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## Commodity Prices and BRIC and G3 Liquidity: A SFAVEC Approach

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### Abstract

This paper investigates the influence of liquidity in the major developed and major developing economies on commodity prices. Liquidity is taken to be M2. A novel finding is that unanticipated increases in the BRIC countries' liquidity is associated with significant and persistent increases in commodity prices that are much larger than the effect of unanticipated increases in G3 liquidity, and the difference increases over time. Over 1999-2012 BRIC liquidity is strongly linked with global energy prices and global real activity whereas G3 liquidity is not. The impact of BRIC liquidity on mineral and metal prices is twice as large as that of G3 liquidity. Granger casualty goes from liquidity to commodity prices. BRIC and G3 liquidity and commodity prices are cointegrated. BRIC and G3 liquidity and global output and global prices are cointegrated. We construct a structural factor-augmented error correction (SFAVEC) model.

## **Keywords**

Commodity Prices, BRIC countries, G3, Global liquidity, SFAVEC

## **JEL Classification**

E31, E32, E51, F01, G15, Q43

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## Commodity Prices and BRIC and G3 Liquidity: A SFAVEC Approach<sup>Δ</sup>

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## Commodity Prices and BRIC and G3 Liquidity: A SFAVEC Approach

### 1. Introduction

The effect of global liquidity on the prices of commodities, goods and assets has been a focus of recent research. Sousa and Zaghini (2007) find that global excess liquidity signals inflationary pressure at a global level. D'Agostino and Surico (2009) demonstrate that global liquidity has predictive power for the US inflation rate. Darius and Radde (2010) show that global liquidity has impact on a commodity price index (but not on equity prices and oil prices). Belke et al. (2010) document that the dramatic increase in global liquidity since 2001 has had impacts on the price of assets in inelastic supply including commodities. Anzuini et al. (2013) find that US monetary expansion has a significant, but modest effect on commodity prices. Ratti and Vespignani (2013) report that increases in global liquidity have had a positive effect on oil prices in recent years. Theoretically increases in liquidity are likely to be associated with a rise in aggregate demand and this will increase the price of most assets including commodity prices.<sup>1</sup>

In this paper we seek to determine the influence of liquidity as it arises from the major developed and major developing economies on commodity prices. Hamilton (2013) notes that the newly industrialized economies have absorbed over two-thirds of the increase in world oil consumption since 1998. Kilian and Hicks (2013) associate the rise in real oil price over 2003-2008 with growth in emerging economies, primarily that in China and India. Radetzki (2006) surmises that in developing Asian countries a dollar added to the GDP uses more than twice the quantity of commodities as does a dollar added to the GDP in OECD countries and notes that between 2000 and 2005, just China's share of global demand growth for petroleum was 28%, for aluminium was more than 50%, for steel was more than 84%, and for copper

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<sup>1</sup> Barsky and Kilian (2004) maintain that monetary policy influences commodity prices through expectations of greater growth and inflation. Frankel and Hardouvelis (1985) argue that movement in commodities prices measure the market's assessment of the stance of monetary policy. Frankel (1984) notes that increase in money will raise the real price of commodities because the prices of many other goods are inflexible in the short.

was 95%. Humphreys (2010) notes that industrialization increases demand for metals substantially and that development in the BRIC economies is a major factor in the boom in metal prices from 2003 to 2008. Roberts and Rush (2010) argue that commodity resources are used intensively in traded goods and that this is a part of the demand for commodities by rapidly developing countries. Dungey et al. (2013) find that shocks to Chinese demand result in sustained increase in commodity prices in the Australian mining sector.

Our view is that it greatly matters in assessing the impact of liquidity on commodity prices as to where the innovation in liquidity is originating. In this paper the major developing economies are taken to be the BRIC countries (Brazil, the Russian Federation, India and China). The major developed economies are taken to be the G3, the world's three leading developed economic blocs - the US, Japan and the European Union (EU). Compared to the G3, the BRIC countries grow and are anticipated to grow faster, use commodities more intensively, and expand liquidity more rapidly. Given availability of data with a monthly frequency liquidity is taken to be M2. By this measure the BRIC countries have become much more important providers of global liquidity in recent years. Over the fourteen years from 1999:01 to 2012:12 M2 is up approximately by a factor of 13.3 in BRIC countries. In comparison, M2 is up by a factor of 2.4 in the G3 over the same period.

A structural factor-augmented vector error correction model is employed in the analysis of the effect of innovations in BRIC liquidity and G3 liquidity on global commodity prices.<sup>2</sup> A structural factor-augmented dimension to the SVEC model will capture the dynamic of the information provided by many variables to the analysis of short and long run influence of liquidity on global commodity prices, global industrial production, global CPI

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<sup>2</sup> The literature on the identification of monetary policy in a VAR framework is expanding in several directions. Bernanke et al. (2005) propose a Factor-augmented VAR (FAVAR) to identify monetary policy shocks. A small number of factors (principal components ) can summarize large amounts of information about an economy and be included in the FAVAR. Dees et al. (2007) propose a global VAR (GVAR). The GVAR combines separate models for each of the many economies linking core variables within each economy with foreign variables using quarterly data. The foreign variables external to a domestic economy are trade-weighted.

and global interest rate. The latter three structural factors are estimated using principal component techniques applied to country level data on industrial production, CPI, and interest rates, respectively. To the best of our knowledge this is one of the few papers that address issues regarding commodity prices using structural factor-augmented vector error correction. Granger casualty goes from liquidity to commodity prices. BRIC M2 and G3 M2 are cointegrated with commodity prices and with global CPI and global output.

The main new finding in this paper is of a much greater impact of positive shocks in liquidity in the largest emerging economies on commodity prices over 1999-2012 than that of positive shocks in liquidity in the largest advanced economies over the same period. The disparity in the effect of BRIC liquidity on commodity prices compared to that of G3 liquidity on commodity prices grows over time. Positive shocks in BRIC liquidity have much larger effects on energy prices, mineral and metal prices, and raw material prices than do positive shocks in G3 liquidity. Shocks to G3 liquidity have larger effects than shocks to BRIC liquidity on precious metal prices. Results are for generalized cumulative impulse response (Pesaran and Shin (1998)) and are invariant to the ordering of the variables. Similar results are obtained from models with identification schemes similar to standard structural recursive systems in the VAR literature. Results are also robust to different measurement of global variables, to treatment of the global financial crisis, and to variation in lag length.

The transmission link between liquidity and commodity prices is discussed in Section 2. The structural factor-augmented vector error correction model for analysis of liquidity and commodity prices is introduced in Section 3. The data, variables and structural factors appear in Section 4 and stationarity and cointegration are discussed in Section 5. The empirical results are presented in Section 6. Robustness of results is investigated in Section 7. Section 8 concludes.

## **2. Liquidity and Commodity Prices: The transmission mechanism**

There are a number of channels by which liquidity measured by monetary aggregates can influence commodity prices. Frankel (1984) maintains that increases in the money stock will influence the real price of commodities in the short-run, because the prices of many other goods are not flexible in the short-run and real interest rates are impacted. In the Frankel (1986) model, real agricultural commodity prices decline and the real interest rate rises in the short-run following a decline in the level of the money supply when the prices of other goods are sticky. In the short-run commodities must be sufficiently undervalued so that there is an expectation of future price increases large enough to offset the higher real interest rate.

Following increases in liquidity an inventory channel for accumulating commodities and might also be at work. Barsky and Kilian (2002) maintain that easy monetary policy indicated by low real interest rates might generate incentives to accrue inventories and lead to high real commodity prices. Alquist and Kilian (2010) note, with lower interest rates, investors have a greater incentive to pursue investment in assets such as oil. Anzuini et al. (2013) also identifies a futures market connection between liquidity and oil prices.

In theory, increases in M2 are associated with a rise in aggregate demand that will increase the price of most assets including commodity prices. Barsky and Kilian (2004) argue that monetary policy may influence commodity prices through expectations of greater growth and inflation. Barsky and Kilian (2002) connect large increases in global liquidity measured by money growth in the United States and nine other OECD countries with the substantial increase in commodity prices preceding the increase in oil prices in 1973-1974. Frankel and Hardouvelis (1985) contend that movement in commodities prices measure the market's assessment of the stance of monetary policy. An expected increase in money growth causes investors to shift out of money and into commodities.

Many commodity prices are determined in markets influenced by global supply and demand effects. The idea that global liquidity can impact commodity prices and other prices has been investigated in the literature. Darius and Radde (2010) find that global liquidity has significant impact on house prices and a commodity price index, but not on equity prices and oil prices. Gerdesmeier et al. (2009) show that high money and credit growth are associated with asset price booms some quarters later. Belke et al. (2010) document that global liquidity has risen since 2001 with impacts on the price of assets in inelastic supply such as commodities. Brana et al. (2012) link global excess liquidity to asset prices in emerging economies.

The novelty in this study is recognition that the effect of liquidity on commodity prices will depend on the source of the change in liquidity across countries. It is hypothesized that increases in liquidity in major emerging economies compared to increases in liquidity in major developed economies will be associated with a disproportionate rise in commodity prices. This conjecture is based on both the finding by a number of authors that growth in emerging market countries is associated with a relatively greater usage of commodities than is expansion in developed economies (see for example, Radetzki (2006), Humphreys (2010), Roberts and Rush (2010)), and the argument by Barsky and Kilian (2004) that monetary expansion may influence commodity prices through expectations of greater growth. Therefore, the increase in liquidity in developing countries is associated with a higher expected growth for commodity demand than an increase in liquidity from developed countries. While the literature has recognized the influence of global liquidity on commodity prices traded on world markets, the contrast of the influence of liquidity as it arises from the major developed and major developing economies on commodity prices has not been made.

