Energy Economics 31 (2009) 838–851

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Commodity prices, interest rates and the dollar ☆

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ARTICLE INFO

Article history:
Received 1 August 2008
Received in revised form 15 March 2009
Accepted 27 May 2009
Available online 10 June 2009

JEL classification:
E37
E47
Q17
Q43

Keywords:
Commodity prices
Interest rates
Exchange rates
VAR models

ABSTRACT

This paper sheds light on recent fluctuations in commodity prices. We investigate whether a decline in real interest rates and the US dollar contributes to higher commodity prices, and whether commodity prices display overshooting behavior in response to changes in real interest rates. We analyze the behavior of real prices of crude oil, food, metals and industrial raw materials. The analysis is based on structural VAR models estimated on quarterly data over the period 1990q1–2007q4. Our results suggest that commodity prices increase significantly in response to reductions in real interest rates. Moreover, oil prices and prices of industrial raw materials tend to display overshooting behavior in response to such interest rate changes. The evidence also suggests that a weaker dollar leads to higher commodity prices. Shocks to interest rates and the dollar are found to account for substantial shares of fluctuations in commodity prices.

1. Introduction

We conduct an empirical analysis to shed light on the recent surge in prices of a broad range of commodities. The increase in commodity prices has coincided with relatively low real interest rates in general and a substantial decline in the value of the US dollar; see IMF (2008) for evidence. The surge in commodity prices is partly, if not predominantly, ascribed to the fall in interest rates and the value of the dollar IMF (2008) and Krichene (2008).[1] However, world economic growth, with substantial contribution from the growth of emerging economies, has also been relatively high over a number of years, until recently. Moreover, commodity prices may also have risen due to spillover-effects between different commodity prices. In particular, high crude oil prices may have contributed to higher prices of other commodities through cost-push effects as their production may depend directly or indirectly on the use of crude oil. In addition, higher prices of crude oil may have lead to higher demand for agricultural commodities to substitute bio-fuel for crude oil.

We focus on to what extent low real interest rates and the decline of the dollar can account for high commodity prices and whether commodity prices tend to display overshooting behavior in response to interest rate changes. It has been long argued by Frankel that commodity prices tend to overshoot in response to interest rates changes, as exchange rates do in Dornbusch's (1976) model; see Frankel (1986, 2006). We also examine the possible contribution of world economic growth and of possible spillover-effects from crude oil prices to prices of other commodities. An adequate account of the contribution of particularly world economic growth is required as it may lead to both higher interest rates and commodity prices; see e.g. Svensson (2006). Accordingly, the current slowdown in world economic growth after several years of high growth may explain the sharp decline in real interest rates as well as commodity prices.

A negative relationship between real interest rates and commodity prices would ensue if we treat commodity prices as flexible asset prices traded in efficient markets; see e.g. Frankel (1986). In efficient markets, expected returns from investing in commodities should equal the returns on investing in financial assets to ensure the absence of arbitrage opportunities. The expected return from investing in commodities would be in terms of expected price increases, adjusted for carrying costs including a risk premium. Thus, in response to a fall in interest rates, current commodity prices would rise more in (percentage terms) than expected prices, i.e. overshoot, to ensure that the expected increase in commodity prices equals the lower real interest rate (and carrying costs); see Frankel (1986).

☆ The views expressed in this paper are those of the author and should not be interpreted as reflecting those of Norges Bank (Central Bank of Norway).

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[1] For example, The Wall Street Journal of April 28, 2008, ascribes the surge in oil prices and other commodity prices to the decline of the dollar, partly because of the loose monetary policy in response to the US subprime crisis.

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doi:10.1016/j.eneco.2009.05.016

A negative relationship between the value of the dollar and dollar prices of commodities follows from the law of one price for tradable goods. Accordingly, a decline in the value of the dollar must be outweighed by an increase in the dollar price of commodities and/or a fall in their foreign currency prices to ensure the same price when measured in dollars. Moreover, as many commodities are priced in dollars in international markets, a weaker dollar may raise the purchasing power and commodity demand of foreign consumers, while reducing the returns of foreign commodity suppliers and possibly their supplies. The price impact of shifts in demand and supply of commodities may be particularly large if the demand or supply of commodities is relatively price inelastic, which is generally believed to be the case for many commodities and especially crude oil; see e.g. Hamilton (2008).

Positive spillover-effects between commodity prices, especially between crude oil prices and other commodity prices, are not obvious in light of economic theory. This is because an increase in the price of a good would generally have both income/expenditure and substitution effects which may outweigh each other, partly or wholly. An increase in the price of a good would make agents shift their demand away from that good to its substitutes, whose prices may increase because of the shift in demand. However, the initial price increase would increase real expenditures of agents and thereby make them reduce their demand for all goods and services. Therefore, whether an increase in the price of a good leads to higher prices of other goods would depend on the strength of the substitution effect relative to the income effect. Thus, it is an empirical issue to what extent increases in different commodity prices fuel each other, in particular, whether one can ascribe increases in e.g. food prices to oil prices.

