LUNDS UNIVERSITET
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Commodity Prices and Interest Rates: the Euro zone

Master Thesis

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Abstract

Commodity prices rose jointly to record levels during the past decade and it has been argued that this development is due to macroeconomic factors. Frankel has presented a theory which explains commodity prices to be negatively correlated to real interest rates. This paper empirically investigates if the real interest rate negatively affects commodity prices and if they exhibit overshooting characteristics, using the Euro real interest rate as a proxy for world interest rate. This is analysed by means of a VAR model, by which the output is used to specify impulse responses and variance decompositions. The obtained result is that the Euro real interest rate negatively affects commodity prices over the medium run. Moreover, the effect on commodity prices of a Euro real interest rate change is bigger than the like of the United States. Therefore the ECB must take into account the endogeneity of commodity prices when performing an effective monetary policy with the aim of keeping inflation level stable.

Keywords: Commodity price, Interest rate, Monetary policy, VAR, Euro

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Introduction

Commodity prices have surged over the last decade, increasing by 130% from 2002 to 2008 (Lustig 2009). A striking feature was that prices of different commodities rose jointly. Most commodity prices peaked in 2008, subsequently fell as the financial crisis hit the global economy, but have recently caught up with the pre-2009 development and reached new all-time highs. The effects have been riots in many developing countries, increased barriers to trade and rising inflation (CNN 2008, Lustig 2009). Moreover, high oil prices have often been held responsible for decreasing productivity and even recession (Barsky and Kilian, 2002). Even if each commodity would only marginally contribute to domestic price pressure, the inflationary impact of commodity prices could be sizable if they move together. Economists have presented theories regarding the causes of the recent rapid joint increase of commodity prices and central banks all over the world are discussing the issue.

Frankel (2008) argues that since commodity prices rose across the board the explanation is macroeconomic, rather than, for example, demand related or stemming from idiosyncratic shocks such as bad weather. Bordo (1980) shows empirically that prices of raw material respond more quickly to monetary growth than manufactured goods. As commodity prices are flexible they accurately reflect monetary policy and since commodity prices are global and increasingly financialized, they should reflect global monetary policy and the monetary policy of the most important economies such as the US and the Euro zone. Indeed, Roache and Rossi (2009) have showed that the increased financialisation of commodity prices in recent years has increased their sensitivity to macroeconomic news. Frankel (2006) and Webb (1988) suggest that commodity prices should be an indicator of monetary policy since they predict inflation. Svensson (2005) agrees that commodity prices, and oil in general, are important components of the CPI and knowledge of the evolution of prices and its driving forces is therefore crucial to conduct effective monetary policy.

Frankel (1986, 2006) presents the hypothesis that commodity prices are negatively correlated to interest rates. He describes a number of channels related to the opportunity cost of investing in real assets, according to which an expansionary monetary policy can cause an increase in commodity prices. His theory is supported by Calvo (2008) and Hamilton (2009), who argue that an explanation for the high commodity prices are the persistently low interest rates, which encourage investors or speculators to shift out of treasury bills and into other liquid assets such as commodities. Krichene (2008) also argues that the simultaneous price increases during 2003-2007 were the effect of a common monetary shock. The overly global expansionary monetary policy led to an increase of all types of credits and the supply constraints coupled with an increased demand caused commodity prices to increase.

The purpose of this thesis is to investigate to what extent the Euro real interest rate, as a proxy for world interest rate, affects world commodity prices. The hypothesis is, in line with Frankel (1986, 2006): there is a negative correlation between real interest rates and commodity prices and in addition, prices respond to interest rate changes by overshooting the equilibrium price. This thesis replicates the work of Akram (2009) which concerns the US real interest rate and investigates the behaviour of commodity prices. His finding is that the US real interest rate negatively affects commodity prices. The article was chosen because it uses well documented econometric methods and has a clear focus area, the United States, which was well suited to adapt to the Euro area. Akram uses US variables of real interest rate and real exchange rate, while there is little research treating the Euro area and commodity prices. The economic importance of the Euro area has grown in recent years in relation to the expansion of the Euro zone and increased usage of the Euro. Since the Euro area is the world's largest trading block (European Commission) there is reason to believe that commodity prices may respond to Euro zone monetary policy.

The model used in this thesis is the same as Akram's (2009): a vector autoregressive (VAR) model, which is commonly used to address questions such as how the economy responds to different economic shocks. Three different VAR models are estimated, which all contain the following four variables: global output (YO), real interest rate (RI), real exchange rate (REX), crude oil price (PCO) and each of them also contain one of the following three variables: food price index (PCF), metal price index (PCM) or industrial price index (PCI). As in Akram (2009), the output of the VARs is used to obtain impulse responses in order to quantify the reaction of an exogenous shock to each variable in the model and to estimate variance decomposition that indicates the individual contributions in a VAR to the modelled variables. The analysis shows that there is a negative correlation between commodity prices and the real interest rates: in response to a 1% increase of the real interest rate oil price decrease by 0.05-0.12%, metals price decrease by 0.12% and industrial prices decrease by 0.12%.

The thesis is structured as follows: in the first section a background regarding commodity prices is presented. After that the Frankel (1986, 2006) theory of overshooting commodity prices is derived followed by a presentation of econometric method and data description.

Lastly, empirical results are presented of the VARs, followed by impulse responses and variance decompositions, as well as a discussion of its implications.

Background

Commodities have always been a fluctuating asset, and a source of concern for policy makers. In the 1970's discussions concerned the oil price shocks and in the 1980's the gold standard was again debated as an alternative monetary regime (Frankel 2006). The recent sharp price increases brought back discussions on determinants of commodity prices to the fore. Disagreements exist between researchers. One theory is that the strong economic growth in the 21st century has increased demand for raw materials from emerging markets. High demand coupled with supply constraints caused an upward pressure on commodity prices (Cevik and Sedik, 2011). Destabilizing speculation is another explanation, IFPRI (2008) have suggested that commodity speculation may be a contributory factor in recent agricultural price rises and have suggested market-calming regulations. Another key driver of the increase in food commodity prices could be, as a response to tariffs and subsidies in the US and Europe (legislation passed in 2005 and implemented in 2006 (Lustig 2009)), that an increased share of maize, corn and oil sales is substituted from food usage to biofuel. Various researches show that these contributory price increases are quantitatively significant (see e.g. Mitchell, 2008). Since all commodity prices have increased more or less simultaneously, it is suggested that price linkages between commodities can lead to co-movements of prices. Baffes (2007) suggests that a link between oil and non-energy commodity prices exists via transportation cost and fertilizer prices because the production of fertilizers is energy-intensive.

It has been noted that there are exchange rate effects on commodity prices. One of the first to observe the link between commodity prices and macroeconomic factors was Schuh (1974) who argued that one should take into account the exchange rate when investigating commodity prices. As most commodities are invoiced in US dollars, exporters may wish to stabilize their purchasing power by raising prices in periods of US dollar weakness. On the demand side, dollar depreciation also implies a lower commodity price for importers whose currency has appreciated against the dollar, who will increase their demand for commodities, which in turn leads to higher prices (Akram 2009). Mitchell (2008) investigates the exchange rate effect by calculating its effect on food prices. By taking into account the elasticity of the pass-through effect, the price increase of food due to decline of the dollar between 2002 and

2008 was calculated to be 20%. Abbott et. al. (2008) emphasise the importance of the depreciation of the dollar as an explanation for commodity price increases in general.

Commodities are mostly prized and traded in dollars and if measured in dollars all commodity prices have increased substantially in the recent decade. Figure 1 shows a steep increase from the bottom reached in 2002 to the all time high in 2008, which is less spectacular when looking at the commodity index in Euros.

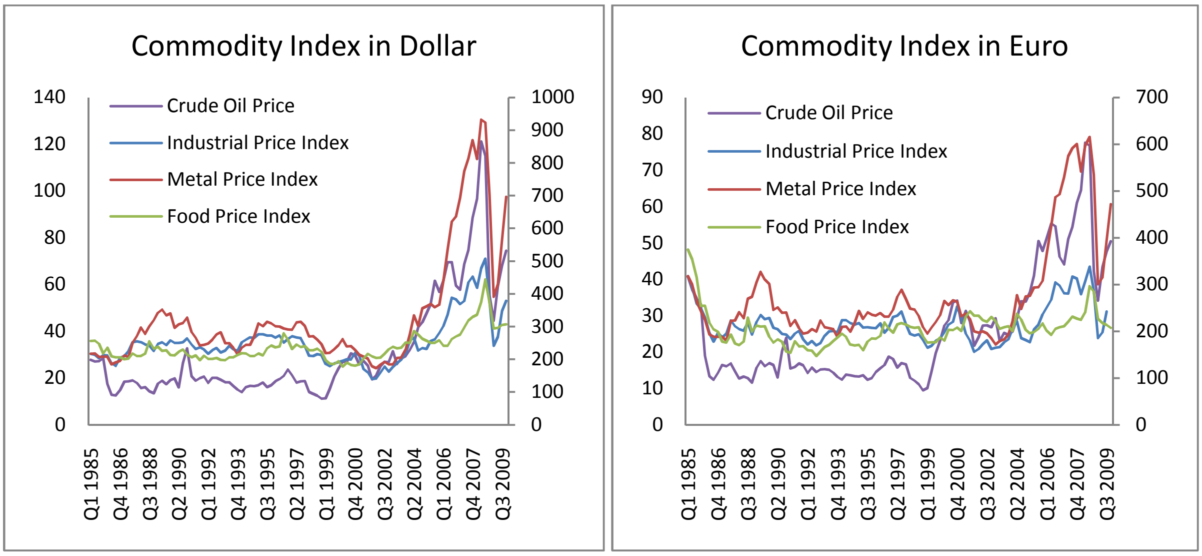

Figure 1 Nominal commodity prices in Dollars and Euros respectively. Oil prices on the right hand axis. Source: CRB, Thompson Reuters, OECD. See Appendix 4 for information on variables.

Measuring commodity prices in US dollar can be misleading since the dollar exchange rate has fluctuated against a range of currencies over the last decades where the latest price increase coincides with a depreciation of the dollar (Gilbert, 2010). World Bank (2010 p.6) writes that during the recovery of commodity prices in 2009 "Dollar price increases also reflected the depreciation of the dollar against major currencies. Yet, expressed in trade-weighted local currency indices, prices rose by much less." The dollar makes commodity prices look more volatile than they are (Mundell, 2002). Using Euro exchange rate would remove dollar volatility from commodity prices, accurately portray economic information and contribute to the field of research. As mentioned, there is not much research treating commodity prices and the Euro, but Cuddington and Liang (2000) argue ex ante that the establishment of the Euro is expected to reduce the volatility of world commodity prices.

Theory

Frankel (1986, 2006) develops a theory that commodity prices are closely and negatively related to interest rates. The relation is such that prices will temporarily adjust to a value above (below) equilibrium in response to a decrease (increase) in the real interest rate, which is to overshoot the equilibrium value. This is fundamentally due to the idea first presented by Okun (1975), that the economy exists of flexible and fixed prices. In Frankel's model commodity prices are flexible while manufacture prices are fixed in the short run. There are a number of channels through which the interest rate negatively affects commodity prices (Frankel 2006):

- Low interest rates decrease the incentive to extract commodities today rather than tomorrow, as the cost and risk of holding inventories "in the ground" decreases, thereby reducing supply.
- Low interest rates reduce the opportunity cost of holding inventories, thereby reducing supply.
- Low interest rates reduce the carrying cost of speculative positions, making it easier to bet on assets such as commodities. Speculators shift out of treasury bills and into commodity contracts and the increased demand puts upward pressure on future and spot prices.