### **3. The model**



In this paper we will construct a structural factor-augmented error correction (SFAVEC) model to estimate the impacts of increases in BRIC and in G3 liquidity on global commodity prices. The econometric strategies in the paper are the following. Global factors for interest rates, industrial production and CPI are estimated using principal component techniques. Two cointegrating vectors involving the factors as well as commodity prices and liquidity indicators are reclaimed. A structural factor-augmented error correction model (SFAVEC) is estimated using as endogenous variables the three factors, the two indicators of the M2 aggregate for developed and developing countries and the commodity price index. The basic model is discussed in this section by highlighting the appealing features of the technique given the nature of the issue being addressed. The data, variables and various test results are examined in detail in subsequent sections.

The use of a SFAVEC model is preferred to the standard VAR model for the following reasons. First, the relationship between liquidity and commodity prices is a global relationship. In consequence, variables for many countries can influence commodity prices. The inclusion of supplementary variables in standard VARs is constrained by degrees-of-freedom problems. To overcome the problem of the small number of variables that can be used in standard VARs, construction of principal components utilizes the information in a large number of variables that can more realistically reflect global influences. A structural interpretation is given to the factors by constructing each factor to represent the same economic variable across countries.<sup>3</sup>

Secondly, a vector error correction model to investigate the relationship between liquidity and commodity prices allows estimation of reasonable steady-state relationships and

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<sup>3</sup> Structural factors in VAR models to better identify the effects of monetary policy have appeared in a number of contributions (for example, by Belviso and Milani (2006), Laganà (2009) and Kim and Taylor (2012), amongst others), but less so in work on commodity prices. An exception is by Lombardi et al. (2012) examining global commodity cycles in a FAVAR model in which two factors represent common trends in metals and food prices. The other variables are global industrial production, US dollar effective exchange rate, US interest rate and the price of oil.

of the adjustment towards the long-run equilibrium of the relevant economic and financial variables. The Frankel (1986) overshooting model of commodity prices emphasizes that following changes in money growth there is short-run adjustment to a new long-run equilibrium between monetary aggregates and commodity prices. Thus, the distinction between short-run and long-run in adjustment vector error correction model is appealing in application to the relationship between liquidity and commodity prices. The plausible steady-state relationships that are examined are between liquidity and commodity prices on the one hand and between liquidity, global output and global prices on the other.<sup>4</sup>

Following Bernanke et al.'s (2005) idea of incorporating principal component vectors in a simultaneous equation model, we construct a structural factor-augmented error correction model.<sup>5</sup> We will work with the following variables: liquidity distinguished between M2 for the G3 economies ( $G3M2_t$ ) and M2 for the BRIC economies ( $BRICM2_t$ ); world commodity prices ( $COM_t$ ); and the global variables for global interest rate ( $GIR_t$ ), global CPI ( $GCPI_t$ ), global industrial production ( $GIP_t$ ). The global variables are structural factors estimated by principal components. We use one factor each for global interest rate, global industrial production and global CPI to retain parsimony in the structural factor-augmented VEC approach. These variables will be defined in the next section.

The SFAVEC model can be expressed as:

$$B_0X_t = \beta + \sum_{i=1}^j B_iX_{t-i} + \omega ECT1_{t-1} + \rho ECT2_{t-1} + \varepsilon_t \quad (1)$$

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<sup>4</sup> In this we follow Browne and Cronin (2010). In keeping with the quantity theory of money, a cointegrating relationship between the price, monetary aggregate and output variables is examined (in line with the empirical studies by Swanson (1998), Bachmeier and Swanson (2005), Garret et al. (2009) and others)

<sup>5</sup> Bernanke et al. (2005) propose a factor-augmented vector autoregressive model (FAVAR) based on the development of principal components analysis outlined by Stock and Watson (2002). A factor-augmented approach has been used by Dave et al. (2013) to isolate the bank lending channel in monetary transmission of US monetary policy and by Gilchrist et al. (2009) to assess the impact of credit market shocks on the US activity. One of the main advantages of this methodology is that a single individual variable or factor can capture the dynamic of a large amount of information contained in many variables. Sims (2002) argues that when deciding policy central banks consider a huge amount of data. An overview of factor-augmented VARs and other models is provided by Koop and Korobilis (2009). Boivin and Ng (2006) caution that expansion of the underlying data could result in factors less helpful for forecasting when idiosyncratic errors are cross-correlated or when a useful factor in a small dataset becomes dominated in a larger dataset.

where  $j$  is optimal lag length, determined by the Schwarz criterion (one lag in this case),  $X_t$  is vector of endogenous variables,  $ECT1_t$  and  $ECT2_t$  are the error correction terms for liquidity and commodity prices and for liquidity, global output and global prices, respectively, and  $\varepsilon_t$  is the vector of structural changes, which is serially and mutually independent.

The vector  $X_t$  is expressed as:

$$X_t = [GIR_t, \Delta \log(G3 M2_t), \Delta \log(BRIC M2_t), \Delta \log(GCPI_t), \Delta \log(GIP_t), \Delta \log(COM_t)] \quad (2)$$

Country-specific SVAR studies such as Kim and Roubini (2000), Kim (2001) and Anzuini et al. (2013) use structural contemporaneous restriction in order to identify the model based on economic theory and/or the estimated time of the central bank reaction to information release. In a study of global variables in this paper there is not strong belief on variable ordering and contemporaneous restrictions. In a country-specific study it is possible to infer that the central bank can or cannot observe inflation contemporaneously based on the date at which inflation indicators is released and can change the interest rate accordingly. At the global level, whether global interest rate responds to global CPI is less clear, as the global variables are composed of several country-specific variables.

Consequently, the generalized cumulative impulse response (GIRF) developed by Koop et al. (1996) and Pesaran and Shin (1998) may be appropriate for this study. Unlike conventional impulse response, generalized impulse response analysis approach is invariant to the ordering of the variables which is an advantage in absence of strong prior belief on ordering of the variables. Pesaran and Shin (1998) show that the generalized impulse response coincides with a Cholesky decomposition when the variable shocked is ordered first and does not react contemporaneously to any other variable in the system.

To assess the robustness of the results we will also examine outcomes obtained from identification strategies for the global variables that reprise those in the literature that are

sensible for analysis of country level variables. Identification strategies that are frequently used in the literature and non-recursive structural alternatives are explored in a section on robustness later in the paper

## 4. Data, Variables and Structural Factors

### 4.1. The data

The model is constructed with monthly data from January 1999 to December 2012. The starting period is dictated by the creation of the European central bank, the availability of Eurozone interest rate data, and the availability of data at monthly frequency for the BRIC countries. It is necessary to use monthly data since the sample period is unavoidably comparatively short. In this study we will use M2 as a measure of liquidity. This is determined by the availability of monthly M2 data for the countries involved over 1997:1 to 2011:12.<sup>6</sup>

The monetary aggregate indicators are M2 for the G3 economies ( $G3 M2_t$ ), US, Japan and the EU (taken to be the Eurozone and UK), and M2 for the BRIC economies ( $BRIC M2_t$ ), Brazil, Russia, India and China. The monetary aggregates are measured in US dollars. Global commodity prices ( $COM_t$ ), overall, energy, non-energy, mineral and metal, precious metal, and raw materials prices are in US dollars. We will also construct a global interest rate ( $GIR_t$ ) variable, a global CPI ( $GCPI_t$ ) variable, and a global industrial

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<sup>6</sup> Different measures of global liquidity have been employed in the literature. Sousa and Zaghini (2007) construct a quarterly (G5) global liquidity indicator based on aggregating broad money indicators for the US (M2), Japan (M2+), the United Kingdom (M4), the Eurozone (M3) and Canada (M2+). The monetary aggregate used for each country is indicated in parenthesis. Belke et al. (2010) build a quarterly global liquidity indicator built on monetary aggregates for the US, the Eurozone, Japan, United Kingdom, Canada, South Korea, Australia, Switzerland, Sweden, Norway and Denmark. The monetary aggregate is M2 for the US, M3 for the Eurozone, M2 plus cash deposits for Japan, M4 for the UK and mostly M3 for the other countries. For a measure of global liquidity based on narrower monetary aggregates Brana et al. (2012) construct a monthly global monetary base founded on the US, United Kingdom, Japan, Australia, New Zealand, Sweden, Denmark, the Eurozone, China, South Africa, ten countries from Central and Eastern Europe including Russia, and Qatar, Kuwait and Saudi Arabia. Darius and Radde (2010) construct a quarterly measure of global liquidity given by the sum of the US monetary base and world international reserves. Ruffer and Stracca (2006) and Brana et al. (2012) review alternative measures of global liquidity.

production ( $GIP_t$ ) variable based the on the interest rate, industrial production and CPI in each of the BRIC and G3 economies. The global commodity price data and commodity price component data are from World Bank and the International Monetary Fund. The M2 data for US, Eurozone, UK, Japan, Brazil and Russian Federation are from International Monetary Fund and the Federal Reserve Bank of St. Louis, while China's and India's M2 are from People's Bank of China and Reserve Bank of India, respectively.<sup>7</sup> The exchange rate data to convert M2 series from domestic currency into US dollars is obtained from Federal Reserve Bank of St. Louis.<sup>8</sup> All other variables are from the Federal Reserve Bank of St. Louis (FRED data).

Information on M2 in US dollars for the BRIC countries and for the G3 over 1999:01-2011:12 is provided in Figure 1. The scale of the right hand side of Figure 1 is for M2 for the BRIC countries and the scale of the left hand side of Figure 1 is for M2 for the G3. BRIC M2 goes from being only about 10% of G3 M2 at the start of the period to being over 50% by the end of the period. The logs of US dollar commodity price index and commodity price component indices for energy commodities, agriculture commodities, mineral and metal commodities, precious metal commodities, and raw materials commodities are shown in Figure 2. The underlying indices are set at 100 for 2005. From 1999:01 to 2012:12 the commodity price index is up by a multiple of 3.71. Over the same period energy prices, agriculture prices, mineral and metal prices, precious metal prices, and raw materials prices have increased by multiples of about 4.22, 3.19, 3.60, 4.01, and 3.19, respectively.