Previous evidence on the empirical relationship between especially interest rates and commodity prices is mixed, while previous studies have not focused on possible overshooting of commodity prices in response to unanticipated shifts in interest rates and other variables. For example, while Frankel (2006) finds evidence of a negative relationship between real interest rates and a number of commodity prices using data including the 1970s, such a relationship is not supported by evidence based on data since the 1980s. This evidence is based on linear bivariate regression models estimated by OLS. Thus, one possible explanation for this finding could be that one needs to control for the effects of macroeconomic activity, the real exchange rate and other possible determinants of commodity prices while investigating the relationship between real interest rates and commodity prices.

One may also argue that a possible relationship between real interest rates and commodity prices is likely to be shock dependent. For example, a shock that increases future commodity prices, such as higher economic growth, may also lead to higher real interest rates; see e.g. Svensson (2006). Thus, a positive relationship between real interest rates and commodity prices may emerge due to simultaneity bias if one does not treat interest rates as endogenous variables. This points to a possible drawback of previous studies employing single equation models to investigate the relationship between commodity prices and financial and real economic variables.

Another possible drawback of single equation models is that they do not enable one to investigate dynamic interaction between commodity prices and financial and real economic variables over different time horizons. Furthermore, they do not enable one to distinguish between effects of anticipated and unanticipated shocks to possible determinants of commodity prices. Another possible explanation of the mixed evidence on the relationship between commodity prices and other macroeconomic and financial variables, not investigated further in this paper, is that such relationships may be non-linear; see e.g. Kyrtsou (2008).

We base our empirical analysis on five-variable vector autoregressive (VAR) models for four commodity prices: real oil prices in the US dollar, aggregate price indices of food, metals and industrial raw materials. Each of the VAR models includes a measure of global activity level, real interest rate, real exchange rate vis-a-vis the US dollar, real oil prices in dollars and the real price of one of the other commodities. We identify structural shocks by imposing a standard recursive causal structure, i.e. a Choleski order, on instantaneous responses to different shocks, originally proposed by Sims (1980). Impulse response analysis based on the structural/identified VAR models enables us to examine effects of shocks to different variables over time while taking into account interactions between the financial and real macroeconomic variables and the commodity prices. We assess the relative contributions of different shocks to fluctuations in the key variables by way of forecast error variance decompositions. The empirical analysis is based on quarterly data for the period 1990q1–2007q4, which extends largely over a single monetary policy regime in the US, i.e. over the Greenspan period.

We find that real commodity prices increase in response to interest rate shocks that lower interest rates. Moreover, commodity prices specifically oil prices and prices of industrial raw materials tend to display overshooting behavior in response to such interest rate shocks, while food prices and metal prices tend to respond gradually. A fall in the value of the dollar due to an exchange rate shock tends to cause higher commodity prices. We also find that interest rates and exchange rate shocks account for substantial shares of fluctuations in commodity prices at all horizons. The contribution of real interest rates relative to the real exchange rate differs across commodity prices considered. Furthermore, we find that negative shocks to world economic activity leads to lower real interest rates and commodity prices. Shocks to world economic activity are found to account for a large share of fluctuations in particularly oil and metal prices.

The paper is organized as follows. The next section briefly presents common arguments for the relationships between commodity prices, real interest rates and the dollar. Section 3 outlines the econometric framework while Section 4 describes the data and properties of the estimated models. Section 5 presents our results, while Section 6 contains our main conclusions. Finally, the appendix offers precise definitions of the variables and additional evidence, which is discussed in Section 5.

2. Commodity prices, interest rates and the dollar

It is common to assume that commodity markets behave like markets for financial assets with flexible prices which tend to be efficient; see e.g. Frankel (2006) and Kellard et al., (1999). In efficient markets, risk adjusted net returns on financial and real assets should be equal. Accordingly, one may posit the following relationship between commodity prices (in logs) and interest rates:

$$\mathbf{E}_t pc_{t+1} - pc_t = i_t + s(i_t), \tag{1}$$

where $\mathbf{E}_t pc_{t+1} - pc_t$ is the expected revaluation of a commodity over a period, measured by the expected price increase from period t to $t+1$, given information available at time t. On the right hand side, "i" is the nominal interest rate while $s(i)$ represents storage costs of a given commodity net of convenience yield, possibly in addition to a fixed risk premium, for simplicity. We assume that storage costs increase with the interest rate; cf. Deaton and Laroque (1996).[2]

Condition (1) states that revaluation gains from a commodity holding, net of storage costs, equals the nominal interest rate. This no-

[2] We assume that $\mathbf{E}_t pc_{t+1} - pc_t \geq 0$, as $i_t \geq 0$ and $s(i_t) \geq 0$.

arbitrage condition may be alternatively posed in real terms by subtracting the general inflation rate from both sides of the equation. The obtained relationship between real commodity prices and the real interest rate is also known as Hotelling's rule; see Hotelling (1931) and also Gray (1914) who implies a similar rule.

