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What Drives the Global Interest Rate*

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Abstract

In this paper we study the drivers of global interest rate. Global interest rate is defined as a principal component for the largest developed and developing economies' discount rates (the US, Japan, China, Euro area and India). A structural global factor-augmented error correction model is estimated. A structural change in the global macroeconomic relationships is found over 2008:09-2008:12, but not pre or post this GFC period. Results indicate that around 46% of movement in central bank interest rates is attributed to changes in global monetary aggregates (15%), oil prices (13%), global output (11%) and global prices (7%). Increases in global interest rates are associated with reductions in global prices and oil prices, increases in trade-weighted value of the US dollar, and eventually to reduce global output. Increases in oil prices are linked with increase in global inflation and global output leading to global interest rate tightening indicated by increases in central bank overnight lending rates.

JEL codes: E44, E50, Q43

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What drives the global interest rate?

1. Introduction

Over the last two decades several important changes have taken place in the global economy with implications for the interaction of global macroeconomic variables including central bank discount rates. These developments include a more integrated global economy, the increasing relative importance of China and India in the global economy, and the different approaches to monetary policy that have been undertaken by the central banks of the largest economies following the global financial crisis (GFC). The World Bank estimates (on a purchasing power parity basis in 2013 US dollars) that the combined GDP of China and India is about 2/3rds of the combined GDP of the US, Euro area and Japan.[1] With the creation of the European Central Bank and fast economic growth in China and India, the central banks of the largest 5 economies (the Euro area, U.S., China, Japan and India) have direct responsibility for stabilizing around 60% of the world economy in recent years.

Policy interest rates set by central banks indicate circumstances within economies with regard to domestic economic growth and inflation. Bernanke (2015) describes the Taylor rule (Taylor; 1993) as an important descriptive device by which central bank interest rate behaviour is captured by variation in inflation relative to target and by output departures from potential. Hofmann and Bogdanova (2012) have documented that for an extended recent period central bank policy rates have been below levels implied by the Taylor rule in most developed and emerging economies. With prolonged economic weakness following the GFC,

[1] China and India are likely to be major sources of global economic growth into the future because of demographics, capital accumulation and development. In recent years, cross capital formation and domestic savings rates as percentages of GDP for China and India have averaged over 40% and 30%, respectively (Kónya; 2015). Improvement in investment markets in China and India would raise growth further. Hsieh and Klenow (2009) find that gaps in marginal products of labour and capital across manufacturing plants, imply that equalization of marginal products would raise manufacturing total factor productivity by 30%–50% in China and 40%–60% in India. China and India will also be major consumers of resources. The US Energy Information Agency estimates that China's oil consumption growth was half of the world's oil consumption increase in 2011. The largest oil consuming countries in 2012 are the US, China, Japan and India in that order. India has increased oil consumption by over 50% over 2000-2010. The IEA projects that "China, India, and the Middle East will account for 60% of a 30% increase in global energy demand between now and 2035" (IEA World Energy Outlook 2012: http://www.worldenergyoutlook.org/pressmedia/quotes/12/).

the central banks of the major developed economies have turned to alternative policies to expand monetary aggregates and hence stimulate the economy.[2]

In this paper we seek to answer the question, what drives the global interest rate over the last fifteen years? The global interest rate reflects the policy interest rates for the main economies set by their central banks. We believe our paper is the first to examine the determinants of interest rates at global level. Understanding the behaviour of the interest rate is crucial to agents making decisions about resource allocation over time in both public and private spheres. We proposed a structural global factor vector error correction model (SGFVEC) for this analysis. The methodology builds on the factor augmented vector autoregressive model (FAVAR) developed by Bernanke et al. (2005).

In the SGFVEC in this paper, structural factors are constructed for central bank interest rates, real output and CPI across the major developed and developing countries, and for oil price across various global oil prices. The collective stance of monetary policy actions by major central banks is in part captured by the level of central bank interest rates at global level and by the level of global liquidity.[3] A factor-augmented error correction dimension to the SGFVEC model will capture the dynamic of the information provided by many variables to the analysis of short and long run interaction of global central bank interest rate and liquidity, global real output, global prices and oil price. It is emphasized that the inclusion of data on China and India along with that of the major developed economies in the analysis of the interaction of macro variables at global level is necessary.

[2] The recent policies followed by central banks include the following. In the U.S., the Federal Reserve (Fed) undertook its first round of quantitative easing (QE1) in late November 2008, followed by QE2 in November 2010, and QE3 in September 2012. While QE1 was implemented by a one-off purchase of U$ 600 billion in mortgage-back securities and QE2 by a one-off purchase of U$ 600 billion in Treasury securities, QE3 is an ongoing programme purchasing around U$ 85 billion per month in different securities. The European Central Bank (ECB) has been buying covered bonds, a form of corporate debt. The Bank of Japan announced enormous expansions to its asset purchase program in October 2011 and April 2013. The latter event is likely to lead to a doubling of the Japanese money supply in a 2-year period.

[3] It is emphasized that this is not the same as the stance of global monetary policy since there is no global central bank. In recent years the effect of global liquidity on the prices of commodities has been emphasized by some researchers. Increases in liquidity raise aggregate demand and thereby increase commodity prices.

Global interest rate is found to rise significantly when global output, global prices and oil prices are increasing. Increases in oil prices are associated with increase in global inflation and global outputs leading to global interest rate tightening. Consistent with a stronger US dollar constituting a tightening of global financial conditions, a positive shock to the trade weighted value of the US dollar results in a significant decline in global interest rates. A positive shock to central bank discount rates leads to statistically significant and persistent decline in global M2, reduced CPI and nominal oil price, and to reduced global output. Positive shocks to global M2, to global CPI, and to global real output are associated with increases in global oil price. Global liquidity and oil price explain statistically significant fractions of forecast error variance decomposition in global interest rates. Global money, global output and global prices are found to be cointegrated. A structural change in the global macroeconomic relationships is found over 2008:09-2008:12, but not pre versus post GFC.

A brief review of the literature is provided in Section 2. The methodology is described in Section 3. The data and global variables and factors are discussed in Section 4. The SGFVEC model is presented in Section 5. The empirical results are presented in Section 6. The robustness of results to alternative definitions of the variables and different model specifications is discussed in Section 7. Section 8 concludes.

2 Literature review

Factor methods have become widely used in the literature to examine the co-movements of country level variables since work by Stock and Watson (1998) and Forni et al. (2000). Building on Stock and Watson (2002), Bernanke et al. (2005) propose a Factor-augmented VAR (FAVAR) to identify monetary policy shocks. Mumtaz and Surico (2009) extend Bernanke et al. (2005) to consider a FAVAR for an open economy. 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 US activity. Le Bihan and Matheron (2012) use principal components to filter out sector-specific shocks to examine the connection between stickiness of prices and the persistence of inflation. Boivin et al. (2009) assume that the connection between sticky prices and monetary policy can be captured by five common factors estimated by principal component analysis. Abdallah and Lastrapes (2013) use a FAVAR model to examine house prices across states in the US.

Global factor variables have been constructed in recent research examining the determinants of commodity prices. Beckmann et al. (2014b) estimate a structural factor augmented VAR to examine the links between monetary policies, commodity prices and share prices with data for the U.S., Euro area, Japan, U.K. and Canada. Juvenal and Petrella (2014) in an examination of the role of speculation in the oil market, construct a factor for speculation based on a large number of macroeconomic and financial variables for the G7. Beckmann et al. (2014a) estimate a Markov switching error correction model based on data for most of the developed OECD counties finds that liquidity influences commodity price with effect that change over time. In many of these studies the influence of the major emerging economies such as China and India on commodity and or oil prices is not usually considered.

3. Outline of Methodology

In line with the dynamic factor models of Bernanke et al. (2005), Stock and Watson (2005), Forni and Gambetti (2010), and others, we construct a global factor-augmented error correction model to examine the relationships between oil prices, global interest rate, global monetary aggregates, global real output and global CPI. Global factors for interest rates, real output and CPI are estimated using principal components. A cointegrating vector for global money, global real output and global price level is utilized. A global factor-augmented error correction model (SGFVEC) is then estimated. The data, variables and various test results are examined in detail in subsequent sections.