#### **4.2. Global interest rate, CPI and industrial production**

In this paper each structural factor will represent an economic or financial category of variable. The interest rate, CPI and industrial production for each of the BRIC and G3

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<sup>7</sup> Note for India the monetary aggregates L2 has been used as a proxy of M2, as the Reserve Bank of India does not report monthly M2 aggregates for this period.

<sup>8</sup> Russian federation exchange rate has been interpolated from the annual series as monthly data for Ruble /US dollars is not available for the full sample period.

economies clearly play a role in the link between global liquidity and commodity prices. A problem is to find a practical way to compress the information on interest rates, CPI and economic activity in each of the G3 and BRIC economies into a few variables. In this section we will construct global indicators of the interest rate, CPI and industrial production based on principal components methodology applied to data for the G3 and BRIC economies. In robustness tests of the results in the paper we will use an alternative method to obtain global indicators of these variables by using nominal GDP weights converted to a single currency (interpolated monthly) applied to the appropriate variable for each individual economy.

The BRIC and G3 economies account for over 75% of global GDP measured by purchase power parity for the full data period. The structural factors or the indicators of global interest rate, global industrial production and of global CPI are the leading principal components of the BRIC and G3 economies' interest rates, industrial production and CPI (in log-level form for industrial production and CPI):

$$GIR_t = [IR_t^{EA}, IR_t^{US}, IR_t^{CH}, IR_t^{Ja}, IR_t^{UK}, IR_t^{In}, IR_t^{Ru}, IR_t^{Br}] \quad (5)$$

$$GIP_t = [IP_t^{EA}, IP_t^{US}, IP_t^{CH}, IP_t^{Ja}, IP_t^{UK}, IP_t^{In}, IP_t^{Ru}, IP_t^{Br}] \quad (6)$$

$$GCPI_t = [CPI_t^{EA}, CPI_t^{US}, CPI_t^{CH}, CPI_t^{Ja}, CPI_t^{UK}, CPI_t^{In}, CPI_t^{Ru}, CPI_t^{Br}] \quad (7)$$

In equation (3),  $GIR_t$  is a vector containing the discount rate of the central banks of the Euro area, UK, US, China, Japan, India, Russia and Brazil. Equations (4) and (5) are vectors containing the industrial production and CPI for the same countries, respectively.

The first principal components obtained from equations (3), (4) and (5) are shown in Figure 3. The first principal component for the global interest rate, which to economize on notation we will refer to as  $GIR_t$ , is the first diagram in Figure 3. It captures the collapse in interest rates at the end of 2008 with the onset of the global financial crisis as well as the relatively low interest rates over the period 2002 to 2006. The first principal component for the CPI indices,  $GCPI_t$ , is the second diagram in Figure 3.  $GCPI_t$  slopes linearly upward.

This indicates an overall flat rate of inflation, consistent with low and moderate CPI in the BRIC and G3 economies over 1999-2012 (the basic data are logs of CPI levels). There are brief periods when CPI seems to flatten out or speed up in line with weaknesses in the global economy and movement in commodity prices.

The first principal component for global industrial production,  $GIP_t$ , is represented in the third diagram in Figure 3. Global industrial production has an upward trend until the global financial crisis in 2008. There is a severe correction in  $GIP_t$  in 2008-2009, reflecting the global financial crisis, with recovery of global industrial production to early 2008 levels only in 2011. Global industrial production also shows a correction in 2001 coinciding with the March-November 2001 recession in the US.

Information on the correlations between country-specific and global factor for the short-term interest rate (IR), for industrial production (IP), and for the CPI in turn are reported in the columns in Table 1. The global factors are given by first principal components for the global interest rate (GIR), global industrial production rate (GIP), and global CPI (GCPI). The global interest rate correlation with country interest rates is high for most countries and low for India and Brazil (with correlation coefficients of 0.32 and 0.38, respectively). The global industrial production correlation with country industrial production is high for each of the BRIC countries (at 0.92 and above), at 0.61 or 0.62 for the Euro area and the US, and low for Japan (at 0.31) and the UK (-0.62). The global CPI correlation is high with all economies CPI's at 0.95 and above, except for the correlation with Japan's CPI.

#### **4.3. Causality test**

Recent international studies such as Anzuini et al. (2013) have examined whether liquidity from developed large economies influences commodity prices. Given that, China is now the second largest economy (measured by US dollars), growth in emerging market countries is associated with a relative greater usage of commodities than in developed

economies, and monetary expansion may influence commodity prices through expectations of greater growth, we consider it important to evaluate whether or not G3 or BRIC M2 or both Granger cause commodity prices.

In Tables 2 and 3 the Granger causality direction results between G3 M2 and commodity prices and between BRIC M2 and commodity prices are reported. The null hypothesis that commodity prices do not Granger cause BRIC M2 and the null hypothesis that commodity prices do not Granger cause G3 M2 cannot be rejected at conventional levels (using most lags structures). These results hold when the test is performed in log-level and in log-difference form.

The null hypothesis that BRIC M2 does not Granger causes commodity prices is rejected at 1% level using both log-level and log-difference form, confirming that causal direction is from BRIC M2 to commodity prices. Results for the G3 M2 and commodity prices are less clear. The null hypothesis that G3 M2 does not granger cause commodity prices is rejected for variables in log-level form but is not rejected in difference-level form. Overall, we conclude that Granger casualty goes from liquidity to commodity prices.

## **5. Stationarity and Cointegration**

In Table 4 the stationary properties of the data are reported. For this purpose both the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) are estimated for all variables. The appeal of using both methods is that they have inverse hypothesis. The null hypothesis for the ADF test is the variable has a unit root and the null hypothesis for the KPSS test is that the variable is stationary. Results show that variables are only first difference stationary. In empirical estimation the interest rate is used in levels in line with most macroeconomics studies.



Here we are interested in cointegration results for two relationships, for BRIC M2, G3 M2 and global commodity prices given that increase on money supply will lead to high prices in the long run, and for BRIC M2, G3 M2, and global activity and global (consumer) prices, motivated by the quantitative theory of money. To formally establish the cointegration relationship among these variables, we use the Johansen's cointegration test.<sup>9</sup> Table 5 reports results for the Johansson cointegration tests using critical values based on MacKinnin-Haug-Michells (1999).

In Table 5.1, results reveal that log of commodity prices, BRIC M2 and G3 M2 have a cointegrated vector when the test is specified with intercept. Results are expanded in Tables 5.1.1 (trace test) and 5.1.2 (Maximum Eigenvalue test) and both test indicate 1 cointegration vector among these 3 variables. In the last column of Table 5.1.1 it is observed that the null hypothesis of the number of cointegration vectors is less or equal than  $r$  is rejected when  $r = 0$  at 1% level, while either the hypothesis of  $r \leq 1$  and  $r \leq 2$  cannot be rejected even at 15% level. In the maximum eigenvalue test (in Table 5.1.2), the null hypothesis that the number of cointegrating vector is  $r$  can only be rejected when  $r = 0$ , while the hypotheses of either  $r = 1$  and  $r = 2$  cannot be rejected even at 20% level.

In Table 5.2, the test for cointegration among global CPI, global output and G3 M2 and BRIC M2 shows one cointegration vector when both intercept and linear trend are introduced to the model. In the last column of Table 5.2.1 it is observed that the null hypothesis of the number of cointegration vectors is less or equal than  $r$  is rejected when  $r = 0$  at 1% level, while the hypotheses of either  $r \leq 1$  and  $r \leq 2$  cannot be rejected even at 30% level. In the maximum eigenvalue test (in Table 5.2.2), the null hypothesis of the number of cointegrating vector is  $r$  can only be rejected when  $r = 0$ , while the hypotheses of either  $r = 1$  and  $r = 2$  cannot be rejected even at 30% level.

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<sup>9</sup> For more detail of this test please see Enders (2004; pp. 362), and Engle and Granger (1987).

The hypothesis of only 1 cointegration vector among global CPI, global output and G3 M2 and BRIC M2 is supported by test results above. For this reason, the following two cointegration vectors are introduced into the SFAVEC model in equations (1) and (2):

$$ECT1_t = \log(COM_t) - \beta - \mu \log(BRIC M2_t) - \sigma \log(G3 M2_t) \sim I(0) \quad (6)$$

$$ECT2_t = \log(GCPI_t) - \beta - \gamma \log(GIP_t) - \pi \log(BRIC M2_t) - \varphi \log(G3 M2_t) - \theta t \sim I(0) \quad (7)$$

## 6. The empirical results

### 6.1. Generalized cumulative impulse responses of global variables to BRIC M2 and G3 M2

We report in Figure 4 the responses of the variables in the SFAVEC model in equations (1)-(2) to one standard deviation generalised cumulative impulse response function in BRIC M2 and in G3 M2.<sup>10</sup> We are using one standard deviation generalised cumulative impulse response function following Pesaran and Shin (1997). The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the cumulative impulse response functions.<sup>11</sup> In the first row of Figure 4 it is found that positive innovations in the BRIC countries' liquidity lead to significant and persistent increases in global interest rates, global industrial production and commodity prices. The rise in commodity prices is sharp in the first three months following the BRIC M2 shock and then gradually continues to increase. Following the BRIC M2 shock, most of the rise in global industrial production occurs in the first four months whereas the global interest rate continues to rise as time goes on. The positive shock in BRIC M2 is associated with a boom in global industrial production and global tightening in monetary policy as indicated by increases in central bank discount

<sup>10</sup> One standard deviation in BRIC M2 is 0.012 and one standard deviation in G3 M2 is 0.015. If the impulses were normalized, this would reduce the apparent impact of shocks on commodity price of G3 M2 compared to BRIC M2. Thus, the cumulative impulse response results reported in this section understate the influence of BRIC M2 compared to G3 M2 somewhat. For purposes of comparison the standard deviation of the overall commodity price variable is 0.046.

<sup>11</sup> The confidence bands are obtained using Monte Carlo integration as described by Sims (1980), where 5000 draws were used from the asymptotic distribution of the VAR coefficient.

rates. Innovations in the BRIC countries' liquidity do not significantly affect global CPI. A positive shock in BRIC M2 is associated with positive increase in G3 M2.

