies, it is observed that the results almost entirely suggest the existence of incomplete pass-through, i.e. a change in exchange rate or oil price is partially transmitted to domestic prices especially in the short-to-medium terms (See Marston 1990; Goldberg and Knetter 1997; Xu and Bernhofen 1999; Ihrig *et al.* 2006; Delatte and Lopez-Villavicencio 2012; Valcarcel and Wohar 2013; Asghar

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[17] PPP argues that the equilibrium market prices of all tradeable goods and services cannot be different in two countries if their prices are expressed in the same currency.

and Naveed 2015; Balcilar and Usman 2018). The main objective of this study is to investigate the exchange rate and oil price pass-through (EROPPT) in Brazil, Russia, India, China, and South Africa (hereafter called the BRICS countries). Put differently, this study investigates whether the shift in the system of exchange rate and trade policy direction towards market-based policies affect the pass-through channel in these countries. As shown by Enerdata (2015), the total GDP of BRICS increased astronomically to about 23% of the world GDP (i.e. USD 16.92 trillion) and the total volume of trade increased from USD 4.4 trillion in 2008 to USD 7.7 trillion, making these countries to account for roughly 18% of the total world trade as against 3% in 1990. The implication of these statistics is that as the BRICS economy becomes more integrated globally and allows the bilateral exchange rates to freely float, the pass-through of exchange rate and oil price tends to become larger due to exchange rate and oil price fluctuations.

The existing empirical studies, until recent times, have assumed that the interactions between exchange rate, oil price, output growth, and domestic prices are linear and symmetric, hence most studies presume that positive and negative changes in exchange rate and oil price transmit the same size and magnitude to domestic prices and output growth. However, there is growing evidence recently that the degree of pass-through is essentially a regime-dependent phenomenon, generated possibly by numbers of factors such as downward price rigidities and upward quantity rigidities (See Correa and Minella 2010; Junttila and Korhonen 2012; Busiere 2012; Shintani *et al.* 2013; Ben Cheikh and Lonhichi 2016; Kilic 2016). The theoretical underpinning this kind of asymmetric effect boils down to pricing-to-market, menu cost of price adjustments, credibility of monetary policy rules etc. For example, Correa and Minella (2010), using a threshold model for Brazil, find that the pass-through elasticity is higher in the short run when the growth of the economy is high, exchange rate depreciates and volatility of exchange rate is low. Junttila and Korhonen (2012) find incomplete regime dependence of pass-through based on the nine OECD countries, confirming the Taylor's hypothesis for these countries. This result concurs with Shintani *et al.* (2013) who attribute the decline in the exchange rate pass-through (ERPT) during the periods of the 1980s and 1990s to a low and stable inflation environment. Similarly, taking the earlier empirical findings of Gagnon and Ihrig (2004) and Choudhri and Hakura (2006) with a pinch of salt, Ben Chiekh and Louhichi (2016) suggest a strong regime-dependent ERPT to inflation based on the panel threshold method, with higher ERPT associated with higher inflation environment. This finding supports Kilic (2016) who finds variations of ERPT across the low and high regimes with evidence of complete pass-through in the long run for high regime periods and incomplete ERPT for low regime periods.

Turning to the pass-through of oil price shocks, Hooker (2002) discovers that the shocks to oil price in the U.S affect core inflation significantly before 1980. However, the size of this effect continues to decline due to a sound and credible monetary policy, labour market flexibility, reduction of energy intensity and a host of other factors. Furtherance to this finding, De Gregorio *et al.* (2007) reveal that the pass-through of oil price in 37 advanced and emerging markets has significantly declined for the past three decades compared to the pass-through in the 1970s and 1980s. Similarly, Chen (2009) confirms that monetary policy is more effective in reducing the inflation rate when a domestic currency appreciates than when it depreciates in the 19 advanced countries explored. In addition, Baharumshah *et al.* (2017) find an insignificant effect of oil price shocks on inflation in Sudan. This finding does not support Balcilar *et al.* (2018a) who divulge that oil price is associated positively with inflation in South Africa; however, the effect of positive shocks in oil price is stronger on inflation than the negative shocks of the same magnitude.

Furthermore, another strand of literature emphasizes the role of oil price in predicting the fluctuations of exchange rate. For example, Krugman (1983), Golub (1983) and Rogoff (1991) all argue that the movements in oil price have an influence on exchange rate. This argument is supported by the recent findings documented by Balcilar *et al.* (2017) that in South African business cycle, the real output growth in the low episode is predicted by the shock to oil price; although the prediction during the low output growth episode is shorter compared to the high output growth episode. On the basis of causal interactions between oil price and output growth, Chen and Chen (2007) and Basher *et al.* (2012) find a strong one-sided causality running from oil price to output growth. This finding is inconsistent with Narayan *et al.* (2008) and Chung and Chang (2012) who find no causality, and Cologni and Manera (2009) who find a two-sided causality for G-7 countries.

To differentiate between linear and nonlinear pass-through of exchange rate and oil price, we carefully put forward a question as to whether changes in exchange rate and oil price of different magnitudes have disproportionate pass-through effects in the BRICS countries. To answer this question, the paper proposes a new approach, which extends Diebold and Yilmaz (DY) (2012) spillover index to incorporate nonlinearity based on a Smooth Transition Vector Autoregressive (VSTAR) model. This approach allows for both period-specific and regime-dependent DY spillover indexes, governed by the selected transition variable between the two district regimes (hereafter called upper and lower regimes). Therefore, this study contributes to the literature on pass-through in the following aspects. First, the paper estimates and compares the results of the linear and nonlinear pass-through of exchange rate and oil price in BRICS countries through the analysis of DY spillover index. Second, on a methodological basis, we extend the literature on DY (2012) spillover index to nonlinearity setting to properly capture the effect of nonlinear dependence in the series. Third, we compute the period-specific and regime-dependent pass-through based on DY (2012) spillover index by generating impulse responses and then forecast-error variance decompositions (FEVDs) with 1000 bootstrap replications. Fourth, even though the linear and nonlinear pass-through of exchange rate and oil price has received enormous attention in the literature, it is clear that, with the exception of the recent paper by Balcilar and Usman (2018), no other evidence has emerged on the basis of DY (2012) spillover index. Relative to Balcilar and Usman (2018), our proposed approach incorporates nonlinearity, and consequently applies three different linearity tests to check the existence of nonlinearity in the series so as to avoid misspecification.[18] Therefore, the findings of this paper will provide a clearer understanding of the dynamics in the form and scale of EROPPT in BRICS countries.

The rest of this paper is organised as follows: Section 5.2 presents the econometric methodology used. In this section, we propose the period-specific and regime-

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[18] The Diebold and Yilmaz (2012) spillover index is based on a vector autoregressive (VAR) model through the forecast-error variance decompositions obtained from generalized impulse response function (GIRF), which does not consider nonlinear dependence in the series. Even though some studies wrap it up with rolling window estimation, it is argued that this method does not properly capture nonlinear interactions of the variables as discussed in Balcilar *et al.* (2018 a, b).

dependent DY spillover indexes using a VSTAR model. Section 5.3 describes data sources and descriptive statistics of the variables used. Section 5.4 discusses the empirical results while section 5.5 contains the summary and conclusions of the paper.

5.2 Econometric Methodology

This study proposes a new approach based on the VSTAR model to estimate the spillover index advanced by Diebold and Yilmaz (DY) (2009) and extended by DY (2012) in order to capture nonlinear and asymmetric pass-through of exchange rate and oil price. Particularly, we extend the DY spillover index originally built on the vector autoregressive (VAR) model using the FEVDs to incorporate nonlinearity based on the VSTAR model. This approach allows for a period-specific DY spillover index and regime-dependent DY spillover index, governed by the selected transition variable between the upper regime and the lower regime. In doing this, we follow Weise (1999) whose work on VSTAR extends nonlinearities to a multi-equation setting based on the earlier single-equation framework advanced by Teräsvirta and Anderson (1992). The *k*-dimensional VSTAR model is specified as:

$$Y_t = \mu^1 + \sum_{i=1}^{p} \Phi_i^1 Y_{t-1} + \left(\mu^2 + \sum_{i=1}^{p} \Phi_i^2 Y_{t-1} \right) F(z_t; \gamma; c) + \epsilon_t \qquad (26)$$

where $Y_t = (Y_{1t}, Y_{2t}, \dots, Y_{Nt})'$ as $(N \times 1)$ time series vector, i.e. (4×1) in this study; Φ_i^1 and Φ_i^2 are $N \times N$ matrices of the autoregressive coefficients; μ^1 and μ^2 are $N \times 1$ vector of constants; ϵ_t is a $N \times 1$ zero mean white noise process with covariance matrix Σ, $\varepsilon_t \sim iid(0, \Sigma)$ and p denotes the appropriate lag order. $F(z_t; \gamma, c)$ is the transition function, which represents two extreme regimes and smooth transition between them, i.e. $F(z_t; \gamma, c) = 0$ and $F(z_t; \gamma, c) = 1$. These two extreme values (0 and 1) stand in for the lower regime and upper regime respectively.

The transition between lower regime periods and upper regime periods is assumed to occur in a smooth manner; hence, use is made of a logistic transition function expressed as follows:

$$F(z_{t-d};\gamma;c) = [1 + \exp\{-\gamma(z_t - c)\}]^{-1} \qquad (27)$$

where γ is the smoothness parameter (adjustment speed), which determines whether the transition between lower regime periods and upper regime periods is characterized by sharpness or smoothness; c represents the threshold and z_t is the transition or transition variable selected as $z_t = Y_{it-d}$, where i comprises of OIL, NEER, CPI, and IPI and d is the delay parameter. If the value of z_t is above the threshold value c, the regime is called the "upper regime"; while, if the value is below the threshold value c, the regime is called "lower regime". As $\gamma \to \infty$, $F(z_t) \to I(Z_t)$, where $I(z_t) = 1$ if $z_t > c$ and $I(z_t) = 0$ if $z_t \leq c$.[19] However, if $\gamma \to 0$, the model becomes a linear VAR as $F(z_t) \to 1/2$.