Consider the example of a 1% monetary expansion illustrated in Figure 2. In the long run we expect all prices to increase by 1%, holding everything else equal (Figure 2a). But in the short run prices of manufactured goods are fixed, so the increase in nominal money supply is an increase in real money supply. The real interest rate will temporarily decrease 1% to r_1 (Figure 2b), either via a fall in the nominal interest rate or an increase in expected inflation, in order to equilibrate money demand. But there is an arbitrage condition: since commodities are storable, the rate of return on interest bearing assets cannot be smaller than commodity prices less storage cost and adjusted for the risk of carrying inventories. Due to the monetary expansion commodity prices, which are flexible, will increase today. But they must increase more than the 1% expected in the long run due to the arbitrage condition which creates expectations of a lower prospective yield in level with the lower real interest rate. Commodity prices thus increase until considered overvalued (at q_1 in figure 2b), thereby fulfilling expectations of a lower prospective yield in level with the lower interest rate (and the other costs of carrying inventories such as storage plus risk premium). Only when expected returns are in balance are firms willing to hold the required level of inventories. Yield expectations will turn out to be rational since the general price level increases with time as the real increase of the monetary level attenuates and its effects on the real interest rate and real price of commodities disappear.

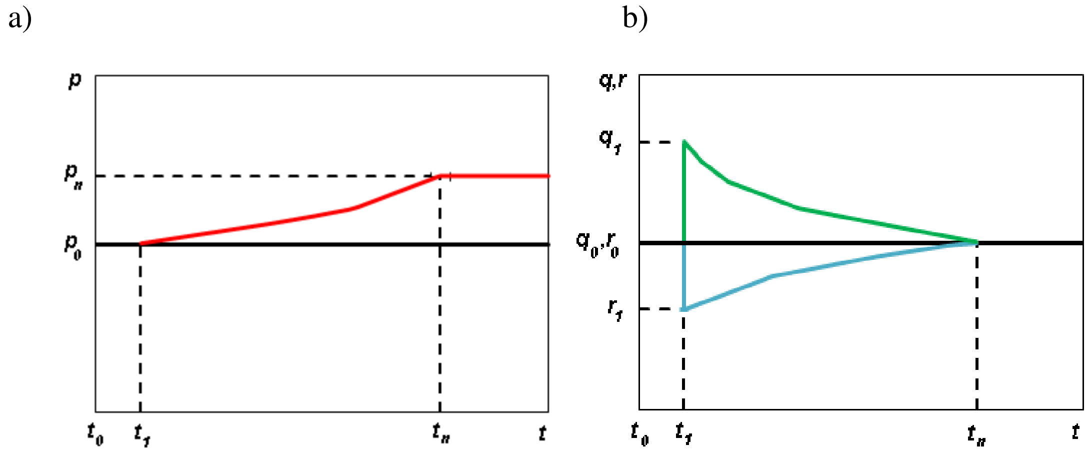

Figure 2a,b. Effect of a monetary expansion. The price level will gradually increase 1% after a 1% monetary expansion. The real interest rate will immediately decrease 1% to equilibrate money demand. Real prices of commodities increase more than 1% to fulfil expectations of lower prospective yield. (Frankel 1986,2006)

The formal model which describes the scenario above is derived in by Frankel (1986, 2006) and built upon the overshooting model of exchange rates first laid out by Dornbusch (1976). Commodities are assumed to be homogenous and storable and posit the following relation to the interest rate:[1]

$$i = \dot{p}_c^e + c \quad (1)$$

where i is the short-term nominal interest rate, $\dot{p}_c^e$ is the expected rate of change of the commodity price and $c = cy - sc - rp$ where cy is the convenience yield from holding the stock (e.g. the insurance value of holding some critical input to production), sc is the storage costs and rp is the risk premium of holding inventories (which is positive if holding inventories is risky). The equation above states the return from holding the commodity for another period, either leaving it in the ground or holding it in inventories, keeping prices constant. Manufactured prices are fixed and adjust only slowly to economical changes according to the formula:

$$\dot{p}_m = \pi(d - \bar{y}_m) + \mu \quad (2)$$

[1] Following the outline by Florez (2010)

where d is the expected log of demand for manufactures, $\bar{y}_m$ is the log of potential output in manufactures and μ is the expected rate of inflation. Excess demand is defined as an increasing function of the price of commodities relative to manufactures and a decreasing function of the real interest rate:

$$d - \bar{y}_m = \delta(p_c - p_m) - \sigma(i - \mu - \bar{r}) \quad (3)$$

where $\bar{r}$ is a constant term. The long-run equilibrium is defined when there is zero excess demand, the relative price of the commodities and manufactures are constant and the real interest rate becomes $\bar{r}$. Substituting (3) into (2):

$$\dot{p}_m = \pi\big(\delta(p_c - p_m) - \sigma(i - \mu - \bar{r})\big) + \mu \quad (4)$$

The money demand equation is the simple form:

$$m - p = \Phi y - \lambda i \quad (5)$$

Where m is the log of nominal money supply, p is the log of the overall price level, y is the log of total output Φ is the elasticity of money demand with respect to output and λ is the semi-elasticity of money demand with the respect of interest rate. The aggregate price level is an average of manufacture prices with weight α and commodity price with weight $(1 - \alpha)$:

$$p = \alpha p_m + (1 - \alpha) p_c \quad (6)$$

Substituting (5) into (6):

$$m - \alpha p_m - (1 - \alpha) p_c = \Phi y - \lambda i \quad (7)$$

The long-run version of the money demand equation is:

$$\bar{m} - \alpha \bar{p}_m - (1 - \alpha) \bar{p}_c = \Phi \bar{y} - \lambda \bar{\imath}$$

Using the result of the long-run real interest $i - \mu = \bar{r}$ we have:

$$\bar{m} - \alpha \bar{p}_m - (1 - \alpha) \bar{p}_c = \Phi \bar{y} - \lambda(\bar{r} + \mu) \quad (8)$$

Taking the difference of (7) and (8):

$$\alpha(p_m - \bar{p}_m) + (1 - \alpha)(p_c - \bar{p}_c) = \lambda(i - \mu - \bar{r}) \quad (9)$$

where it is assumed no changes in the money supply ($m = \bar{m}$) and fixed output at potential output ($y = \bar{y}$). We combine equation (1) and (9):

$$\dot{p}_c^e = \frac{\alpha}{\lambda}(p_m - \bar{p}_m) + \frac{(1-\alpha)}{\lambda}(p_c - \bar{p}_c) + \mu + \bar{r} - c \qquad (10)$$

Combining equations (4) and (9), and using normalization ($\bar{p}_c - \bar{p}_m = 0$):

$$\dot{p}_m = \pi\left(\delta[(p_c - \bar{p}_c) - (p_m - \bar{p}_m)] - \frac{\sigma}{\lambda}\alpha[(p_m - \bar{p}_m) + (1-\alpha)(p_c - \bar{p}_c)]\right) + \mu$$

$$\dot{p}_m = \pi(p_c - \bar{p}_c)\left[\delta - \frac{\sigma(1-\alpha)}{\lambda}\right] - \pi(p_m - \bar{p}_m)\left[\delta - \frac{\sigma\alpha}{\lambda}\right] + \mu \qquad (11)$$

The model is closed by assuming rationality: $\dot{p}_c = \dot{p}_c^e$.

The differential between (10) and (11) is written in matrix form by Frankel in which he solves for and finds the characteristic roots (θ). Using the negative characteristic roots ($-\theta$) which guarantee that the system is stable, the solution can be written as:

$$\dot{p}_m = -\theta(p_m - \bar{p}_m) + \mu$$

$$\dot{p}_c = -\theta(p_c - \bar{p}_c) + \mu + \bar{r} + c \qquad (12)$$

Using the arbitrage condition (1) and that $i - \mu = \bar{r}$ (12) can be rewritten as:

$$\dot{p}_c = -\theta(p_c - \bar{p}_c) + \dot{p}_c^e$$

Assuming that $\dot{p}_c = \dot{p}_m = \dot{p}$

$$\dot{p}_c = -\theta(p_c - \bar{p}_c) + \dot{p}^e \qquad (13)$$

Equation (13) is the same as the Dornbusch overshooting model, but with the price of commodities in place for price of foreign exchange and with the convenience yield in place for the foreign interest rate. It represents the arbitrage condition; the difference between keeping the commodity for another period of time, or selling it at today's price and receiving interest. In equilibrium the expected return from selling today and keeping another period should be the same (see equation (1)). Expressing (13) in real terms:

$$\dot{p}_c^e = -\theta(q - \bar{q}) + \dot{p}^e \qquad (14)$$

Where $(q = p_c - p)$ and $\bar{q}$ is the long-run equilibrium real price of the commodity. If the commodity is not lying on its long-run value, it should move back to the equilibrium value over time with the speed of θ. Combining (14) with (1):

$$q = \bar{q} - \frac{1}{\theta}(i - \dot{p}^e - c)$$

And can be rearranged as:

$$q - \bar{q} = -\frac{1}{\theta}(i - \dot{p}^e - c) \qquad (15)$$

which says that the real price of a commodity is determined by the speed of adjustment parameter θ and inversely related to the real interest rate relative to the cost of holding inventories (remember that $(c = cy - sc - rp)$). Frankel (2006 p. 298) writes "when the real interest rate is low, as in 2001 to 2005, money flows into commodities, just as it flows into foreign currencies, emerging markets and other securities. Only when the prices of these alternative assets are perceived to lie sufficiently above their future equilibriums will the arbitrage condition be met." The reason for the overshooting, that is to take on a value above equilibrium, is that commodities adjust rapidly to monetary changes, while prices of manufactures adjust slowly. Equation (15) is used to compute a VAR model in order to econometrically investigate the effect of real interest rate on commodity prices.

Econometric Method

The empirical analysis is based on a vector autoregressive (VAR) model, which is commonly used to address questions such as how the economy responds to different economic shocks. A VAR describes the dynamic evolution of a number of variables from their common history and the advantage of using it is that it considers the variables simultaneously and can therefore be parsimonious and include fewer lags. It is one way of modelling endogeneity between variables in time series, a form of regression where all variables in a vector are regressed with lagged variables of each other. The VAR models used is the exact same as Akram (2009) uses, namely 3 different VARs consisting of five variables all expected to influence commodity prices based on economic theory and previous research. Written in matrix form the model looks as equation 16:

$$\begin{pmatrix} YO_t \\ RI_t \\ REX_t \\ PCO_t \\ PCX_t \end{pmatrix} = \begin{pmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{pmatrix} + \begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \theta_{14} & \theta_{15} & \theta_{16} & \theta_{17} & \theta_{18} & \theta_{19} & \theta_{20} \\ \theta_{21} & \theta_{22} & \theta_{23} & \theta_{24} & \theta_{25} & \theta_{26} & \theta_{27} & \theta_{28} & \theta_{29} & \theta_{30} \\ \theta_{31} & \theta_{32} & \theta_{33} & \theta_{34} & \theta_{35} & \theta_{36} & \theta_{37} & \theta_{38} & \theta_{39} & \theta_{40} \\ \theta_{41} & \theta_{42} & \theta_{43} & \theta_{44} & \theta_{45} & \theta_{46} & \theta_{47} & \theta_{48} & \theta_{49} & \theta_{50} \\ \theta_{51} & \theta_{52} & \theta_{53} & \theta_{54} & \theta_{55} & \theta_{56} & \theta_{57} & \theta_{58} & \theta_{59} & \theta_{60} \end{pmatrix} *$$

$$\begin{pmatrix} YO_{t-1} & YO_{t-2} \\ RI_{t-1} & RI_{t-2} \\ REX_{t-1} & REX_{t-2} \\ PCO_{t-1} & PCO_{t-2} \\ PCX_{t-1} & PCX_{t-2} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{pmatrix} \quad (16)$$

where ε_{it} is assumed to be white noise. YO is global output, RI is real interest rate, REX is euro real exchange rate, PCO is real price of crude oil and PCX is real price of food, metals or industrials depending on which of the three alternative VARs is estimated. All variables are in logs and seasonally adjusted.