In the second row of Figure 4 shocks to the G3 economies' liquidity are not associated with statistically significant changes in global interest rates, global CPI, global industrial production, or BRIC M2. A positive innovation in G3 M2 does lead to an increase in commodity prices that is statistically significant for ten months. However, positive innovations in BRIC M2 are linked with a positive effect on commodity prices that is three times as large as the effect of unanticipated increases in G3 liquidity on commodity prices after three months. The magnitude of this relatively larger effect of BRIC M2 compared to G3 M2 on commodity prices then slowly grows over time.<sup>12</sup>

## **6.2. Historical cumulative contributions of BRIC and G3 M2 on commodity prices**

The cumulative contributions to commodity price of the structural shocks to G3 M2 and to BRIC M2 are reported in Figure 5a from estimating the SFAVEC model in equations (1)-(2). The cumulative contributions of structural shocks to commodity price are the moving average of the last 12 months to improve the readability of the plot. Contextual information in Figure 2 shows that commodity prices fell during 2001 with recession in the US and fell sharply at the end of 2008 during the global financial crisis. Commodity prices rose particularly strongly over 2006-2008.

In Figure 5a the rapid increase in commodity price leading to a peak in June 2008 is associated with positive structural shocks to BRIC M2. The fall in commodity price from July 2008 to January 2009 is associated with the global financial crisis during late 2008, recession in the US over December 2007 to June 2009, and weak growth in Europe. Figure 5a suggests that BRIC M2 and G3 M2 did not contribute to this decline in commodity price. The

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<sup>12</sup> The one standard deviation generalised cumulative impulse response functions of the variables in the SFAVEC model in equations (1)-(2) to shocks to all the variables is available as Figure 10 in the Appendix A.

cumulative impact of the BRIC countries' M2 on the commodity price is positive in the recovery of commodity price during 2009 and 2010.

Figure 5b shows the difference in the cumulative effect on commodity price of structural shocks to BRIC M2 and G3 M2 (BRIC-G3 M2) over 1999:01-2012:12. A positive (negative) value for BRIC-G3 M2 indicates a larger (smaller) effect of BRICM2 on commodity price than that of G3M2. In Figure 5b the contribution to commodity price of liquidity in BRIC countries relative to that of liquidity in G3 countries is much bigger since 2005. The relative contribution of the BRIC countries' liquidity to commodity price is particularly important during 2006 through 2008 and from the end of 2009 through 2010, in line with the rise in the economic importance of the BRIC economies.

### **6.3. Generalized cumulative impulse response of commodity price components**

We now examine the response of commodity price components to innovations in BRIC M2 and in G3 M2. In the SFAVEC model in equations (1) and (2) the variable  $\Delta \log(COM_t)$  is replaced by the log difference of a commodity price component index (one at a time). The commodity price component indices considered are for energy commodities, agriculture commodities, mineral and metal commodities, precious metal commodities, and raw materials commodities. The responses of the commodity price component indices innovations in BRIC M2 and in G3 M2 are shown in first row and in the second row, respectively, in Figure 6.

It is found that positive innovations in the BRIC countries' liquidity lead to statistically significant and persistent increases in global energy prices. The rise in energy prices is very steep in the first two months and then energy prices continue to rise. Shocks to G3 liquidity have a small positive effect on global energy prices that is not statistically significant. Positive innovations in both G3 and BRIC liquidity have positive and statistically significant effects on agricultural prices that persist over time. The size of the effects of G3

and BRIC liquidity on agricultural prices are similar in the first few months, with a tendency for the BRIC effect to grow larger over time while the G3 effect does not (after the first four months).

Positive shocks in G3 and BRIC liquidity have positive and statistically significant effects on mineral and metal prices that persist over time. The size of the impact of BRIC M2 on mineral and metal prices is over 60% larger than that of G3 M2 three months after the shock. The BRIC liquidity effect on mineral and metal prices continues to grow larger over time and after twenty months is over twice the size of the effect of increases in G3 liquidity. Positive innovation in BRIC M2 accompanies statistically significant and growing increase in raw materials prices. Positive shocks to G3 M2 have a positive effect on global raw materials prices that is statistically significant over a two to six month window. Increases in both G3 and BRIC liquidity have positive and statistically significant effects on precious metal prices that persist over time. On precious metal prices, the size of the effects of G3 M2 is twice as large as that of the effects of and BRIC M2.

The overall conclusion of this section is that positive shocks in BRIC M2 have much larger effects on commodity prices, energy prices, mineral and metal prices, and raw material prices than do positive shocks in G3 M2. Shocks to G3 liquidity did not have a statistically significant effect on global energy prices. It is only on precious metal prices that shocks to G3 M2 have larger effects than shocks to BRIC M2. The results for the effects of structural innovations in BRIC M2 and in G3 M2 on commodity price component indices is consistent with the result in the previous sub-section that the magnitude of the positive effect of positive BRIC M2 innovations compared to positive G3 M2 innovations on commodity prices is much larger and that the disparity grows over time.

## **7. Robustness analysis**

In this section we evaluate the robustness of our model by exploring outcomes when using different indicators for global interest rates, industrial production and CPI, lag structures, dummy variables to reflect the global financial crisis, and non-recursive structural identification restrictions widely used in the SVAR literature.

### **7.1. Global variables: alternative global weights**

In the earlier analysis the influence of global interest rate, global industrial production and global CPI is captured by the leading principal components from interest rates, industrial production and CPI in the BRIC and G3 economies. Beyer et al. (2000), Giese and Tuxen (2007), and Belke et al. (2013) aggregate global variables by using nominal GDP weights converted to a single currency (interpolated monthly). We constructed a global indicator of interest rate, CPI and industrial production by using nominal GDP relative to total GDP (G3 and BRIC GDP) weights for the US, Eurozone, UK, Japan, Brazil, Russia, India and China economies. These three global indicators are substitute for  $GIR_t$ ,  $\Delta \log(GCPI_t)$  and  $\Delta \log(GIP_t)$  in equations (1) to (2). The cumulative impulse responses are re-estimated from the reconstituted SFAVEC model.

The first and second rows of Figure 7 show the response in global variables to one standard deviation generalised impulses in BRIC M2 and in G3 M2, respectively. Positive innovations in the BRIC countries' liquidity lead to significant and persistent increases in global interest rates, global industrial production and commodity prices. As before, following the BRIC M2 shock, the rise in commodity prices is steep in the first few months and then continues to increase. A difference from before (reported in Figure 4) is that now positive innovations in BRIC M2 significantly affect global CPI.

In the second row of Figure 7 shocks to the G3 economies' liquidity are not associated with statistically significant changes in global interest rates or global industrial production. A positive innovation in G3 M2 does lead to an increase in commodity prices that

is larger than in the earlier principal component model and is statistically significant for twenty months. However, positive innovations in BRIC M2 continue to be linked with a positive effect on commodity prices that is larger than is the effect of unanticipated increases in G3 liquidity on commodity (although not by as great a margin). The magnitude of this relatively larger effect of BRIC M2 compared to G3 M2 on commodity prices slowly grows over time.

## **7.2. Alternative lag-lengths**

An alternative lag selection can be selected using the Akaike information Criterion (AIC) rather than SC criterion used in our previous estimation. The AIC select two lags (rather than one) in estimation of the SFAVEC model described in equations (1) and (2). The model is re-estimated with two lags and generalized cumulative impulse response results are very similar to those obtained in Figure 4. While results stay statistically significant the confidence bands around point estimates tend to increase slightly (results are available under request).

## **7.3. Global financial crisis**

The global financial crisis was associated with dramatic changes in commodity prices. To deal with the global financial crisis we introduce a dummy variable that takes the value 1 from July 2008 to December 2008 and 0 otherwise into equation (1).<sup>13</sup> Results are essentially unchanged from those in Figure 4 from following this strategy for dealing with the global financial crisis (and are available from the authors).

## **7.4. Structural identification strategies**

We evaluate different alternative contemporaneous restrictions based on Kim and Roubini (2000) and Anzuini et al. (2013). In these studies the basic variables are a central

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<sup>13</sup> Perri and Quadrini (2011) identify the third and fourth quarter of 2008 as being the global financial crises period. To correspond to this analysis we identify July 2008 to December 2008 as being the crisis period. With monthly data a narrower focus is possible. We experiment with September 2008 to November 2008 as being the global financial crises without changing results.

bank controlled interest rate, a monetary aggregate, CPI, industrial production and commodity price/oil price. Monetary policy shocks are identified using what Forni and Gambetti (2010) refer to as a standard scheme, in which the impact effects on both industrial production and consumer prices are zero. Building on the identification strategies commonly used in the literature, completion of the model requires recognition and specification of the contemporaneous restrictions appropriate for the relationship between G3 M2 and BRIC M2. The four possibilities for whether G3 M2 and BRIC M2 respond or do not respond to each other in the same month are presented in equations (8) to (11) when building on the Kim and Roubini (2000) model.

In the Kim and Roubini (2000) model, consistent with Sims and Zha (1995)'s dynamic stochastic general equilibrium model, the monetary policy feedback rule is based on the recognition of information delays that do not allow the monetary policy to respond within the month to price level and output events. The monetary policy rule responds contemporaneously to G3 and BRIC M2. The world price of commodities (or the world price of oil in Kim and Roubini (2000)) influences the first principal component for the global interest rate to capture systematic response to (negative) supply shocks and inflationary pressure.

