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Abstract

This paper investigates the relationship between oil prices and the global economy. In modelling this relationship, a new approach is proposed in which we introduce the use of a factor error correction model to compress data from the largest developed and developing economies. An important feature of this model is that at global level, we find that global money, output and prices are cointegrated, which is supportive of the quantity theory of money. Positive innovation in global oil price is connected with global interest rate tightening. Positive innovation in global money, CPI and outputs is connected with an increase in oil prices while positive innovations in global interest rate are associated with a decline in oil prices. The US, Euro area and China variables are the main drivers of global factors.

Keywords: Global interest rate, global monetary aggregates, oil prices, GFVEC

JEL Codes: E44, E50, Q43

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Oil prices and the economy: A global perspective

1. Introduction

Global demand for oil in recent decades has been driven by rapid growth in major developing economies.[1] The US Energy Information Agency estimates that China's oil consumption growth was half of the world's oil consumption increase in 2011. The International Energy Agency (IEA) forecasts China will be the world's largest net importer of oil on an annual basis in 2014 and that thereafter the gap will widen. 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 surge in demand for oil by China and India is forecasted by the IEA to continue well into the future.[2]

It has been stressed in the literature that the behaviour of commodity prices is closely intertwined with the conduct of monetary policy. Barsky and Kilian (2002) argue that monetary policy influences commodity prices through expectations of greater growth and inflation. Frankel and Hardouvelis (1985) maintain that movement in commodities prices measure the market's assessment of the stance of monetary policy. The empirical literature on the relationship between commodity prices and monetary policy has focused on the latter being expressed by the US interest rate as an indicator of monetary policy (Frankel, 2008; Frankel and Rose, 2010). Salient observations however, are that the US is no longer as dominant in the world economy as it once was and US consumption of oil (about 20% of the world total in 2012) has been declining in recent decades. In contrast, oil demand is on an upward trajectory in emerging economies. When considering the world price for oil it is

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[1] Kilian and Hicks (2013) connect real oil price increases with strong growth forecasts in emerging economies (especially in China and India) over 2003-2008 and the decline in real oil prices after mid 2008 with forecasts of decline in global growth. Beirne et al. (2013) estimate the effects of individual countries on oil demand and find that China's GDP growth attaches a premium to the price of oil that is rising over time. Hamilton (2013) notes that the newly industrialized economies have absorbed over two-thirds of the increase in world oil consumption since 1998.

[2] 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"… "By 2035, almost 90% of Middle Eastern oil flows to Asia" (IEA World Energy Outlook 2012: http://www.worldenergyoutlook.org/pressmedia/quotes/12/).

necessary to consider the influence of global variables, including global variables that reflect the stance of monetary policy in the major developing and developed countries.

In this paper we seek to determine the interaction of global interest rates, global real output, and global CPI with world oil prices. A global factor vector error correction model (GFVEC) is employed in the analysis of the interaction of innovations in global interest rates with global oil prices and other variables. The collective stance of monetary policy actions by major central banks is captured by the level of central bank interest rates at global level.[3] A factor-augmented dimension to the GFVEC model will capture the dynamic of the information provided by many variables to the analysis of short and long run interaction of global oil price, global real output, global CPI and global interest rate. Global factors are estimated using principal component techniques applied to interest rates, real output across countries, and CPI across countries, respectively.

Global money, global output and global prices are found to be cointegrated, consistent with the quantity theory of money holding at global level. We find that Granger causality goes from liquidity to oil prices and from oil prices to the global interest rate, global output and global CPI. Positive innovations in world oil price are connected with statistically significant extended positive effects on global interest rates and global real output. A positive shock in world oil price is linked with a statistically significant decline in the trade weighted value of the US dollar. Positive innovation in the global interest rate leads to statistically significant and persistent decreases in global oil price. Statistically significant persistent increases in global oil price are associated with positive shocks to global M2, to

[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. 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. Ratti and Vespignani (2013) find that global liquidity a positive effect on oil prices in the past decade.

global CPI and to global real output, and to negative innovations in the trade weighted value of the US dollar.

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 market for oil. A global factor is also estimated for the global price of oil from the various leading oil price indices. The equivalent variables for the US and China Granger cause the global interest rate, global M2, global output and global CPI. The Euro area variables Granger causes the global interest rate, global output and global CPI (but not global M2). Japan influences global M2 and global output and India influences global output and global CPI. All five economies influence global output. The Granger causality results indicate a degree of interdependence between China and the global economy comparable to levels of interdependence between the global economy and the US, Euro area and Japan.

The methodology in the study is described in Section 2. Global variables are discussed in Section 3 and Granger causality among the economy and global variables is investigated in Section 4. The GFVEC 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. Methodology

Factor methods have become widely used in the literature to examine the comovements of aggregate variables since work by Stock and Watson (1998) and Forni et al. (2000).[4] In line with the dynamic factor models of Bernanke et al. (2005), Stock and Watson

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[4]A number of issues have been addressed recently using factor methods. 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

(2005), Forni and Gambetti (2010), and others, we construct a global factor 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 error correction model (GFVEC) is then estimated. The data, variables and various test results are examined in detail in subsequent sections.

The main advantage of this approach in a global setup is that it is possible to compress data for many countries in single factor without losing degrees of freedom, allowing for the influence of both large developed and developing economies.[5] A single individual variable or factor can capture the dynamic of a large amount of information contained in many variables.[6] 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.[7]

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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. Beckmann et al. (2014) examine the effect of global shocks on policy making for the US, Euro area, Japan, UK 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.

[5] In our view this is clear advantage over models such as Anzuini (2012) or Kim and Roubini (2000) where oil prices only interact with one individual economy.

[6] 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.

[7] 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.

We favour the global factor approach over other possible ways to model the global economy, especially over a short period January 1999 to December 2012. 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 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.