We need to impose stationarity on the series in order to make inference on the coefficients estimated by the VAR. Doing a simple plot of series shows that they are to a large extent trending and one may therefore suspect that non-stationarity is present. The existence of stationarity or non-stationarity could be investigated by a vector error correction model (VECM) which is used to find cointegration. Since that type of inference is not the aim of this thesis and I am following the procedure of Akram (2009) who is not estimating the VECM, it is not investigated further in this paper. In order to facilitate interpretation of the dynamics of the VAR, impulse response and variance decomposition is applied.

Impulse response is a simulation which shows the short run adjustment to shocks in terms of a standard error increase in ε_{it} keeping all variables at date t and before constant. A Choleski factorization is used, which ensures a strict causal ordering in the contemporaneous relationships between the endogenous variables. The variable most affected by the others is ordered last in the model. This formulation ensures that the shocks are independent of each other. Without economic theory on the dynamics of the group there is no rationale for the ordering of the residuals, therefore when choosing the ordering we make assumptions on the relations. By means of economic theory the order of the shocks are as in Akram (2009) in equation 17:

$$e_t = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{yo} \\ \varepsilon_{ri} \\ \varepsilon_{rex} \\ \varepsilon_{pco} \\ \varepsilon_{pcx} \end{bmatrix} \quad (17)$$

where the “*” stands for parameter values and “0” represents that the associated fundamental shock does not contemporaneously affect the corresponding endogenous variable. Non-energy commodity prices are placed last based on the assumption that commodity market shocks have no contemporaneous effect on the macroeconomic variables placed above. Global output is placed first, which assumes that demand shocks instantaneously affect all equations in the system. This particular order is suggested by Bernanke et al. (2005) and used in other economic research treating commodity prices (see eg. Lombardi et al. 2010). It insures that the estimated impact of the last variable, which is the focus, is produced by the joint impact of other macroeconomic variables.

Having looked at how variables react to economic shocks, further information can be gained from investigating variance decomposition. Variance decomposition of shocks show individual contributions in a VAR to the modelled variables. It investigates how much of the forecast error variance of a given variable can be explained by exogenous shocks to the other variables and the importance of a variable’s shock on each endogenous variable can be analysed. The same Choleski factorization as explained for impulse responses is used in variance decomposition.

Data description

The sample consists of quarterly data series from 1985Q1 to 2009Q4. Given that we don’t have a global variable for real interest rate the Euro interest rate is used as a proxy. The real interest rate is calculated by subtracting the quarterly inflation rate, calculated from the quarterly harmonized index of consumer prices (HICP), from the short term interest rate. Since the Euro area is chosen for analysis, the real exchange rate is the real effective exchange rate (REER) of the Euro. World output is proxied by the OECD industrial production. The real price of crude oil is calculated by transforming the spot price in USD per barrel into Euro by multiplying it with the Euro(17)/USD exchange rate and converted into real values by deflating the price by HICP. The food, metal and industrial indexes are measured in USD and transformed into Euro by multiplication with the Euro(17)/USD exchange rate and converted into real values by deflating the price by HICP. All variables appear in logs and are seasonally adjusted.

Table 1 shows information regarding time series. The variables from left to right are: real price index of food, real price index of industrials, real price index of metal, real crude oil price, real exchange rate, real interest rate and global output. The Jarque-Bera test of normality shows us that PCI, PCM, PCO and REX are normally distributed.

	PCF	PCI	PCM	PCO	REX	RI	YO
Mean	5.322873	5.366866	5.573452	3.119343	4.693890	1.451998	4.418982
Median	5.254753	5.368977	5.499797	3.051497	4.677516	1.460921	4.448585
Maximum	6.305449	6.135354	6.164511	4.103892	4.863873	2.457475	4.690977
Minimum	5.066801	4.953774	5.045357	2.215993	4.549798	-1.804023	4.129998
Std. Dev.	0.225151	0.230303	0.279350	0.436432	0.074997	0.729749	0.164567
Skewness	2.164448	0.480219	0.495651	0.422423	0.197482	-1.230908	-0.126862
Kurtosis	8.633640	3.649191	2.604130	2.447507	2.241291	5.849063	1.771618
Jarque-Bera	210.3218	5.599547	4.747467	4.245887	3.048485	59.07372	6.555408
Probability	0.000000	0.060824	0.093132	0.119679	0.217786	0.000000	0.037715
Sum	532.2873	536.6866	557.3452	311.9343	469.3890	145.1998	441.8982
Sum Sq. Dev.	5.018613	5.250892	7.725601	18.85684	0.556837	52.72082	2.681151
Observations	100	100	100	100	100	100	100

Table 1 Descriptive statistics of data sample used for estimation of VAR models

Lag Selection

Information criterion is a common method used to determine lag length in a model. It provides a trade-off between goodness-of-fit and the simplicity of the model. The most common information criteria are Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC), where the model showing the lowest AIC or BIC in absolute value is preferred. BIC is considered to favour more parsimonious models than AIC, because penalty for the number of regressors is higher for BIC than AIC (Verbeek, 2009), so I use BIC to decide the number of lags. As seen in Table 2 each VAR is specified using 2 lags.

	VAR with PCF	VAR with PCM	VAR with PCI
AIC	4	4	3
BIC	2	2	2

Table 2 Lag selection, tested for up to 5 lags.

VAR model

5 equations are estimated simultaneously in the VAR(2) models, all of them considered endogenous and dependent both on its own and other's variables lags. The estimated VARs contains variables in logs of global output, real interest rate, real exchange rate, real crude oil

price, and one of the following price indexes: real food price, real metal price or real industrial price. Estimation technique is ordinary least squares (OLS). Output of the VAR including metal price index is presented in Table 3.[2] For output of the other two VARs, see Appendix 1.

Global output is positively affected by global output in the first quarter, and negatively in the second quarter, implying that the effect rapidly disappears. Output is negatively related to the real interest rate, as expected by economic theory. It is negatively related to oil price in the first lag by a small coefficient, a relation which turns positive in the second lag. It is negatively related to metal prices as is expected. The real interest rate is strongly and positively affected by global output, the parameters are big. The real interest rate is positively affected by oil price and metal price, most likely in order to mitigate increased inflation. Crude oil is positively and strongly related to global output showing big parameters and positively affected by metal prices, implying cross-price effects. The relation of metal price index to global output is positive, consistent with theory. The relation to the real interest rate is of the expected sign in the first lag, but the estimate is small. Metal prices are affected positively by oil price, which gives evidence of cross-price effects.

The two VARs presented in Appendix 1 are similar in output. In order to further investigate the dynamics of the VAR model we turn to impulse response analysis and variance decomposition.

	Global Output	**Real Interest Rate**	**Real Exchange Rate**	**Crude Oil Price**	**Metal Price Index**
Global Output (-1)	1.603698***	10.14874***	-0.249929	1.346634	4.285646***
	(0.10877)	(2.83505)	(0.27475)	(1.81094)	(0.99229)
	[14.7436]	[3.57974]	[-0.90967]	[0.74361]	[4.31894]
Global Output (-2)	-0.640232***	-9.693044***	0.242243	-1.182887	-4.239101***
	(0.10403)	(2.71149)	(0.26277)	(1.73201)	(0.94905)
	[-6.15417]	[-3.57480]	[0.92188]	[-0.68295]	[-4.46670]
Real Interest Rate (-1)	-0.013267***	0.381300***	0.003615	-0.089014	-0.018601
	(0.00382)	(0.09948)	(0.00964)	(0.06354)	(0.03482)
	[-3.47602]	[3.83292]	[0.37494]	[-1.40081]	[-0.53423]
Real Interest Rate (-2)	0.001787	0.874700***	0.001837	0.018590	-0.023280

[2]If there is stationarity in the series statistical inference would become invalid, therefore interpret the parameters of the VAR with caution. The VAR model itself is not problematic; a VECM which would be used in the presence of non-stationarity is simply a conversion of a VAR.

	(0.00412)	(0.10740)	(0.01041)	(0.06861)	(0.03759)
	[0.43361]	[8.14407]	[0.17645]	[0.27096]	[-0.61929]
Real Exchange Rate (-1)	0.001446	0.529829	1.245379***	-0.036718	-0.196855
	(0.04221)	(1.10011)	(0.10661)	(0.70272)	(0.38505)
	[0.03426]	[0.48161]	[11.6814]	[-0.05225]	[-0.51124]
Real Exchange Rate (-2)	0.003173	-1.848712	-0.319326***	0.118164	0.617816
	(0.04301)	(1.12101)	(0.10864)	(0.71607)	(0.39236)
	[0.07377]	[-1.64914]	[-2.93937]	[0.16502]	[1.57460]
Crude Oil Price (-1)	0.004908	0.042767	0.009031	0.992896***	0.089344
	(0.00692)	(0.18033)	(0.01748)	(0.11519)	(0.06312)
	[0.70935]	[0.23717]	[0.51681]	[8.61995]	[1.41557]
Crude Oil Price (-2)	-0.011085	0.050364	0.001540	-0.170425	-0.060603
	(0.00681)	(0.17754)	(0.01721)	(0.11341)	(0.06214)
	[-1.62725]	[0.28367]	[0.08951]	[-1.50275]	[-0.97524]
Metal Price Index (-1)	-0.024416**	0.834332***	0.035598	-0.075269	0.686348***
	(0.01206)	(0.31426)	(0.03045)	(0.20074)	(0.10999)
	[-2.02505]	[2.65494]	[1.16888]	[-0.37496]	[6.23995]
Metal Price Index (-2)	0.026663**	-0.787891***	-0.031020	0.182430	0.246464**
	(0.01220)	(0.31795)	(0.03081)	(0.20310)	(0.11129)
	[2.18567]	[-2.47801]	[-1.00671]	[0.89824]	[2.21468]
C	0.165043**	3.148597	0.317221	-1.055233	-1.853062**
	(0.09918)	(2.58499)	(0.25051)	(1.65121)	(0.90477)
	[1.66410]	[1.21803]	[1.26629]	[-0.63907]	[-2.04810]

Table 3 Output of VAR including metal price index. Standard errors in () and t-statistics in []. Includes 98 observations after adjustments. *** denotes significance of the estimate at $\boldsymbol{\alpha = 1}$%, ** denotes significance of the estimate at $\boldsymbol{\alpha = 5\%}$ and * denotes significance of the estimate at $\boldsymbol{\alpha = 10\%}$.