A single individual variable or factor can capture the dynamic of a large amount of information contained in many variables.[4] Facing a large number of variables included in this study, we use principal component indexes as indicators capturing the effects of global interest rates, global real output and global price levels by compressing local information on these variables for the US, Euro area, China, India, and Japan.[5]

Use of factor analysis for crude oil prices is appropriate for analysis of the behaviour of the global economy since Brent and West Texas Intermediate (WTI) crude oil price data have diverged sharply in recent years. Prior to the global financial crisis (GFC) the WTI crude oil price usually exceeded the Brent by at most a few dollars per barrel, but since the GFC Brent crude oil price has occasionally topped WTI crude oil price by $28 per barrel. A global factor for oil price better captures the movement in oil price relevant for the global economy than do the individual prices for Brent, WTI and Dubai oil. The use of factor analysis it is also appropriate in modelling the global economy considering the growing importance of emerging economies in the global economy and world commodity markets.

We favour the global factor approach over other possible ways to model the global economy, especially over a short period January 1999 to December 2013. The issue of global variables or global methods have come up in several ways. Use of GDP weights to construct global variables and conduct analysis with quarterly data rather than use a factor analysis

[4] 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.

[5] Note that it may be unwise to include more economies that have small global weight, because it might over-represent their impact on global factors estimated by principle component methods. On a GDP PPP basis economies outside the largest five are much smaller individual economies. Activity in the five major economies captures global influences on the global market for oil.

with monthly data, would reduce the number of observations considerably, and GDP is not necessarily the best measure of individual economies influences on oil prices. Factors allow abstraction of the underlying processes within groups of variables that might not be obtained by aggregating variables.

We also follow Pesaran et al. (2004) and Dees et al. (2007) GVAR model in the sense that the interaction of the global economy is considered.[6] In the SGFVEC model in this paper the global factors are treated as endogenous and the interaction of global shocks can be explicitly examined.

4. Data and global factors

4.1. The Data.

The data are monthly from January 1999 to December 2013. The starting period coincides with the creation of the European Central Bank and data on CPI and interest rate for this block is only available from January 1999. Monthly data is used to overcome the limitation of few observations obtained from quarterly data over a 14 year period. Data are obtained on the central bank discount rate, monetary aggregate M2, consumer price index, and industrial production index for each of the five largest economies given by the Euro area, the US, Japan, China and India. The discount rate is the interest rate charged to banks by the country's central bank.[7] Oil prices are given by the Brent, Dubai and West Texas Intermediate US dollar international indexes for crude oil prices. The trade weighted index for the US dollar completes the data.[8] Data on each country are from the Federal Reserve Bank of St. Louis (FRED data) and data on oil prices are from the World Bank.

[6] Note that for example Dees et al. (2007) the GVAR model 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.
[7] For the Federal Reserve the federal funds rate is used in place of the discount rate.
[8] Major currencies index from the Federal Reserve System of the United State includes: the Euro Area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden. Weights are discuss in: http://www.federalreserve.gov/pubs/bulletin/2005/winter05_index.pdf

Information on the interest rate, liquidity (measure by M2 in US dollars), CPI and real output for the US, Euro area, China, India, and Japan over 1999:01-2013:12 are shown in Figure 1. The central bank discount rate for each of the five economies has varied over time. Although at widely different levels, the interest rates all show declines following the March-November 2001 recession in the US. With the exception of India, central bank discount rate register increases during the commodity price boom over 2005-2008 and fall during the global financial crises. Liquidity (M2 in US dollars) increases over the fourteen years from 1999:01 to 2013:12 by approximately a factor of 12 in China, 4.8 in India, 2.3 in the US, 2.6 in Euro area, and by 2 in Japan.

The consumer price level is up by a factor of 1.34 in China, 2.4 in India, 1.4 in the US, 1.35 in Euro area, and down by 4% in Japan. Compared to the US, the Euro area and Japan, China and India have grown much faster in recent years. For example, over the fourteen years from 1999:01 to 2013:12 real output is up approximately by factors of about 2.9 and 2.3 in China and India, respectively, and up by only about 14% and 6% in the US and the Euro area, respectively, and down by about 3% in Japan. On the basis of GDP in purchasing power parity in 2013 (in declining order) the US, Euro area, China, India, and Japan, are by far and away the largest economies in the world.

4.2 The global factors

Principal components indexes are constructed for each group of variables for the five economies. These are global factors for the global interest rate (GIR_t), global CPI ($GCPI_t$) and global real output (GY_t).[9] A global money monetary aggregate M2 ($GM2_t$), the sum of M2 monetary aggregates across economies (in US dollars), captures the effect of liquidity. Global oil prices (GOP), is constructed by using a unique principal component index based

[9] Industrial production is used as a measure of country's real output. This measure is generally used when monthly data are utilized (for example, Kim and Roubini (2000)).

on information for the Brent, Dubai and West Texas Intermediate US dollar based international indexes for crude oil prices.

The indicators of global interest rate, global real output and of global CPI are the leading principal components for interest rates, real output and CPI (in log-level form for real output and CPI) of the US, Euro area, China, India, and Japan. These are given by

$$GIR_t = [IR_t^{Ea}, IR_t^{US}, IR_t^{Ch}, IR_t^{Ja}, IR_t^{In}], \quad (1)$$

$$GY_t = [Y_t^{Ea}, Y_t^{US}, Y_t^{Ch}, Y_t^{Ja}, Y_t^{In}], \quad (2)$$

$$GCPI_t = [CPI_t^{Ea}, CPI_t^{US}, CPI_t^{Ch}, CPI_t^{Ja}, CPI_t^{In}], \quad (3)$$

where the superscripts *Ea, US, Ch, Ja,* and *In*, represent the Euro area, US, China, Japan, and India, respectively, in equations (1), (2) and (3). In equation (1), GIR_t is a vector containing the discount rate of the central banks of the Euro area, US, China, Japan and India.[10] Equations (2) and (3) are vectors containing the real output and CPI for the same economies, respectively.[11]

The indicator for global oil prices is the leading principal component of the Dubai, Brent and West Texas Intermediate oil prices and is given by

$$GOP_t = [OP_t^{Dubai}, OP_t^{WTI}, OP_t^{Brent}] \quad (4)$$

A global factor for oil price better captures movement oil price relevant for the global economy than the individual prices for Brent, Dubai and WTI oil. US dollar indexes for Brent, Dubai and WTI crude oil prices are shown in Figure 2. Before the GFC, the WTI and Brent crude oil prices were within a couple of dollars of each other, with WTI usually at a

[10] 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 factors represent common trends in metals and food prices.

[11] The first principal component for country CPIs to indicate global inflation is similar to Ciccarelli and Mojon (2009) method of identifying global inflation based on price indices for 22 OECD countries and a factor model with fixed coefficients. Within the factor analysis framework, a different approach is taken by Mumtaz and Surico (2012) who derive factors representing global inflation from a panel of 164 inflation indicators for the G7 and three other countries.

premium relative to Brent. Since 2011, WTI has traded at a significant discount to Brent and on September 21, 2011, the discount achieved $28.49 per barrel. The price gap between Brent and Dubai also fluctuates. Before 2011, Brent crude oil typically traded at a one or two dollar premium relative to Dubai crude oil. The premium for Brent over Dubai surged to $7.60 per barrel in 2011 with the crisis in Libya, before falling to a low of $1.1 per barrel in November 2012, and surging again to almost $6 per barrel in August 2013. Movement in these price gaps reflect changes in the market conditions in various parts of the world driven by economic and political considerations.[12]

Figure 3 shows the variance of the principal components using normalised loadings for the interest rate, for real output, and for the CPI and oil price. For each variable a diagram shows the variance accounted for by the first principal component, by the second principal component, third principal component, etc. The first principle component for each variable captures most of the variation in each variable across the five economies (for the interest rate, real output and CPI) and the three oil price indices. For the global CPI and global oil price the first principal components capture nearly all of the information in the five economy level consumer price indices (88%) and the three oil price indices (99%). The first principal component for output (interest rates) captures 60% (46%) of the news in the five economy level outputs (interest rates). We use one factor (the principal component) for the global interest rate, global real output, global CPI, and global oil price to keep the total number of variables in the estimation of the global relationship to a minimum.