Following the literature, the M2 monetary aggregates respond contemporaneously to the domestic interest rate, CPI and industrial production implying that real demand for money depends on the interest rate and real income. Restrictions in both the CPI and output equations (four and fifth equations respectively) are standard in the economic literature. It is assumed that firms do not change their output and price contemporaneously in response to unexpected financial signals. The CPI and IP are assumed to be influenced in the same period by oil or commodity prices on the ground that commodities (e.g. oil and gas) are



crucial inputs for many sectors.<sup>14</sup> Commodity price (or oil price) is taken to be contemporaneously exogenous to all variables in the model due to information delay.

$$B_o X_t = \begin{bmatrix} 1 & -b_{01} & -b_{02} & 0 & 0 & -b_{05} \\ -b_{10} & 1 & 0 & -b_{13} & -b_{14} & 0 \\ -b_{20} & -b_{21} & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & -b_{35} \\ 0 & 0 & 0 & 0 & 1 & -b_{45} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} GIR_t \\ \Delta \log(G3 M2_t) \\ \Delta \log(BRIC M2_t) \\ \Delta \log(GCPI_t) \\ \Delta \log(GIP_t) \\ \Delta \log(COM_t) \end{bmatrix} \quad (8)$$

$$B_o X_t = \begin{bmatrix} 1 & -b_{01} & -b_{02} & 0 & 0 & -b_{05} \\ -b_{10} & 1 & 0 & -b_{13} & -b_{14} & 0 \\ -b_{20} & -b_{21} & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & -b_{35} \\ 0 & 0 & 0 & 0 & 1 & -b_{45} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} GIR_t \\ \Delta \log(BRIC M2_t) \\ \Delta \log(G3 M2_t) \\ \Delta \log(GCPI_t) \\ \Delta \log(GIP_t) \\ \Delta \log(COM_t) \end{bmatrix} \quad (9)$$

$$B_o X_t = \begin{bmatrix} 1 & -b_{01} & -b_{02} & 0 & 0 & -b_{05} \\ -b_{10} & 1 & 0 & -b_{13} & -b_{14} & 0 \\ -b_{20} & 0 & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & -b_{35} \\ 0 & 0 & 0 & 0 & 1 & -b_{45} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} GIR_t \\ \Delta \log(G3 M2_t), \\ \Delta \log(BRIC M2_t), \\ \Delta \log(GCPI_t) \\ \Delta \log(GIP_t), \\ \Delta \log(COM_t) \end{bmatrix} \quad (10)$$

$$B_o X_t = \begin{bmatrix} 1 & -b_{01} & -b_{02} & 0 & 0 & -b_{05} \\ -b_{10} & 1 & -b_{12} & -b_{13} & -b_{14} & 0 \\ -b_{20} & -b_{21} & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & -b_{35} \\ 0 & 0 & 0 & 0 & 1 & -b_{45} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} GIR_t \\ \Delta \log(G3 M2_t), \\ \Delta \log(BRIC M2_t), \\ \Delta \log(GCPI_t) \\ \Delta \log(GIP_t), \\ \Delta \log(COM_t) \end{bmatrix} \quad (11)$$

In the setup in equation (8), G3 M2 influences BRIC M2 contemporaneously and not vice versa. In equation (9), BRIC M2 influences G3 M2 contemporaneously but is not influenced by G3 M2 contemporaneously. In equation (10), G3 M2 and BRIC M2 do not influence each other contemporaneously. Finally, in equation (11), G3 M2 and BRIC M2 influence each other contemporaneously.

<sup>14</sup> These restrictions have been used by Gordon and Leeper (1994), Sims and Zha (2006), Christiano *et al.* (1999) and Kim (2001).

Anzuini et al. (2013) have an alternative identification setup and treat oil prices and/or commodity prices as contemporaneously endogenous. They describe equilibrium in the commodity market as the result of arbitrage in a financial market in which all variables have contemporaneous effects on the commodity price. As in Kim and Roubini (2000), Anzuini et al. (2013) assume that the current level of prices and industrial production are not available to the monetary authorities and that the demand for real money balances depends on real activity and the nominal interest rate. Given price stickiness, real activity responds to price and financial signals only with a lag. Anzuini et al. (2013) differ from Kim and Roubini (2000) in assuming that the commodity price index does not to affect real activity or consumer prices contemporaneously. An identification system analogous to Anzuini et al. (2013) is given in equation (12).

$$B_o X_t = \begin{bmatrix} 1 & -b_{01} & -b_{02} & 0 & 0 & -b_{05} \\ -b_{10} & 1 & 0 & -b_{13} & -b_{14} & 0 \\ -b_{20} & 0 & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ -b_{50} & -b_{51} & -b_{52} & -b_{53} & -b_{54} & 1 \end{bmatrix} \begin{bmatrix} GIR_t \\ \Delta \log(G3 M2_t), \\ \Delta \log(BRIC M2_t), \\ \Delta \log(GCPI_t) \\ \Delta \log(GIP_t), \\ \Delta \log(COM_t) \end{bmatrix} \quad (12)$$

In equation (12), G3 M2 and BRIC M2 are treated as contemporaneously exogenous. The model in equation (12) is just identified. With the inclusion of the assumption in equation (12) that commodity price is endogenous to all other variables, assumptions that either G3 M2 or BRIC M2 influences the other contemporaneously would render the model unidentified.

#### 7.4.1. Log likelihood (LR) over-identifying restrictions test

We use the log likelihood ratio (LR) test for over-identification restrictions to assess if these restrictions fit the data. Results for this test are presented in Table 6 for restrictions proposed in equations (8) to (12). In Table 6, column 2 shows the number of over identified restriction and column 3 shows the chi-square values. In column 4 the probability values of

rejecting the null hypothesis of “restrictions are valid” are presented. The probability values show that this test strongly rejects the restrictions imposed in model 8 to 11 at the 5% level. Among these models, the model in equation (8), the model that only restricts the contemporaneous impact of BRIC M2 on G3 M2, is marginally the best model. In contrast, the restrictions imposed in equation (12) cannot be rejected even at the 30% level, indicating that these restrictions fit the data fairly well compared to the models in equation (8) through (11).

#### **7.4.2. Cumulative impulse responses of global variables to BRIC M2 and G3 M2 with alternative contemporaneous restrictions**

The models with identification restrictions in equations (8) and (12) represent restriction on the interaction of global variables that are considered to be sensible for variables at a country level. Figure 8 shows the responses of the variables in the SFAVEC model in equations (1), (2) and (8) to one standard deviation cumulative impulse response function in BRIC M2 and in G3 M2. Figure 9 shows the responses of the variables in the SFAVEC model in equations (1), (2) and (12) to one standard deviation cumulative impulse response function in BRIC M2 and in G3 M2. The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.

In both sets of results, positive innovations in BRIC M2 are linked with a positive effect on commodity prices that are much larger than the effect of unanticipated increases in G3 liquidity on commodity prices after two or three months. In the first row of Figures 8 and 9 BRIC M2 has a statistically effect on commodity prices. In second row of Figure 8 G3 M2 does not have a statistically effect on commodity prices and in the second row of Figure 9 G3 M2 does have a statistically effect on commodity prices, but the effect is only half as large as that of BRIC M2 on commodity prices. In addition, global industrial production responds significantly to BRIC M2 (and not to G3 M2) in both sets of result, in line with the

generalized cumulative impulse response result for global industrial production already noted.

Overall, the cumulative impulse response results in Figure 9 from the model in the equations (1), (2) and (12) are similar to the responses of the variables in the SFAVEC model in equations (1)-(2) to one standard deviation generalised cumulative impulse responses in Figure 4 . A difference between sets of result is that G3 M2 no longer responds significantly to BRIC M2 in the first row of Figure 9. However, in the system of equations (1), (2) and (12) underlying the result in first row of Figure 9, G3 M2 and BRIC M2 are restricted to not influence each other contemporaneously.

Results in Figure 8 from the model in the equations (1), (2) and (8) have several differences compared to the generalized cumulative impulse responses of the variables in Figure 4. This is consistent with the rejection of the restrictions in the model compared to the null hypothesis of the Cholesky decomposition restrictions outline in section 7.4.1.

## **8. Conclusion**

In this paper we investigate the influence of liquidity as it arises from the major developed and major developing economies on commodity and disaggregated commodity prices. The magnitude of the positive effect on commodity prices of positive BRIC liquidity innovations compared to that of positive G3 liquidity innovations on commodity prices is much larger and the disparity grows over time. Positive shocks in BRIC liquidity have much larger effects on energy prices, mineral and metal prices, and raw material prices than do positive shocks in G3 liquidity. It is only on precious metal prices that shocks to G3 M2 have larger effects than shocks to BRIC M2. A positive shock in BRIC M2 is associated with a boom in global industrial production and global tightening in monetary policy as indicated by

increases in central bank discount rates. Global industrial production and global interest rates do not respond significantly to innovations in G3 M2.

Results are robust to alternative identification schemes in the structural factor-augmented vector error correction model, to different measurement of global variables, to treatment of the global financial crisis, and to variation in lag length. Findings suggest during what Hamilton (2013) refers as a “new industrial age” (1997-2010), characterized by billions of people making the transition from agricultural to industrial activity with increases in real income beyond subsistence levels, increases in liquidity in the major developing countries have much more powerful consequences for global commodity prices than do increase in liquidity in advanced countries.

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Table 1: Correlation between country-specific and global factors.

Country/Global	Global/Country IR	Global/Country IP	Global/Country CPI
Euro area	0.84	0.61	0.99
US	0.89	0.62	0.99
China	0.62	0.93	0.95
Japan	0.51	0.31	-0.75
UK	0.89	-0.62	0.97
India	0.32	0.92	0.95
Russia	0.68	0.99	0.99
Brazil	0.38	0.97	0.99

Notes: Correlations between country-specific and global factor for the short-term interest rate (IR), for industrial production (IP), and consumer price index (CPI) are reported in the columns in Table 1. The global factors are given by first principal components for the global interest rate (*GIR*), global industrial production rate (*GIP*), and global CPI (*GCPI*).

Table 2: Granger causality tests 1999:1-2012:12 (log-level).