Impulse Response Analysis

The impulse response functions are based on estimates from each of the three VAR models and with a Choleski order as specified above. Impulse responses trace the dynamic of a standard error random shock of an independent variable to a dependent variable, in this case modelled 50 quarters ahead. Asymptotic normally distributed 95% confidence intervals are provided for inference.[3] These are shown in graphs as dashed red lines. Graphs show on the X-axis each quarter and on the Y-axis the magnitude of responses in % deviation from equilibrium to one standard error random shock. Graphs showing shocks to the VAR that includes metal price index are presented in full and after the results are discussed and compared to Akram (2009).

[3] Asymptotic normally distributed confidence intervals can exhibit bad small sample properties (Kilian, 1998). I tried Monte Carlo but got unreasonable results, most likely I have too few observations.

A positive shock to world output is presented in Figure 3, column 1. The shock is significant for 6 quarters and leads to a higher real interest rate, which is significant for 9 quarters. The exchange rate, defined here as domestic currency per foreign currency, depreciates over 3 quarters. Oil price increases by 0.07% for a year and metal prices increase by 0.08% over 5 quarters. All effects due to an output shock are found to be significant only in the short run. The second column in Figure 3 shows responses to a shock to the real interest rate, which takes on a higher value during 8 quarters. A positive shock to the real interest rate depresses economic activity over the medium run by -0.02%, an effect which is significant over 15 quarters. Effects on the exchange rate are insignificant. The real interest rate increase causes oil price decrease over 12 quarters by -0.11% and metal prices decrease over 13 quarters by the same size. The third column presents a shock to the exchange rate. The effect on oil price of an exchange rate shock is insignificant, while metal prices increase due to the depreciation by 0.15%.

Consider shocks to commodity prices in Figure 4. In column 1, a shock, which increases the oil price, depresses economic activity over the quarters 5-10 of -0.008%. Effect on the real interest rate and exchange rate is insignificant. A positive spill-over effect is found on metal prices which increase over 3 quarters by 0.02%. In column 2 a shock to metal prices depresses global output over a 1 year horizon and increases the real interest rate at over 3 quarters of 0.06%. Effects on the exchange rate and oil prices are insignificant. All responses have the expected sign.

The two VARs including food price index and industrial price index show similar results. The main difference is that food and oil does not show a significant price decrease in response to an interest rate shock. Effects on commodity prices in response to an exchange rate shock are also insignificant. In the VAR modelling industrial prices effects on commodity prices to a real interest rate shock is insignificant. (see appendix 2)

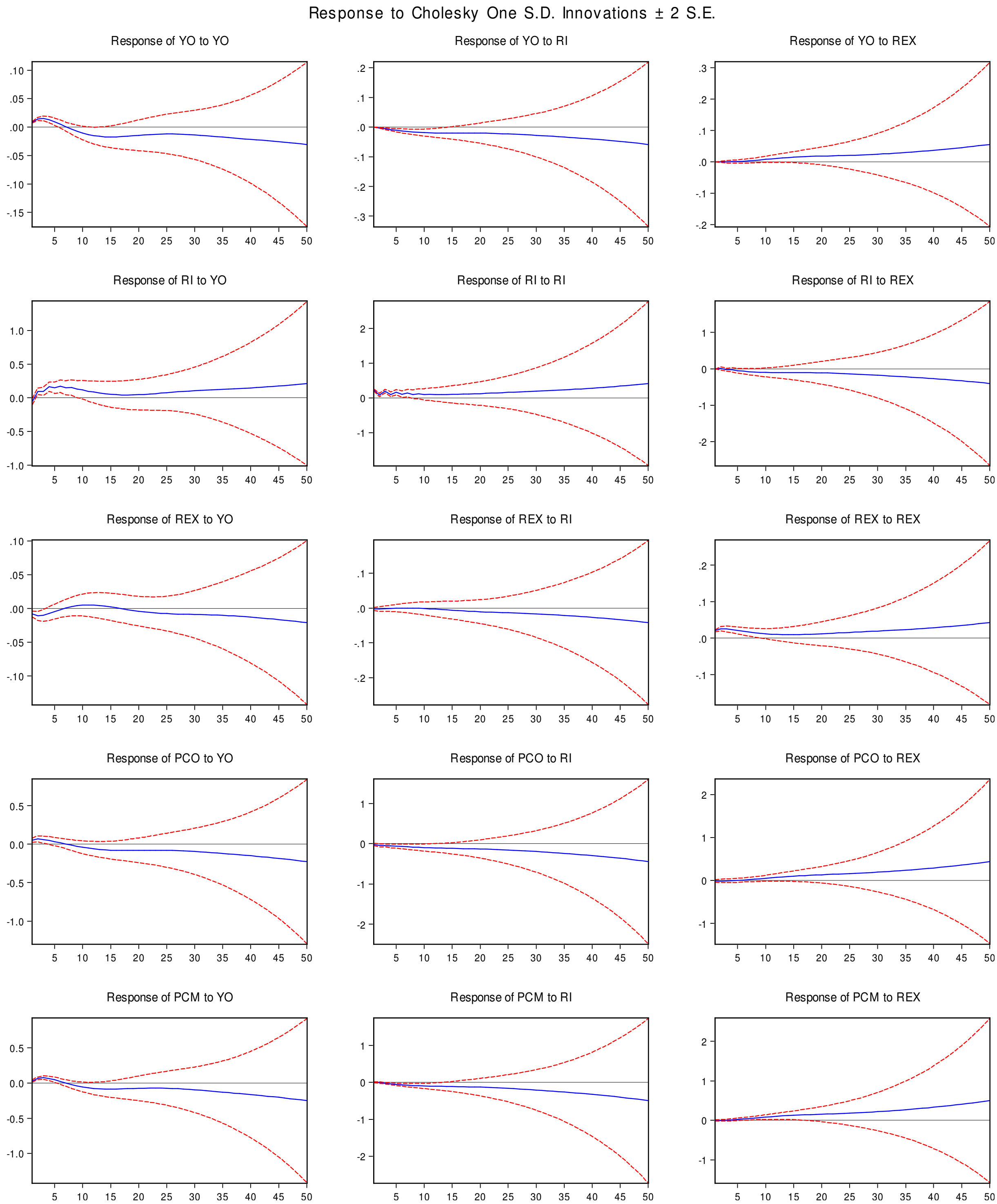

Figure 3 Impulse response graphs showing shocks to global output, real interest rate and real exchange rate in the VAR model including metal price index.

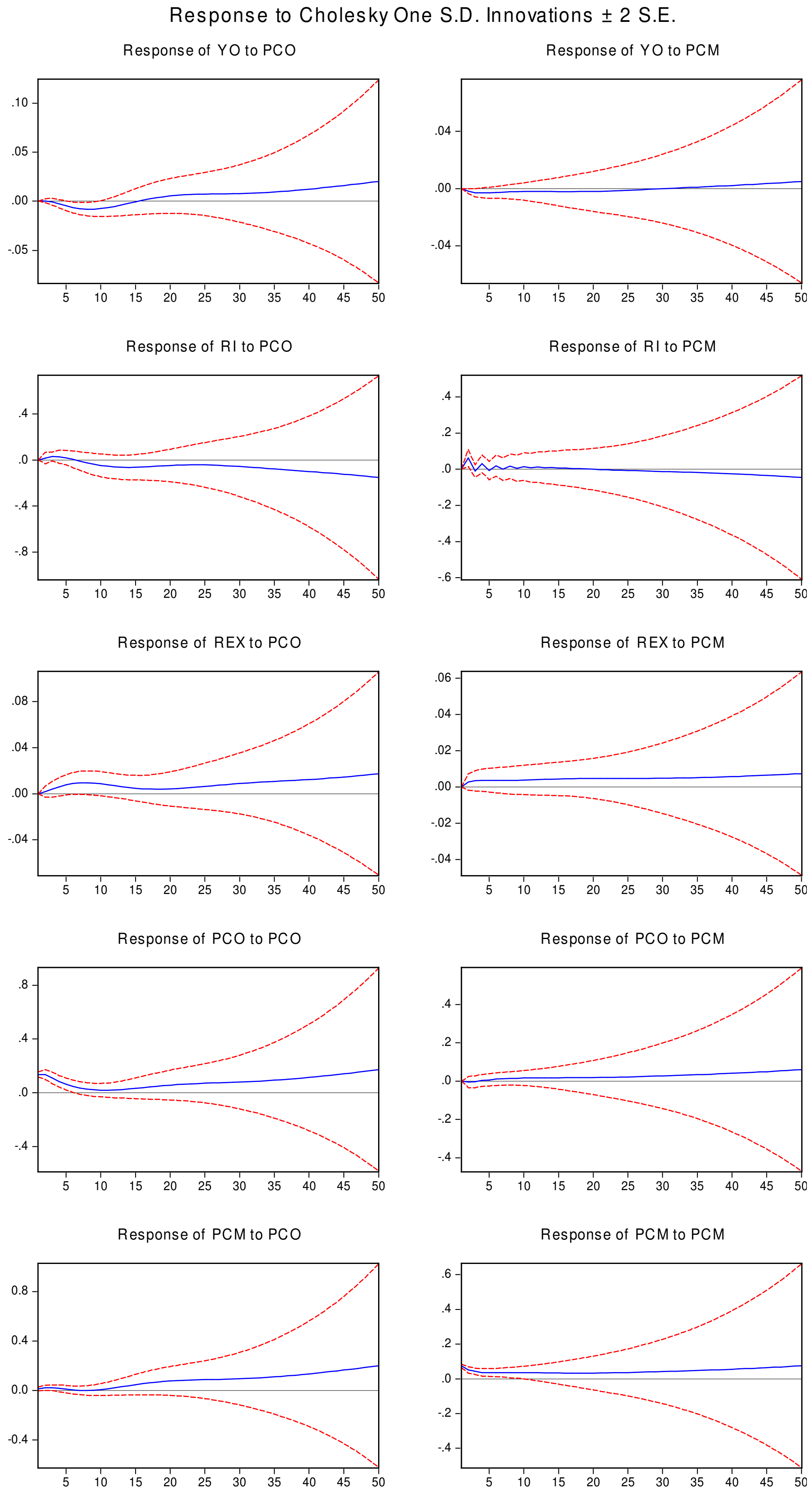

Figure 4 Impulse response graphs showing shocks to oil price and metal price index in the VAR model including metal price index.

In all three VAR models an output shock causes the interest rate to rise, as economic theory would predict, to stabilize demand and inflation. Indeed, European Central Bank (ECB) overall aim is price stability of the economy. Akram finds the same result. An output shock causes an appreciation of the exchange rate, most likely due to higher demand of the currency because strong economic performance increases the investment rate. Akram also finds this effect to be statistically insignificant. Strong global economic performance increases the oil price in the short run. Over the first 4 quarters it increases by up to 0.07% in all three VARs. A positive significant relationship of commodity prices in response to increased global activity is found in all models but not for food price index. Since supply of commodities, especially oil, is relatively inelastic (Hamilton, 2009), increased demand will push up prices in the short run until production is adjusted. Akram finds the similar relation although with statistical significance over a horizon of 10-20 quarters. This difference is related to how long period the output shock lasts, which is smaller in the Euro zone than in the US. The positive correlation between real interest rates and commodity prices in response to the output shock lends support to the argument that the relationship between real interest rates and commodity prices is shock dependent as argued by Svensson (2006). It could mean that the income effect dominates the discounting effect of higher interest rate on the present value of commodity prices in response to an output shock.