To compute the DY total, directional and net spillover indexes for each of the regimes with H-step-ahead, the generalized impulse responses and FEVDs are required (See DY, 2009; 2012). However, it is clear that the computation of impulse response (IR) functions based on nonlinear multivariate models has posed a methodological issue in the literature since analytical solution does not exist. This is because the impulse responses are not proportional to the size of shocks; hence, it depends on both the size and sign of the shocks as well as the "history" i.e. the initial value. To circumvent this problem, we follow a bootstrap approach described in Koop et al. (1996) and Pesaran

[19] In this case, $F(z_t;\gamma,c)$ converges to an indicator function $I(z_t) = 1(z_t > c)$, where $1(a > b)$ takes a value of 1 if $a > b$ is true and zero, otherwise.

and Shin (1998) and recently used by Balcilar et al. (2016; 2018b) to obtain regime-specific impulse responses and variance decompositions, which are history, shocks and composition dependent. Following Balcilar et al. (2016; 2018b) we obtain the impulse responses using 1000 bootstrap replications.

In this paper, we use two different impulse response definition for the VSTAR model, period-specific and regime-dependent impulse responses which, respectively, allows us to obtain impulse responses corresponding to specific regime histories and impulse responses that would hold when the economy fully adjust to a particular regime. Consider the following definition of the GIRF:

$$\mathrm{GIRF}\left(h, \epsilon_t^{\delta}, \Gamma, \Omega_{t-1}\right) = E\left[Y_{t+h} \middle| \epsilon_t^{\delta}, \Gamma, \Omega_{t-1}\right] - \left[Y_{t+h} | \Gamma, \Omega_{t-1}\right] \tag{28}$$

where $h = 1,2, \dots, H$ is forecast horizon or impulse response steps, ϵ_t^{δ} is a vector of shocks, $E[\cdot]$ is the expectation operator, Γ is a vector of all parameters of model in Eqs. (26)-(27) and $\Omega_{t-1} = \{\omega_{t-j}: j \geq 1\}$ is the set of possible random histories in the set $t = 1,2, \dots, T$. That the history Ω_{t-1} is random implies it can be replaced by an appropriate subset. Moreover, we have to draw values Ω_{t-1} from the set $\Omega_{t-1} = \{\omega_{t-j}: j \geq 1\}$ when we compute GIRF and its density. Given the whole history $t = 1,2, \dots, T$, we define two subsets of the random history Ω_{t-1}: $\Omega_{t-1}^1 = \{\omega_{t-j}: j \geq 1, z_t \leq c\}$ corresponding to lower regime periods and $\Omega_{t-1}^2 = \{\omega_{t-j}: j \geq 1, z_t > c\}$ corresponding upper regime periods. Thus, we obtain two period-specific DY indexes by drawing the initial history from either the set Ω_{t-1}^1 or Ω_{t-1}^2, corresponding to lower- and upper-regime periods, respectively. These period-specific DY indexes are based on the FEVDs obtained from period-specific impulse responses $\mathrm{GIRF}_1\left(h, \epsilon_t^{\delta}, \Gamma, \Omega_{t-1}^1\right)$ and $\mathrm{GIRF}_2\left(h, \epsilon_t^{\delta}, \Gamma, \Omega_{t-1}^2\right)$, respectively.

In the limit case as $\gamma \rightarrow \infty$, the VSTAR model can be represented by a piecewise linear two-regime model:

$$Y_t = \mu^1 + \sum_{i=1}^{p} \Phi_i^1 Y_{t-i} + \epsilon_t, \quad \text{if } z_t \leq c \tag{29}$$

$$Y_t = \mu^2 + \sum_{i=1}^{p} \Phi_i^2 Y_{t-i} + \epsilon_t, \quad \text{if } z_t > c \tag{30}$$

This representation allows us to drive regime-dependent impulse responses which are independent of the history. Regime-dependent impulse response functions are obtained as $\mathrm{GIRF}_1(h, \epsilon_t^{\delta}, \Gamma_1) = E[Y_{t+h} | \epsilon_t^{\delta}, \Gamma_1] - [Y_{t+h} | \Gamma_1]$ and $\mathrm{GIRF}_2(h, \epsilon_t^{\delta}, \Gamma_2) = E[Y_{t+h} | \epsilon_t^{\delta}, \Gamma_2] - [Y_{t+h} | \Gamma_2]$, where $\Gamma_1 = \{\mu^1, \Phi_1^1, \Phi_2^1, \dots, \Phi_p^1, \Sigma\}$ and $\Gamma_2 = \{\mu^2, \Phi_1^2, \Phi_2^2, \dots, \Phi_p^2, \Sigma\}$. Regime dependent impulse responses calculated in this way allows us to obtain regime-dependent spillover indexes. Significant differences exist between period-specific and regime-dependent impulse responses. The regime-dependent impulse response function is history independent and all the dynamics is governed by parameters specific to a regime, with no role played by the value of the transition variable z_t because no regime switching is allowed during the impulse horizon, i.e. we either have $F(z_t; \gamma, c) = 0$ or $F(z_t; \gamma, c) = 1$, implying that the economy fully adjusted to the corresponding regime. On the other hand, the period-specific impulse response function is history dependent and dynamics are governed by parameters of the both regimes with weights determined by the value of $F(z_t; \gamma, c)$, which varies during the impulse horizon as the transition variable $z_t = Y_{it-d}$ also dynamically forecasted.

Both regime-dependent and period-specific impulse responses will generate two sets of impulse responses between the variables obtained from the relevant definition of GIRF_m, $m = 1,2$. Let $N \times N$ matrix $C_{m,h}$ denote the whole set of GIRFs at step h among N variables. FEVDs relating to variable pairs (i, j) will also depend on m. Therefore, following Pesaran and Shin (1998), the H-step-ahead generalized FEVD denoted by $\theta_{m,ij}(H)$ is used to compute period-specific and regime-dependent DY spillover index as shown in Eq. (31). More so, to compute DY spillover index based on linear VAR, the m-regimes are ignored, indicating that the spillover index does not depend on the upper or lower regimes, rather it depends on the shocks in variables. The regime-specific FEVD can be defined as:

$$\theta_{m,ij}(H) = \frac{\sum_{h=0}^{H}\left(e_i' C_{m,h} e_j\right)^2}{\sum_{h=0}^{H}\left(e_i' C_{m,h} C_{h,m}' e_i\right)} \tag{31}$$

where e_i shows the selection vector with one as the i-th element, and zero otherwise. However, it is clear that the sum of the elements in every row is not equal to unity due to non-zero covariance in the generalized decomposition i.e. $\sum_{j=1}^{N} \theta_{m,ij}(H) \neq 1$. To this extent, we normalize each entry of the variance decomposition matrix by the sum of the row as presented below:

$$\tilde{\theta}_{m,ij}(H) = \frac{\theta_{m,ij}(H)}{\sum_{j=1}^{N} \theta_{m,ij}(H)} \tag{32}$$

where $\sum_{j=1}^{N} \tilde{\theta}_{m,ij}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}_{m,ij}(H) = N$. Given this clarification, the total spillover index for both the upper and lower regimes can be constructed as follows:

$$S_m^T(H) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\theta}_{m,ij}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{m,ij}(H)} * 100 = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\theta}_{m,ij}(H)}{N} * 100 \tag{33}$$

where $S_m^T(H)$ represents the total spillover index. All the parameters as appearing in Eq. (33) remain as defined previously. Furthermore, we compute the directional spillover index by focusing clearly on two main spillover dimensions: the directional spillovers received by variable i from other variables j, and the directional spillovers transmitted by variable i to other variables j. To start with, we compute the directional spillovers received by variable i from other variables j as:

$$\mathrm{DS}_{\mathrm{m},\mathrm{i}\leftarrow\mathrm{j}}(\mathrm{H}) = \frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ij}}\,(\mathrm{H})}{\sum_{\mathrm{i},\mathrm{j}=1}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ij}}\,(\mathrm{H})} * 100 = \frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ij}}\,(\mathrm{H})}{\mathrm{N}} * 100 \qquad (34)$$

More so, the directional spillovers transmitted by variable i to other variables j are computed as:

$$\mathrm{DS}_{\mathrm{m},\mathrm{i}\rightarrow\mathrm{j}}(\mathrm{H}) = \frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ji}}\,(\mathrm{H})}{\sum_{\mathrm{i},\mathrm{j}=1}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ji}}\,(\mathrm{H})} * 100 = \frac{\sum_{\mathrm{j}=1,\mathrm{j}\neq\mathrm{i}}^{\mathrm{N}} \tilde{\theta}_{\mathrm{m},\mathrm{ji}}\,(\mathrm{H})}{\mathrm{N}} * 100 \qquad (35)$$

Finally, to compute the net spillovers between variable i and to all other variables j for each regime, we take the difference between Eq. (34) and Eq. (35) as follows:

$$\mathrm{NS}_{\mathrm{m},\mathrm{i}}(\mathrm{H}) = \mathrm{DS}_{\mathrm{m},\mathrm{i}\rightarrow\mathrm{j}}(\mathrm{H}) - \mathrm{DS}_{\mathrm{m},\mathrm{i}\leftarrow\mathrm{j}}(\mathrm{H}) \qquad (36)$$

where $\mathrm{NS}_{\mathrm{m},\mathrm{i}}(\mathrm{H})$ is simply the net spillover, which is expressed as the difference between the gross shocks transmitted to and those received from all other variables.