The global vector autoregressive model (GVAR) by Pesaran et al. (2004) and Dees et al. (2007) is a powerful framework for examination of spillovers among countries. In the GVAR model domestic variables for a given country interact with the corresponding foreign variables treated as weakly exogenous. In 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. In the GFVEC model in this paper the global factors are treated as endogenous and the interaction of global shocks can be explicitly examined.

3. Data and global factors

3.1. The Data.

The data are monthly from January 1999 to December 2012. 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 13 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. 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 of St. Louis (FRED data) and data on oil prices are from the World Bank.

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 1999:01-2012:12 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 2012:12 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 2012:12 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 2012 (in declining order) the US, Euro area, China, India, and Japan, are by far and away the largest economies in the world.

3.2 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 ($GCPI_t$)

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[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

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 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

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

[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)).
[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.

Figure 2 contains a plot of the variance of the principal components using normalised loadings for the interest rate, real output, CPI and oil price. Each plot for shows the variance accounted for by the first component and then for the second, third etc. components for each variable. 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, in particular, 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 interest rates (output) captures 60% (46%) of the news in the five economy level interest rates (output). 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 that 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 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.[12] The first principal component for the global interest rate, to be referred to as GIR_t, is drawn in Figure 3a 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

[12] Note that with the 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.

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 3b. In Figure 3 $GCPI_t$ 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 3c. 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 3d. 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 is shown in Figure 3e. The trade weighted US dollar peaks in early 2002 and then shows a gradual downward with a levelling off in recent years. The log of global M2 is shown in Figure 3f 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 M2, the 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 interest rates is high for the Euro area, China and Japan (over 75% for each), 54% for the US and only 29% for India. The global real output correlation with country level real output is high for the US and India (88% each), and at 71%, 65% and 63% for Japan, Euro area and

China, respectively. The global CPI correlation is high with that of each economy with correlations at 82% and above.

4. Causality tests

We now examine the direction of causality between the variables at global level and also the causality between the developed and developing large economies and the variables at global level. The issue of causality between global variables and global oil price is not usually addressed in the literature, but is clearly of interest given the increased interconnectedness of the world economy. Work on the impact of a large economy on other economies has naturally focused on the role of the US in the international transmission of shocks.[13] China and India are now a large economies and their impact on global variables needs to be examined along with that of the US, Euro area and Japan.

4.1 Directional influence amongst global variables.

In Table 2 the Granger causality direction results for the global interest rate, global M2, global output and global CPI with global oil price are presented. The balance of the evidence is that global oil price Granger causes global interest rate, global output and global CPI, and not the reverse of these outcomes. These results supplement the large literature assigning oil price shock a major role in influencing real activity in individual economies by suggesting that even global variables are influenced by oil prices. Hamilton's (1983) influential paper on the effect of oil prices on the US economy over the post-World War II period treated oil prices changes as exogenous. This supposition was maintained by Lee et al. (1995), Hamilton (1996) and Bernanke et al. (1997), among many others, who documented a

[13] With regard to monetary policy, Kim (2001) and Canova (2005) find that monetary expansion in the US causes economic expansion in the non-US G-6 and in Latin America by lowering interest rates across these economies.

negative connection between oil price increases and real activity in the US.[14] Kilian (2009) in a major contribution finds that oil price increases associated with increases in global aggregate demand have a positive effect on GDP growth, and that oil price increases due to concern about oil supply shortages lower real GDP growth. Hamilton (2009) also distinguishes oil price shocks due to demand and supply side influences.

It is found in Table 2 that global oil price does not Granger cause global M2, but global M2 does Granger cause global oil price. This latter result is in line with the literature documenting a positive effect of global liquidity on commodity prices. Belke et al. (2010) find that global liquidity has significant impact on commodity prices, and Ratti and Vespignani (2013) show that increases in global real M2 lead to statistically significant increases in real oil prices in recent years. Overall, we conclude that Granger causality goes from liquidity to oil prices and from oil prices to the global interest rate, global output and global CPI.[15]

4.2 Which economies drive global variables?

With the upward surge of large developing economies such as China and India and the creation of the euro area in January 1999, a natural question arises: which economies drive the global economy? To approach this question a standard Granger casualty test is used in Tables 3 a, b, c and d. In Table 3a, results for Granger causality test between global interest rate and country-specific interest rates are shown. Similarly, in Tables 3b, 3c and 3d results are presented for Granger causality test between global M2, global real output and global CPI and their corresponding country-specific variables**.**

[14] A significant negative association between oil price shocks and economic activity has been found for most countries in their samples by Cologni and Manera (2008) and Kilian (2008) for the G-7, Jimenez-Rodriguez and Sanchez (2005) for G-7 and Norway, and Cunado and Perez de Garcia (2005) for Asian countries.

[15] These results are in line with findings by Bodenstein et al. (2012). They develop a DSGE model and analyse interdependency between monetary policy and the global oil market and argue that "… there is consensus that causality in this relationship (referring to monetary policy and oil prices) run from the event of oil market to monetary policy as well of shifts of monetary policy to the supply of oil and demand of oil in global markets" (Bodenstein et al. (2012); page 51).

In Table 3a it is found that the interest rate in China Granger causes the global interest rate and vice versa at all lag lengths. This result is consistent with the view that China has become a major force in the world economy. There is also evidence that interest rates in the US, Euro area and Japan Granger cause the global interest rate and vice versa, depending on lag length. The interest rate in India and the global interest rate do not influence each other.

In Table 3b it is found that global M2 is Granger caused by M2 in China, Japan and the US. Only Japan's M2 Granger causes global M2. Global output is driven by output in all five economies (with the US and Euro area having stronger results). Global output Granger causes output in the US, Euro area, China and Japan. Global inflation is driven by inflation in the US, Euro area, China and India, but not by inflation in Japan. Inflation in China and the Euro area is Granger caused by global inflation.