Alternative principal components can also be derived from the equations (1) through (4). These alternatives are: normalise loadings (where the variance is equal to the estimated eigenvalues; normalise scores (with unit variances with symmetric weights); and with equal

[12] WTI represents the price oil producers receive in the U.S. and Brent and Dubai represents the prices received internationally. The WTI and Brent crude oils share a similar quality and Dubai has higher sulphur. The recent negative premium for WTI relative to Brent is usually explained in terms of oil production in the US exceeding cheap transportation capacity by pipeline to refiners on the US Gulf Coast. Fluctuation in the premium for Brent over Dubai is usually tied to political events in North Africa and the Middle East.

weighted scores and loadings. The representation for equal weighted scores and loadings falls in between those for normalise loadings and normalise scores. In the basic model constructing principal components we will use normalise loadings and consider use of normalise scores in a section on the robustness of results.[13] The first principal component for the global interest rate, to be referred to as GIR_t, is drawn in Figure 4a for normalise loadings, normalise scores, and with equal weighted scores and loadings. It captures the fall in interest rates at the end of 2008 with the onset of the global financial crisis as well as the fall in interest rates during and following the 2001 recession in the US. The first principal component for the CPI indices, $GCPI_t$, is shown in Figure 4b. In Figure 4 $GCPI_t$ slopes upward. The slight concavity in the curve over 2000-2006 indicates higher CPI over this period followed by an overall flat rate of inflation in the last half of the sample.

The first principal component for global real output, GY_t, is represented in Figure 4c. Global real output 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 real output to early 2008 levels only in 2011. Global real output also shows a correction in 2001 coinciding with the March-November 2001 recession in the US. The principle component for crude oil prices is shown in Figure 4d. Oil price rose sharply from January 2007 to June 2008. Concurrent with the global financial crisis and the weak global economy the oil price fell steeply until January 2009 before substantially rebounding over the next few years. The log of the trade weighted index of the US dollar (USTWI) is shown in Figure 4e. The trade weighted US dollar peaks in early 2002 and then shows a gradual

[13] Note that with normalise loading option more weight is given to variables (countries in this case) with higher standard deviation. With scores options all the variables are given equal weight (by standardising them). The direct implication in this study by choosing normalise loading is that more weight is given to developing economies which generally have higher standard deviation in this sample. This a desirable future of this option considering the views of Hamilton (2009; 2013) and Kilian and Hicks (2013) that for the period of analysis oil prices are largely influenced by the surge in growth in developing economies.

downward with a levelling off in recent years. The log of global M2 is shown in Figure 4f and shows an upward trend.

Information on the correlations between country-specific and global factor for M2, short-term interest rate, real output and CPI are reported in the columns in Table 1. The global factors are given by first principal components for global interest rate (GIR), global real output (GY), and global CPI (GCPI). The global M2 is highly correlated with M2 in each of the five economies. The global interest rate correlation with country central bank interest rates is 72% or higher for the US, Euro area, China and Japan, but only 10% for India. The global real output correlation with country level real output is high for the US and Euro area (90% and 89%), and at 71%, 70% and 62% for China, India and Japan, respectively. The global CPI correlation is very high with that for US, Euro area, China and India (each over 97%). The global CPI correlation with the CPI for Japan is very different with a value of negative 79%. This reflects the extraordinary behaviour of prices in Japan over 1999:01 to 2013:12 compared to the other major economies.

5. The Model

In our baseline model we follow the literature which study the monetary transmission shocks at national level (see for example, Kim and Roubini (2000) and Dedola and Lippi (2005).

The SGFVEC model can expressed as:

$$B_0 X_t = \beta + \sum_{i=1}^{j} B_i X_{t-i} + \varphi ECT1_{t-1} + \rho Break_t + \varepsilon_t \quad (5)$$

where j is optimal lag length, determined by the Schwarz criterion (three lags in this case), X_t is vector of endogenous variables, ECT_t is an error correction terms consistent with the quantitative theory of money and is discussed in more in detail in a later section and $Break_t$

is a dummy variable which takes the value of 1 from 2008:M9 to 2008:12 and zero otherwise (as explained in the following section).

The matrix B_0X_t in equation (5) is given by:

$$B_oX_t = \begin{bmatrix} 1 & -b_{01} & 0 & 0 & 0 & -b_{05} \\ -b_{10} & 1 & -b_{12} & -b_{13} & 0 & 0 \\ 0 & 0 & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ -b_{50} & -b_{51} & -b_{52} & -b_{53} & -b_{54} & 1 \end{bmatrix} \begin{bmatrix} \Delta\log(GIR_t) \\ \Delta\log(GM2_t) \\ \Delta\log(GCPI_t) \\ \Delta\log(GY_t) \\ \Delta\log(GOP_t) \\ \Delta\log(USTWI_t) \end{bmatrix} \quad (6)$$

Consistent with Gordon and Leeper (1994), Christiano *et al.* (1999), Kim and Roubini (2000), Sims and Zha (2006) the impact effects of financial shocks on industrial production and consumer prices are zero, but contemporaneous response to both monetary aggregates and oil prices. Monetary aggregates M2 respond contemporaneously to the domestic interest rate, CPI and real output assuming that the real demand for money depends contemporaneously on the interest rate and real income. The CPI is influenced contemporaneously by both real output and oil prices, while real output is assumed to be influenced by oil prices. [14]

Oil prices are assumed to be contemporaneously exogenous to all variables in the model on the ground of information delay. Given the forward looking nature of exchange rate on asset prices and this variable's information is available daily, the exchange rate is assumed to respond contemporaneously to all variables in the model.

The vector X_t is expressed as:

$$X_t = [GIR_t, \Delta\log(GM2_t), \log(GCPI_t), \Delta\log(GY_t), \Delta\log(GOP_t), \Delta\log(USTWI_t)], \quad (7)$$

where the variables are affirmed as the global interest rate (GIR_t), global M2 ($GM2_t$), global CPI ($GCPI_t$), global output (GY_t), oil price (GOP_t), and the trade weighted US dollar exchange rate ($USTWI_t$). Δ is the first difference operator.

[14] Forni and Gambetti (2010) refer to the assumption that output and consumer prices within a country do not respond contemporaneously to financial variables as a standard identification scheme in the literature.

These structural impulse responses are very similar the generalized impulse responses reported in Figure 5b. A positive innovation in oil price is associated with a statistically significant positive effect on the global interest rate and on global real output. Positive shocks to oil price have significant effects on global M2 and global CPI at impact only. A positive shock in oil price leads to a significant decline in the trade weighted value of the US dollar.

In terms of restrictions imposed in previous models, Kim and Roubini (2000), following Sims and Zha (1995), introduce oil price into a VAR analysis. The central bank reaction function responds contemporaneously to domestic monetary aggregates, nominal exchange rate and oil prices as information regarding other variables are not available within a month. In line with Dedola and Lippi (2005) measures of commodity price other than oil price are now introduced into the VAR model. Construction of principal components utilizes the information in a large number of variables that can more realistically reflect global influences that cannot be used individually in standard VARs.

5.1. The long run relationship among real money and real output at global level.

Motivated by the quantity theory of money, we investigate whether a long run relationship applies to the global variables output, consumer prices and money. At country level the issue of whether the quantity theory of money holds is frequently investigated and held to be an important relationship in understanding the behaviour of output and inflation.[15] Our empirical analysis shows that an equilibrium relationship hold between these variables and that global money has a role to play in influencing global output and prices. A cointegration relationship among global money, global output and global prices is found to exist. The error correction term in equation (1) is given by the following:

$$ECT_t = log(GCPI_t) - \alpha - \theta log(GY_t) - \delta \log(GM2_t) + \rho t \sim I(0) \qquad (3)$$

[15] See for example, investigations of cointegrating relationship between price level, monetary aggregate and output for the US by Swanson (1998), Bachmeier and Swanson (2005), Garret et al. (2009), Browne and Cronin (2010), and others.