Null Hypothesis: variable x does not Granger cause variable y

Alternative Hypothesis: variable x Granger cause variable y

Granger test/Lags		1	3	6	12
COM does not Granger cause BRIC M2	F-Stat.	0.15	0.35	0.71	1.47
	Prob.	0.69	0.78	0.63	0.14
BRIC M2 does not Granger cause COM	F-Stat.	3.08***	8.05***	4.71***	3.15***
	Prob.	0.08	0.00	0.00	0.00
COM does not Granger cause G3 M2	F-Stat.	0.22	0.26	1.53	1.16
	Prob.	0.63	0.85	0.17	0.31
G3 M2 does not Granger COM	F-Stat.	6.37***	4.52***	2.39**	2.29***
	Prob.	0.01	0.00	0.03	0.02

Notes: Variables are in logs. \*\*\*, \*\*, \* Indicates rejection of the null hypothesis at 1, 5 and 10% level of significance (respectively).

Table 3: Granger causality tests 1999:1-2012:12 (log-first difference).

Null Hypothesis: variable x does not Granger cause variable y

Alternative Hypothesis: variable x Granger cause variable y

Granger test/Lags		1	3	6	12
COM does not Granger cause BRIC M2	F-Stat.	0.20	1.76	2.22**	1.51
	Prob.	0.65	0.15	0.03	0.12
BRIC M2 does not Granger cause COM	F-Stat.	7.04***	4.77***	2.32**	2.27***
	Prob.	0.00	0.00	0.04	0.00
COM does not Granger cause G3 M2	F-Stat.	0.24	2.28*	1.34	0.96
	Prob.	0.62	0.08	0.24	0.48
G3 M2 does not Granger COM	F-Stat.	1.17	1.49	1.28	1.41
	Prob.	0.28	0.22	0.27	0.17

Notes: Variables are in logs. \*\*\*, \*\*, \* Indicates rejection of the null hypothesis at 1, 5 and 10% level of significance (respectively).

Table 4: Test for unit roots 1999:1-2012:12: Data in level

Null Hypothesis for ADF test: the variable has a unit root					
Alternative Hypothesis for ADF test: the variable has not a unit root					
Null Hypothesis for KPSS test: variable is stationary					
Alternative Hypothesis for KPSS test: variable is not stationary					
Level	ADF	KPSS	First difference	ADF	KPSS
$\log(G3 M2_t)$	-0.13	1.61***	$\Delta\log(G3 M2_t)$	-12.4***	0.09
$\log(BRIC M2_t)$	2.20	1.62***	$\Delta\log(BRIC M2_t)$	2.6*	0.73
$\log(GCPI_t)$	0.47	1.62***	$\Delta\log(GCPI_t)$	-8.31***	0.13
$\log(GIP_t)$	-1.48	1.48***	$\Delta\log(GIP_t)$	-5.93***	0.08
$\log(Commodities_t)$	-1.52	1.53***	$\Delta\log(Commodities_t)$	-8.86***	0.04
$\log(Energy_t)$	-2.20	1.52***	$\Delta\log(Energy_t)$	-9.70***	0.07
$\log(Agricultural_t)$	-0.66	1.52***	$\Delta\log(Agricultural_t)$	-8.16***	0.11
$\log(Food_t)$	-0.77	1.53***	$\Delta\log(Food_t)$	-8.26***	0.10
$\log(Min. and metal_t)$	-1.31	1.39***	$\Delta\log(Min. and metal_t)$	-8.13***	0.07
$\log(Precious met._t)$	0.50	1.58***	$\Delta\log(Precious metal._t)$	-11.8***	0.21
$\log(Raw material._t)$	-1.00	1.45***	$\Delta\log(Raw material._t)$	-5.98***	0.07

Notes: The first difference of the series is indicated by  $\Delta$ . The lag selection criteria for the ADF is based on Schwarz information Criteria (SIC) and for the KPSS is the Newey-West Bandwidth. \*\*\*, \*\*, \* Indicates rejection of the null hypothesis at 1, 5 and 10% level of significance (respectively).

Table 5: VAR Johansen cointegration test summary:

## 5.1 Cointegration test: logs of commodity prices and money (G3 and BRIC)

Endogenous variables: $\log(Commodity\ prices_t)$ , $\log(G3 M2_t)$ , $\log(BRIC M2_t)$			
Exogenous variables: $\log(Global\ industrial\ production_t)$ , $Global\ interest\ rate$			
Test Type	None trend and Intercept		Linear trend and Intercept
Trace	1		0
Max-Eig	1		0

Notes: \*Critical values based on MacKinnon-Haug-Michelis (1999). \*\*Selected (0.05 level\*) Number of Cointegrating Relations by Model.

## 5.1.1 Unrestricted cointegration rank test (Trace)

Null hypothesis: The number of cointegrating vectors is less than or equal to r

Alternative hypothesis: There are more than r cointegrating vectors

Hypothesized	Eigenvalue	Trace	0.05	Prob.**	
Null	Alternative	Statistic	Critical Value		
$r=0,$	$r \geq 1$	0.22	58.28	35.19	0.00
$r \leq 1,$	$r \geq 2$	0.06	16.32	20.26	0.16
$r \leq 2,$	$r \geq 3$	0.03	5.03	9.16	0.27

## 5.1.2 Unrestricted cointegration rank test (Maximum eigenvalue)

Null hypothesis: The number of cointegrating vectors is r

Alternative hypothesis: There are (r+1) cointegration vectors

Hypothesized	Eigenvalue	Max-eigenvalue	0.05	Prob.**	
Null	Alternative	Stat.	Critical Value		
$r=0,$	$r=1$	0.22	41.96	22.29	0.00
$r=1,$	$r=2$	0.06	11.28	15.89	0.23
$r=2,$	$r=3$	0.03	5.03	9.16	0.27

\*\*MacKinnon-Haug-Michelis (1999) p-values

5.2 Cointegration test: logs of global CPI (*GCPI*), money (G3 M2 and BRIC M2) and global output (*GIP*).

Endogenous variables: $\log(\text{Commodity prices}_t), \log(\text{Global Money}_t)$		
Exogenous variables: $\log(\text{Global industrial production}_t), \text{Global interest rate}$		
Test Type	None trend and Intercept	Linear trend and Intercept
Trace	2	1
Max-Eig	2	1

Notes: \*Critical values based on MacKinnon-Haug-Michelis (1999). \*\*Selected (0.05 level\*) Number of Cointegrating Relations by Model.

### 5.2.1 Unrestricted Cointegration Rank Test (Trace)

Null hypothesis: The number of cointegrating vectors is less than or equal to r

Alternative hypothesis: There are more than r cointegrating vectors

Hypothesized		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
Null	Alternative				
r=0,	r $\geq$ 1	0.36	104.71	63.87	0.00
r $\leq$ 1,	r $\geq$ 2	0.10	31.92	42.91	0.39
r $\leq$ 2,	r $\geq$ 3	0.05	13.64	25.87	0.68

\*\*MacKinnon-Haug-Michelis (1999) p-values

### 5.2.2 Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Null hypothesis: The number of cointegrating vectors is r

Alternative hypothesis: There are (r+1) cointegrating vectors

Hypothesized		Eigenvalue	Max-eigenvalue Stat.	0.05 Critical Value	Prob.**
Null	Alternative				
r=0,	r=1	0.36	72.78	32.11	0.00
r=1,	r=2	0.10	18.28	25.82	0.35
r=2,	r=3	0.05	8.43	19.38	0.78

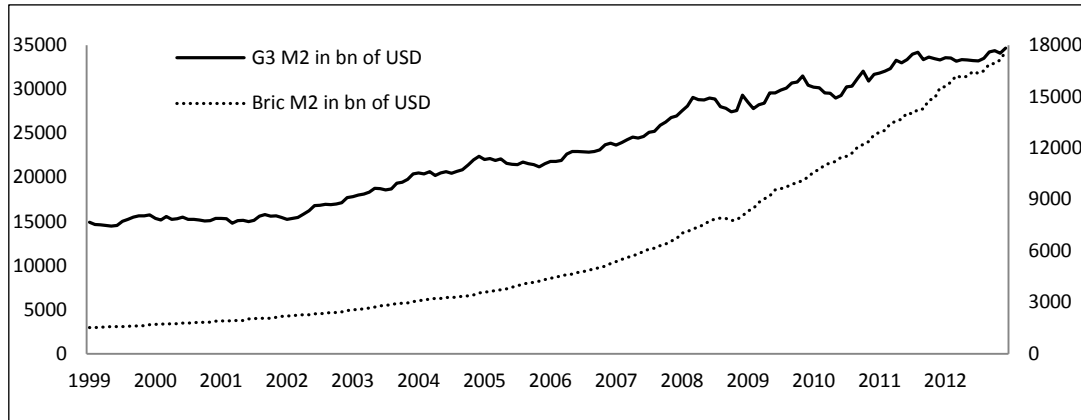
\*\*MacKinnon-Haug-Michelis (1999) p-values

Table 6: LR test for over-identified restrictions.

Equation	LR $\sim \chi^2(q - k)$	Chi-square value	Probability
8	2	7.10	0.03
9	2	7.27	0.02
10	3	14.71	0.00
11	1	6.19	0.01
12	0	0.81	0.36

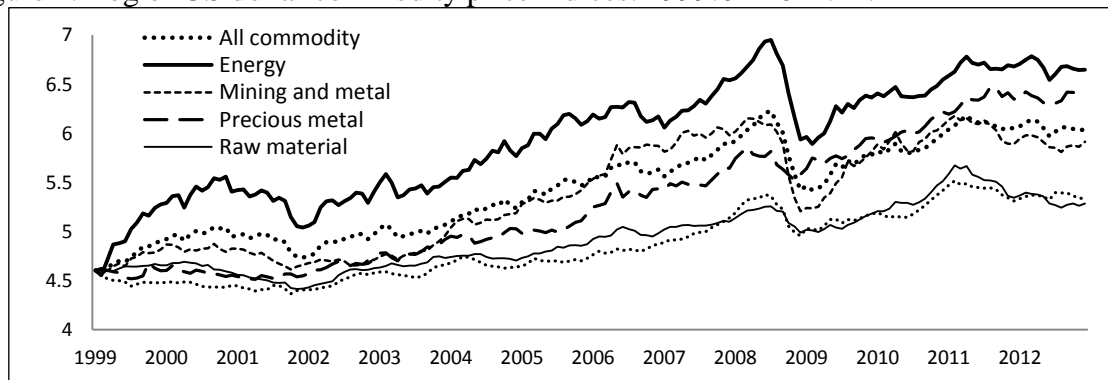
\*Null hypothesis: restrictions are valid. \*\*q is the number of restrictions.