In summary, the results indicate that the US and China have most breadth of influence across the global variables for interest rate, liquidity, output and consumer prices. It is found that in terms of Granger causality the US and China influence the global interest rate, global M2, global output and global CPI. The Euro area influences the global interest rate, global output and global CPI (but not global M2). Japan influences global M2 and global output (but not the global interest rate and global CPI). India influences global output and global CPI (but not global interest rate and global M2), suggesting that India is most divorced from the global economy at least in terms of the financial variables (GIR and GM2). All five economies influence global output. The results indicate a degree of interdependence between China and the global economy that is similar to levels of interdependence between the global economy and either the US, Euro area, or Japan.

5. The Model

The GFVEC model can expressed as:

$$B_0X_t = \beta + \sum_{i=1}^{j} B_iX_{t-i} + \varphi ECT1_{t-1} + \varepsilon_t \qquad (5)$$

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 discuss more in detail in section 3.3.

The vector X_t is expressed as:

$$X_t = [GIR_t, \Delta\log(GM2_t), \log(GCPI_t), \Delta\log(GY_t), \Delta\log(GOP_t), \Delta\log(USTWI_t)] \qquad (6)$$

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) and Anzuini et. al. (2012) 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 Generalized impulse response

The impact of shocks to variables in the GFVEC model will be examined 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), Kim (2001) and Anzuini et al. (2013)). In a study of global variables there is not strong belief on variable ordering and contemporaneous restrictions. 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. Other specification strategies are discussed in later sections.

5.2 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.[16] 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:

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

In Table 4 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 5. Table 5a 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

[16] 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.

intercept and trend. In Table 5b, 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 ⩽ 1 and r ⩽ 2 cannot rejected even at 20% level. In the maximum eigenvalue test in Table 5c, 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.

6. Empirical Results

6.1 Generalized cumulative impulse responses of oil price to global variables

We first examine the response of oil price components to innovations in the global variables. The responses of the oil in the GFVEC model in equations (5) and (6) to one standard deviation generalised cumulative impulse response function in the global variables are reported in Figure 4a. 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.[17] In the first diagram in Figure 4a it is found that positive innovations in the global interest rate leads to statistically significant and persistent decreases in global oil price. The implication is that monetary easing on a global scale will raise oil prices.

In Figure 4a 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 second 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

[17] 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.

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 diagram in Figure 4a, a negative innovation in the trade weighted value of the US dollar rate leads to statistically significant and persistent increase in global oil price in US dollars. With a stronger US dollar, oil consumers outside the US have to pay more in local currency for oil, with the result that overall demand for oil is reduced at a given US dollar price for oil. This leads to a weakening in the global oil price in US dollars terms.

6.2. Generalized cumulative impulse responses of global variables to oil prices

We now turn to examination of the response of global variables to oil prices shocks. The responses of the global variables in the GFVEC model in equations (5) and (6) to one standard deviation generalised cumulative impulse response function in the global price of oil are reported in Figure 4b. In the first diagram in Figure 4b, a positive innovation in oil price is associated with a statistically significant positive and increasing effect on the global interest rate. Increases in global oil price lead to monetary tightening on a global scale as indicated by increases in the global interest rate. At impact, positive shocks to oil price have significant effects on global M2 and global CPI, but the effects thereafter are statistically insignificant. A positive innovation in oil price is associated with a statistically significant positive effect on global real output that peaks at five months and then gradually declines but remains statistically significant up to 18 months. In the fifth diagram in Figure 4b, a positive innovation in (US dollar) oil price leads to a decline in the trade weighted value of the US dollar rate.

In short, in this section it is found that a positive innovation in oil price is connected with increasing global interest rates, with a statistically significant positive effects on global real output for up to 18 months, and a decline in the trade weighted value of the US dollar rate. Positive innovation in the global interest rate leads to statistically significant and persistent decreases in global oil price. Persistent increases in global oil price are attendant on positive shocks to global M2, to global CPI and to global real output, and on negative innovations in the trade weighted value of the US dollar.

7. Robustness of results to alternative specifications

In this section the robustness of results to changing the definition of the global variables, to alternative identification restrictions, and to different definitions of the principal components is examined.

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 on GDP based on 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).[18] 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 5, the global variables created with principal components are plotted for both the group of five largest economies and the group of eight largest economies are reported.[19] For conciseness the group of five largest economies is termed G5 and the group of eight

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

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 probably due to Brazil and Russia both having had substantial increases in price levels (compared to the other economies) over 1999-2012. 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 generalized cumulative impulse responses of oil price to global variables based on the eight largest economies are presented in Figure 6a. Results are similar to those obtained based on analysis of the five largest economies. It is found that that monetary easing on a global scale will significantly raise oil prices. Positive innovations in global M2, in global CPI, and in global real output, lead to statistically significant and persistent increases in global oil price. The effect of global CPI on oil price is more pronounced using the G8 variables using the G5 variables. A negative innovation in the trade weighted value of the US dollar rate continues to lead to statistically significant and persistent increase in global oil price.

The generalized cumulative impulse responses of global variables to oil price are shown in Figure 6b. Based on the eight largest economies, a positive shock to oil price now generates a statistically significant positive effect on global CPI and also generates a larger positive effect on global output than did the analysis based on the G5 variables. Results are similar based on the eight largest economies to those obtained based on the five largest economies with regard to a positive innovation in oil price being associated with statistically significant positive (negative) effect on the global interest rate (trade weighted value of the US dollar).

7.2 Different identification restrictions

Our baseline model presented in equations 1-6 is based on the generalized cumulative impulse response (GIRF) developed by Koop et al. (1996) and Pesaran and Shin (1998) on the grounds that contemporaneous restrictions are not establish in the literature for global variables. Most macro-models for the evaluation of the transmission of shocks address and describe identifying restrictions for national variables (see for example, Kim and Roubini (2000), Kim (2001), Dedola and Lippi (2005), or Anzuini et al. (2013)). In this section we consider impulse response results with identifying restrictions based on Kim and Roubini (2000) and compare these results with those obtained with generalized impulse response function. In the Kim and Roubini (2000) model, the monetary policy feedback rule does not allow monetary policy to respond within the month to price level and output events, but allows 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.[20] 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.