In Table 2 the stationary properties of the data are reported. Augmented Dickey-Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) are estimated for all variables. 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. `

Results for test of cointegration among global money, global real output and global prices are presented in Table 4. Table 4a reports that the Johansen cointegration test points to a unique cointegration vector when no trend and intercept is used and when trend and intercept is used. Following the literature, we specified the error correction term using intercept and trend. In Table 4b, the trace cointegration test reveals 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 $r \leqslant 1$ and $r \leqslant 2$ cannot rejected even at 20% level. In the maximum eigenvalue test in Table 4c, 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 rejected even at 15% level.

5.2. Structural Break and the Global Financial Crisis

Figure 4 shows an important change in behaviour of global interest rates from 2008:M9, during after the period of the global financial crisis. Consequently, several dummy variables to capture a possible structural break are tested in this section. In Table 3 the log likelihood ratio test (LR) is presented to evaluate the model in equations (5)-(7) with different dummy variables. We test dummy variables for 3 periods. First, to capture change in relationships between variables during the most intense period of the GFC a dummy variable from 2008:09 to 2008:12 is introduced. A change in relationships may be suggested by the drop in global government interest rates in Figure 4a. Second, to test for the effect of change in the relationships between variables connected with possible systematic change in monetary policy during and after the global financial crises, a dummy variable is introduced from 2009:01 to the end of the sample. A systematic change in monetary policy would be reflected in quantitative easing in the developed countries discussed earlier. Thirdly, to capture the effects of both the first two dummy variables, a dummy variable is introduced from 2008:09 to the end of the sample. This dummy variable captures systematic change that immediately started with the initial shock of the GFC that continues beyond the crisis through to the present.

Results in Table 3, shows that LR test rejects the null hypothesis at 1% level of no structural break for the dummy variable from the period 2008:09 to 2008:12 (the chi-square value is 39.66). The null hypothesis of no structural break for the dummy variables from the periods 2008:09 to 2013:12 and from 2009:01 to 2013:12 cannot be rejected. In line with these results we include a dummy variable, value 1 over 2008:09 to 2008:12 and 0 otherwise, in the model in equations (5) to (7).

6. Empirical Results

The responses of variables in the SGFVEC model (in equations (5), (6) and (7)) to one-standard deviation structural innovations are shown in Figure 5. The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.[16] The first row in Figure 5 shows the response of the global interest rate to structural innovations in the global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate, in turn. Similarly, the second, third, fourth, fifth and sixth rows show the response of global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate, respectively, to structural

[16] 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.

innovations in GIR_t, $\Delta\log(GM2_t)$, $\Delta\log(GCPI_t)$, in $\Delta\log(GY_t)$, $\Delta\log(GOP_t)$, and $\Delta\log(USTWI_t)$ in turn.

6.1. Response of global interest rate to structural shocks

It is not clear from the literature what the effects on global interest rates should be from structural shocks to the global variables. The countries in the G5 have different exchange rate regimes, capital controls and monetary policies. There is no global central bank and the global interest represents the first principal component of the data on the discount rates of the G5.

In the first row of Figure 5, a positive shock to global M2 is associated with a rising global interest rate over time. A result not inconsistent with Thornton's (2014) observation that a liquidity effect, an injection of reserves that decreases the nominal interest rate, is not observed at country level. Also in the first row of Figure 5, positive shocks to global CPI, to global real output, and to oil price lead to statistically significant and persistent increases in the global interest rate (in the third through fifth diagrams in row 1).

The results in Figure 5 indicate that is a general tightening of monetary policy on a global level as indicated by a rise in the global interest rate when global level liquidity is increasing, the economy is heating up and oil prices are rising. A positive shock to the trade weighted value of the US dollar results in a significant decline in global interest rates.

Shin (2014) argues that a stronger US dollar constitutes a tightening of global financial conditions. In a globalized economy, a rise in the US dollar increases the burden of dollar-denominated debt repayment and results in a tightening of global financial conditions that central banks seek to offset. In the last column of Figure 5, a positive shock to the trade weighted value of the US dollar is connected with a rise in global M2 as well as a fall in global interest rates. Consistent with a rise in the US dollar being associated with more constrictive global financial conditions (for given central bank interest rates) there are declines in CPI, real output and oil prices for extended periods.

6.2. Response of global variables to structural shock to global interest rate

In the first column of Figure 5, a positive shock to global interest rates leads to statistically significant and persistent decline in global M2. Monetary tightening at global level is connected with reduced CPI and nominal oil price, and after a positive bump to reduced global output. In the second column of Figure 5, a positive shock to global M2 is linked with increases in CPI and in nominal oil price, and after four months with increased global output.

6.3. Liquidity and structural shocks

The second column in Figure 5 reports the effects on the global variables of a positive structural shock to liquidity. Global liquidity significantly impacts global CPI 3 and 4 months later. The impact on oil price is statistically significant after 3 months and remains so over the 20 month horizon. A positive innovation in global liquidity significantly impacts output over a 5 to 13 month horizon. The trade weighted value of the US dollar declines with a positive innovation in global M2 and the effect is immediate and persists over the entire horizon. In line with results in the literature, increase in global liquidity is associated with global expansion and rising oil and global consumer prices.

6.4. The oil price and structural shocks

The impulse responses of oil price to global variables are presented in the fifth row of Figure 5. A negative shock to global interest rates and positive shocks to global M2, to global CPI, and to global real output, lead to statistically significant and persistent increases in global oil price (in the first through fourth diagrams). A positive innovation in M2 supports a higher level of spending with positive effects on nominal oil price. A positive shock in the global CPI, reflects a negative shock to the real price of oil and an increase in oil price. A positive innovation in global real output indicates a higher level of global real activity with concomitant increases in the demand for crude oil and an increase in the global oil price.

In the fifth column of Figure 5, a positive innovation in oil price is associated with a statistically significant positive effect on the global interest rate and on global real output. Positive shocks to oil price have significant effects on global M2 and global CPI at impact only. A negative shock in oil price leads to a statistically significant increase in the trade weighted value of the US dollar.

6.5. Variance decomposition

An important question concerns how much of the variation in global interest rates, global M2, global price level, global output and oil price is explained by the variables in the model. Decomposition of the forecast error variance into components provides insight on the percent contribution of the structural shocks to the variation of GIR, GM2, GCPI, GY and oil price.

Table 5 panel reports the fraction of forecast error variance decomposition (FEVDs) of global interest rate set by central banks. Global M2, global output and oil price each make statistically significant contributions to forecasting the variation in global interest rate over different time horizons. The contribution of global M2 explains 51.40% of the variation in global interest rate in the first month. This fraction declines over time and becomes 15.30% at the 36 month horizon. Oil price does not make a statistically significant contribution to forecast error variance decomposition of global interest rate in the first 6 months, but does at and after the 12 month horizon. The contribution of oil price to explaining the variation in global interest rate rises over time, becoming 10.6% at 12 months and 13.10% at 36 months. The contribution of global output to explaining the variation in global interest rate also rises over time and becomes a statistically significant 10.7% at the 24 month horizon. Global CPI and the trade weighted USD dollar do not contribute significantly to explaining variation in global interest rate.

In Table 5 past own value of the global price level and past own value of the nominal oil price explain very large fractions of the global price level and of nominal oil price, respectively, at all horizons over 1 to 48 months. In contrast, at the 24 month horizon, about 46% of movement in global interest rate can be attributed to changes in global monetary aggregates (15%), oil prices (13%), global output (11%) and global CPI (7%). At the 24 month horizon, about 40% of movement in global monetary aggregates is forecasted by change in the global interest rate. At the 24 month horizon, about 30% of movement in global output is attributed to changes in global interest rate (9%), global monetary aggregates (6%) and oil prices (18%).

The results in Table 5 are supportive of the view that change in nominal oil price significantly influences forecast error variance decomposition of global interest rate and global output.

7. Alternative specifications (Robustness analysis)

In this section we estimate the model described in section 5 using data for the largest eight economies, examine generalised impulse response functions from the model, and estimate the model with principal components based on normalize scores (not loadings).