The no-arbitrage condition (1) implies a negative relationship between commodity prices and interest rates.[3] It follows that a decline in the nominal interest rate will coincide with a contemporaneous increase in commodity prices, at given expected future commodity prices. This may be explained as follows. First, lower nominal interest rates would make agents invest less in bonds and more in commodities. The rise in commodity demand would put upward pressure on commodity prices. Second, lower interest rates would by reducing carrying costs also increase the inventory demand for commodities and thereby their prices. And third, lower nominal interest rates, ceteris paribus, would make it less profitable to extract exhaustible commodities such as oil and minerals to place the proceeds in bonds; cf. Hotelling (1931). The lower supply of commodities would contribute to raising their prices. In addition to the above effects of lower real interest rates, they may raise economic activity and thereby the demand for commodities and their prices.

Building on Dornbusch's overshooting model for exchange rates, Frankel (1986) argues that commodity prices may overshoot their long run equilibrium values in response to a fall in nominal interest rates induced by e.g. higher money supply. This may be because prices of manufactured goods, which tend to be sticky, make the general price level and inflation rate less responsive to shifts in the money supply in the short run. Thus, nominal interest rates as well as real interest rates may fall in response to higher real money supply in the short run. Expected commodity prices may only rise in proportion to the accompanying rise in (nominal) money supply, as implied by monetary theory. In order to ensure no-arbitrage, current commodity prices, pc_t, may increase more (in percentage terms) than their expected prices given information at time t, $\mathbf{E}_t pc_{t+1}$. Their rise must be sufficient to ensure that the expected rise in commodity prices, $\mathbf{E}_t pc_{t+1} - pc_t$, equals the nominal interest rate and carrying costs; see Frankel (1986) for a detailed outline of the overshooting argument.

A negative relationship between the value of the dollar and commodity prices in dollars can be based on the following relationship:

$$pc^f = e + pc, \tag{2}$$

where pc is a commodity price in dollars, e is the nominal dollar exchange rate in terms of units of a foreign currency, while pc^f is the commodity price in units of a foreign currency; the prices and the exchange rate are in logs. If a commodity is mainly priced in dollars, as is the case for crude oil, its price in foreign currencies can be derived from Eq. (2), abstracting from tariff and non-tariff based transactions costs. It is seen that a depreciation of the dollar, reduction in e, would lead to lower foreign prices of a given commodity and thereby to higher foreign demand as well as lower foreign supply of the commodity. This may contribute to a higher dollar price (pc) of the commodity; see e.g. Ridler and Yandle (1972).

Eq. (2) may also be interpreted as the law of one price for commodities that are traded abroad as well as in the US and are priced in both foreign currency and the US dollar. Commodities of a given kind are relatively homogenous and internationally tradable goods. Hence, for such goods, Eq. (2) requires that commodity prices are the same when measured in dollars. It follows that a depreciation of the dollar would reduce the price of a commodity priced in dollars for foreigners relative to the price of their commodity priced in foreign currency. Arbitrage would ensure that the commodity price in dollars rises and/or the commodity price in the foreign currency falls.

A decline in the value of the dollar may be due to a reduction in the US interest rates. Uncovered interest rate parity implies that the expected depreciation of the dollar would be inversely related to the interest rate spread between the US and abroad. Moreover, a reduction in the US interest rates may cause a substantial short-term depreciation of the dollar, consistent with Dornbusch's overshooting model. Given the large influence of the US interest rates on world interest rates, it follows that a fall in US interest rates may both directly, as argued above, and indirectly via the depreciation of the dollar lead to higher commodity prices.

3. Structural VAR models

The empirical analysis is based on VAR models. The VAR models would, after an appropriate identification of shocks, allow us to examine the response of commodity prices to unanticipated shocks particularly to interest rates and the dollar exchange rate, while taking into account the dynamic interaction between commodity prices and macroeconomic variables. To identify the shocks, we rely on the standard Choleski scheme.

Let us consider the following structural form of a VAR model:

$$Az_t = A_1 z_{t-1} + A_2 z_{t-2} + \dots + A_p z_{t-p} + B\varepsilon_t \tag{3}$$

where $\varepsilon_t \sim (0, \Sigma_\varepsilon)$. A is a $k \times k$ invertible matrix of structural coefficients, which characterize contemporaneous relationships among the variables in z, while A_is ($i = 1,2,\dots,p$) are $k \times k$ matrices characterizing dynamic interactions between the k variables. B is also a $k \times k$ matrix of structural coefficients representing effects of k structural shocks, whose variance–covariance matrix contains $k(k+1)/2$ distinct elements.

The reduced form corresponding to the structural VAR model is obtained by premultiplying Eq. (3) with the inverse of A, A^{-1}:

$$z_t = \overset{*}{A_1} z_{t-1} + \overset{*}{A_2} z_{t-2} + \dots + \overset{*}{A_p} z_{t-p} + u_t \tag{4}$$

where $A_i^* = A^{-1} A_i$. The reduced form residuals are related to the structural residuals by:

$$u_t = A^{-1} B\varepsilon_t, \tag{5}$$

where $u \sim (0, \Sigma_u)$, and Σ_u is the variance–covariance matrix of the reduced form residuals consisting of $k(k+1)/2$ distinct elements; see e.g. Amisano and Giannini (1997).