[20] These restrictions are also used by Gordon and Leeper (1994), Sims and Zha (2006), Christiano *et al.* (1999) and Kim (2001). The impact effects of monetary policy shocks on industrial production and consumer prices are zero. Forni and Gambetti (2010) refer to this as a standard identification scheme.

In line with this discussion of identifying restrictions based on Kim and Roubini (2000), the matrix B_0X_t in equation (5) is given by:

$$B_oX_t = \begin{bmatrix} 1 & -b_{01} & 0 & 0 & 0 & -b_{05} \\ -b_{10} & 1 & -b_{12} & -b_{13} & 0 & 0 \\ 0 & 0 & 1 & -b_{23} & -b_{24} & 0 \\ 0 & 0 & 0 & 1 & -b_{34} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ -b_{50} & -b_{51} & -b_{52} & -b_{53} & -b_{54} & 1 \end{bmatrix} \begin{bmatrix} \Delta \log(GIR_t) \\ \Delta \log(GM2_t) \\ \Delta \log(GCPI_t) \\ \Delta \log(GY_t) \\ \Delta \log(GOP_t) \\ \Delta \log(USTWI_t) \end{bmatrix} \quad (7)$$

Figures 7a and 7b show the responses of variables in the GFVEC model in equations (1) and (7) to one-standard deviation structural innovations. The dashed lines represent a one standard error confidence band around the estimates of the coefficients of the impulse response functions.[21] The impulse responses of oil price to global variables based on the five largest economies are presented in Figure 7a. Generally results are not as statistically significant as the generalized impulse response. In Figure 7a shocks to monetary easing and CPI, and negative innovation in the trade weighted value of the US dollar do affect raise oil prices, but the effect is smaller and statistically significant for as long as before.

The impulse responses of global variables to oil price are presented in Figure 7b. These structural impulse responses are very similar the generalized impulse responses reported in Figure 4b. 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.

7.3 Different weights in principal components

Our baseline model in section 5 uses principal components with normalise loadings. In this section we use principal components with normalise scores. Results with principal components with normalise scores are very similar to those for principal components with

[21] 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.

normalise loadings. The generalized cumulative impulse responses of oil price (global variables) to global variables (oil price) with principal components with normalise scores are shown in Figure 8a (8b).

8. Conclusion

This paper examines the interaction of global interest rates, global real output, and global CPI with world oil prices and the trade weighted value of the US dollar. A global factor vector error correction model is utilized to examine the dynamic interaction of these variables. Structural factors are constructed to capture information provided by many variables (countries). Global factors are estimated using principal component techniques applied to interest rates, real output and CPI across countries. The collective stance of monetary policy actions by major central banks is caught by the level of global interest rates. A global factor is also estimated for the global price of oil from the various leading oil price indices.

In line with the quantity theory at country economy level, global money, global output and global prices are found to be cointegrated. Granger causality is found to go from global liquidity to oil prices and from oil prices to the global interest rate, global output and global CPI. Monetary tightening indicated by positive innovation in central bank discount rates results in significant and sustained increases in oil prices. Positive shocks to global M2, to global CPI, and to global real output, lead to statistically significant and persistent increases in global oil price. A negative innovation in the trade weighted value of the US dollar rate leads to statistically significant and persistent increase in global oil price in US dollars. A rise in oil price results in significant increases in global interest rates. A positive innovation in oil price is associated with a statistically significant positive effect on global real output. A positive innovation in (US dollar) oil price leads to a decline in the trade weighted value of the US dollar rate.

Granger causality test from economy level to global level variables shows that for the period 1999-2012, the US and China variables Granger cause the global variables, global interest rate, global M2, global output and global CPI. The Euro area variables Granger cause 3 out of 4 global variables (global interest rate, global output and global CPI), and India and Japan Granger cause 2 out of 4 global variables (Japan's variables influence global M2 and global output while India's variables influence global output and global CPI). The results indicate a degree of interdependence and influence between China and the global economy that is somewhat similar to levels of interdependence between the global economy and either the US or Euro area.

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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	0.96	0.76	0.65	0.96
US	0.99	0.54	0.88	0.95
China	0.99	0.76	0.63	0.86
Japan	0.93	0.77	0.71	0.82
India	0.97	0.29	0.88	0.89

Table 2: Granger causality tests for global variables 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	24
GOP does not Granger cause GIR	2.78***	2.17*	3.57***	2.51***	1.79**
GIR does not Granger cause GOP	0.70	0.87	0.69	1.34	1.56*
GOP does not Granger cause GM2	0.01	0.39	1.85*	1.22	0.79
GM2 does not Granger GOP	6.83***	3.46***	2.18**	1.82*	0.94
GOP does not Granger cause GY	1.51	8.33***	5.99***	3.20***	2.13***
GY does not Granger cause GOP	0.23	1.98	1.06	1.50	0.81
GOP does not Granger cause GCPI	1.99	2.14*	1.40	2.45***	1.85**
GCPI does not Granger cause GOP	0.66	2.13*	1.32	1.53	1.12

Table 3a: Granger causality tests for GIR vs. country-specific IR 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	24
USIR does not Granger cause GIR	12.7***	7.78***	5.54***	2.91***	1.42
GIR does not Granger cause USIR	33.02***	4.82***	2.55***	1.21	0.97
EAIR does not Granger cause GIR	4.27***	5.69***	2.79***	1.10	0.97
GIR does not Granger cause EAIR	6.00***	2.39*	4.47	1.37	1.81***
CHIR does not Granger cause GIR	14.23***	9.24***	3.80***	3.24***	2.26***
GIR does not Granger cause CHIR	7.17***	4.81***	3.12***	3.24***	1.79***
INIR does not Granger cause GIR	0.39	0.44	0.52	0.35	0.48
GIR does not Granger cause INIR	0.15	0.33	0.18	0.30	0.36
JAPIR does not Granger cause GIR	0.84	0.57	0.89	2.36***	1.57*
GIR does not Granger cause JAPIR	1.99	3.13***	1.56	1.49	1.25