7.1. G8 economies

We now consider the robustness of results to expanding the analysis from the five largest economies to the eight largest economies based on GDP on a PPP basis. This means in constructing principal components for the interest rate, output and inflation we add data on these variables for Russia, Brazil and the U.K. to that for the US, Euro area, Japan, China and India. Our first preference is to use data from the five largest economies because these economies are much closer in size than when sixth, seventh and eights economies are included (Russia, Brazil and the U.K. respectively).[17] However, the major developing economies taken to be the BRIC countries, Brazil, the Russian Federation, India and China, have dramatic increases in real income in recent years and their inclusion along with the largest developed economies in an analysis of global effects of oil prices is a reasonable robustness analysis. The global measure of M2 will now be the sum of M2 in the largest eight economies in US dollars.

In Figure 6, the global variables created with principal components for both the group of five largest economies and the group of eight largest economies are plotted.[18] For conciseness the group of five largest economies is termed G5 and the group of eight largest economies is termed G8. The global interest rate (first principal component) based on the G5 is slightly higher (lower) in the first (second) half of the sample than that based on the G8. However, the movements in both G5 and G8 based global interest rates closely track one another.

The global CPI based on data for the G8 has steeper slope the global CPI based on data for the G5. This is due to Brazil and Russia both having had substantial increases in price levels (compared to the other economies) over 1999-2013. Global output given by the principal component for output in the G8 has less steep recessions following 2001 (the recession in the US) and that following the global financial crisis than indicated by the principal component for output in the G5. M2 for the G8 shows similar pattern to that for the G5.

The response of variables in the SGFVEC model (in equations (5) and (6)) for G8 variables to one-standard deviation structural innovations are shown in the first rows in

[17] Note that the risk of including economies of different sizes may lead to the overrepresentation (weights) of small economies when principal components are used.
[18] The G8 economies account for around 70% of world GDP measure by real PPP in US DOLLARS.

Figures 7. The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.[19]

The first row in Figure 7 shows the response of the global interest rate to structural innovations in the global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate, in turn. A general tightening of monetary policy on a global level (based on data for the G8), indicated by a rise in the global interest rate, is linked with positive innovations in liquidity, output, CPI and oil price and with a negative innovation in the trade weighted value of the US dollar. These results for the effects on global interest rate of structural shocks to the variables in the model with data on the G8 are very similar to those noted with data on the G5.

7.2. Generalized impulse response

The impact of shocks to variables in the SGFVEC model can also be examine using generalized cumulative impulse response (GIRF) developed by Koop et al. (1996) and Pesaran and Shin (1998). 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.

Country-specific SVAR studies 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 (for example Kim and Roubini (2000))In a study of global variables there is not strong belief on variable ordering and contemporaneous restrictions. At

[19] 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.

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.

We report in the second row of Figure 7 the responses of the global interest rate in the SGFVEC model in equations (5) and (7) to one standard deviation generalised cumulative impulse response function in global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate. We are using one standard deviation generalised cumulative impulse response function following Pesaran and Shin (1998). The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the cumulative impulse response functions.[20]

The results for effects on GIR in the second row of Figure 7 are based on G5 variables. Positive shocks to global M2, to global CPI, to global real output, and to oil price lead to statistically significant positive effects on the global interest rate that increase over time. A positive shock to the trade weighted value of the US dollar results in a significant decline in global interest rates. The results of the generalised cumulative impulse response are very similar to those from the impulse response results from the structural model in equation (6), and confirm the finding of a rise in the global interest rate when global level liquidity is increasing, the economy is growing and oil prices are increasing.

The generalised cumulative impulse response functions of global M2 and oil price to one standard deviation shocks in the variables in the SGFVEC model are reported in the second rows of Figures 8 and 9, respectively. The generalised cumulative impulse responses are very similar to those obtained the impulse response results from the structural model specified in equation (6).

7.3. Different weights in principal components

[20] 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.

Our baseline model uses principal components with normalise loadings to construct the variables GIR, GCPI, GY and GOP. In this section we use principal components with normalise scores to construct these variables. The responses of these variables, constructed with normalise scores in the SGFVEC model (in equations (5), (6) and (7)), are examined to one-standard deviation structural innovations in the variables in the model. The cumulative impulse response function of the global interest rate with normalise scores to one standard deviation shocks in the variables in the model are reported in the third row of Figure 7. Results are virtually identical to those obtained in the first row of Figure 5 for our baseline model using principal components with normalise loadings.

The cumulative impulse response functions of global M2 and oil price to one standard deviation shocks in the variables in the SGFVEC model using principal components with normalise scores are reported in the third rows of Figures 8 and 9, respectively. The impulse responses for GM2 and GOP are very similar to the impulse response results for these variables reported in Figure 5 for the baseline model using principal components with normalise loadings.

8. Conclusion

A structural global factor vector error correction model is estimated to examine the interaction of global interest rates, monetary aggregates, and output and consumer prices and oil prices at global level. The major economies are taken to be the world's three largest developed economic blocs (the US, Japan and the Euro area), and the two largest emerging market economies, China and India, that are increasingly important in shaping the global economy. Global money, global output and global prices are found to be cointegrated. A structural change in the global macroeconomic relationships is found over 2008:09-2008:12, but not pre versus post GFC.

It is found that there is statistically significant rise in global interest rates when global consumer prices and oil prices are increasing. This indicates a general easing of monetary policy on a global level given economic weakness and falling prices. A positive shock to global interest rate leads to statistically significant and persistent decline in global M2, reduced CPI and nominal oil price, and after several months to reduced global output. A positive shock to the trade weighted value of the US dollar results in a significant decline in global interest rates. A stronger US dollar constitutes a tightening of global financial conditions that central banks seek to offset by reducing discount rates. Increases in oil prices are associated with increase in global inflation and global output leading to global interest rate tightening.

A negative shock to global interest rates leads to statistically significant and persistent increases in global oil price. Positive shocks to global M2, to global CPI, and to global real output are associated with increases in global oil price. These shocks are consistent with higher levels of global real activity and thus with increases in global oil price. A positive shock in oil price leads to a significant decline in the trade weighted value of the US dollar. Global liquidity, global output and oil price explain statistically significant fractions of forecast error variance decomposition in the principal component for global interest rates, in amounts given by 15%, 11% and 13%, respectively.

Results are robust to alternative identification schemes in the structural global factor 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 that when considering movement in the global level of central bank interest rates it is necessary to consider the influence of global variables that reflect developments in the major developing and developed countries.

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Table 1. Correlation between the logs of country-specific and global variables

Country	M2 in US dollars	Interest rate	Real output	CPI
Euro area	0.95	0.81	0.89	0.99
US	0.99	0.84	0.90	0.99
China	0.99	0.72	0.71	0.97
Japan	0.92	0.75	0.62	-0.79
India	0.97	0.10	0.70	0.98

Table 2. Test for unit roots 1999:1-2013:12: 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 ($GM2_t$)	0.92	1.61***	Δlog ($G3M2_t$)	-12.90***	0.24
log ($GCPI_t$)	-1.92	1.52***	Δlog ($GCPI_t$)	1.00***	0.73
log (GIP_t)	-2.94*	0.77***	Δlog (GIP_t)	-4.56***	0.09
log (GOP_t)	-2.51	1.51***	Δlog (GOP_t)	-10.01***	0.11
log ($USTWI_t$)	-0.99	1.41***	Δlog ($USTWI_t$)	-9.22***	0.09

Notes: The first difference of the series is indicated by Δ.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 3. LR test

Null hypothesis for LR test: no structural change

Alternative hypothesis for LR test: structural change

	Degree of freedom	χ^2 critical value with at 95%	χ^2 value
Dummy variable: 2008:M9 to data end	6	12.59	5.95
Dummy variable: 2008:M9 to 2008:M12	6	12.59	39.66***
Dummy variable: 2009:M1 to data end	6	12.59	2.14

Notes: The LR test is $LR = (T - m)(ln|\Sigma_r| - ln|\Sigma_{ur}|) \sim \chi^2(q)$, where: T is the number of observations, m is the is the number of parameters in each equation of the unrestricted system plus contains, Σ is the determinant of the residual covariance matrix, and q is the number of dummy variables times number of equations.