To infer estimates of the structural form parameters from estimates of the reduced form parameters, we impose only exact identifying restrictions to make our results less dependent on potentially invalid restrictions. These restrictions are based on the following assumptions. Consistent with common practice, we assume that the structural variance–covariance matrix, Σ_ε, is a diagonal matrix, which is normalized to be an identity matrix, I_k, without loss. And, based on a Choleski decomposition of the reduced form variance–covariance matrix Σ_u, we assume that A is an identity matrix, while B is a lower triangular matrix. The contemporaneous relationships among the k endogenous variables are modeled through

[3] Alternatively, current commodity prices can be considered equal to the discounted value of expected future prices net of storage costs. Lower interest rates would raise the present value of expected future prices net of storage costs and thereby current commodity prices.

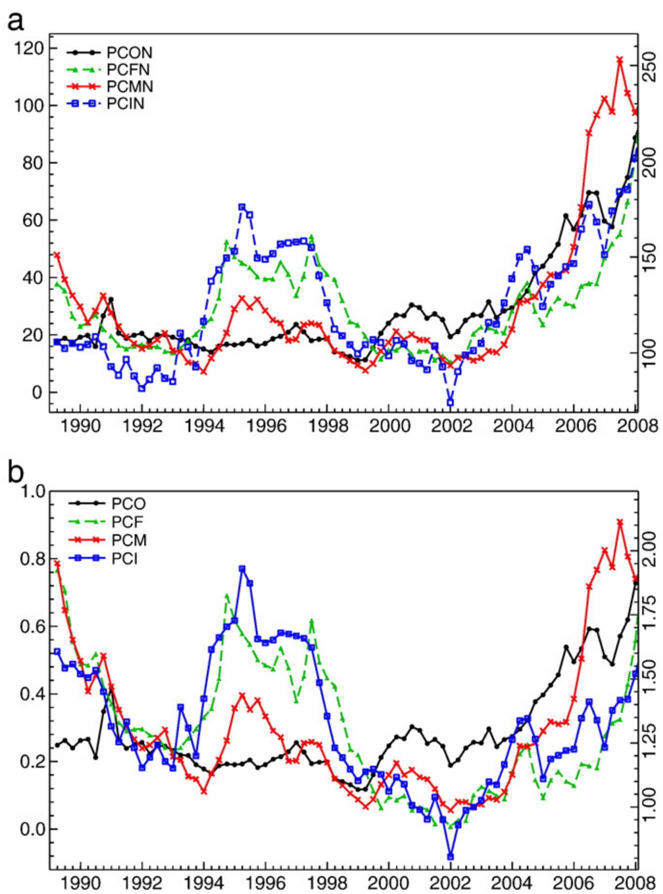

Fig. 1. Nominal and real prices of crude oil in dollars, PCON and PCO, respectively, and indices of nominal and real prices of food (PCFN and PCF), metals (PCMN and PCM) and industrial raw materials (PCIN and PCI) over the period 1989q1–2007q4. The oil prices are marked on the left axes.

B, representing instantaneous effects of structural shocks on the endogenous variables. We examine effects of structural shocks over time by impulse response analysis.

4. Empirical analysis

4.1. Data and model specification

Fig. 1 displays nominal and real values of the commodity prices over the period 1989q1–2007q4. *PCO* is the real price per barrel of crude oil in dollars, *PCF* is the real price of food, *PCM* is the real price of metals and *PCI* is the real price of industrial raw materials. The real values of the commodity prices including oil have been obtained by deflating the nominal commodity price by the US consumer price index. Except for the nominal oil price, which is in dollars per barrel, the other commodity prices refer to The Economist's commodity price indices. Postfix “N” is used to distinguish a nominal commodity price from the corresponding real commodity price.

In nominal terms, the boom in commodity price over about the last five years of the sample period is remarkable both in size and in breadth; see Fig. 1. In contrast with earlier rises and falls of commodity prices, prices of all commodities have risen to relatively high levels. For example, oil prices remained relatively stable while the other commodity prices experienced large fluctuations in the mid-1990s. In real terms, the rise in some commodity prices during the mid-1990s is comparable to the increase in commodity prices during the last years of the data sample, except that oil prices and especially metal prices did not rise as much as they did during the latter years.

Low real interest rates and relatively weak dollar have been mentioned as possible driving forces behind the recent increase in commodity prices; see e.g. IMF (2008) and Krichene (2008). However, available empirical evidence is not unambiguous on this issue. For illustration, Figs. 2 and 3 display cross plots between real prices of the different commodities in logs against the real interest rate (*ri*) and the real value of the dollar (*rex*), respectively. *ri* refers to the short-term real interest rate for the US, which has been obtained by subtracting the four-quarter US consumer price inflation from the one month money market interest rate quoted per annum, while *rex* is the effective real exchange rate for the US; see Appendix A for details. We use the US real interest rates as indicators of global real interest rates.