Prior to the estimation of the VSTAR model, we carry out linearity tests to help determine whether nonlinearity is required in our study as suggested by Hubrich and Teräsvirta (2013) and Teräsvirta and Yang (2014). To achieve this, we apply three different versions of linearity tests. The first linearity test is the F version of the linearity test, which uses the Lagrange Multiplier (LM) test discussed in Granger and Teräsvirta (1993) and Weise (1999). This test is carried out equation by equation for excluding all parameters that are function of the nonlinear parameter γ. The second linearity test is the Likelihood Ratio (LR) linearity test for excluding all parameters that are function of the nonlinear parameter γ in all the equations described in

Teräsvirta and Yang (2014). The null hypothesis for all the tests is $H_0: \gamma = 0$ i.e. linearity and the alternative is $H_1: \gamma > 0$ i.e. nonlinear (VSTAR) model. Furthermore, we perform a second round equation by equation F-linearity test, the system LR linearity test, and the Rao's version of F-test (F_{RAO}) for excluding all parameters that are function of the nonlinear parameter γ in all the equations described in Rao (1973). The LR and F_{RAO} which is basically applied to the system as a whole using the selected transition variables for each country investigated. As discussed in the literature, VSTAR models are faced with the problem of identification under linearity since the test statistic is a function of unknown parameters. Therefore, to solve this problem, we use 1-st, 2-nd and 3-rd order Taylor expansions based on the F linearity test as described in Teräsvirta and Yang (2014). The choice of the equation by equation F linearity test is supported by the argument put forward by Camacho (2004) that when transition variable is assigned to each equation, testing for linearity is often performed based on the equation by equation. The 1-st, 2-nd and 3-rd order Taylor expansions approach is equally used for computing the LR linearity test.

5.3 Data and Descriptive Statistics

The monthly time series data are collected for the seasonally adjusted consumer price index (CPI), nominal broad effective exchange rate (NEER), crude oil price, and the seasonally adjusted industrial production index (IPI).[20] The crude oil price series corresponds to the spot price of crude oil expressed in USD and then converts to the national currencies of each country under consideration. For Brazil and India, we explore data from 1986M01-2018M04, and for China and South Africa, the data spans

[20] The manufacturing production index is used in measuring output growth instead of production for South Africa because of data availability.

from 1990M01-2018M04 while in the case of Russia, we use data from 1995M01-2018M04. We collect data on CPI from the International Financial Statistics database. The data on NEER and IPI are obtained from the Thomson Reuters DataStream while data on crude oil price (expressed in USD) is obtained from the US Energy Information Administration (EIA, 2018). These variables are converted to their natural logarithms for the stability of the variance.

To estimate our models, the prerequisite condition is that all the variables must be stationary. Therefore, we test for the stationarity properties of the variable using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) nonstationarity tests. The results of these tests as disclosed in Balcilar and Usman (2018)[21], indicate that all the series are nonstationary in their levels; however, they become stationary after their first differences. The implication of these results is that the analysis of this paper will be based on the log-growth rate in percent of the variables, computed as $\pi_t = \log(y_t/y_{t-1}) \times 100$ where π_t is the log-growth rate of the variables, y_t is the log-level variable, and y_{t-1} is simply the one period lag of the log-level variable.

Table 6 (See Chapter 3) summarizes the descriptive statistics of the log-level and log-growth of monthly frequency data on CPI, IPI, NEER, and oil price for the BRICS countries. Panel A and Panel B indicate that the total number of observations for Brazil and India is 388 and 387. In the case of China and South Africa, the total number of observation is 340 and 339 while it is 280 and 279 for Russia. In Panel B, the variable with the highest mean in Brazil is found to be CPI while the lowest is found to be

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[21] The results of the stationarity properties of the series are presented in a study by Balcilar and Usman (2018)

NEER. For Russia, India, China and South Africa, oil price is found to have the highest mean growth rate. The variable with the lowest mean growth for Russia, India, China and South Africa is found to be NEER. The statistical characteristics of the variables further reveal that the skewness of the variables exhibits both positive and negative distribution while the kurtosis of the variables is all positive, indicating leptokurtic distribution. To this extent, the values of the Jarque-Bera normality test apparently reject the null hypothesis of the normal distribution of the variables, which further motivates the VSTAR model.

5.4 Empirical Results and Findings

5.4.1 Time Series Plot of Data in Levels

We begin our analysis by examining the time series plots of the variables (OIL, CPI, NEER, and IPI) in levels as displayed in Figures 3-7 (See Chapter 3). These figures help to understand the visual properties of the series such as the drift, trend, and structural breaks (See Balcilar *et al.* 2018a,b; Balcilar and Usman 2018). Specifically, Figure 3 illustrates the time plots of all the variables in levels for Brazil. We observe based on the graph that OIL and IPI slope upward continuously until the movement becomes stable beginning from 1995. For NEER, we observe that the curve slopes downward, suggesting depreciation of the domestic currency. This series eventually becomes relatively stable in early 1995 due to the macroeconomic policy introduced by the Brazilian government called "Plano Real" or "Real Plan" in 1994 to curb hyperinflation that has erupted the economy. Consequently, the growth of output slowdown beginning from 1995 (i.e. the economy faces the trade-off between inflation and growth). In addition, the plot of the CPI indicates upward random movements characterized by time trend and structural breaks. The structural breaks identified can be traceable to the shocks in oil price and exchange rate over the years.

Figure 4 presents the time plot of the variables in levels for Russia. We observe, based on the figure that OIL and CPI exhibit an upward movement with evidence of time trend. We also observe that NEER and IPI are characterized by fluctuations, which are apparently more noticeable in IPI. While the NEER slopes downward, there is clear-cut evidence that IPI is increasing in Russia until the recent drop in prices of the international crude oil erupted in 2014. This perhaps affects the output growth significantly in Russia. Furthermore, the time series plots for India and South Africa in Figures 5 and 7 display similar results with Russia. As can be seen, the OIL and CPI exhibit upward movement, indicating the presence of time trend. However, the NEER and IPI are found to exhibit fluctuations over the study period. More so, while the IPI is found sloping upward, the NEER is downward sloping, pointing to the long-run depreciation of the rupee.

In China, the time series plots of all the variables are divulged in Figure 6, which shows large fluctuations and structural breaks in all the variables with no clear-cut evidence of time trend. The increase in OIL in the early 1990s as shown in the graph is traceable to the Gulf War in 1990 and 1991 and other several crises, which erupted in the mid-east. The Figure further reveals several spikes as well as up and down movements in the CPI. However, compared to other variables, structural breaks are more prevalent in other variables than CPI. Furthermore, the NEER exhibits downward fluctuations in the early 1990s and a huge decline around 1994. This eventually begins to rise beginning from 1995, although with evidence of fluctuations and structural breaks. This rise is traceable to structural change in the economy of China, which led to relatively price stability.

5.4.2 Linearity Tests

Tables 7(a)-(e) disclose the results of the F and LR linearity tests based on the 4-variable VAR. While the F linearity test is performed equation by equation with exclusion of all parameters that are function of the nonlinear parameter γ, LR linearity test is carried out on the system as a whole with exclusion of all parameters that are function of the nonlinear parameter γ in the equations. The lag length selected for the test is one, which is based on the Schwarz Information Criterion.[22] The results of the F linearity test using 1-st, 2-nd and 3-rd order Taylor expansions–denoted respectively with H_{01}, H_{02}, and H_{03}–suggest the rejection of the linearity hypothesis in favour of nonlinear VAR. Similarly, the results of the LR linearity tests reveal that in all the equations except South Africa, the linearity hypothesis is rejected, implying that a nonlinear VAR is appropriate. In the case of South Africa, the results indicate that LR test is only significant at 1% and 5% levels in the 1-st and 3-rd order Taylor expansions where a lag of NEER is used as a transition variable. In overall, both F and LR versions of linearity tests suggest a nonlinearity; hence, VSTAR is most appropriate for this paper. Furthermore, based on the results of the linearity tests, we select ΔOIL_{t-1} as a transition variable (z_t) for Brazil and Russia, ΔIPI_{t-1} for China and India, while ΔNEER_{t-1} for South Africa. The choice of the transition variables is congenial to Teräsvirta and Anderson (1992), Granger and Terasvirta (1993), Weise (1999) and Balcilar *et al.* (2016). [23]

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[22] The choice of Schwarz information criterion is that it is suitable and appropriate since we have a large sample size.

[23] The selection of appropriate transition variables is carried out by estimating linearity tests for all the potential candidates and chooses the candidate whose test statistic value has the smallest p-value.

5.4.3 Second Round Linearity Tests

Having identified the transition variables, we further conduct three different linearity tests, namely: the F version of the LM linearity test, LR linearity test and the F_{RAO} version of linearity test on the baseline models using the selected transition variables for each country investigated. The Rao's (1973) version of F-test (F_{RAO}) as a system linearity test excludes all nonlinear parameters in all the equations. As already discussed in the preceding section, the LM linearity test is an equation by equation test while LR linearity test is basically applied to the system as a whole. The null hypothesis of linearity i.e. the coefficient parameters on the $F(\mathrm{z_t}) = 0$ is tested in each equation and the system as a whole.[24] The results in Table 10 posit that the linearity is apparently rejected once again in all the equations with $\Delta\mathrm{OIL}_{t-1}$ as a transition variable for Brazil and Russia, $\Delta\mathrm{IPI}_{t-1}$ for India and China as well as $\Delta\mathrm{NEER}_{t-1}$ for South Africa. This confirms the presence of asymmetry on the channels of pass-through of the exchange rate and oil price in BRICS countries. Precisely, the selection of the transition variables, z_t for each country is based on the LM_3 test for linearity, LR test and F_{RAO} test for exclusion of nonlinear part.