Figure 1: BRIC M2 and G3 M2 in billions of US dollars: 1999:01-2012:12.



Notes: The BRIC countries are Brazil, Russia, India and China. G3 economies are the US, EU and Japan. Data are monthly over 1999:01-2012:12 in billions of US dollars. The scale of the right hand side of Figure 1 is for M2 for the BRIC countries and the scale of the left hand side of Figure 1 is for M2 for the G3.

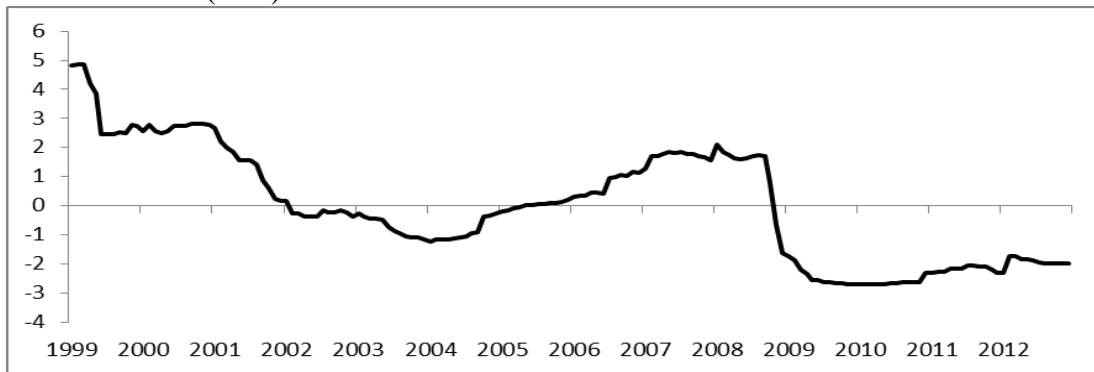
Figure 2: Log of US dollar commodity price indices: 1999:01-2012:12.



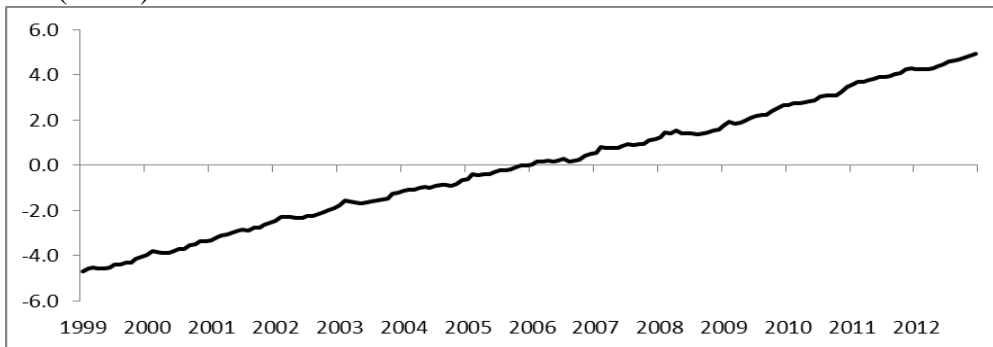
Notes: The US dollar commodity price component indices are for energy commodities, agriculture commodities, mineral and metal commodities, precious metal commodities, and raw materials commodities.

Figure 3: Principal components estimation of global variables: 1999:01 to 2012:12.

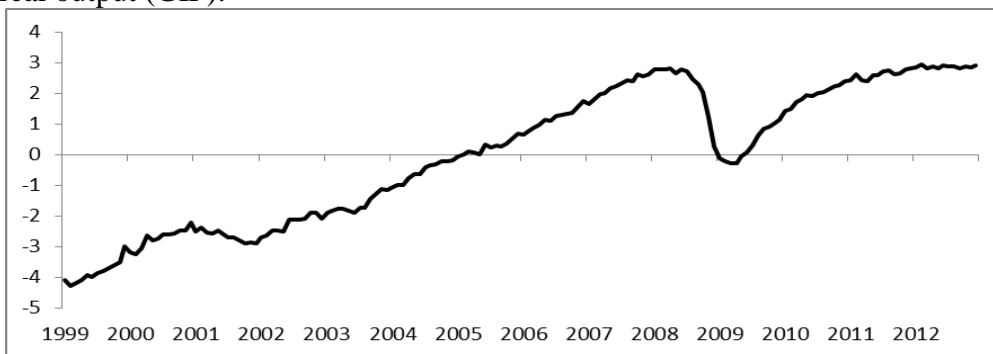
Global interest rate (GIR):



Global CPI (GCPI):

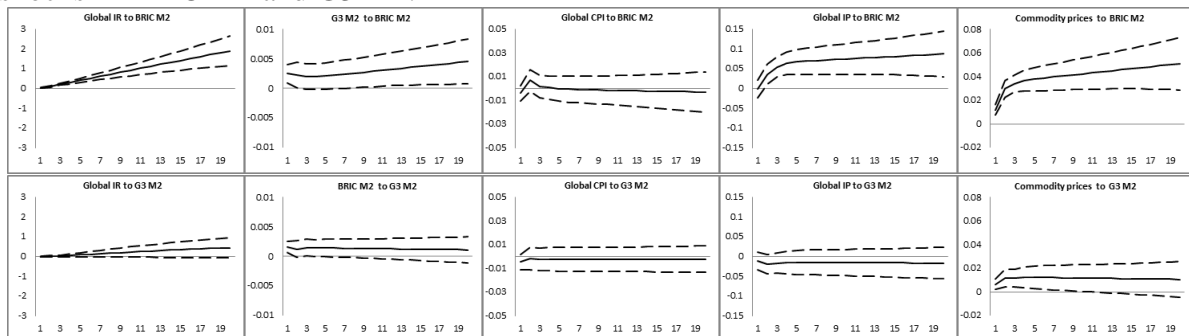


Global real output (GIP):



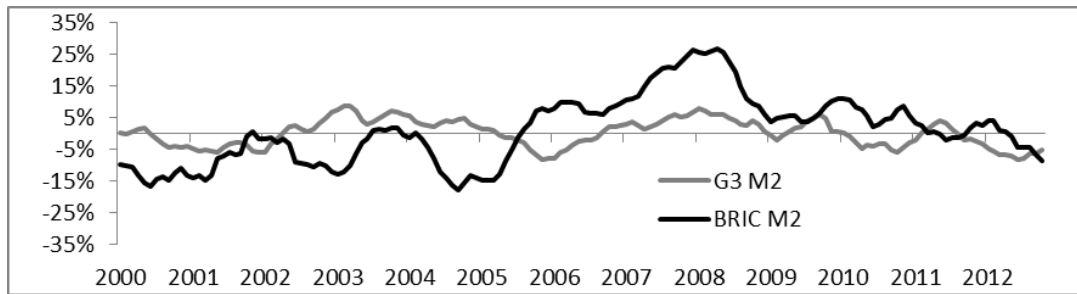
Notes: The principal components of the BRIC and G3 economies' short-term interest rate, industrial production, and CPI are taken to represent global interest rate, global industrial production, and global CPI, respectively.

Figure 4: One standard deviation generalised cumulative response of global variables to shocks in BRIC M2 and G3 M2.



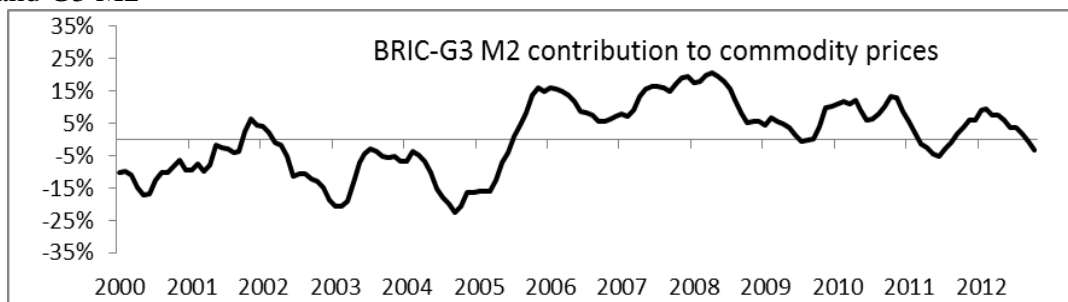
Notes: results based on the SFAVEC model in equations (1)-(2). The global variables are based on principal components.

Figure 5a: Cumulative effect of structural shocks to BRIC M2 and to G3 M2 on commodity price.



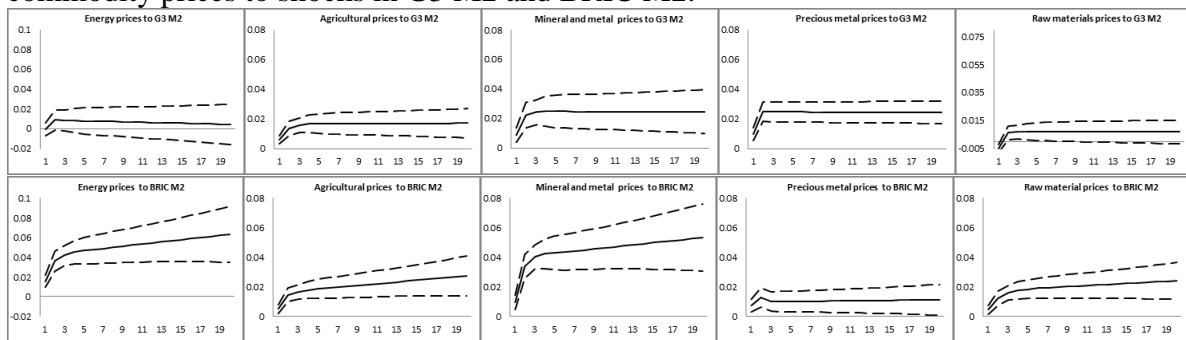
Notes: Results are obtained from estimating the SFAVEC model in equations (1)-(2). The cumulative contributions of structural shocks to commodity price are the moving average of the last 12 months expressed at an annualized rate.