Table 3b: Granger causality tests for GM2 vs. country-specific M2 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	24
USM2 does not Granger cause GM2	7.98***	3.58***	2.32**	2.25**	1.92**
GM2 does not Granger cause USM2	0.06	1.31	0.63	0.62	0.85
EAM2 does not Granger cause GM2	0.34	1.11	1.23	0.90	0.95
GM2 does not Granger cause EAM2	0.00	1.47	1.13	1.20	1.30
CHM2 does not Granger cause GM2	7.41***	2.42*	1.17	1.17	1.44
GM2 does not Granger cause CHM2	0.97	0.49	0.82	0.81	1.10
INM2 does not Granger cause GM2	3.46*	1.10	1.63	1.30	0.81
GM2 does not Granger cause INM2	0.75	1.83	1.07	1.36	1.17
JAPM2 does not Granger cause GM2	5.73***	5.20***	2.94***	2.07**	1.10
GM2 does not Granger cause JAPM2	5.17***	4.59***	2.15*	1.63*	1.48*

Table 3c: Granger causality tests for GY vs. country-specific Y1999:1-2012:12 (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	24
USY does not Granger cause GY	0.29	2.02	5.39***	3.55***	2.27***
GY does not Granger cause USY	0.84	6.34***	3.07***	2.17**	1.51*
EAY does not Granger cause GY	1.87	2.88**	5.40***	3.57***	2.28***
GY does not Granger cause EAY	1.58	4.05***	1.34	2.07**	1.44
CHY does not Granger cause GY	0.01	4.66***	1.95*	1.28	1.40
GY does not Granger cause CHY	21.66***	1.37	0.99	1.51	1.57*
INYdoes not Granger cause GY	0.02	4.32***	2.21*	1.48	1.26
GY does not Granger cause INY	0.18	2.47*	1.68	1.11	1.32
JAPY does not Granger cause GY	2.29	3.24***	1.14	0.96	0.70
GY does not Granger cause JAPY	0.21	2.95***	2.52**	1.97**	1.62*

Table 3d: Granger causality tests for GCPI vs. country-specific CPI 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	24
USCPI does not Granger cause GCPI	3.06**	1.37	1.97	2.21**	1.00
GCPI does not Granger cause USCPI	1.74	1.70	0.68	1.26	1.20
EACPI does not Granger cause GCPI	2.94*	1.89	4.09***	2.25***	1.39*
GCPI does not Granger cause EACPI	3.33*	1.04	1.79	2.28***	2.24
CHCPI does not Granger cause GCPI	1.24	1.00	5.29***	6.75***	1.95**
GCPI does not Granger cause CHCPI	4.43**	12.60***	13.46***	4.28***	1.83**
INCPIdoes not Granger cause GCPI	3.56*	1.23	5.23***	4.13***	1.23
GCPI does not Granger cause INCPI	0.13	1.37	0.86	1.45	0.24
JAPCPI does not Granger cause GCPI	1.42	0.60	1.22	0.91	1.07
GCPI does not Granger cause JAPCPI	2.37	2.46*	1.65	1.80*	1.35

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 ($GM2_t$)	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 5. 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

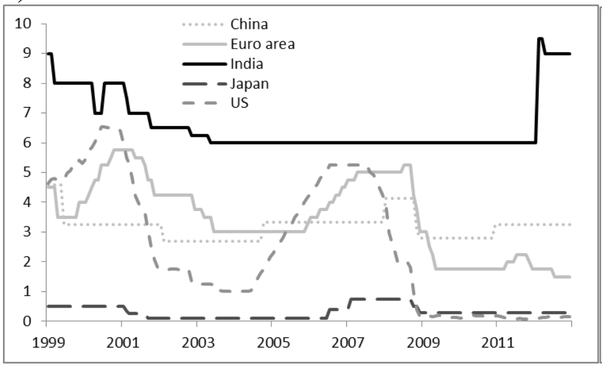
Alternative hypothesis: there are (r+1) cointegrating vectors

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

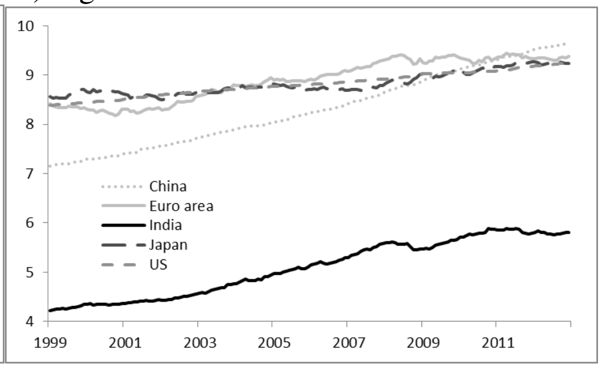
**MacKinnon-Haug-Michelis (1999) p-values