[24] Following Balcilar *et al.* (2016), the *F*-tests applied are based on the Wald statistics with the heteroscedasticity-consistent covariance matrix estimate proposed by White (1980).

Table 10: Second Round of Linearity Tests

Parameter	System	*Equation* OIL	CPI	NEER	IPI
Brazil					
F linearity test		3.625** (0.000)	12.894*** (0.000)	6.727*** (0.000)	6.068*** (0.000)
LR linearity test	75.463***				
F_{RAO} linearity test	3.876***				
Russia					
F linearity test		1.411 (0.000)	7.878*** (0.000)	2.245+ (0.000)	12.832*** (0.000)
LR linearity test	107.304***				
F_{RAO} linearity test	5.674***				
India					
F linearity test		1.151 (0.000)	2.287+ (0.000)	6.837*** (0.000)	1.899 (0.000)
LR linearity test	48.505***				
F_{RAO} linearity test	2.464***				
China					
F linearity test		1.629 (0.000)	3.294* (0.000)	33.525*** (0.000)	13.042*** (0.000)
LR linearity test	166.770***				
F_{RAO} linearity test	8.974***				
South Africa					
F linearity test		1.571 (0.000)	1.335 (0.000)	1.916 (0.000)	2.458* (0.000)
LR linearity test	28.648*				
F_{RAO} linearity test	1.446+				

Note: +, *, **, and *** denote significance at 10%, 5%, 1%, and 0.1%, respectively.

5.4.4 Analysis of Spillover Tables

The results of the directional, total and net spillover indices are reported based on the FEVD of a standard VAR and VSTAR framework. We make use of the month horizon, $H = 10$-step ahead FEVD for all countries in both the VSTAR and linear VAR models. As disclosed in Tables 11(a)–(c) up to 15(a)–(c), adding up the off-diagonal columns amount to what we refer to as the "contribution from others", which indicates the overall contribution of shocks to other variables to the FEVD of a particular in the model. More so, adding up the off-diagonal rows gives what we refer to as the "contribution to others", which literally indicates the overall contribution of shocks to a particular variable to the FEVDs of other variables in the model. These two contributions are referred to as "directional spillovers". That is, each individual variable as presented in the columns of the spillover tables contain the contribution of a variable to the FEVD of other variables. Likewise, the contribution of the other variables to the FEVD of a particular variable in the model is presented in the rows of the spillover tables. The total spillover index is computed as the ratio of the sum of all variables in the (4×4) matrix without own-variables to the sum of all (4×4) matrix. Finally, we calculate the net spillover effect by taking the difference between "contribution to others" and "contribution from other". This makes us to conclude whether a particular variable is "a net transmitter" or "a net receiver" in the model estimation.

5.4.4.1 Spillovers Table for Brazil

Tables 11(a) – (c) report the results of the directional, total and net spillovers for Brazil on the basis of nonlinear (VSTAR) and linear VAR models. The results based on the period-specific DY spillovers in Table 11(a) divulge that in the upper regime periods, the contribution of NEER to the FEVD of OIL is found to be 12.7%, followed by the contribution to CPI with about 11.3% and lastly the contribution to IPI with 2.9%. On the other hand, the contribution of OIL to the FEVD of NEER is the highest with about 2.0%. This is closely followed by the contribution to IPI with 1.8% and the contribution to CPI with 1.7%. The results also indicate that in the lower regime periods, the NEER explains about 1.0%, 0.9% and 0.3% to the FEVDs of CPI, OIL, and IPI, while the OIL explains about 0.9%, 0.6% and 0.4% to the FEVD of IPI, CPI and NEER. In the regime-dependent DY spillovers, the NEER and OIL appear to contribute greatly to other variables. As disclosed by Table 11(b), the contribution of NEER to the FEVD of CPI is the largest with about 24.6% in the upper regime, followed by the contribution to IPI with about 22.0% while the contribution to OIL is the least with 19.3%. Similarly, the contribution of OIL to the FEVD of IPI is having the largest with about 36.4%. This is followed by the contribution to CPI with about 30.7%, and finally to NEER with about 22.6%. In the lower regime, the results explicitly show that CPI has the largest contribution from NEER with about 31.3%. The second largest receiver of the contribution of NEER is IPI with about 21.1% while to OIL is 15.7%. More so, the contribution of OIL to CPI is the largest among the variables captured. Specifically, OIL contributes about 31.9% to the FEVD of CPI. This is followed by 29.8% and 27.5% received by the NEER and IPI from the OIL. Comparing with the case of a linear VAR model disclosed in Table 11(c), the results suggest that NEER transmits the largest contribution to the CPI in Brazil. In other words, NEER contributes about 13.2% to the FEVD of CPI, followed by the contribution to OIL with about 3.5% and to IPI with about 1.4%. In the same manner, the contribution of OIL to the FEVD of NEER is the largest with about 28.5%. This is largely followed by the contribution to CPI with 25.8% and lastly to IPI, which is found to be 3.3%.

In addition, the results of the total spillover index on the basis of the period-specific for Brazil show an estimated value of 50.7% in the upper regime periods and 62.1% in the lower regime periods. In the regime-dependent DY spillovers, the results reveal the total of 63.1% in the upper regime and 55.9% in the lower regime, while for the linear model the total spillover index is 35.4%, which is lower than the results revealed by the nonlinear model. Furthermore, the total contribution to other variables based on the period-specific model suggests that NEER pass-through the total of 26.8% in the upper regime periods and 2.1% in the lower regime periods. The results further show that the total pass-through of OIL to other variables in the upper regime periods is 5.5% and 1.9% in the lower regime periods. With respect to regime-dependent total spillovers, we discover that in the upper regime the total pass-through of NEER is 65.8% to other variables while the total pass-through of OIL to other variables is 89.8%. Similarly, in the lower regime, the total pass-through of NEER is slightly higher than the upper regime with about 68.0% while the total pass-through of OIL slightly dampens in the lower regime to 89.1%. In the case of a linear VAR, the results indicate that the total pass-through of OIL to the FEVD of other variables is about 58.6% while the NEER is estimated to be 18.1% of the total contribution to other variables.

The results further provide that the total contributions from other variables to OIL and NEER have dominance among the variables. In the upper (lower) regime periods for the period-specific case, it is clear that OIL receives 85.7% (95.6%) of the total contribution from other variables, followed by NEER with about 80.9% (95.5%). With respect to regime-dependent spillovers, NEER and OIL receive about 51.4% and 49.3% from other variables in the upper regime while in the lower regime the contribution receives by the OIL drops to 30.8% while that of NEER increases to 55.3%. In the case of a linear VAR model, the total contribution from other variables to NEER is about 65.8% and to OIL is found to be 26.1%. The implication for these findings is that in the nonlinear VAR, particularly the period-specific spillovers, the net spillover effects of NEER and OIL are negative, indicating that these variables receive from other variables than they contribute to other variables. In the regime-dependent spillovers, the net spillover effects of NEER and OIL are positive, indicating that these variables transmit to other variables than they receive from other variables. However, in the linear model, the net spillover effect of OIL is 32.5% and NEER is -47.7, indicating that OIL contributes to other variables more than it does receive from other variables while NEER receives higher than it does contribute to other. To this extent, we conclude that in the period-specific DY spillovers, NEER and OIL are "net receivers" while in the regime-dependent DY spillovers, they are "net transmitters". However, in the linear VAR, OIL is "a net transmitter" but NEER is "a net receiver".

5.4.4.2 Spillovers Table for Russia

The results in Tables 12(a) – (c) present the directional, total and net spillovers for Russia. The results as shown in Table 12(a), therefore, pontificate that the period-specific spillovers in the upper regime periods indicate that NEER contributes about 0.9% to the FEVD of OIL. This is notably followed by the contribution to IPI with 0.5% and CPI with about 0.4%. Similarly, the contribution of OIL to the FEVDs of IPI, CPI and NEER is 1.1%, 0.6%, and 0.1% respectively. In the lower regime periods, it is evident that the contribution of NEER to IPI is the largest with 2.6%. This is followed by the contribution of NEER to OIL and CPI with 0.2% for each. However, OIL contributes about 1.2%, 0.6% and 0.1% to the FEVDs of IPI, CPI and NEER, indicating therefore that the behaviours of the IPI are affected mostly by the shocks to NEER and OIL. Concerning the results of the regime-dependent spillovers disclosed in Table 12(b), we find that in the upper regime, NEER pass-through about 44.1% to the FEVD of CPI, followed by 7.9% pass-through to OIL and 4.5% pass-through to IPI. More so, in terms of the pass-through of OIL, we record that about 45.4% is contributed to CPI, 33.3% to NEER and 3.5% to IPI. The evidence further shows that in the lower regime, the contribution of NEER to CPI is the largest also with about 29.7%. This is followed by the contribution of NEER to IPI with 14.9% and finally to OIL with 6.4%. In a similar development, the contribution of OIL to CPI is the largest among the variables. Specifically, OIL contributes about 39.6% to the FEVD of CPI, followed by NEER with about 33.7% and IPI with about 9.8%.

In different development, we find based on the results of the linear VAR in Table 12(c) that the pass-through of NEER account for 41.0% of the behaviours of CPI, 3.7% of IPI and 0.2% of OIL; whereas OIL contributes about 21.7%, 23.7% and 2.6% to the FEVDs of NEER, CPI and IPI respectively. The implication for our findings is that CPI is highly susceptible to NEER and OIL movements in Russia.