Table 4. Cointegration test: logs of global CPI (GCPI), money (G3 M2 and BRIC M2) and global output (GY).

a) Cointegration test with different specifications

Endogenous variables: log(global CPI_t), log(global $M2_t$), log(global real $output_t$)		
Test Type	None trend and Intercept	Linear trend and Intercept
Trace	1	1
Max-Eig	1	1

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

b) 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≥1	0.19	45.5	29.79	0.00
r≤1	r≥2	0.05	9.94	15.49	0.28
r≤2	r≥3	0.00	0.24	3.94	0.62

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

c) 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	0.22	60.83	42.9	0.00
r=1	r=2	0.07	20.9	25.88	0.18
r=2	r=3	0.04	7.94	12.52	0.25

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

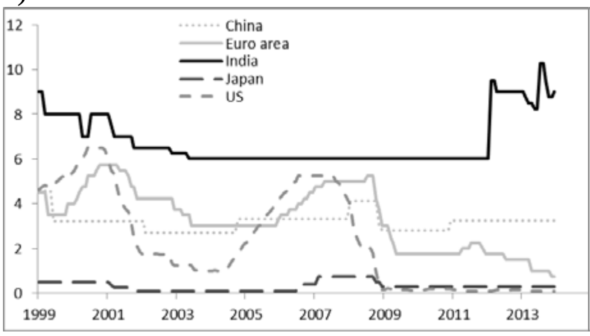
Table 5: Variance decomposition of Global interest rates.

Months/ Variables	Global central banks interest rates	Global monetary aggregates	Global CPI	Global outputs	Oil prices	US TWI
1	45.95	51.43*	1.02	1.51	0.09	0.00
3	48.11*	45.98*	1.52	1.80	2.07	0.52
6	54.63*	29.88*	4.10	6.09	5.06	0.25
12	54.90*	18.73*	5.93	9.70	10.59*	0.15
24	54.20*	15.43*	6.60	10.68*	12.96*	0.14
36	54.15*	15.28	6.64	10.71*	13.09*	0.14
48	54.14*	15.27	6.64	10.72*	13.09*	0.14

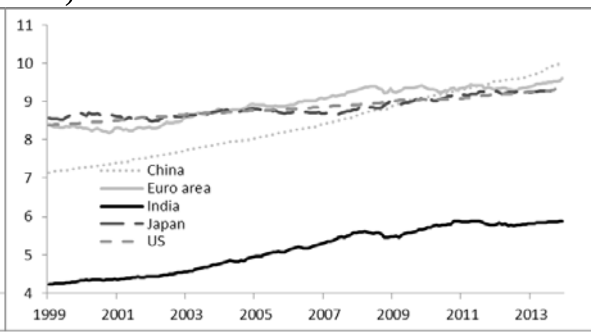
Where * indicate coefficients are statistically significant at 10% level.