The cross plot between real oil prices and real interest rates suggests a negative relationship between these variables and lends support to the conjecture that low real interest rate may have contributed to high oil prices. However, the corresponding cross plots for prices of food, industrial raw materials and metals suggest positive relationships between commodity prices and real interest rates. The

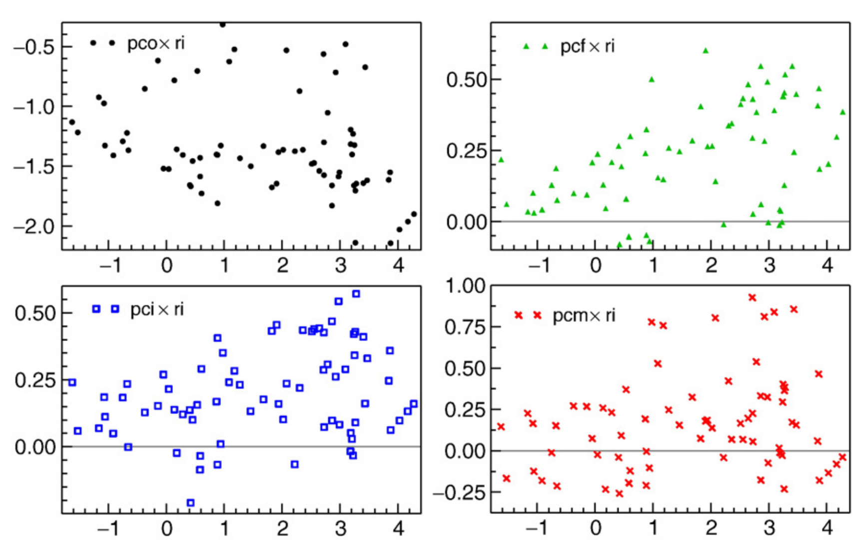

Fig. 2. Cross plots: Real commodity prices (in logs) vs real interest rates. The cross plots for four different (groups) of commodity prices are based on quarterly observations over the period 1990q1–2007q4.

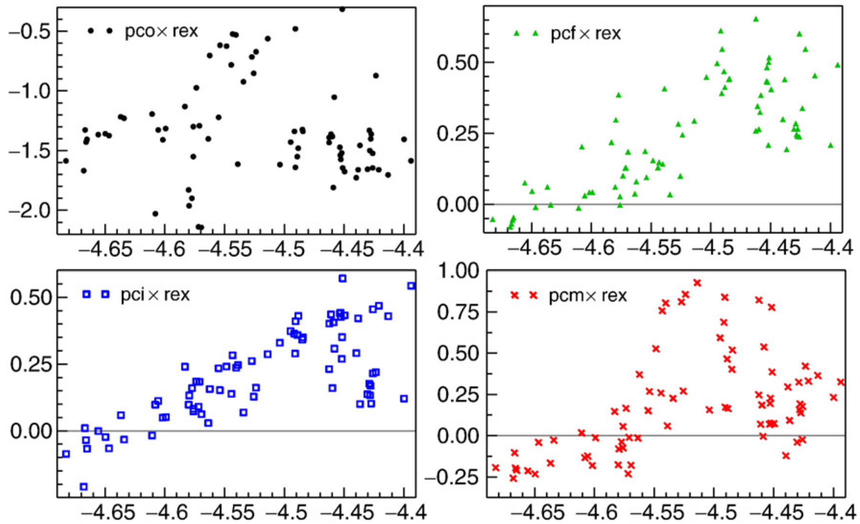

Fig. 3. Cross plots: Real commodity prices vs the real exchange rate; in logs. The cross plots for four different (groups) of commodity prices are based on quarterly observations over the period 1990q1–2007q4.

ambiguous relationship between real interest rates and different commodity prices is consistent with earlier empirical evidence based on bivariate linear models.

The cross plot between real oil prices and real value of the dollar suggests absence of a (linear) relationship between real oil prices and the real value of the dollar. Accordingly, a relatively weak dollar does not contribute systematically to high real oil prices. However, in the case of the other commodity prices, the cross plots are positive and suggest that a weak dollar goes together with high commodity prices.

The cross plots between commodity prices and financial variables offer mixed evidence on the relationships between commodity prices and interest rates and the dollar. However, in order to draw valid conclusions regarding the relationships between commodity prices and the financial variables, one needs to control adequately for other relevant variables.

4.1.1. Model specification

We formulate VAR models for seasonally adjusted quarterly time series for the following aggregate variables in logs: *yo*, *ri*, *rex*, *pco* and *pcxo*, where *pcxo* = *pcf*, *pcm*, *pci*. Here, *yo* is the log of industrial production volume in the OECD countries which is included to take into account interaction between the global economic activity level, financial variables and commodity prices. The VAR models are based on quarterly data for the period 1990q1–2007q4.

We do not include all of the commodity prices simultaneously in the model to limit the size of the model as we have a small number of observations. However, we take into account possible interdependence between oil prices and other commodity prices by retaining oil prices in the models as we add the other commodity prices in turn.

Table 1
Lag selection tests for the three VAR models.