Furthermore, the results of the VSTAR model based on the period-specific estimates show that, in the upper regime periods, the total spillover index is estimated to be 11.0% and in the lower regime periods, it is found to be 15.5%. In the regime-dependent DY spillovers, the results indicate the total spillover index of 38.1% in the upper regime and 43.5% in the lower regime. However, the result of the total spillover index in the linear VAR model is found to be 24.7%, which is lower by comparison with the regime-dependent DY total spillovers. More so, the results of the total contribution to other variables reveal that in the period-specific case, the shocks to OIL contribute 1.8% to the FEVD of other variables both in the upper and lower regime periods, whereas the contribution of NEER accounts for about 9.8% in the upper regime periods and 3.0% in the lower regime periods. With respect to the regime-dependent spillovers, the total contribution of OIL to other variables in the upper regime is as high as 82.3% and that of NEER is 56.5%. In the lower regime, the contribution of OIL accounts for 83.1% and that of NEER accounts for 50.9%. Similarly, in the linear model the shocks to OIL and NEER pass-through the total of about 58.6% and 18.1% to other variables. Comparing these results, we discover that the contributions of OIL and NEER to other variables are much higher in the regime-dependent model compared to period-specific and linear VAR. Furthermore, the total contribution from other variables to the FEVDs of OIL and NEER based on the period-specific DY spillovers suggests that in the upper (lower) regime periods, OIL receives 36.8% (51.2%) from other variables while NEER receives 0.6% (5.1%) from other variables. Similarly, in the regime-dependent DY spillovers, OIL receives 11.2% (13.4%) in the upper (lower) regime and NEER receives 42.5% (59.2%) in the upper (lower) regime. The case of the linear VAR model reveals that OIL and NEER receive a total of 0.4% and 23.0% from other variables. Consequently, the net spillover effect of NEER is positive and that of OIL is negative in the upper regime periods of the period-specific of the DY spillovers while in the lower regime periods they are all negative. In the case of regime-dependent spillovers, the net spillover effects of OIL and NEER are positive in the upper regime while in the lower regime, OIL is positive and NEER is negative. In the linear model, it is evident that the net spillover effects of OIL and NEER are all positive.

5.4.4.3 Spillovers Table for India

Tables 13(a) – (c) divulge the results for India. The results in the upper regime periods of period-specific DY spillovers as disclosed in Table 13(a) indicate that NEER transmits the highest of 0.7% to the FEVD of IPI, followed by 0.1% transmission from NEER to OIL and CPI for each. More so, OIL transmits about 1.2% and 0.4% to IPI and CPI respectively. However, there is no evidence to support that OIL contributes to NEER in India. This result is inconsistent with Brayek *et al.* (2015) who report that oil price and exchange rate have feedback effect during the crisis period. Our result conforms to the recent study of Yang *et al.* (2017) who conclude that the rate at which crude oil price and exchange rate co-move could diverge over time. In the lower regime periods, the NEER contributes 27.5%, 0.8% and 0.2% to the FEVD of OIL, IPI, and CPI while OIL contributes to IPI with 2.9% and CPI with 0.4%. There is no evidence of spillover from OIL to NEER as well. Furthermore, the findings based on the regime-dependent DY spillovers in Table 13(b) demonstrate that in the upper regime the contribution of OIL to NEER is the largest with about 57.4%. This is fragrantly followed by the contribution to CPI with about 40.4% and to IPI with 14.0%. The contribution of NEER to the OIL is found to be 5.6%, and to CPI and IPI is 4.6% and 0.7% respectively. However, in the lower regime, it is documented that OIL contributes 42.7% to the CPI's FEVD and likewise contributes to the IPI and CPI with 11.9% and 0.5% respectively. In addition, NEER contributes about 6.5% to CPI, 0.4% to IPI and no evidence of any contribution from NEER to OIL. Regarding the linear VAR in Table 13(c), the results portray that NEER apparently contributes 0.6% and 0.3% to the FEVD of IPI and CPI, while no evidence is found that NEER affects the behaviours of OIL in India. In addition, there is established evidence that OIL accounts for 4.1%, 1.1% and 0.8% of the behaviours of the NEER, IPI, and CPI for India.

In the period-specific DY spillovers, the results demonstrate that the total spillover index is 4.3% in the upper regime periods and 12.8% in the lower regime periods while in the regime-dependent DY spillovers, it is recorded that the total spillover index is 40.2% in the upper regime and 17.3% in the lower regime. In the case of linear VAR, the result of the total spillover index is 2.6%. Furthermore, the total contribution to other variables reveals that in the upper regime periods, OIL transmits about 1.7% while NEER transmits just about 0.8%. However, in the lower regime periods, the total transmission of OIL declines to 1.6% and that of NEER astronomically increases to 28.5%. Regarding the regime-dependent DY spillovers, we observe that in the upper regime the total contribution of OIL to other variables is very high i.e. 111.8% while for NEER is 10.8%. Comparing with the lower regime, the total contribution of OIL declines to 55.1% and equally NEER decline to 6.9%. In the same way, in the linear model, it is evident that the total contribution of OIL to other variables is 6.0% while that of NEER is 0.9%. In contrast, the total contribution from other variables to OIL and NEER is 2.7% and 11.1% in the upper regime periods, while in the lower regime periods, this contribution increases extremely to 42.0% for OIL but in the case of NEER, it slightly increases to 3.4%. The evidence from the regime-dependent spillovers indicates that the total contribution from other variables to OIL and NEER is 5.8% and 58.2% while in the lower regime, we find 0.2% and 2.7% respectively. In the linear model, the results suggest that OIL and NEER receive 0.2% and 6.8% of the total contribution from other variables. Thus, the net spillover effect in the upper regime periods becomes -9.4% for OIL and -1.8% for NEER as well as -40.5% for OIL and 25.1% for NEER in the lower regime periods. In the upper regime of the regime-dependent DY spillovers, the net spillover effect show about 106.0% for OIL and -47.4% for NEER. In the lower regime, it is recorded that the net spillover effect of OIL is 54.9% and NEER is 4.2%. However, in the linear model, the net spillover effect of OIL is 5.8% and that of NEER is -5.9%.

5.4.4.4 Spillovers Table for China

Tables 14(a) and (c) show the results of the VSTAR and linear VAR models for China. On the individual directional basis, we find in Table 14(a) of period-specific DY spillovers that in the upper regime periods, the NEER contributes to the FEVD of IPI with 3.5%. This is followed by the contribution to OIL with about 1.1% and CPI with 0.6%. Similarly, OIL contributes to NEER with 0.9%, followed by CPI with 0.7% and IPI with 0.5%. In the lower regime periods, the shocks to NEER notably spillover to IPI with 2.4%, followed by 2.1% to OIL and 0.7% to CPI while the contribution of OIL to NEER is found to be 1.0%, to CPI is 0.6% and to IPI is 0.5%. With respect to the regime-dependent DY spillovers as contained in Table 14(b), it is evident that that in the upper regime, the NEER has the largest contribution to the FEVD of OIL with about 42.7% and to CPI and IPI with 42.5% for each. The contribution of OIL to the FEVDs of CPI, NEER, and IPI is found to be 31.0% for each. This is even higher than the response to own variable. In the lower regime, the contribution of NEER and OIL to individual variables is low. Particularly, the contribution of NEER to the FEVD of CPI is 3.3%. This is followed by the contribution to IPI with 0.9% and to OIL with 0.1%. On the other hand, the contribution of OIL to CPI is the largest with about 62.4%, followed by the contribution to NEER with 42.1% and IPI with 7.8%. For the linear model as displayed in Table 14(c), it is recorded that the shocks to NEER seemingly contribute about 12.7% to IPI, followed by 4.0% to CPI and 1.0% to OIL while that of OIL contributes about 1.5% to CPI, 1.2% to NEER and 0.6% to IPI. The implication for these findings is that the shocks to OIL and NEER are mostly affecting the behaviours of CPI in the VSTAR model while in the linear model IPI is mostly affected in China.

The results further pontificate that the total spillover index for China in the upper regime periods of the period-specific DY spillovers is found to be 7.1% while in the lower regime periods, it is 17.7%, which is higher than the upper regime periods. In the case of regime-dependence, the total spillover index is 75.0% in the upper regime and 33.4% in the lower regime. However, in the linear model, the total spillover index is found to be 8.9%. The total contribution to other variables based on the results of the upper regime periods in the period-specific DY spillovers shows that the shocks to OIL and NEER contribute the total of 2.1% and 5.3% to the FEVDs of other variables. In the lower regime periods, the contribution of OIL to other variables remains unchanged i.e. 2.1% while that of NEER slightly decreases to 5.1%. However, in the case of regime-dependent DY spillovers, the total contribution of OIL and NEER is 92.9% and 127.7% in the upper regime and 112.3% and 4.3% in the lower regime. The results in the linear model, OIL and NEER contribute the total of 3.4% and 16.8% to other variables, which is higher than in the nonlinear model. However, the contribution from other variables to OIL is found to be 15.6% and 3.5% for NEER in the upper regime periods, whereas, in the lower regime periods, the contribution receives by the OIL skyrockets to 58.6% while NEER slightly increases to 3.7%. In the case of regime-dependent spillovers, the total contribution from others to OIL is 69.1% and to NEER is 57.6% in the upper regime while in the lower regime we found just 0.2% to OIL and 45.2% to NEER. For a linear model, OIL receives about 1.1% and NEER receives 8.5%. To this extent, the results of the net spillover effects disclose that OIL is negative in both upper and lower regime periods of period-specific DY spillovers while NEER is positive, indicating that OIL is a “net receiver” and NEER is a “net transmitter”. More so, in the upper and lower regimes of the regime-dependent DY spillovers, the net spillover effect of OIL is positive while NEER is negative. This suggests that OIL is a “net transmitter” and NEER is a “net receiver”. Finally, in the linear model, the net spillover effects of OIL and NEER are positive; hence, they are regarded as “net transmitters or givers”.