Figure 5b: Difference in cumulative effect on commodity price of structural shocks to BRIC M2 and G3 M2



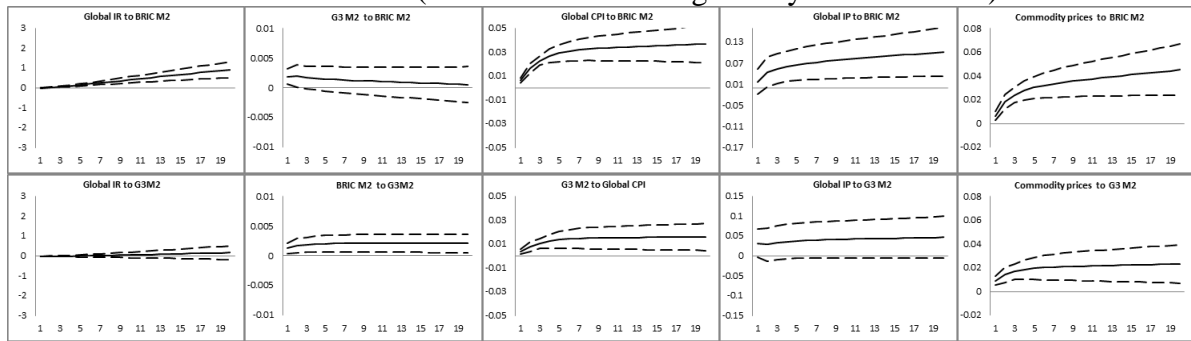
Notes: A positive (negative) value for difference in cumulative effect of structural shocks to BRIC M2 and G3M2 on commodity price, BRIC-G3 M2, indicates larger (smaller) effect of BRICM2 on commodity price than that of G3M2.

Figure 6: One standard deviation generalised cumulative impulse response of disaggregated commodity prices to shocks in G3 M2 and BRIC M2.



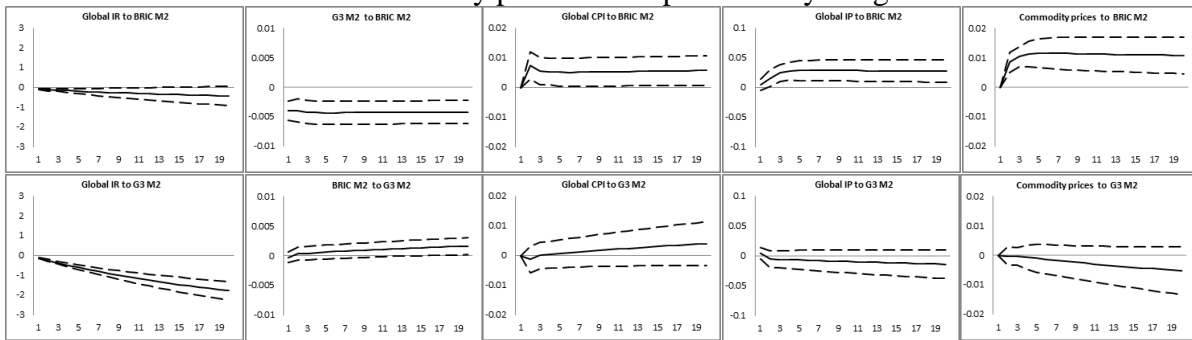
Notes: Results are based on the SFAVEC model in equations (1) and (2). The commodity price component indices considered are energy commodities, agriculture commodities, mineral and metal commodities, precious metal commodities, and raw materials commodities.

Figure 7: One standard deviation generalised cumulative impulse of global variables to shocks to BRIC M2 and G3 M2 (Global variables weighted by nominal GDP).



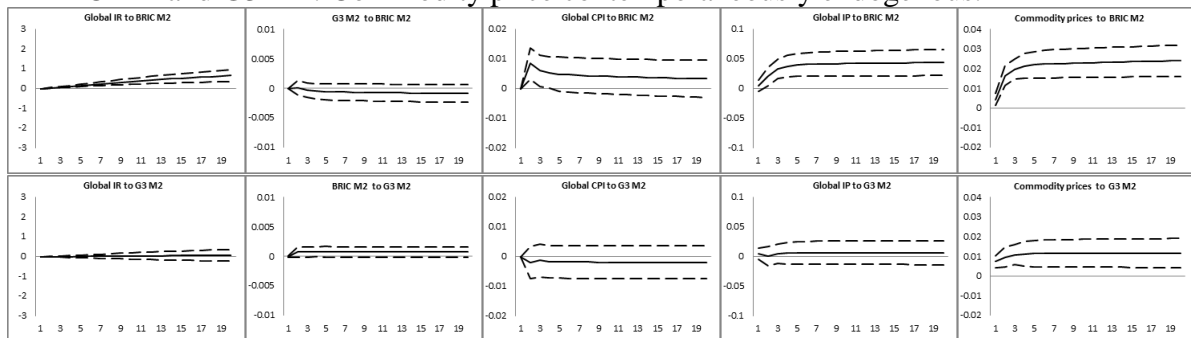
Notes: Results based on the SVEC model in equations (1) and (2) with global variables constructed by summing national variables weighted by relative nominal GDP.

Figure 8: One standard deviation cumulative impulse response of global variables to shocks in BRIC M2 and G3 M2: Commodity price contemporaneously exogenous.



Notes: Results are based on the SFAVEC model in equations (1), (2) and (8). The global variables are based on principal components.

Figure 9: One standard deviation cumulative impulse response of global variables to shocks in BRIC M2 and G3 M2: Commodity price contemporaneously endogenous.

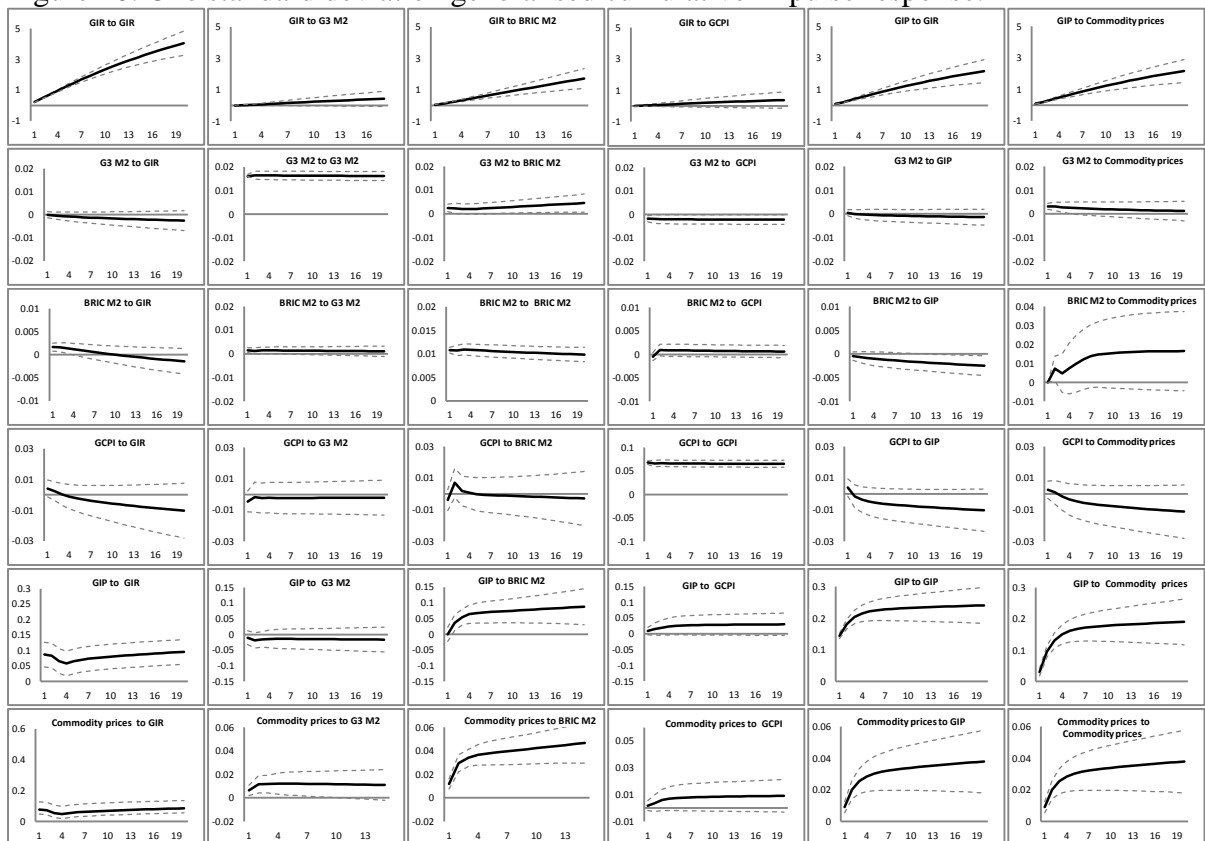


Notes: Results are based on the SFAVEC model in equations (1), (2) and (12). The global variables are based on principal components.

Appendix A: One standard deviation generalised cumulative impulse response.

The one standard deviation generalised cumulative impulse response functions of the variables in the SFAVEC model in equations (1)-(2) to shocks to all the variables are reported in Figure 10.

Figure 10: One standard deviation generalised cumulative impulse response.



Notes: The one standard deviation generalised cumulative impulse response functions of the global interest rate (Global IR), G3 M2, BRIC M2, global CPI (Global CPI), global industrial production (Global IP), global commodity price (Commodity prices) to structural innovations in all the endogenous variables in the SFAVEC model in equations (1)-(2). The global variables are based on principal components.