Figure 1

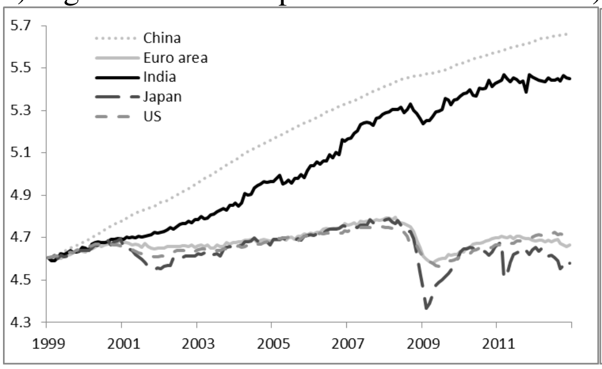
a)G5 Interest rate



b)Logs of G5 M2 in US dollars



c)Logs of G5 real output



d)Logs of G5 CPI

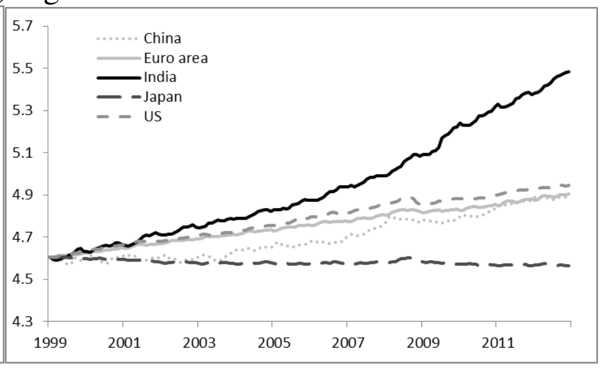


Figure 2. Scree plot (ordered eigenvalues) for global principal components

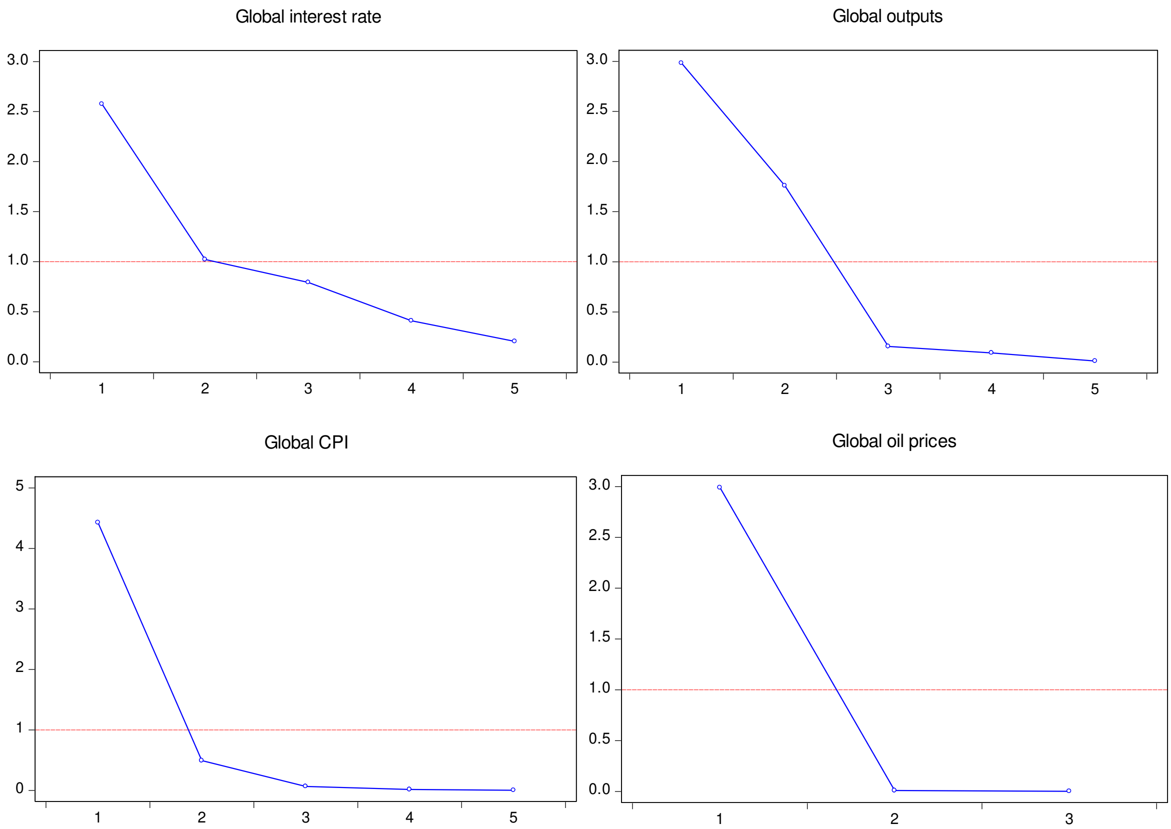
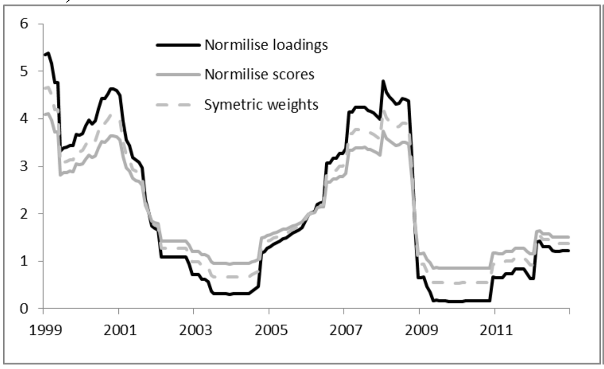
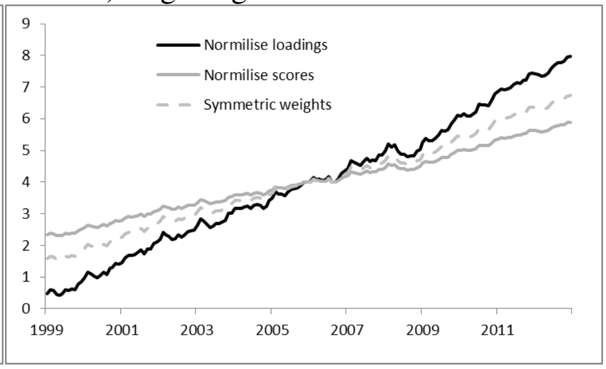


Figure 3. Global variables (principal components)