5.4.4.5 Spillovers Table for South Africa

Tables 15(a) – (c) clearly divulge the empirical results for South Africa. According to the results of the upper regime periods of period-specific DY spillovers in Table 15(a), the pass-through of NEER explains roughly 3.9%, 1.6% and 0.4% to the FEVD of OIL, IPI, and CPI while the pass-through of OIL explains 1.0%, 0.6% and 0.2% to the FEVD of IPI, CPI and NEER in South Africa. In the lower regime periods, the contribution of NEER to OIL increases to about 32.5%, to CPI decreases to 1.0% while to IPI remains unchanged at 0.4%. In Table 15(b), which shows the regime-dependent DY spillovers, it is observed that in the upper regime the NEER contributes to the FEVD of CPI with 3.5%, contribute to IPI with 0.8% and 0.5% to OIL. On the other hand, OIL contributes to CPI with 65.8%, NEER with 36.3% and IPI with 16.8% in the lower regime. However, in Table 15(c) i.e. the linear model, we discover that the shocks to NEER contribute about 3.3% to CPI, 1.0% to OIL and 0.3% to IPI. Similarly, the contribution of OIL to NEER is about 5.5%, the contribution to CPI accounts for 2.6% and the contribution to IPI is just 1.0%.

The results show further that the total spillover index in the upper regime periods of the period-specific DY spillovers is estimated to be 8.4% and in the lower regime periods, we find it to be 14.5%. However, in the regime-dependent DY spillovers, the upper regime discloses a total spillover index of 54.0% while in the lower regime, it is 32.9%. For the linear model, it is discovered that the total spillover index is 3.8%, which is lower than those found by the results of the nonlinear models. More so, the total contribution of NEER to other variables in the upper regime periods of the period-specific DY spillovers is 5.9% and OIL is found to be 1.8%. In the lower regime periods, the total contribution of NEER and OIL increases astronomically in the case of NEER to 33.9% and slightly increases to 2.0% for OIL. Regarding the total contribution to other variables in the upper regime of the regime-dependent DY spillovers, we discover that NEER contributes about 26.5% and OIL contributes about 178.3%. The results of the linear model indicate that the total contribution of OIL to other variables is 8.9% and that of NEER is 4.7%. Conversely, the total contribution of the other variables to NEER and OIL indicates that OIL receives the highest contribution with about 25.3% and 3.1% receives by NEER in the upper regime periods of the period-specific DY spillovers. In the lower regime periods, OIL receives 49.4% and NEER receives about 1.8%. The results also show that in the upper regime of the regime-dependent DY spillovers, NEER receives about 71.0% and OIL receives about 0.7%. In the lower regime, it is revealed that the total contribution received by OIL remains the same at 0.7% while it declines drastically to 36.7% in the case of NEER. However, in the linear model, we find that the total contribution received by OIL is the lowest, accounting for about 1.2% while NEER receives about 6.0% from other variables. Hence, in the period-specific DY spillovers, the net spillover effect of OIL is negative in both the upper regime and lower regime is negative and positive in the case of NEER. For regime-dependent DY spillovers, the net spillover of OIL is positive while NEER is negative both in the upper and lower regime. With respect to the linear model, the net spillover for OIL is positive and that of NEER is negative.

The results of the spillover indexes discussed for all the BRICS countries indicate significant differences in the estimates of the linear and nonlinear models in terms of the magnitudes of the spillovers and the classification of each variable as a net-receiver or net-transmitter. As we have seen, the DY spillover estimates are higher in the case of nonlinear model compared to linear model for all the countries in our analysis. This result could possibly be traceable to the limitation of the linear VAR to account for nonlinear dependence in the series as discussed by Balcilar et al. (2016; 2018a,b). Therefore, the results of the DY spillovers based on the linear VAR model tend to be unreliable and misleading since the effects of asymmetries are not captured by the estimation. More so, regime-dependent DY indexes reflect the case where an economy completely adjusts to specific-regime. The regime-dependent DY index estimates show that this case is quite different from the period-specific DY index estimates in terms of the magnitudes of the spillovers and classification of variable as net-receiver or net-transmitter. As the regime-dependent case reflects an extreme end, it does not reflect the state of an economy in a particular period. Thus, in the presence of smooth-transition, a model that assumes instantaneous switching, such as the threshold VAR, leads to incorrect spillover estimates. Furthermore, we observe differences between the two regimes. With respect to period-specific DY spillovers, it is revealed that the magnitudes of the lower regime periods are higher than the upper regime periods for all the countries. In the case of regime-dependent, the magnitudes of the upper regime are higher than the lower regime except for Russia where the reverse is the case. These findings therefore provide strong evidence of asymmetric pass-through.

5.5 Conclusion

The extent to which EROPPT influences domestic prices is a major concern for the government and monetary authority, given the central objective of price stabilization. This issue has been rekindled by the recent upsurge of interest to adjust the pattern of the balance of payment. While several studies have estimated the form and the scale of EROPPT to developed and developing countries based on the linear and nonlinear models, some recent study point to the fact that the kind of nonlinear pass-through elasticity is a regime-dependent phenomenon. To this end, the main objective of this study is to estimate the degree of EROPPT to inflation in BRICS countries. We investigate whether the changes in exchange rate and oil price of different magnitudes have disproportionate effects on inflation in BRICS Countries. To achieve this objective, we propose a new approach, which extends the DY (2012) spillover index to incorporate nonlinearity based on a VSTAR model. This approach allows for a smooth period-specific and regime-dependent DY spillover indexes, governed by the selected transition variable between the upper regime and the lower regime.

The results of the linearity tests using the *LM, LR,* and F_{RAO} versions of linearity tests indicate the presence of nonlinearity for the BRICS countries. The results further provide that there are significant differences between the lower and upper regimes in the period-specific and regime-dependent EROPPT. In addition, the regime-dependent EROPPT spillover is higher compared to when a linear VAR assumption is not relaxed. Therefore, our results corroborate the recent arguments in the literature that the pass-through is a regime-dependent phenomenon. The policy implication of the findings of this paper is that government and policymakers need to take into consideration the different dependence of exchange rate and oil price pass-through while making decision on the monetary policy frameworks.

Table 11(a): Period-Specific DY Spillover Index for Brazil

	Upper Regime Periods					Lower Regime Periods				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	14.3	72.0	12.7	1.0	85.7	4.4	94.5	0.9	0.3	95.6
CPI	1.7	86.1	11.3	0.9	13.9	0.4	98.2	1.0	0.4	1.8
NEER	2.0	77.8	19.1	1.1	80.9	0.6	94.7	4.5	0.2	95.5
IPI	1.8	17.4	2.9	77.9	22.1	0.9	54.2	0.3	44.6	55.4
Contr. to Others	5.5	167.3	26.8	3.1	202.7	1.9	243.4	2.1	0.9	248.3
Contr. Incl. Own	19.8	253.3	45.9	80.9	Total Spillover	6.3	341.6	6.6	45.5	Total Spillover
Net Spillover	-80.2	153.3	-54.1	-19.1	Index = 50.7%	-93.7	241.6	-93.4	-54.5	Index = 62.1%

Table 11(b): Regime-Dependent DY Spillover Index for Brazil

	Upper Regime					Lower Regime				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	50.7	29.2	19.3	0.8	49.3	69.2	15.0	15.7	0.1	30.8
CPI	30.7	43.5	24.6	1.2	56.5	31.9	36.6	31.3	0.1	63.4
NEER	22.6	28.1	48.6	0.7	51.4	29.8	25.4	44.7	0.1	55.3
IPI	36.4	36.8	22.0	4.7	95.3	27.5	25.7	21.1	25.8	74.2
Contr. to Others	89.8	94.1	65.8	2.7	252.5	89.1	66.1	68.0	0.4	223.7
Contri. Incl. Own	140.5	137.7	114.4	7.5	Total Spillover	158.4	102.7	112.8	26.2	Total Spillover
Net Spillover	40.5	37.7	14.4	-92.5	Index = 63.1%	58.4	2.7	12.8	-73.8	Index = 55.9%

Table 11(c): Linear VAR DY Spillover Index for Brazil

	OIL	NEER	CPI	IPI	From others
OILPRICE	73.9	3.5	21.4	1.2	26.1
NEER	28.5	34.2	36.3	1.0	65.8
CPI	26.8	13.2	58.5	1.5	41.5
IPI	3.3	1.4	7.3	88.0	12.0
Contr. to others	58.6	18.1	65.1	3.7	145.4
Contri. incl. own	132.5	52.2	123.6	91.7	Total Spillover
Net Spillover	32.5	-47.7	23.6	-8.3	Index = 35.4%

Table 12(a): Period-Specific DY Spillover Index Russia

	Upper Regime Periods					Lower Regime Periods				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	63.2	26.9	9.0	0.8	36.8	48.8	50.4	0.2	0.6	51.2
CPI	0.6	98.7	0.4	0.3	1.3	0.6	98.8	0.2	0.3	1.2
NEER	0.1	0.3	99.4	0.3	0.6	0.1	4.8	94.9	0.3	5.1
IPI	1.1	3.8	0.5	94.6	5.4	1.2	0.8	2.6	95.4	4.6
Contri. to Others	1.8	31.0	9.8	1.5	44.0	1.8	56.0	3.0	1.2	62.1
Contri. Incl. Own	65.0	129.7	109.2	96.1	Total Spillover	50.6	154.8	97.9	96.6	Total Spillover
Net Spillover	-35.0	29.7	9.2	-3.9	Index = 11.0%	-49.4	54.8	-2.1	-3.4	Index = 15.5%