	VAR with *pcf*	VAR with *pcm*	VAR with *pci*
Akaike information criterion	2	2	2
Final prediction error	2	2	2
Hannah–Quinn criterion	1	1	1
Schwarz criterion	1	1	1

Up to 5 lags considered; effective sample 1991q2–2007q4.
Note: See e.g. Lütkepohl, and Krätzig (2004) for details.

As we are primarily interested in estimating parameters that describe the system's dynamics, we formulate the VAR models in (log) levels of the variables to allow implicitly for cointegration between possibly integrated variables.[4] A VAR model for first differences of variables may lead to biased estimates if cointegrating variables in levels are omitted. In the absence of cointegration between integrated variables, consistent estimates of parameters describing the system's dynamics can still be obtained from a VAR model in levels; see e.g. Sims et al. (1990). Incorporating information about the number and identity of cointegrating relationships and using a vector equilibrium correcting model can lead to more efficient estimates than VAR in levels, especially in small samples. However, one faces the risk of imposing invalid assumptions; see e.g. Hamilton (1994, pp. 651–653) for a discussion.

Two lags of the variables beside intercepts have been found to adequately characterize the VAR models.[5] We allowed for up to five lags of each of the variables. Table 1 shows that the commonly employed model selection criteria suggest one or two lags of each of the variables. We retain two lags for each of the variables to safeguard against possible misspecification of the dynamic properties of the models.

To identify the shocks, we order the variables in the VAR models, and thereby the corresponding shocks, as $(yo, ri, rex, pco, pcxo)'$. This implies,

$$B\varepsilon = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{bmatrix} \begin{bmatrix} \varepsilon_{yo} \\ \varepsilon_{ri} \\ \varepsilon_{rex} \\ \varepsilon_{pco} \\ \varepsilon_{pcxo} \end{bmatrix},$$

where $\varepsilon_{pcxo} = \varepsilon_{pcf}, \varepsilon_{pcm}, \varepsilon_{pci}$ and B is a lower diagonal matrix consistent with the Choleski decomposition. The "*" entries in the matrix represent unrestricted parameter values. The zeros suggest that the

[4] Preliminary analysis suggests that e.g. different pairs of the commodity prices may be cointegrated. However, the results regarding the degree of integration of the real commodity prices and cointegration between them are sensitive to tests used and sample period considered.

[5] Our results are quite invariant to trend adjustment of variables by way of including a deterministic trend in the VAR models.

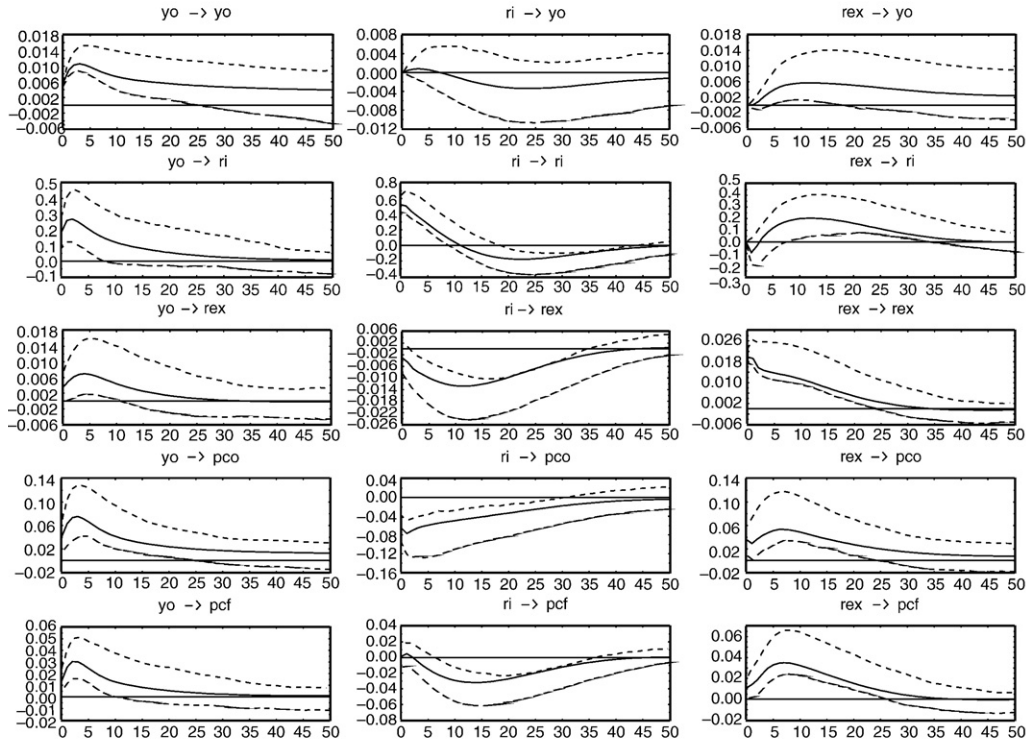

Fig. 4. For VAR model with food prices, impulse responses (in %) to one standard error shocks to output, interest rate and real exchange rate, in the three columns respectively (dashed lines: 95% confidence intervals). Quarters on the horizontal axis, here and elsewhere.