A shock to the real interest rate depresses economic activity over the long run, consistent with economic theory since a high interest rate discourages borrowing and postpones purchases and investments. Effects on exchange rate appreciation are significant only in the short run in all three models, which conforms to results by Akram. A higher real interest rate has a significantly negative effect on oil prices in the VARs modelling metal prices by -0.11% over 12 quarters and the shock decrease metal prices by -0.11% over 13 quarters. These results confirm Frankel's theory (1986, 2006) that commodity prices are negatively related to interest rates, but it gives no support to the feature of overshooting commodity prices. The response of commodity prices is larger in the Euro area than what Akram found for the US case; he found price decreases of -0.06% in the VAR with metal prices and between -0.06% and -0.02% in the other two VARs.

A shock that depreciates the real exchange rate increases economic activity and leads to lower real interest rates. The exchange rate depreciation leads to higher industrial prices and metal prices of 0.03% and 0.15% after a few quarters, which are higher levels than Akram found for the US exchange rate, of 0.02-0.06%. No significant effect on oil prices due to exchange rate depreciation is found. In the US case Akram found significant exchange rate effects in all VAR models, this is not the case for the Euro zone. There also seems to be a delay before the exchange rate translates into higher prices.

An oil price shock depreciates economic activity over a period of 10-12 quarters. The adverse effect of such a supply shock is expected and confirmed by other studies (see eg. Anzuini et al. 2007). The shock causes increased real interest rate, most likely due to higher inflation. The real exchange rate depreciates in the short run. Metal and industrial prices increase significantly as an effect of the increased crude oil price by 0.02% and 0.03%. This result is expected since industrial and metal production is energy-intensive and is confirmed by other research (Lombardi et al. 2010). It shows that there are linkages between commodity prices which cause them to co-move, thereby having a substantial effect on inflation.

A shock to food, metal, and industrial prices all cause economic activity to decrease in the short run. The effect on the interest rate due to a commodity price shock is positive over 2-3 quarters, possibly in response to inflation. No exchange rate effects are found. A price increase in the respective models of food and metal causes no statistically significant change in oil prices, but an increase in prices of industrials causes oil prices to decrease. It could be that the reduced economic activity due to higher industrial prices lowers oil prices through a reduced demand effect.

Variance Decomposition

Variance decomposition assesses the individual shock contributions to the total variability of the time series at different time horizons. In the diagrams presented below the X-axis shows forecasted quarters and the Y-axis shows percentages of the variance of the error made in forecasting the specific variable given the shocks. A VAR model with industrial material is analysed here, while variance decomposition based on the two other estimated VAR models are presented in appendix 3. For each variable the biggest contributor to variance is the own shock, but other characteristics are also found.

In Figure 5, variance decomposition of shocks to the VAR model including metal prices is presented. The first diagram shows that commodity prices account for a relatively small share of output fluctuations. In the short run oil prices have a bigger importance, up to 10% in quarter 9. The real exchange rate is increasing in importance over the long run, the share of output fluctuations due to real exchange rate shock increases up to 36%. The real interest rate is an important factor in the medium run, while decreasing in the long run. In the second graph fluctuations of the interest rate are to a large extent attributable to the interest rate itself, global output and the real exchange rate. Metal prices have a bigger importance than oil prices in the short run, while in the medium run oil prices take over. Variance of the real interest rate is largely attributable to output in the short run and real exchange rate in the longer run. In the third graph fluctuations of the real exchange rate are, other than attributable to an exchange rate shock, 14% attributable to global output in the short run and 12% attributable to the oil price in the medium run. Metal prices are a low explanatory factor. Regarding the oil price, fluctuations are due to oil price shock itself and 17% attributable to global output in the short run. Over the medium and long run both the interest rate and the exchange rate have increasing importance in determining price fluctuations, of 41% and 40% respectively, confirmed by Akram's findings. Metal price is a low explanatory factor. In the last graph fluctuations to metal prices are much attributable to metal prices themselves and 50% to output in the short run. In the medium run output decreases in importance and instead the real exchange rate and the real interest rate accounts for around 40% of variability.

The main difference of the VAR model with food price index is that food is less vulnerable to global output shocks. This could be reasonable since food consumption is relatively stable and people normally don't eat more when economic activity increases. In the VAR with industrial prices, the interest rate has lower influence on fluctuations of commodities than in the other two VARs.

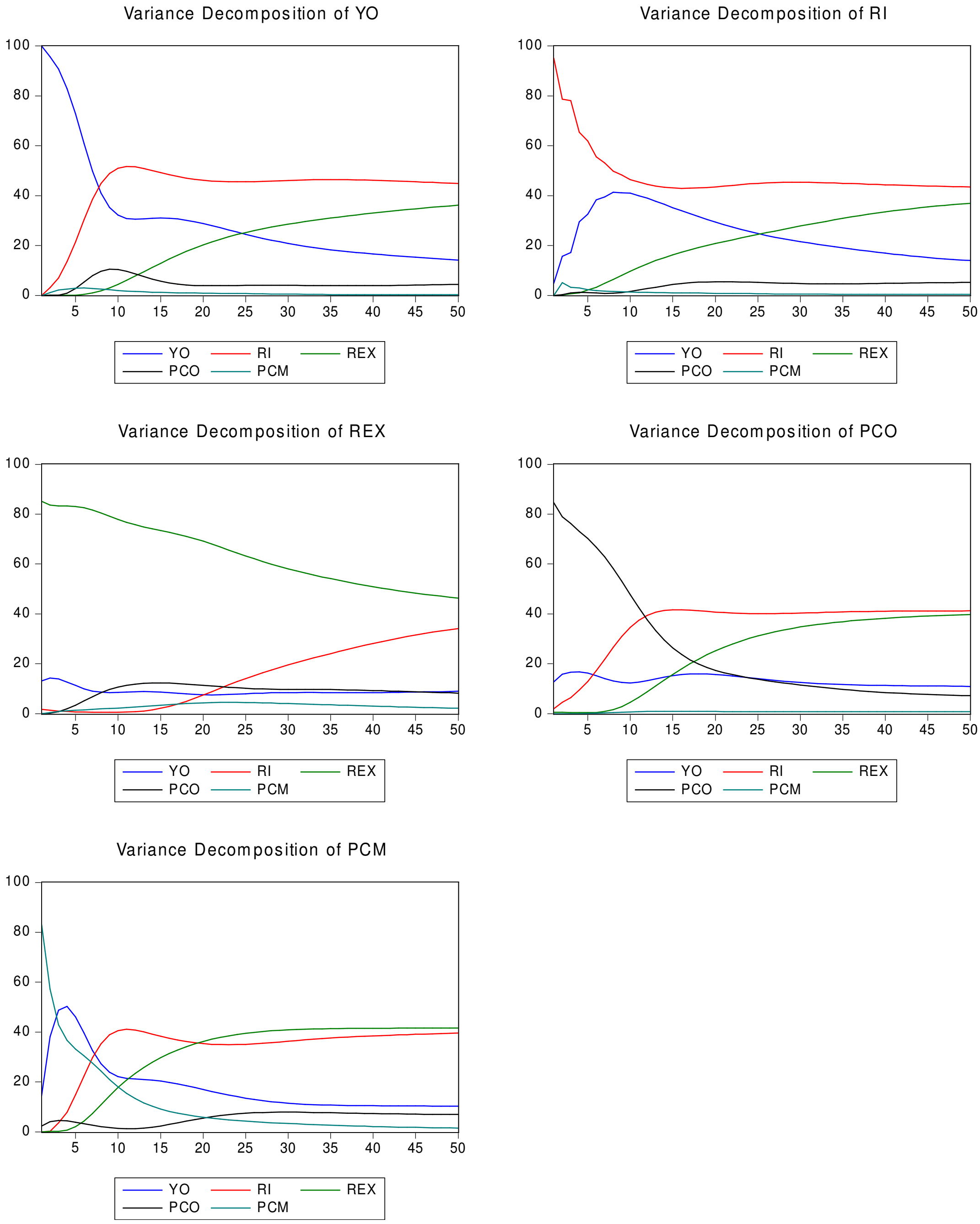

Figure 5 Variance decomposition of VAR model including metal price index.

For all commodity prices, fluctuations are attributable to shocks to global output in the short run. Over the medium run and long run both the interest rate and the exchange rate have increasing importance in determining price fluctuations. In the VARs the interest rate accounts for 20-40% of oil and metals price fluctuations over all time horizons. It lies around 20% for food and industrials. The high explanatory factor of the interest rate is also found in Akram (2009); thereby I am able to replicate the result that the interest rate is an important factor for commodity price determination. That there is a delay in interest rate effects in variance decomposition may be explained by the fact that monetary policy works with a lag.

This analysis shows that fluctuations in the short run are mainly due to output shocks and increased demand for commodities. Over the medium run fluctuations are due to the real interest rate, and as impulse responses shows negative correlation between commodity prices and real interest rate, there is evidence that the low real interest rates in recent years have increased commodity prices. It can also be read from the variance decomposition graphs that oil prices account for a large share of exchange rate fluctuations, around 20%, which is most likely due to a terms-of-trade effect. The exchange rate lies consistently around the level of 40% over the medium term for all commodities, showing that exchange rate depreciation will affect commodity prices positively in the medium run. Variance decompositions show evidence of cross-price effects, most notably that oil price shocks account for 25% of industrial price fluctuation and 5-10% of metal price fluctuation.

Discussion

The results in this analysis show that the Euro real interest rate affects commodity prices over the medium term. Evidence presented shows that shocks to the real interest rate significantly decrease real oil and metal prices for the duration of the shock. These results confirm the research by Akram (2009). In addition Akram (2009) finds evidence of overshooting of oil price which explains some of the volatility that commodity prices exhibit; however I am unable to replicate those findings for the Euro zone. When looking at the variance decomposition graphs there is evidence that output shocks account for the largest commodity price fluctuations in the short-run, not considering the commodity shock itself, showing the interest rate and exchange rate to grow in importance in the medium run. This analysis has shown that the reaction of commodity prices to shocks depend on the type of shock, which could explain the development post-financial crisis in 2008 (see Figure 1) of a simultaneous decrease of commodity prices and interest rates. When global activity stagnated as a result of the financial crisis Central Bank response was to lower interest rates. The output shock, which affects commodity prices in the short run, caused prices to decrease rapidly. In the medium run the interest rate effect increased and pushed up commodity prices again. This econometric analysis has shown that commodity prices are affected by monetary policy and thereby there is evidence that the accommodative economic policy of recent years in the Euro area by means of an interest rate close to the zero bound caused higher commodity prices.

Shocks to the real exchange rate significantly increase real price of metals and industrials. Most oil is traded in US dollars, which could explain why no significant exchange rate effects have been found for oil price. Needless to say, the price of a commodity measured in a currency is affected by the price of the currency. As Mundell (2002) argues, one should not look at one currency when analysing prices of commodities since it is a world traded good. To get the full picture it is necessary to collect a basket of currencies and compare world prices to that. Exchange rate fluctuations change relative prices, but that is not a concern of central banks. Turning the focus to inflation, the role of ECB is to ensure price stability with the aim at keeping inflation close to or below 2% and only when there is an overall increase in prices is there inflation. The analysis in this paper has shown that commodity prices co-move, suggesting that commodity price increases should not be taken by ease. Jointly increasing commodity prices result in higher costs for companies and households and causes sizable and persistent inflation.