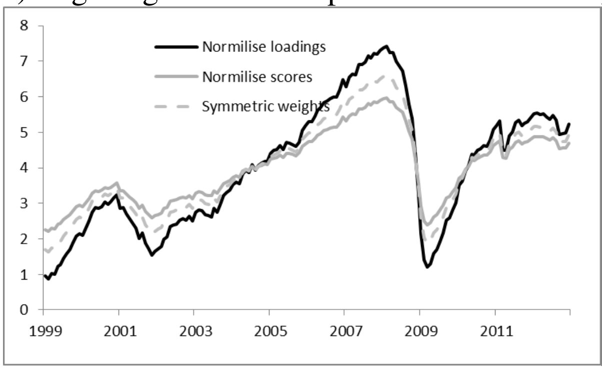
a) Global interest rate



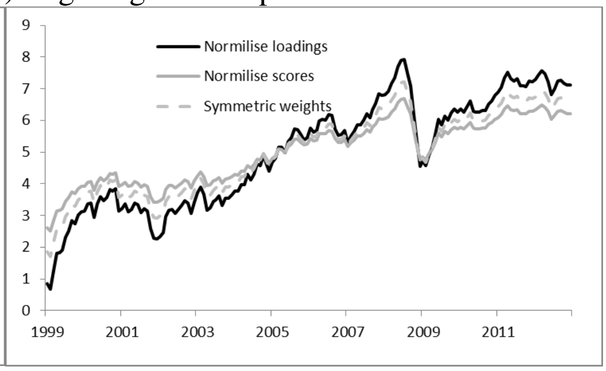
b) Logs of global CPI



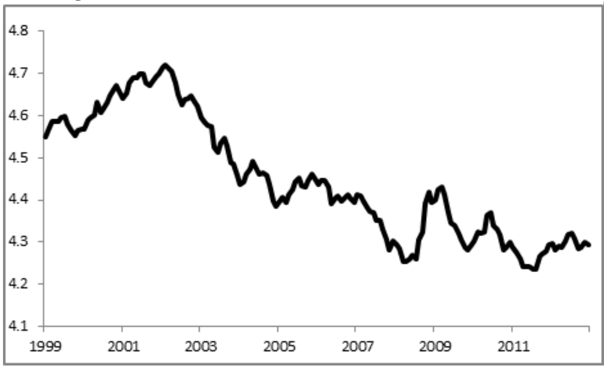
c) Logs of global real output



d) Logs of global oil prices



e) Logs of TWI of US dollar



f) Logs of global liquidity in US dollars

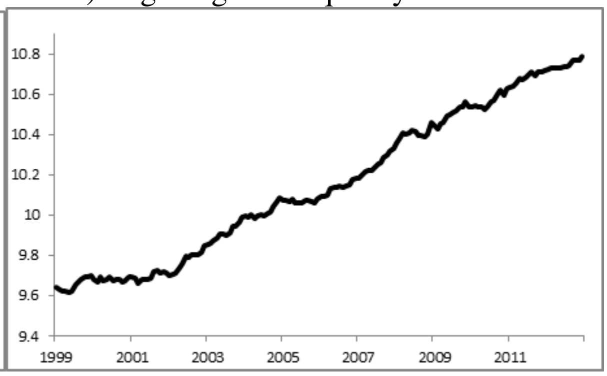


Figure 4a Responses of oil prices to global variables 1999:01 to 2012:12

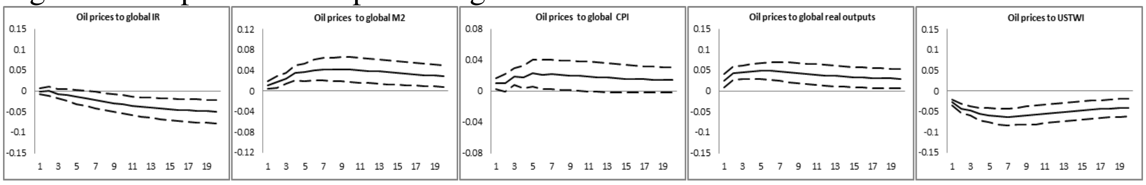
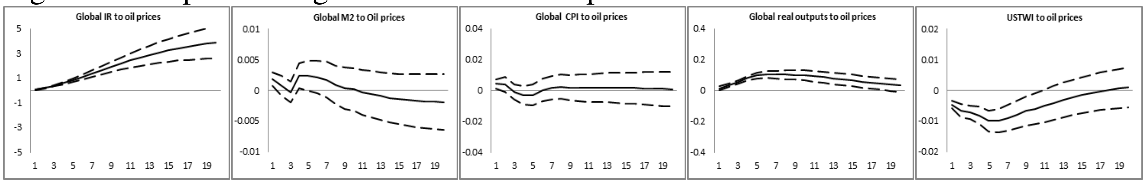


Figure 4b Responses of global variable to oil prices 1999:01 to 2012:12



Figures 5 Global principal components estimation: G5 vs. G8 largest economies.