Figure 1. Macro variables

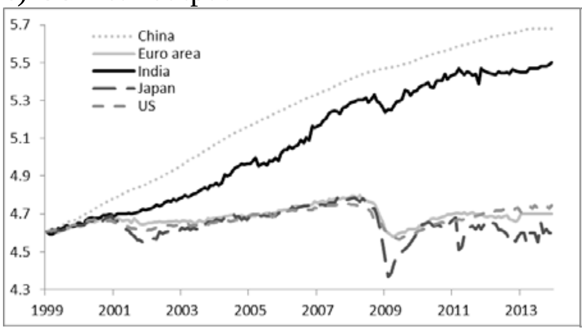
a) G5 Interest rates



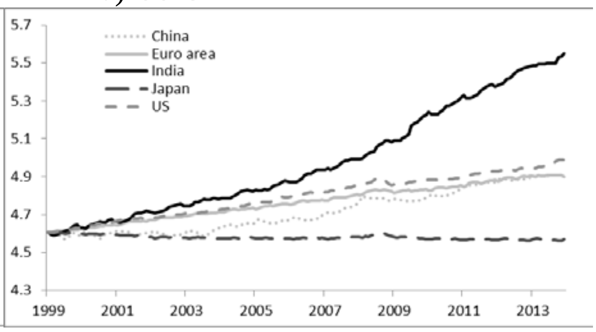
b) G5 M2



c) G5 Real output

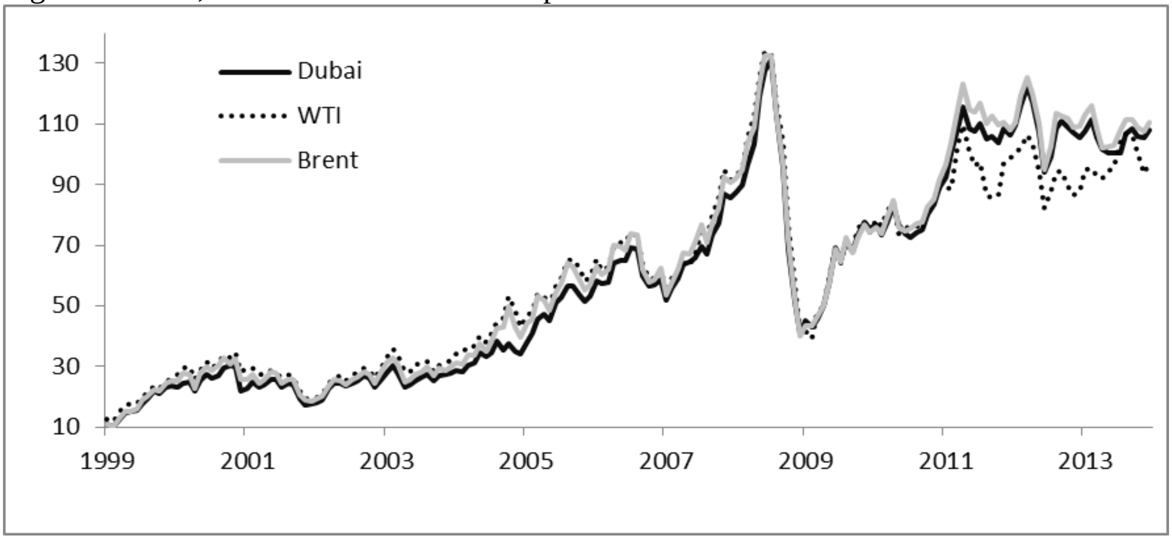


d) G5 CPI



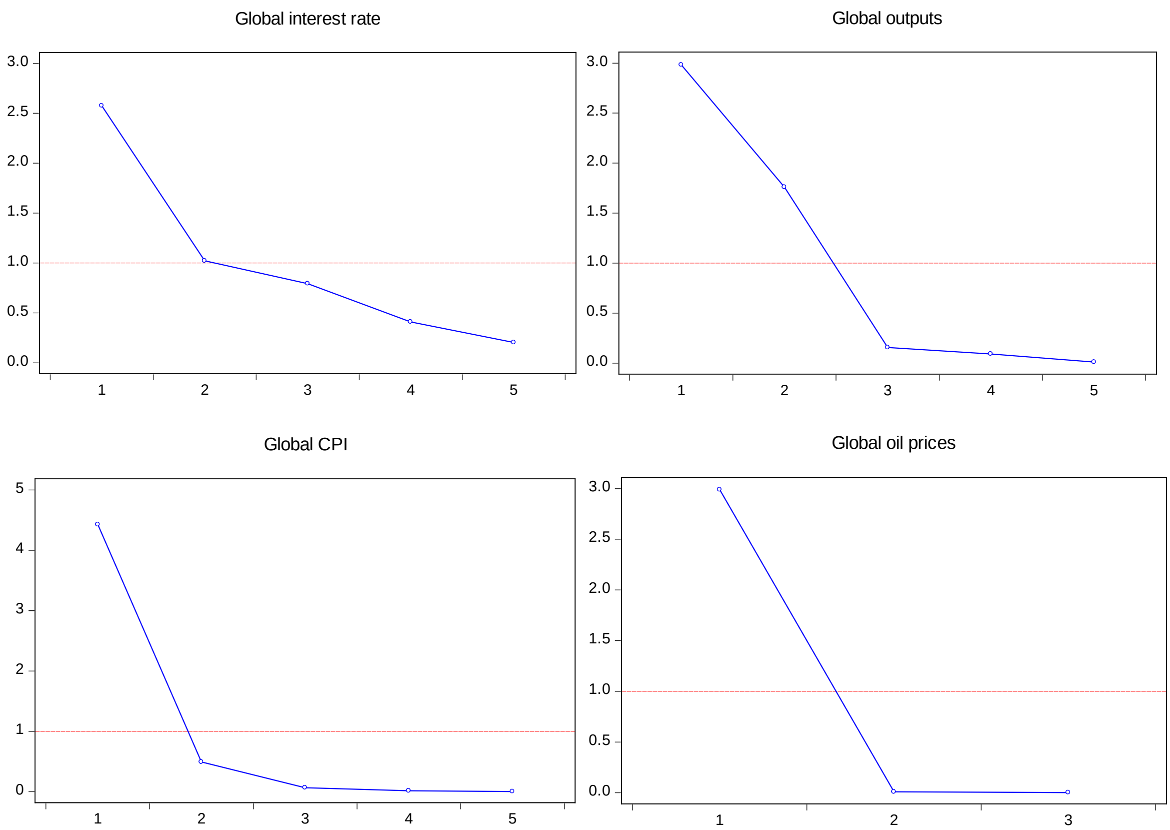
Notes: Central bank discount rates, M2 monetary aggregates, consumer price indices, and industrial production indices are for each of the five largest economies (the G5). The G5 consists of the US, the Euro area, Japan, China and India. Interest rates are in percent. Log of M2 data in US dollars is shown. Logs of industrial production and the CPI are also shown. Data are monthly.

Figure 2. Brent, Dubai and WTI crude oil prices



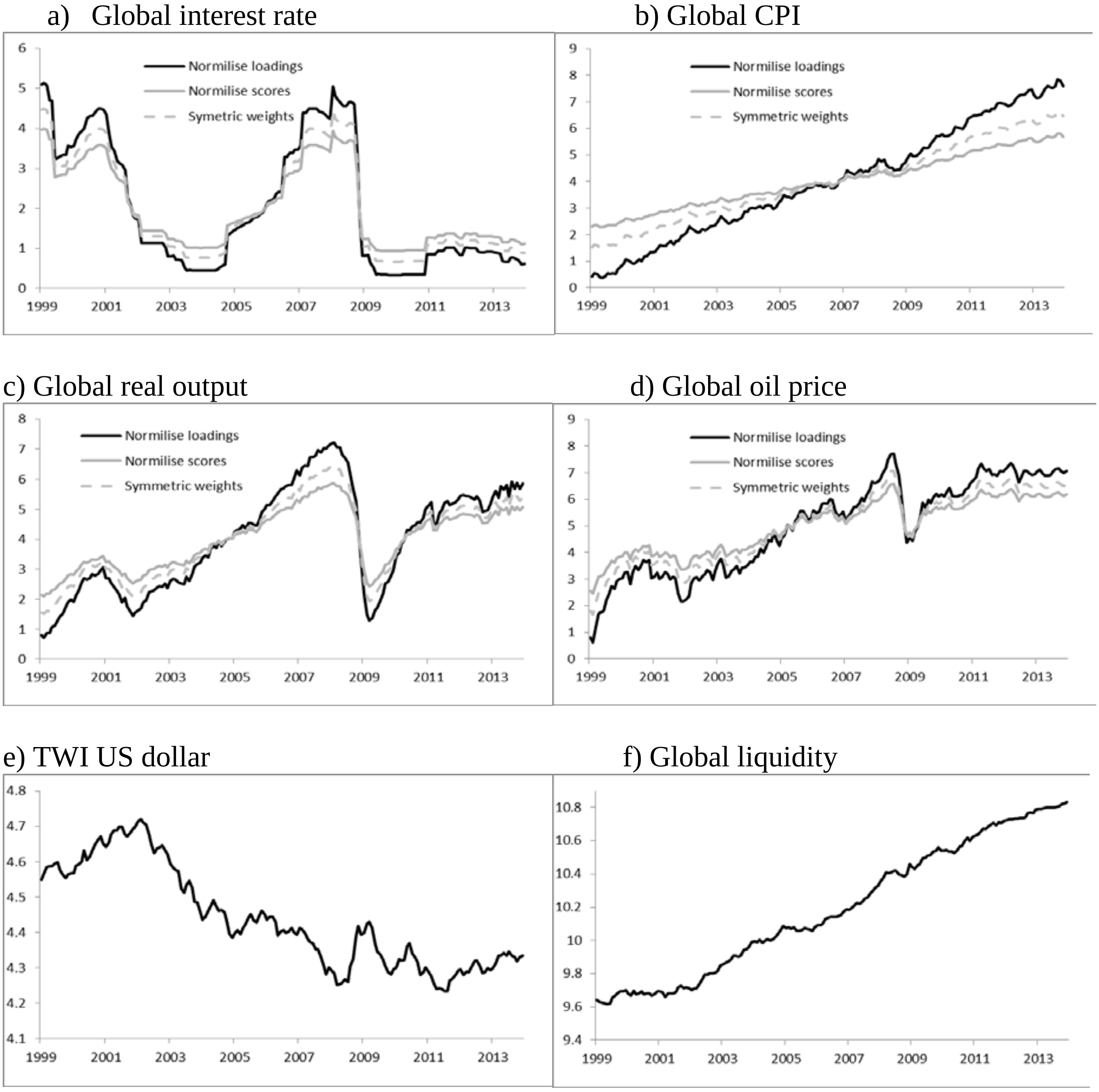
Notes: Brent, Dubai and West Texas Intermediate crude oil prices are US dollar indices. Data are monthly.

Figure 3. Scree plot (ordered eigenvalues) for global principal components



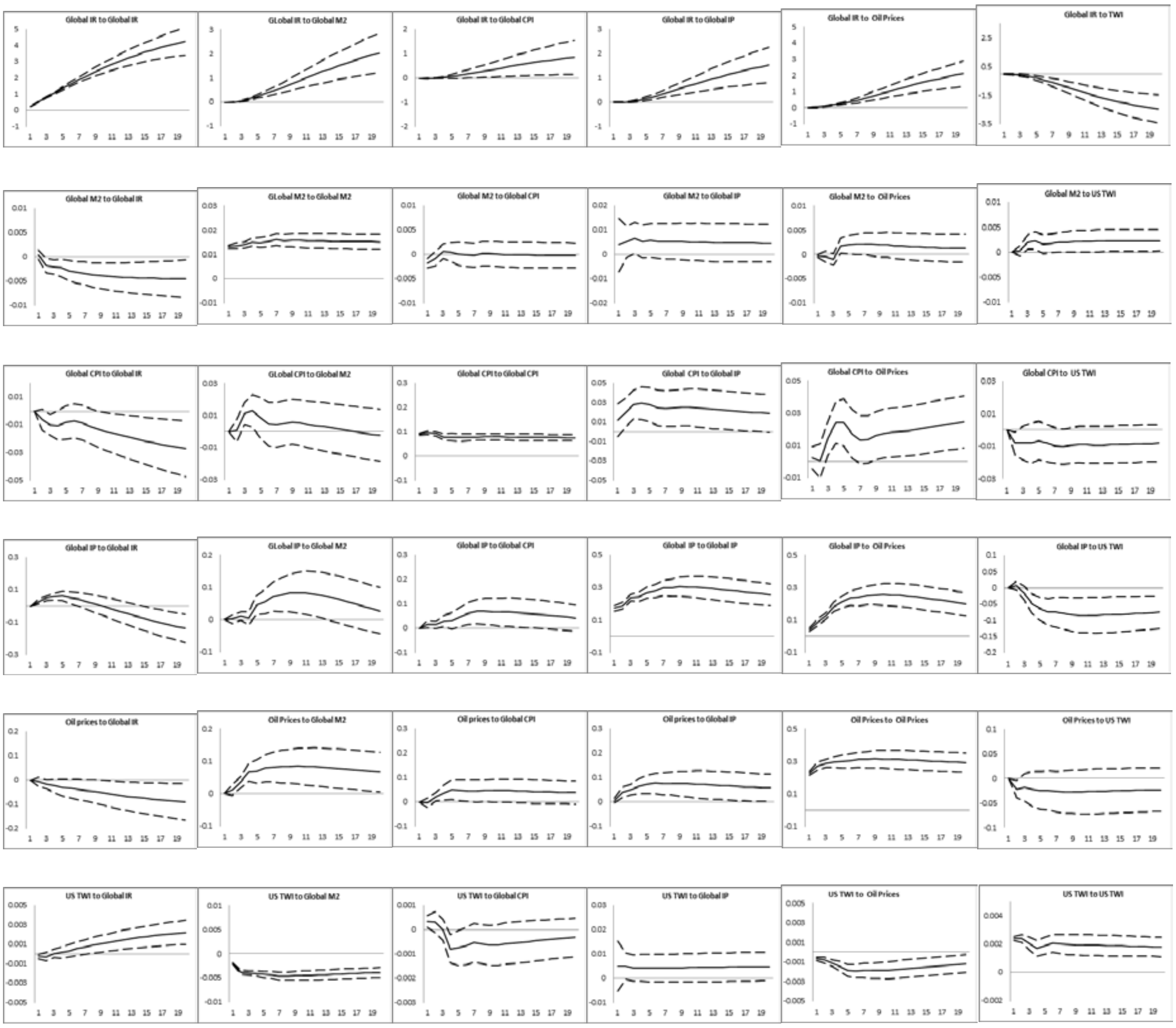
Notes:

Figure 4. Global variables (principal components)



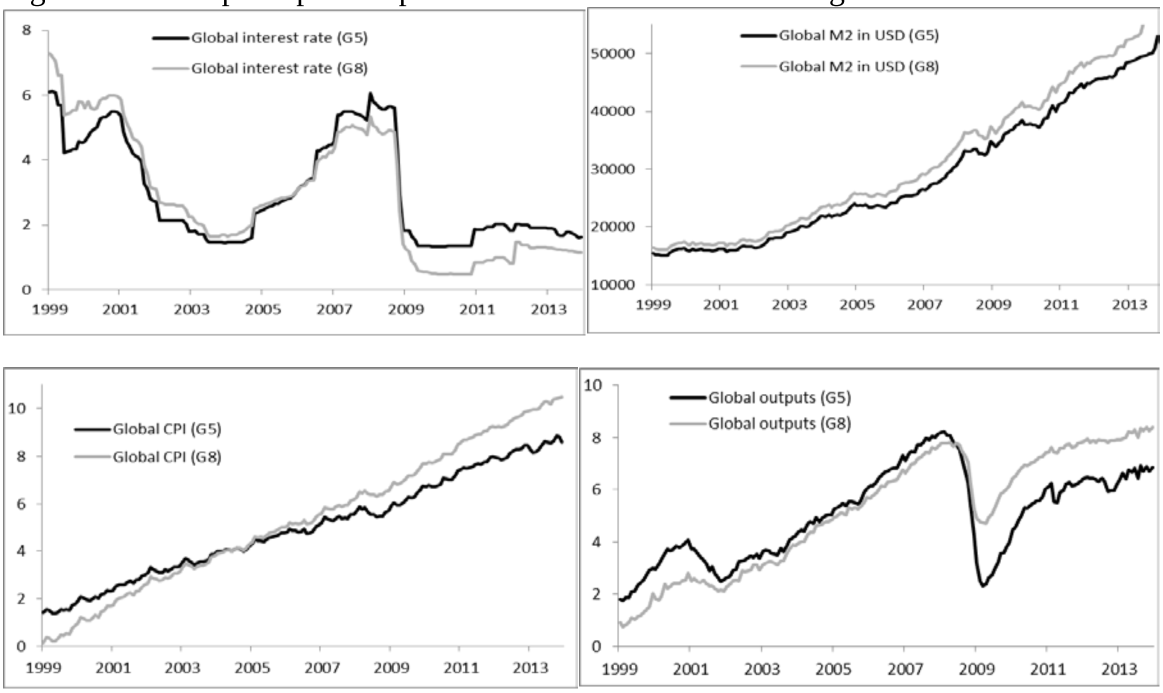
Notes: The leading principal components for global interest rates, global real output and global CPI (in log-level form for real output and CPI) are each obtained from data on central bank interest rate, real output and CPI for the US, Euro area, China, India, and Japan. The leading principal component for oil price is obtained from data on the Dubai, Brent and West Texas Intermediate oil prices. Alternative principal components are shown for normalise loadings, normalise scores and with equal weighted scores and loadings. TWI US dollar is the log of the trade weighted index of the US dollar. Global liquidity is the log of global M2 which is the sum in US dollars of M2 for the US, Euro area, China, India, and Japan.

Figure 5. Cumulative Impulse Response Function 1999:01 to 2013:12



Notes: In the Figure, each row shows the cumulative impulse response of a variable to one-standard deviation structural innovations in the global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate, respectively. The variables being impacted in the first through sixth row are in descending order global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate. The impulse responses are obtained from the SGFVEC model in equations (5), (6) and (7). The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.

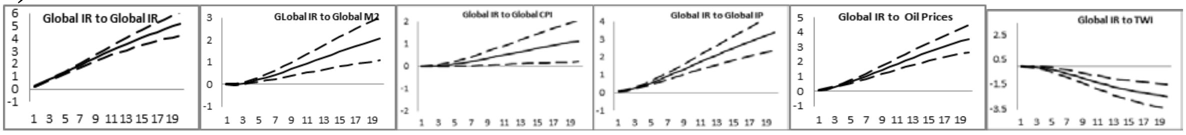
Figure 6. Global principal components estimation: G5 vs. G8 largest economies.



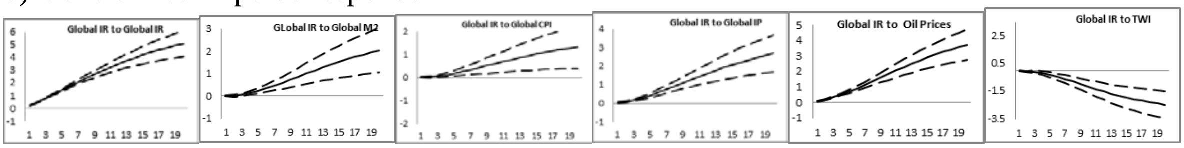
Notes: The G5 consists of the US, Euro area, China, India, and Japan. The G8 consists of the G5 plus Brazil, Russia and the U.K.

Figure 7. Responses of global interest rate to key variables using alternative specifications 1999:01 to 2013:12

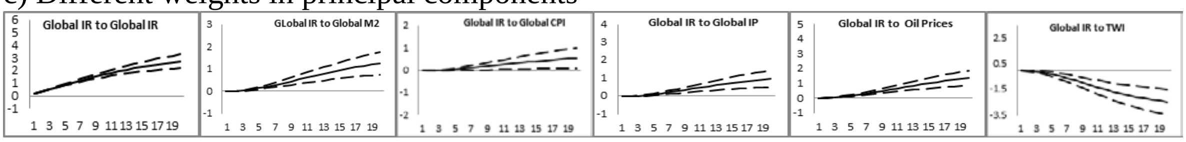
a) G8 economies



b) Generalized impulse response



c) Different weights in principal components



Notes: The first row in Figure 7 shows the response of the global interest rate to one-standard deviation structural innovations in the global interest rate, global M2, global CPI, global output, oil price, and the trade weighted US dollar exchange rate using data for the G8 economies and based on the structural restrictions in equation (6). The second row in Figure 7 shows the generalized impulse responses in the global interest rate (to one-standard deviation structural innovations) using data for the G5 economies. The third row in Figure 7 shows the impulse responses of the global interest (to one-standard deviation structural innovations) using data with principal components constructed with normalise scores and based on the structural restrictions in equation (6) for the G5 economies. The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.