The central argument of Frankel (2008) is that there is information to be gathered from high real commodity prices despite the volatility, because it can be a signal that monetary policy is loose and therefore be a useful monetary indicator. However, central banks seem to disagree on the role of commodity prices in monetary policy. In the speech announcing the first increase of the ECB key interest rate for almost three years in April 2011, ECB president Jean-Claude Trichet noted that "strong economic growth in emerging markets, supported by ample liquidity at the global level, may further fuel commodity price rises." (Trichet, 2011). Ben Bernanke, Chairman of the Federal Reserve, does not acknowledge that US monetary policy might be a cause to the high commodity prices but calls them "transitory" (Kemp, 2011). Policy response to increasing commodity prices must depend on the type of shock affecting the economy and a first step is to agree on what is driving the development, whether it is demand or interest rates. As monetary policy works with a lag, targeting demand shocks, which in this analysis is shown to be important for commodity prices in the short run, is not effective monetary policy. Instead central banks must agree on the endogeneity of commodity prices to monetary policy and reach a consensus on how to accommodate a stable inflation level, because one central bank cannot act alone to stabilise world market inflation pressure.

Whether one comes closer to the truth about commodity prices by looking at the Euro area instead of the US as a proxy for world interest rate is up for debate. This analysis has shown that in comparison to Akram (2009), effects on commodity prices due to a Euro real interest rate shock are bigger in size. This implies that Euro zone monetary policy is more important than US monetary policy in determining commodity prices. As noted above, the Euro area is the world's largest trading block and therefore possesses big economic importance. This calls for further research to gain deeper knowledge on how and to what extent Euro monetary policy affects commodity prices. Research could also be made by taking an average of the biggest economies and their real interest rates to use that as a proxy for world real interest rate.

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Appendix 1

	Global Output	Real Interest Rate	Real Exchange Rate	Crude Oil Price	Industrial Price Index
Global Output (-1)	1.615973***	10.79363***	-0.291866	2.979514	3.497657***
	(0.11042)	(2.92414)	(0.27761)	(1.81104)	(0.88251)
	[14.6348]	[3.69122]	[-1.05135]	[1.64519]	[3.96329]
Global Output (-2)	-0.653336***	-10.16697***	0.288403	-2.736950	-3.592880***
	(0.10712)	(2.83672)	(0.26931)	(1.75690)	(0.85613)
	[-6.09915]	[-3.58406]	[1.07089]	[-1.55783]	[-4.19665]
Real Interest Rate (-1)	-0.011308***	0.335701***	0.002669	-0.045285	-0.006615
	(0.00385)	(0.10197)	(0.00968)	(0.06315)	(0.03077)
	[-2.93674]	[3.29222]	[0.27574]	[-0.71707]	[-0.21495]
Real Interest Rate (-2)	0.002154	0.867200***	0.002296	0.031248	0.038761
	(0.00412)	(0.10898)	(0.01035)	(0.06749)	(0.03289)
	[0.52340]	[7.95777]	[0.22192]	[0.46298]	[1.17853]
Real Exchange Rate (-1)	0.000154	0.596997	1.245524***	-0.071927	0.114879
	(0.04231)	(1.12035)	(0.10636)	(0.69388)	(0.33812)
	[0.00365]	[0.53287]	[11.7101]	[-0.10366]	[0.33975]
Real Exchange Rate (-2)	0.009947	-1.950855*	-0.321865***	0.358399	0.219657
	(0.04314)	(1.14240)	(0.10846)	(0.70754)	(0.34478)
	[0.23058]	[-1.70768]	[-2.96769]	[0.50655]	[0.63710]
Crude Oil Price (-1)	0.006995	0.034264	0.006469	1.056857***	0.166579***
	(0.00695)	(0.18393)	(0.01746)	(0.11391)	(0.05551)
	[1.00707]	[0.18629]	[0.37048]	[9.27764]	[3.00087]
Crude Oil Price (-2)	-0.010130	-0.005156	0.003397	-0.152197	-0.080719
	(0.00721)	(0.19081)	(0.01811)	(0.11817)	(0.05759)
	[-1.40592]	[-0.02702]	[0.18755]	[-1.28791]	[-1.40172]
Industrial Price Index (-1)	-0.032291**	0.780751**	0.054633	-0.515135**	0.608033***
	(0.01470)	(0.38938)	(0.03697)	(0.24116)	(0.11752)
	[-2.19613]	[2.00512]	[1.47791]	[-2.13609]	[5.17406]
Industrial Price Index (-2)	0.025741*	-0.485737	-0.046852	0.422027*	0.088628
	(0.01317)	(0.34882)	(0.03312)	(0.21604)	(0.10528)
	[1.95421]	[-1.39250]	[-1.41478]	[1.95346]	[0.84187]
C	0.177524*	1.510850	0.296940	-1.618512	0.139544
	(0.10208)	(2.70318)	(0.25663)	(1.67419)	(0.81583)
	[1.73913]	[0.55892]	[1.15706]	[-0.96674]	[0.17105]

Table 4 Estimation output of VAR model including industrial price index. Standard errors in () and t-statistics in []. Includes 98 observations after adjustments.

	Global Output	Real Interest Rate	Real Exchange Rate	Crude Oil Price	Food Price Index
Global Output (-1)	1.487508***	12.65943***	-0.037387	1.233372	0.725005
	(0.09640)	(2.58019)	(0.24876)	(1.64097)	(0.73718)
	[15.4313]	[4.90639]	[-0.15029]	[0.75161]	[0.98348]
Global Output (-2)	-0.536552***	-12.53198***	0.059744	-0.955563	-0.754330
	(0.08937)	(2.39223)	(0.23064)	(1.52143)	(0.68348)
	[-6.00351]	[-5.23863]	[0.25904]	[-0.62807]	[-1.10367]
Real Interest Rate (-1)	-0.012493***	0.351598***	0.005566	-0.058205	0.019479
	(0.00364)	(0.09754)	(0.00940)	(0.06204)	(0.02787)
	[-3.42829]	[3.60454]	[0.59184]	[-0.93824]	[0.69895]
Real Interest Rate (-2)	0.002280	0.860688***	0.002843	0.033572	0.005902
	(0.00403)	(0.10798)	(0.01041)	(0.06868)	(0.03085)
	[0.56511]	[7.97063]	[0.27305]	[0.48885]	[0.19130]
Real Exchange Rate (-1)	-0.024212	0.772055	1.248921***	-0.150959	-0.302991
	(0.04261)	(1.14056)	(0.10996)	(0.72538)	(0.32587)
	[-0.56820]	[0.67691]	[11.3577]	[-0.20811]	[-0.92980]
Real Exchange Rate (-2)	0.017690	-2.100493*	-0.300287***	0.327617	0.258649
	(0.04269)	(1.14276)	(0.11017)	(0.72678)	(0.32649)
	[0.41434]	[-1.83810]	[-2.72556]	[0.45078]	[0.79220]
Crude Oil Price (-1)	0.002772	0.123507	0.011517	1.000887***	0.001543
	(0.00671)	(0.17973)	(0.01733)	(0.11430)	(0.05135)
	[0.41288]	[0.68719]	[0.66465]	[8.75630]	[0.03006]
Crude Oil Price (-2)	-0.005849	0.056858	-0.001509	-0.136949	0.027436
	(0.00690)	(0.18457)	(0.01779)	(0.11738)	(0.05273)
	[-0.84822]	[0.30807]	[-0.08482]	[-1.16670]	[0.52030]
Food Price Index (-1)	-0.038105***	0.682530*	-0.001903	-0.201837	0.718459***
	(0.01418)	(0.37953)	(0.03659)	(0.24137)	(0.10843)
	[-2.68742]	[1.79837]	[-0.05200]	[-0.83620]	[6.62579]
Food Price Index (-2)	0.024538*	-0.824961**	0.014496	0.197579	0.051841
	(0.01365)	(0.36544)	(0.03523)	(0.23242)	(0.10441)
	[1.79727]	[-2.25742]	[0.41143]	[0.85010]	[0.49652]
C	0.345966**	5.448752	0.033324	-1.584652	1.415835
	(0.16037)	(4.29262)	(0.41386)	(2.73005)	(1.22643)
	[2.15728]	[1.26933]	[0.08052]	[-0.58045]	[1.15443]

Table 5 Estimation output of VAR model including food price index. Standard errors in () and t-statistics in []. Includes 98 observations after adjustments

Appendix 2

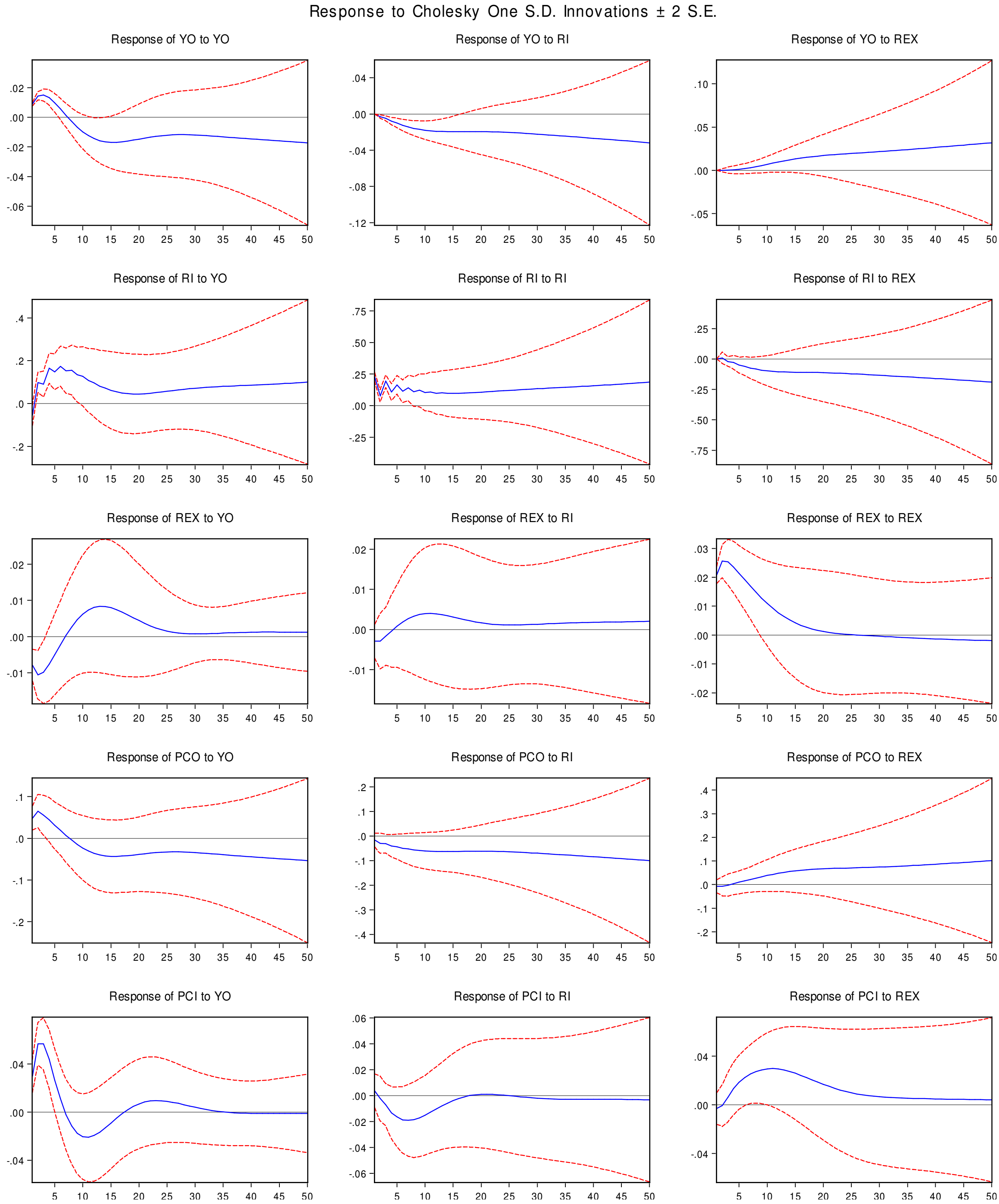

Figure 6 Impulse response graphs showing shocks to global output, real interest rate and real exchange rate in VAR model including industrial price index.