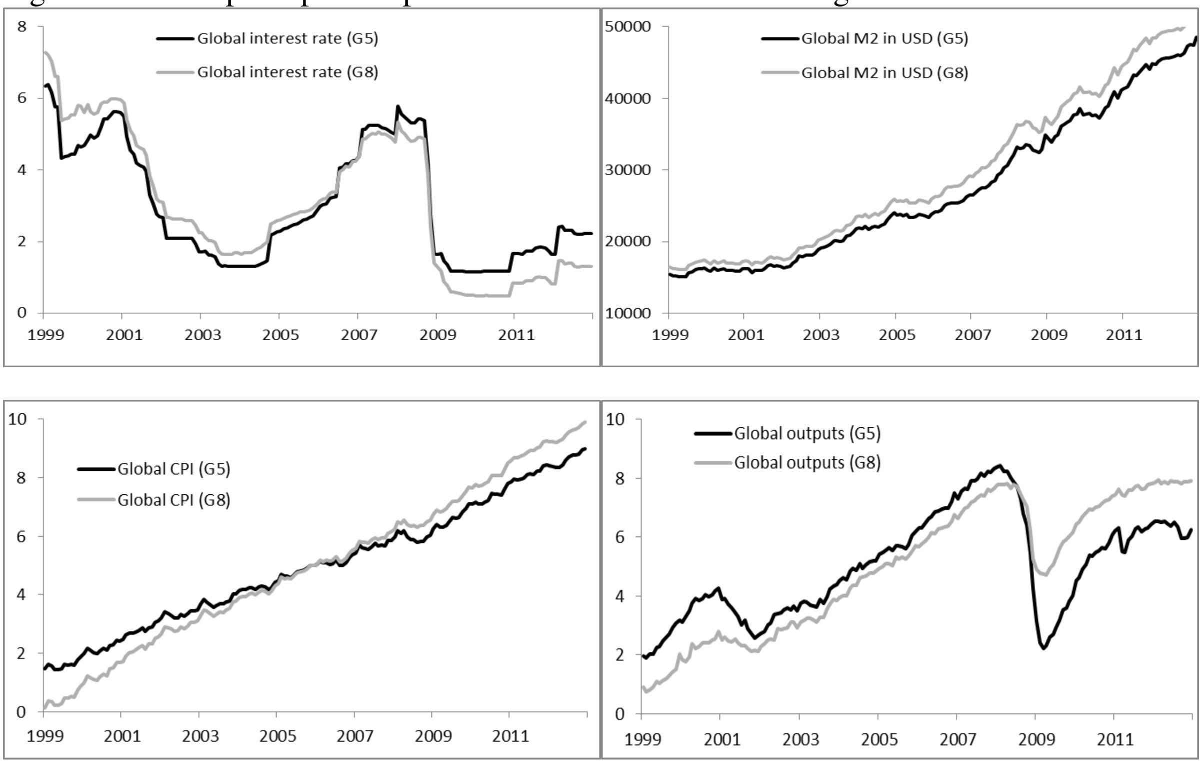


Figure 6a. Responses of oil prices to global variables 1999:01 to 2012:12 (G8 economies)

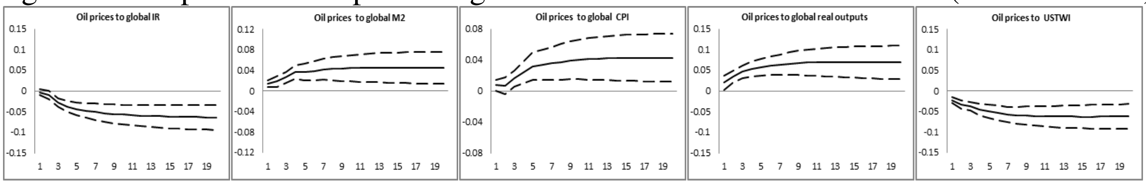


Figure 6b. Responses of global variables to oil prices 1999:01 to 2012:12 (G8 economies)

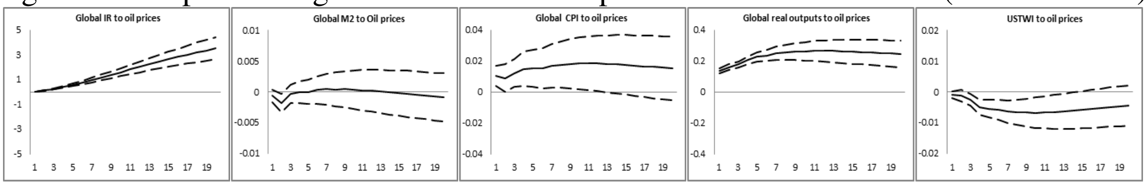


Figure 7a. Responses of oil prices to global variables 1999:01 to 2012:12 (contemporaneous restrictions)

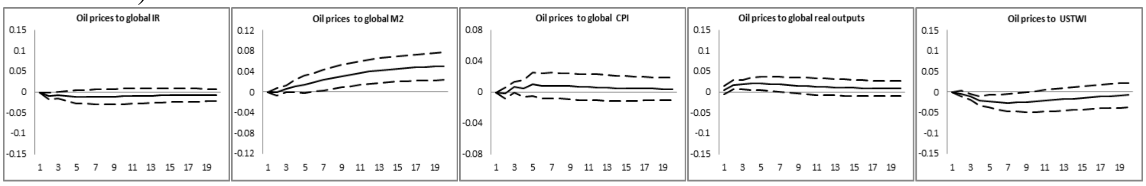


Figure 7b. Responses of global variables to oil prices 1999:01 to 2012:12 (contemporaneous restrictions)

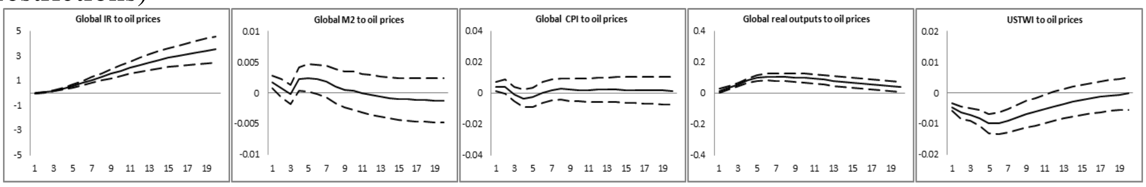


Figure 8a. Responses of oil prices to global variables 1999:01 to 2012:12 (normalise scores)

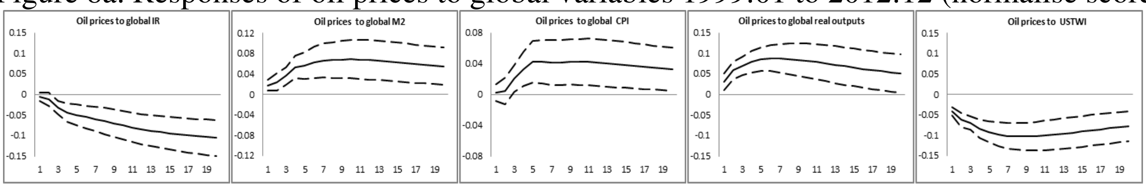


Figure 8b. Responses of global variables to oil prices 1999:01 to 2012:12 (normalise scores)