associated fundamental shock does not contemporaneously affect the corresponding endogenous variable. Specifically, the first row in matrix *B* implies that output (*yo*) may respond contemporaneously to only ε_{yo}, while the other four shocks do not have contemporaneous effects on *yo*. The second row implies that the real interest rate (*ri*) may respond contemporaneously to both ε_{yo} and shocks directly to the real interest rate ε_{ri}, while the third row implies that the real exchange rate (*rex*) may respond contemporaneously to ε_{yo} and ε_{ri}, in addition to shocks directly to the exchange rate, ε_{rex}. We assume that shocks to commodity prices exclusive oil ($pcxo = pcf$, pcm, pci) do not have contemporaneous effects on oil prices, while the converse may not be the case. The former commodity prices may respond contemporaneously to all of the shocks.

The ordering of *yo*, and hence of ε_y, at the top followed by the real interest rate and then by the real exchange rate is consistent with much previous work; see e.g. Eichenbaum and Evans (1995) and Favero (2001, Ch. 6) and the references therein. Given the focus of this study on the response of commodity prices to real interest rates and the exchange rate, we have deviated from the previous studies and placed them after the latter variables. Previous work employing VAR models to investigate the monetary policy response to macroeconomic variables often places commodity prices before the real interest rate and/or the real exchange rate. There, commodity prices have often been included as possible solutions to price and/or exchange rate puzzles; see Hanson (2004) and the references therein.

Empirical studies of the reaction functions of monetary policy authorities in many OECD countries do not offer strong evidence of immediate interest rate response to exchange rates or commodity prices. It is still a contentious issue in the literature whether monetary policy authorities under (flexible) inflation targeting regimes respond to asset prices; see Clarida et al. (1998), Chadha et al. (2004) and the references therein.

One could argue that real exchange rates of commodity-producing countries should be allowed to respond immediately to fluctuations in commodity prices. While there is some evidence that currencies of commodity-producing countries tend to respond to commodity prices in the long run, evidence of a contemporaneous relationship between these variables is ambiguous, especially for OECD countries; see e.g. Akram (2004) and Cashin et al. (2004). One may also argue that the dollar effective real exchange rate, based on currencies of both commodity importing as well as commodity exporting countries, is likely to be less sensitive to movements in commodity prices including oil. Finally, it seems reasonable that oil prices do not respond contemporaneously to shocks in the other commodity prices, while the converse may be the case for the other commodity prices.

5. Empirical results

5.1. Impulse response analysis

In the following, we analyze impulse responses based on the three VAR models. We present 95% confidence intervals obtained by bootstrapping together with the impulse responses to different shocks.[6] Given the small sample of the data, more reliable small sample inference may be possible by bootstrapping than by relying on asymptotic theory.

The results for the three VAR models are largely the same and are generally consistent with theories suggesting a negative relationship between (real) interest rates and commodity prices, and theories suggesting a negative relationship between the real value of the dollar

[6] We employ the bootstrap method suggested by Hall (1992). The number of bootstrap replications is set to 1500, though it does not matter much if one uses fewer replications.

and commodity prices. The results also support an overshooting response of some commodity prices, specifically of oil prices and prices of industrial raw materials, to real interest rate shocks.

The results of shocks to global output, proxied by OECD industrial production (*yo*), and oil prices are consistent with a large number of studies based on VAR models; see e.g. Kilian (2008). Accordingly, high economic activity induced by output shocks raises real interest rates and commodity prices, particularly oil prices. Shocks to real oil prices reduce output and real interest rates. The effects of oil prices on output are quite persistent.

In the following, we present the results for the VAR models with food prices (*pcf*) in detail in Figs. 4–6 and comment briefly on notable differences in results based on the other two VAR models. The latter results are presented in detail in Appendices B.1 and B.2. It should be noted that the impulse responses are quite uncertain in general as the corresponding 95% confidence intervals are relatively wide.

The impulse responses of the VAR model with food prices which are presented in Fig. 4 can be summarized as follows. An exogenous increase in world economic activity represented by *yo* due to own shock, ε_y, leads to higher real interest rates and commodity prices; see column 1. The effects on oil prices and food prices are statistically significant at the 5% level in the short run, i.e. over the horizon of 20 and 10 quarters, respectively. We note that effects on *yo* of the transitory shock die out relatively slowly and contribute to positive effects on oil prices over the simulation horizon of 50 quarters. 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; c.f. Svensson (2006). This suggests that the demand or income effects of higher *yo* dominate the discounting effect of higher real interest rates on the present value of commodity prices. The effect on the real exchange rate is weak and mostly statistically insignificant.

A shock to real interest rates depresses economic activity while the real exchange rate appreciates over almost all horizons; see column 2. The behavior of the real exchange rate is consistent with a bulk of studies suggesting gradual exchange rate appreciation and thereafter gradual depreciation; see e.g. Eichenbaum and Evans (1995) and Bjørnland (2005). Such behavior does not conform with the behavior of the real exchange rate predicted by the overshooting model of exchange rates.