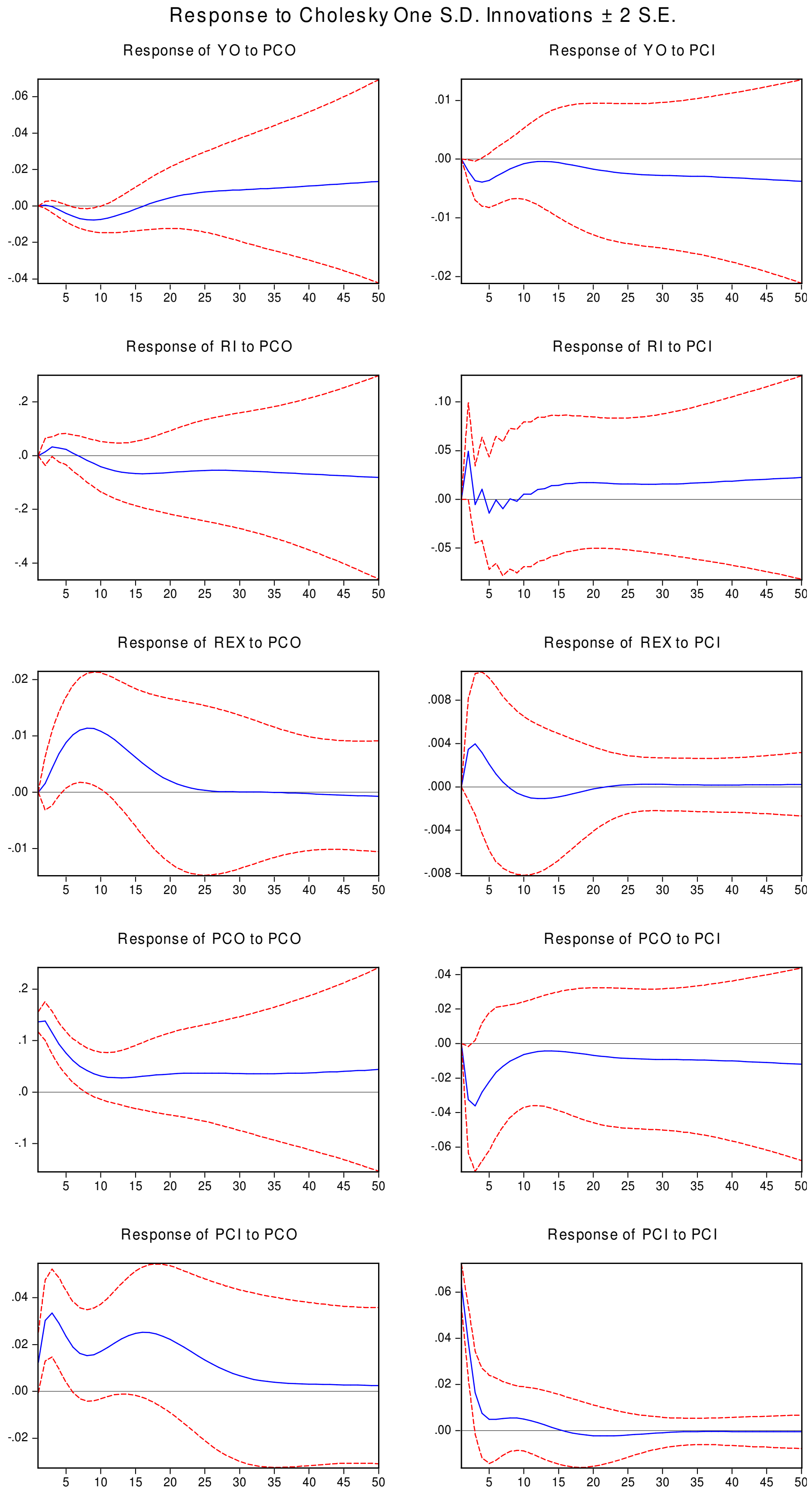

Figure 7 Impulse response graphs showing shocks to oil price and industrial price index in VAR model including industrial price index.

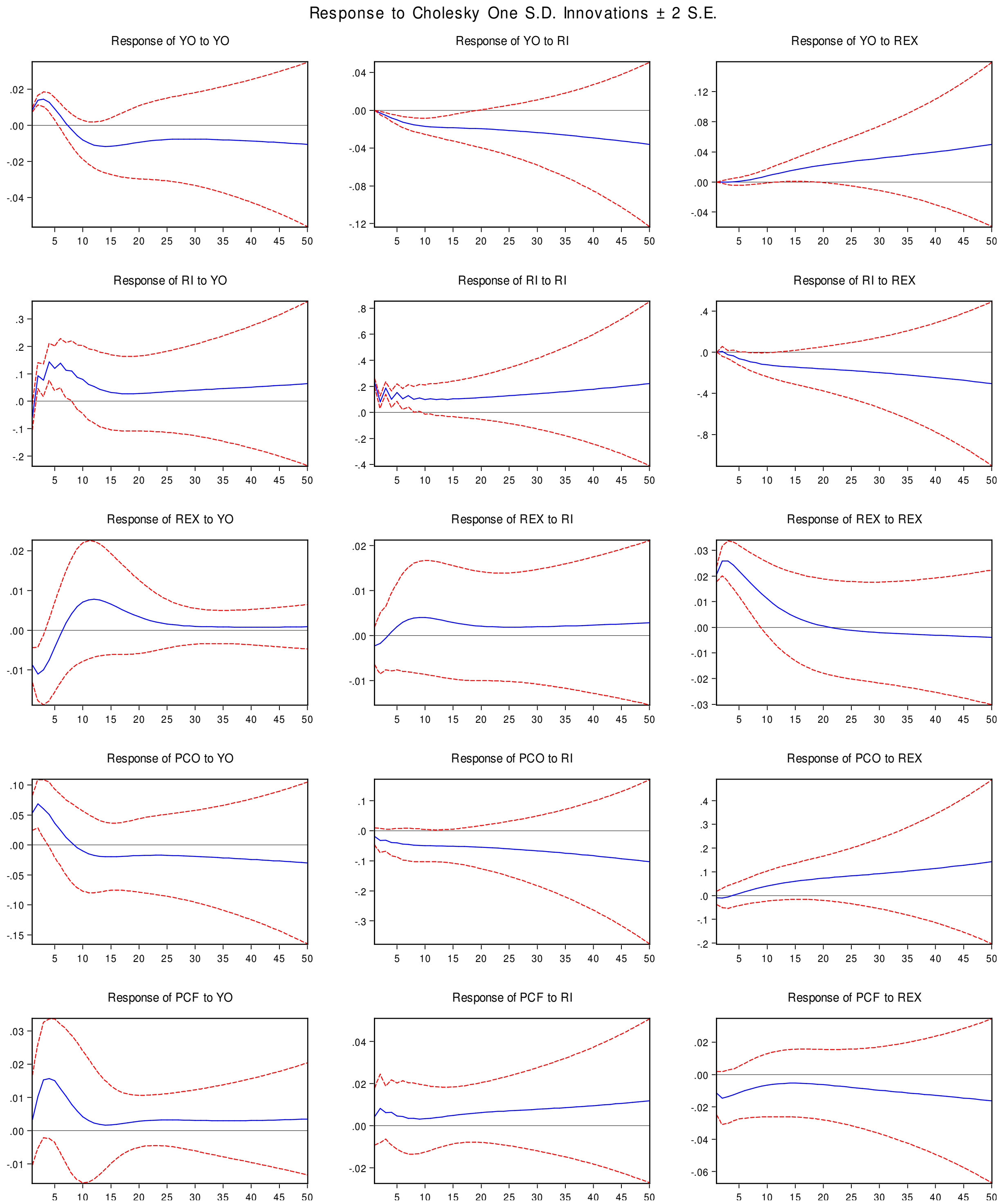

Figure 8 Impulse response graphs showing shocks to global output, real interest rate and real exchange rate in VAR model including food price index.