Table 12(b): Regime-Dependent DY Spillover Index for Russia

	Upper Regime					Lower Regime				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	88.8	1.3	7.9	2.0	11.2	86.6	4.3	6.4	2.7	13.4
CPI	45.4	9.6	44.1	0.9	90.4	39.6	26.0	29.7	4.7	74.0
NEER	33.3	6.1	57.5	3.0	42.5	33.7	21.1	40.8	4.4	59.2
IPI	3.5	0.3	4.5	91.7	8.3	9.8	2.7	14.9	72.6	27.4
Contr. to Others	82.3	7.7	56.5	5.9	152.4	83.1	28.2	50.9	11.8	174.0
Contr. Incl. Own	171.2	17.3	114.0	97.6	Total Spillover	169.7	54.2	91.7	84.4	Total Spillover
Net Spillover	71.2	-82.7	14.0	-2.4	Index = 38.1%	69.7	-45.8	-8.3	-15.6	Index = 43.5%

Table 12(c): Linear VAR DY Spillover Index for Russia

Variable	OIL	NEER	CPI	IPI	From others
OILPRICE	99.6	0.2	0.0	0.2	0.4
NEER	21.7	77.0	1.2	0.1	23.0
CPI	23.7	41.0	35.3	0.0	64.7
IPI	2.6	3.7	4.4	89.4	10.6
Contr. to others	48.0	44.9	5.6	0.3	98.7
Contr. incl. Own	147.6	121.9	40.9	89.6	Total Spillover
Net Spillover	47.6	21.9	-59.1	-10.3	Index = 24.7%

Table 13(a): Period-Specific DY Spillover Index India

	Upper Regime Periods					Lower Regime Periods				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	88.9	0.8	0.1	10.1	11.1	58.0	4.8	27.5	9.8	42.0
CPI	0.4	99.0	0.1	0.5	1.0	0.4	98.9	0.2	0.5	1.1
NEER	0.0	2.3	97.3	0.4	2.7	0.0	3.1	96.6	0.3	3.4
IPI	1.2	0.7	0.7	97.5	2.5	1.1	2.9	0.8	95.2	4.8
Contr. to Others	1.7	3.8	0.8	11.0	17.3	1.6	10.7	28.5	10.6	51.4
Contr. Incl. Own	90.6	102.8	98.2	108.4	Total Spillover	59.5	109.6	125.1	105.8	Total Spillover
Net Spillover	-9.4	2.8	-1.8	8.4	Index = 4.3%	-40.5	9.6	25.1	5.8	Index = 12.8%

Table 13(b): Regime-Dependent DY Spillover Index for India

	Upper Regime					Lower Regime				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	94.2	0.1	5.6	0.2	5.8	99.8	0.0	0.0	0.1	0.2
CPI	40.4	18.1	4.6	36.9	81.9	42.7	46.1	6.5	4.6	53.9
NEER	57.4	0.2	41.8	0.6	58.2	0.5	0.0	97.3	2.2	2.7
IPI	14.0	0.3	0.7	85.1	14.9	11.9	0.1	0.4	87.6	12.4
Contr. to Others	111.8	0.6	10.8	37.6	160.8	55.1	0.1	6.9	7.0	69.1
Contr. Incl. Own	206.0	18.7	52.6	122.7	Total Spillover	154.9	46.3	104.2	94.6	Total Spillover
Net Spillover	106.0	-81.3	-47.4	22.7	Index = 40.2%	54.9	-53.7	4.2	-5.4	Index = 17.3%

Table 13(c): Linear VAR DY Spillover Index for India

Variable	OIL	CPI	NEER	IPI	From others
OILPRICE	99.8	0.0	0.1	0.0	0.2
NEER	4.1	93.2	2.6	0.1	6.8
CPI	0.8	0.3	98.6	0.3	1.4
IPI	1.1	0.6	0.5	97.8	2.2
Contr. to others	6.0	0.9	3.3	0.4	10.5
Contr. Incl. Own	105.8	94.1	101.9	98.2	Total Spillover
Net Spillover	5.8	-5.9	1.9	-1.8	Index = 2.6%

Table 14(a): Period-Specific DY Spillover Index China

	Upper Regime Periods					Lower Regime Periods				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	84.4	1.3	1.1	13.2	15.6	41.4	55.7	2.1	0.8	58.6
CPI	0.7	96.6	0.6	2.1	3.4	0.6	96.4	0.7	2.2	3.6
NEER	0.9	0.5	96.5	2.1	3.5	1.0	0.7	96.3	2.0	3.7
IPI	0.5	2.1	3.5	93.9	6.1	0.5	2.2	2.3	95.0	5.0
Contr. to Others	2.1	3.9	5.3	17.4	28.6	2.1	58.7	5.1	5.1	70.9
Contr. Incl. Own	86.5	100.5	101.8	111.2	Total Spillover	43.5	155.1	101.3	100.1	Total Spillover
Net Spillover	-13.5	0.5	1.8	11.2	Index = 7.1%	-56.5	55.1	1.3	0.1	Index = 17.7%

Table 14(b): Regime-Dependent DY Spillover Index for China

	Upper Regime					Lower Regime				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	30.9	0.2	42.7	26.2	69.1	99.8	0.0	0.1	0.1	0.2
CPI	31.0	0.2	42.5	26.4	99.8	62.4	20.8	3.3	13.5	79.2
NEER	31.0	0.2	42.4	26.4	57.6	42.1	0.3	54.7	2.9	45.3
IPI	31.0	0.2	42.5	26.4	73.6	7.8	0.2	0.9	91.1	8.9
Contr. to Others	92.9	0.5	127.7	79.1	300.1	112.3	0.6	4.3	16.5	133.6
Cont. Incl Own	123.8	0.6	170.1	105.4	Total Spillover	212.1	21.4	59.0	107.6	Total Spillover
Net Spillover	23.8	-99.4	70.1	5.4	Index = 75.0%	112.1	-78.6	-41.0	7.6	Index = 33.4%

Table 14(c): Linear VAR DY Spillover Index for China

Variable	OIL	NEER	CPI	IPI	From others
OILPRICE	98.9	0.1	0.5	0.4	1.1
NEER	1.2	94.0	4.0	0.8	6.0
CPI	1.5	4.0	91.5	2.9	8.5
IPI	0.6	12.7	6.6	80.1	19.9
Contr. to others	3.4	16.8	11.1	4.1	35.4
Contr. incl. Own	102.3	110.8	102.7	84.2	Total Spillover
Net Spillover	2.3	10.8	2.6	-15.8	Index = 8.9%

Table 15(a): Period-Specific DY Spillover Index South Africa

	Upper Regime Periods					Lower Regime Periods				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	74.7	20.5	3.9	0.9	25.3	50.6	16.2	32.5	0.7	49.4
CPI	0.6	98.7	0.4	0.3	1.3	0.6	98.1	1.0	0.3	1.9
NEER	0.2	2.8	96.9	0.2	3.1	0.2	1.5	98.2	0.1	1.8
IPI	1.0	0.7	1.6	96.8	3.2	1.2	3.1	0.4	95.3	4.7
Contr. to Others	1.8	24.0	5.9	1.4	33.1	2.0	20.8	33.9	1.1	57.9
Contr. Inclu. Own	76.4	122.6	102.8	98.2	Total Spillover	52.6	118.9	132.2	96.4	Total Spillover
Net Spillover	-23.6	22.6	2.8	-1.8	Index = 8.3%	-47.4	18.9	32.2	-3.6	Index = 14.5%

Table 15(b): Regime-Dependent DY Spillover Index for South Africa

	Upper Regime					Lower Regime				
Variable	OIL	CPI	NEER	IPI	From others	OIL	CPI	NEER	IPI	From others
OIL	99.3	0.0	0.6	0.1	0.7	99.3	0.0	0.5	0.1	0.7
CPI	63.0	7.0	24.9	5.2	93.0	65.8	23.4	3.5	7.3	76.6
NEER	65.0	0.0	29.0	6.0	71.0	36.3	0.0	63.3	0.4	36.7
IPI	50.3	0.0	1.0	48.7	51.3	16.8	0.0	0.8	82.4	17.6
Contr. to Others	178.3	0.0	26.5	11.3	216.0	118.9	0.0	4.8	7.8	131.7
Contr. Inclu. Own	277.6	7.0	55.5	59.9	Total Spillover	218.2	23.4	68.1	90.2	Total Spillover
Net Spillover	177.6	-93.0	-44.5	-40.1	Index = 54.0%	118.2	-76.6	-31.9	-9.8	Index = 32.9%

Table 15(c): Linear VAR DY Spillover Index for South Africa

Variable	OIL	NEER	CPI	IPI	From others
OILPRICE	98.8	1.0	0.0	0.2	1.2
NEER	5.2	93.9	0.9	0.0	6.1
CPI	2.6	3.3	94.0	0.1	6.0
IPI	1.0	0.3	0.4	98.3	1.7
Contr. to others	8.9	4.7	1.3	0.2	15.0
Contr. Inclu. Own	107.6	98.5	95.3	98.6	Total Spillover
Net Spillover	7.7	-1.4	-4.7	-1.5	Index = 3.8%

Chapter 6

CONCLUSION

The general objective of this thesis is to investigate the pass-through of exchange rate and oil price in the emerging market economies with a special focus on the BRICS and Nigerian economies. The choice of the BRICS countries and Nigeria is informed by the large fluctuations in their exchange rates following a significant shift in the directions of the exchange rate and trade policies towards market-based policies. As shown by several empirical studies, the phenomenon of large exchange rate fluctuations coincides with the periods of high inflation and low output growth. This consequentially affect the low inflation levels and price stability objectives of the monetary policy. Therefore, investigating the dynamics of the pass-through of exchange rate and oil price movements on inflation and output growth will assist the monetary policy authorities to understand the process of price determination and conduct a sound monetary policy.