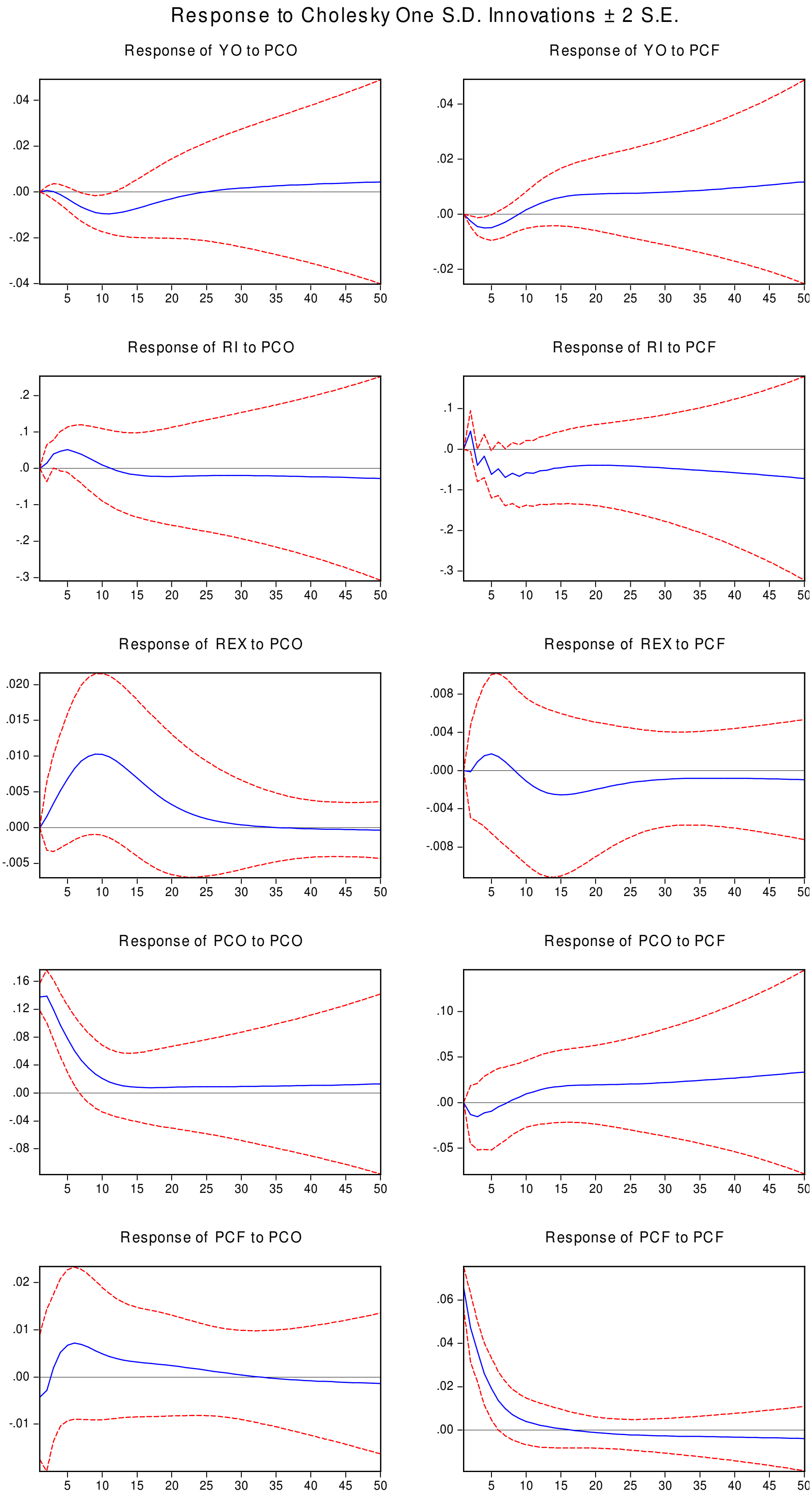

Figure 9 Impulse response graphs showing shocks to oil price and food price in the VAR model including food price index.

Appendix 3

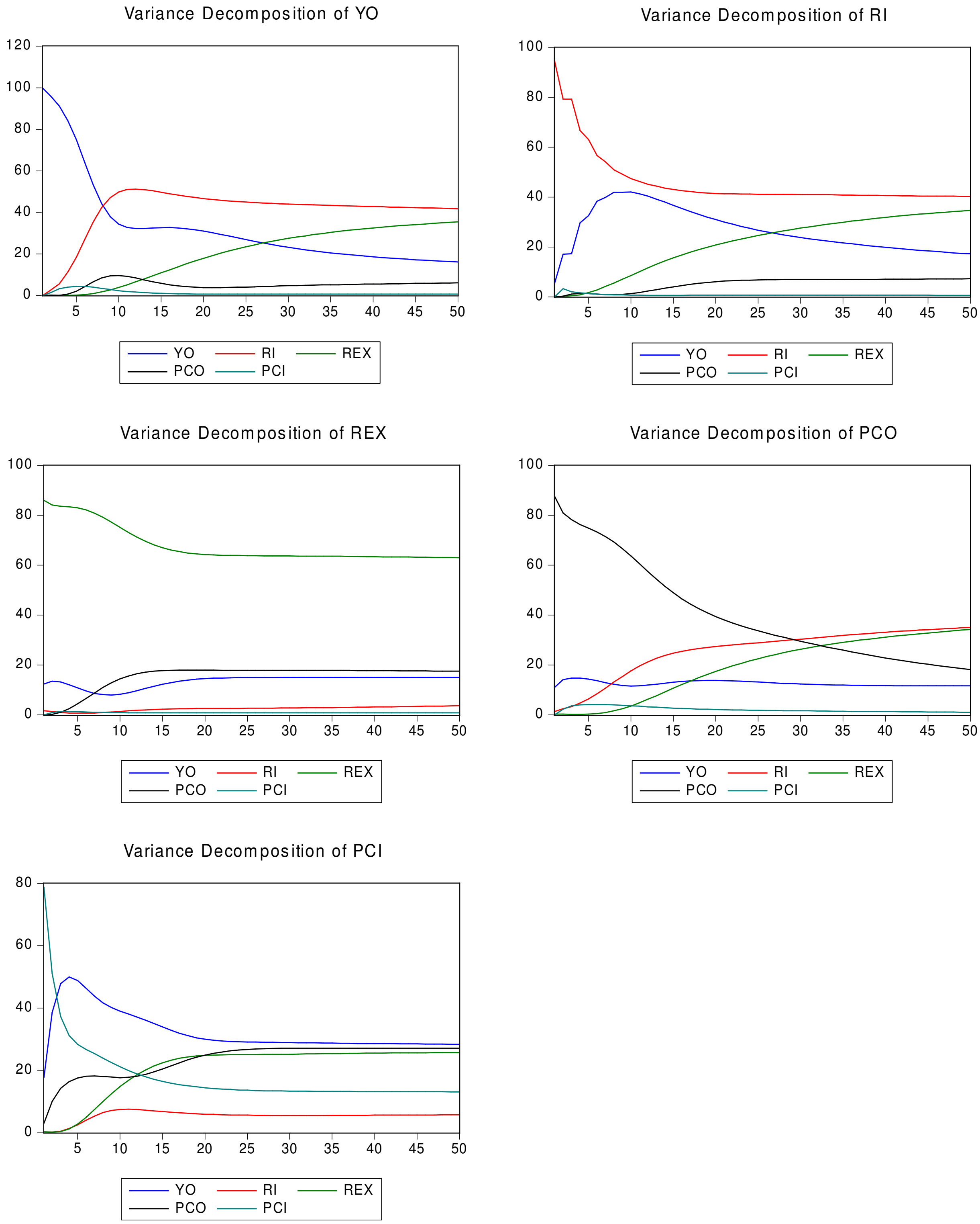

Figure 10 Variance decomposition graphs of VAR model including industrial price index.

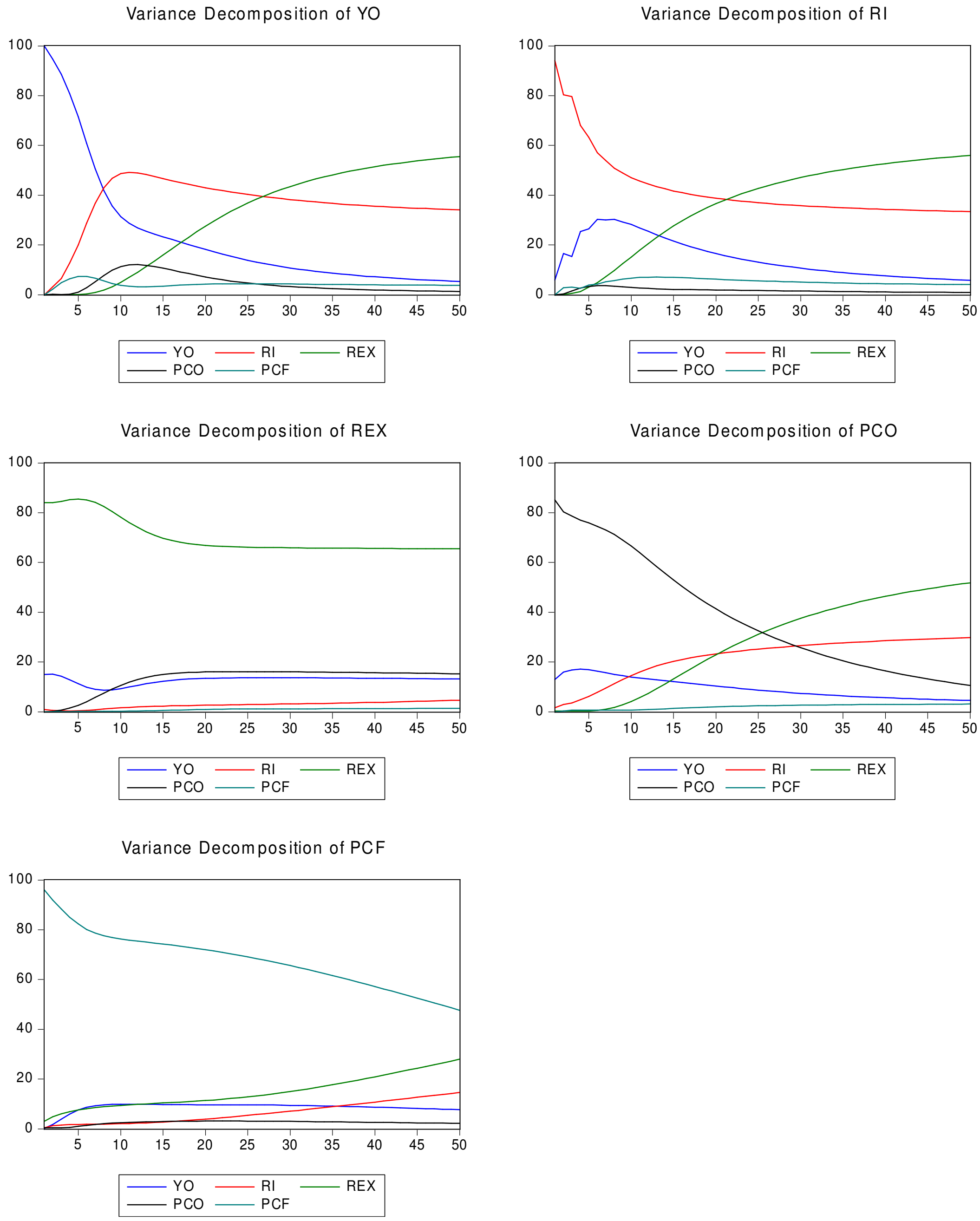

Figure 11 Variance decomposition graphs of VAR model including food price index.

Appendix 4

Quarterly time series data ranging from 1985Q1–2009Q4 which includes 100 observations, 98 observations in the VARs after adjustments.

PCO: Spot market and crude oil import costs: Crude oil spot prices, *IEA Energy Prices and Taxes* Statistics (database). doi: 10.1787/data-00447-en (Accessed on 7 April 2011). Data converted into logged real price index measured in Euro.

PCF: CRB Spot Index Foodstuffs, *Commodity Research Bureau* (Accessed 4 April 2011 via Datastream). Base year: 1951. Data converted into logged real price index measured in Euro.

PCM: CRB Spot Index Metals, *Commodity Research Bureau* (Accessed 4 April 2011 via Datastream). Base year: 1951.

PCI: TR Equal Weight CCI Industrials Index, *Thompson Reuters* (Accessed 4 April 2011 via Datastream). Base year 1971. Data converted into logged real price index measured in Euro.

RI: Short-term Interest rate: Area Wide Model (2010) *The Euro Area Business Cycle Network.* Available at: http://www.eabcn.org/area-wide-model (Accessed: 22 April 2011). Converted into real interest rate by subtracting the quarterly consumer price inflation, which in turn was calculated from the HICP.

REX: Real Effective Exchange Rate: Eurostat (2011). Name: ert_eff_ex_q (Accessed 22 April 2011). Base year: 1999.

HICP: Harmonised Index of Consumer Prices: Area Wide Model (2010) *The Euro Area Business Cycle Network.* Available at: http://www.eabcn.org/area-wide-model (Accessed: 22 April 2011). Used to convert nominal values into real values.

Exchange Rate: Currency Exchange Rate, Euro(17)/US$: Main Economic Indicators: OECD.Stat. Used to convert US$ prices into Euro.