This thesis makes significant contributions to the literature especially in the area of linear and nonlinear pass-through by exploring econometric techniques that are more novel and robust. In testing for the pass-through, we depart from estimating the first stage of pass-through, which is concerned with the pass-through of exchange rate and oil price shocks to import prices to the second stage, which focuses apparently on the pass-through to inflation following changes in exchange rate and oil price. This departure is because inflation has remained the bane of growth and development in these economies. Therefore, chapter 2, which follows the introductory chapter, revisits the ERPT to two largest economies in Africa (Nigeria and South Africa) by incorporating structural breaks based on the Maki cointegration test and a flexible estimation approach of the Autoregressive Distributed Lag (ARDL) model. Having tested for the unit root and cointegration, the empirical results find that the long-run pass-through is complete in Nigeria while it is incomplete in South Africa. For short run, we find incomplete ERPT in both Nigeria and South Africa. In overall, the results indicate that prices are much stickier in South Africa than in Nigeria. The comparison between Nigeria and South Africa confirms the role of inflation targeting and Central Bank credibility on the ERPT. The results indicate further that output growth in Nigeria increases inflation in the long run while it is anti-inflationary in the short run. For the case of South Africa, the effect of output growth is negatively insignificant both in the long run and short run. In addition, the long-run and short-run effects of oil price are negative for Nigeria but significant only for long run. However, for South Africa both the long-run and short-run effects of oil price are positive but only significant in the short run. Another interesting result found is that the structural breaks identified for the countries have significant effects in both countries. Additionally, the deviation from the long-run equilibrium is reversed back more quickly in Nigeria than in South Africa. These results indicate that credible monetary policy framework and inflation targeting reduce ERPT by creating nominal anchors for inflation expectations and interest rate, which is confirmed by the much lower ERPT finding for South Africa in both the long run and short run.

Even though several studies have come to the limelight in the literature of asymmetric EROPPT, there is a common limitation of the literature. This limitation is that many of these studies focus mostly on the direction of the pass-through and the role of inflation volatility in the pass-through without giving due consideration to whether the state of the economy matters for pass-through. This creates a missing gap in the literature. In Chapter 3, we investigate not only the question of whether there is EROPPT but also the extent to which the pass-through is asymmetric or state dependent in the BRICS countries. This Chapter applies the nonlinear VSTAR model, which allows a smooth transition pass-through, governed by the selected transition variables. The results of the linearity tests based on the three linearity tests – *LM*, *LR*, and F_{RAO} versions indicate the presence of nonlinearity in all the equations in each of the country. The results based on the model estimations reveal both positive and negative asymmetric relationship among the variables in all the equations in the upper and lower regime periods. However, to understand the dynamics of the pass-through, the nonlinear Generalized Impulse Response Functions (GIRFs) is explored with 1000 bootstrap repetitions being generated. The results find evidence of period specific pass-through between the upper and lower regime periods, governed by the selected transition variables. We also find asymmetric pass-through in all the countries with strong evidence of higher pass-through when the size of the shocks to the transition variable moves the system above a threshold level. The result further divulges that output growth asymmetrically reacts to the shocks. The implication of these findings is that the pass-through is strongly affected by the state of the economy. Finally, the results found in this paper are robust to the linearity tests, nonlinear VSTAR model, and nonlinear GIRFs.

In Chapter 4, we investigate the pass-through of exchange rate and oil price in the BRICS countries through the analysis of Diebold and Yilmaz (2012) spillover index and rolling-window. In this Chapter, the emphasis is placed on the spillovers of exchange rate and oil price to not only inflation but to all other variables captured in the model estimation. In addition, three categories of spillover indexes are revealed namely: directional spillovers; total spillovers, and net spillovers. Finally, the rolling window approach is explored to capture the effects of historical events, crises, as well as other factors that characterize the channels of the pass-through. The results showed that, (i) there is strong evidence of the directional spillovers in all the countries; (ii) the total spillover is low with Brazil having the highest and India having the lowest. This suggests that a larger percentage of shocks is explained by idiosyncratic shocks; and (iii) the net spillover of oil price (output growth) is positive (negative) for all the countries, indicating that oil price (output growth) contributes to the forecast error variance decomposition of all other variables more(less) than what it receives from other variables. In the case of exchange rate, the net spillover effect is only positive for Russia and China while consumer price index is positive only for Brazil and China. In addition, we estimate the overall spillover indexes and the bivariate version of the spillover estimates from the NEER and oil price for all the countries through the rolling-spillover approach. The findings reveal that the spillovers in BRICS countries are interrupted by the structural changes over time. However, even though the spillover exhibits significant fluctuations, there is no clear-cut evidence of trends among the variables. Therefore, these findings have policy implications for the attainment of the recent monetary policy of inflation targeting to attain low and stable prices.

Furthermore, the Diebold and Yilmaz (2012) spillover index, which is based on a generalized vector autoregressive (VAR) model through the forecast-error variance decompositions does not consider nonlinear dependence in the series. Even though some studies wrap it up with rolling window estimation, it is clear that the rolling window cannot properly capture nonlinear interactions of the variables (See Balcilar *et al.* (2018 a,b). To solve this problem, Chapter 5 aims at investigating whether changes in exchange rate and oil price of different magnitudes have disproportionate pass-through effects in the BRICS Countries. To this end, we extend the Diebold-Yilmaz (DY) spillover index to incorporate nonlinearity based on a Vector Smooth Transition Autoregressive (VSTAR) model. This approach allows for a smooth period-specific and regime-dependent DY spillover indexes, governed by the selected transition variable between the upper and lower regimes. Having established nonlinearity using the *LM*, *LR*, and F_{RAO} versions of linearity tests, the empirical results further provide that there are significant differences between the lower and upper regimes in the period-specific and regime-dependent EROPPT. In addition, the regime-dependent EROPPT elasticity is higher compared to when the linear VAR assumption is imposed. The results, therefore, corroborate the recent arguments in the literature that the pass-through is a regime-dependent phenomenon. The policy implication of the findings of this Chapter is that government and policymakers need to take into consideration the different dependence of exchange rate and oil price pass-through in the course of designing and implementing monetary policy rules.

Finally, the issue of the pass-through has macro and micro phases. In this thesis, the focus is on the pass-through of exchange rate and oil price to aggregate economy. For a better understanding of this issue in the emerging market economies, it is suggested that further research should focus on the pass-through of exchange rate and oil price based on disaggregated data and prices at industry and firm levels.

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APPENDIX

Unit Root Tests

Country	Variable	ADF at Level		ADF at First Difference		PP at Level		PP at First Difference	
		Constant	Constant & Trend	Constant	Constant & Trend	Constant	Constant & Trend	Constant	Constant & Trend
Brazil	LCPI	-4.0204***	-2.5957	-3.8179***	-4.9733***	-4.9203***	-2.2379	-3.2385**	-4.2717***
	LIPI	-1.3423	-3.0194	-19.0718***	-19.0463***	-1.4701	-3.8500**	-33.9359***	-33.8790***
	LNEER	-4.1486***	-2.1794	-4.3206***	-7.2699***	-4.8194***	-2.1423	-5.6629***	-7.1113***
	LOILPRICE	-5.4725***	-2.5467	-7.8758***	-9.4712***	-4.7792***	-1.8822	-12.7085***	-13.4337***
Russia	LCPI	-2.9529**	-2.1489	-6.0588***	-6.5156***	-4.9588***	-3.5335**	-11.5212***	-12.2573***
	LIPI	-0.9550	-1.7404	-18.8856***	-18.8574***	-1.1317	-3.6201**	-29.1702***	-29.3109***
	LNEER	-1.7620	-2.4344	-12.2546***	-12.2400***	-1.9859	-2.4633	-12.2131***	-12.1986***
	LOILPRICE	-2.2109	-1.7946	-14.2205***	-14.2817***	-2.1279	1.9370	-14.1991***	-14.2924***
India	LCPI	-1.2143	-1.9576	-3.7336***	-3.8661**	-1.7658	-1.5355	-12.8164***	-12.8026***
	LIPI	-0.8036	-2.4742	-20.4269***	-20.4153***	-0.3321	-4.5876***	-35.9359***	-36.0356***
	LNEER	-2.7724*	-2.9380	-16.6481***	-16.7965***	-3.0834**	-2.9569	-16.5111***	-16.6191***
	LOILPRICE	-1.6547	-3.4506**	-15.8220***	-15.8188***	-1.0503	-2.9462	-15.6921***	-15.7746***
China	LCPI	-1.8768	-2.3128	-5.9446***	-5.9484***	-1.9946	-2.2319	-15.3677***	-15.3494***
	LIPI	-3.6905***	-4.4095***	-7.7957***	-7.7891***	-11.7845***	-12.0457***	-45.3432***	-46.6968***
	LNEER	-1.7106	-2.6311	-16.4236***	-16.5446***	-1.8566	-2.6779	-16.4197***	-16.5410***
	LOILPRICE	-1.6478	-2.8392	-13.4606***	-13.4406***	-1.4345	-2.5687	-12.9425***	-12.9186***
S/Africa	LCPI	-4.2950***	-4.6261***	-6.4612***	-12.7199***	-3.9070***	-4.2830***	-13.0615***	-13.5275***
	LIPI	-1.3204	-2.2489	-11.1353***	-11.1269***	-1.4753	-3.4710**	-30.0709***	-30.0448***
	LNEER	-1.2832	-2.8545	-13.9928***	-13.9856***	-1.2425	-2.6055	-13.9039***	-13.8951***
	LOILPRICE	-0.9977	-2.4097	-16.0355***	-16.0153***	-0.9937	-2.6771	-15.8826***	-15.8622***

Notes: ***, ** and * denote significance level at 1%, 5% and 10%