In contrast, oil prices fall immediately and thereafter increase gradually in response to the real interest rate shock, consistent with Frankel's (1986) overshooting model of commodity prices. Food prices also decline, but with a delay, before rising gradually as the effects of the interest rate shock dissipate over time.

A depreciation of the real exchange rate, i.e. an increase in *rex*, owing to the exchange rate shock leads to lower real interest rates in the short run, higher economic growth and higher commodity prices; see column 3. In particular, oil prices and food prices increase significantly for about 6 years. The real exchange rate depreciation leads to higher real interest rates over time, which could be the result of central banks' response to possibly higher inflation brought about by exchange rate pass-through to consumer prices.

Fig. 5 presents the impulse responses for shocks to oil and food prices. It is seen that a shock to oil prices depresses economic activity over a relatively long time period in a statistically significant manner; c.f. Hamilton (1983). Real interest rates fall in the short run, while the real exchange rate tends to depreciate in the short run as well as in the medium run. The positive oil price shock lowers food prices in the very short run. A possible interpretation is that demand for food goods falls due to the reduction in economic activity which reduces food prices. It could be that the income effect dominates the substitution effect, as oil may not be a close substitute for the aggregate of food items. The results might have been different if we had used prices of a subaggregate of food items that are key inputs in bio-fuel production.

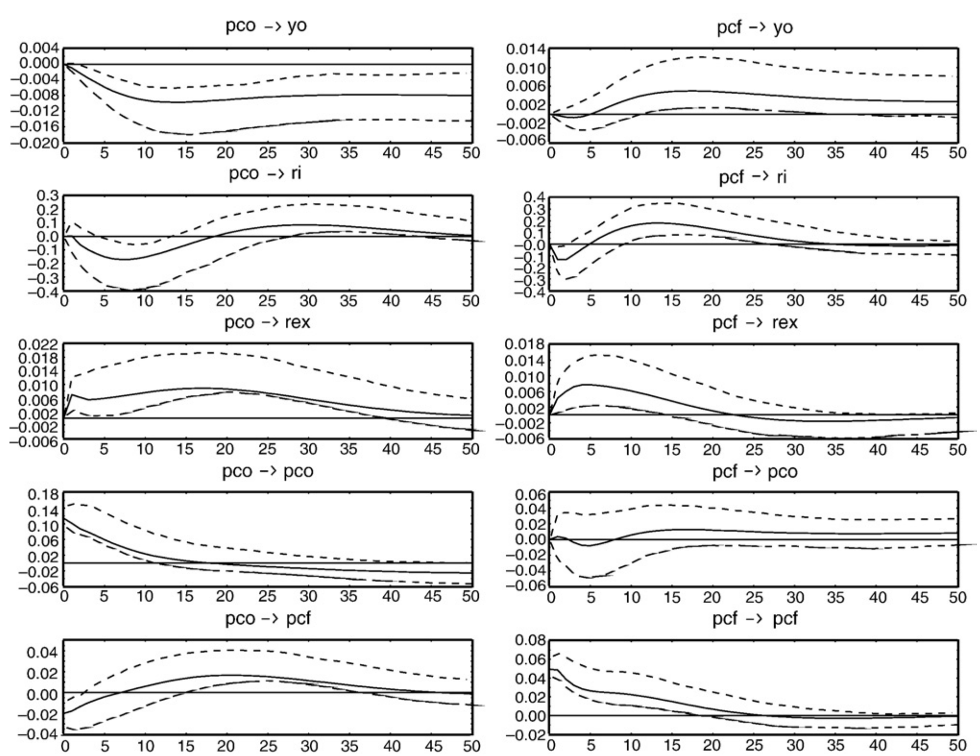

Fig. 5. For VAR model with food prices, impulse responses to one standard error shocks to oil prices and food prices, in the two columns respectively (dashed lines: 95% confidence intervals). Changes in the real interest rate are presented in percentage points, here and elsewhere.

The second column of Fig. 5 shows that a shock to food prices depreciates the real exchange rate in the short run, possibly because of terms of trade effects on the real exchange rate. The increase in the activity level, which could be due to the real exchange rate depreciation, and food prices may explain the accompanying increase in real interest rates in the medium run. Interest rate setting in a large number of countries is usually responsive to economic activity and consumer price inflation, which partly depends on food price inflation.

The impulse responses based on VAR models that include metal prices (*pcm*) and industrial raw material prices (*pci*) are largely the same as those for the VAR model with food prices; see Figs. 7–10 in Appendix B.1. One notable difference relative to the latter model is that prices of industrial raw materials overshoot their long run values in response to the shock to interest rates.

Regarding the response to commodity price shocks, Fig. 9 shows that metal prices (*pcm*) do not respond to oil price shocks in the very short run, which contrasts with the response of food prices and prices of industrial raw materials. It is possible that expenditure and substitution effects outweigh each other in this case.

5.2. Forecast error variance decomposition of shocks

In the following, we investigate contributions of different structural shocks to fluctuations in the modeled variables. Fig. 6 shows forecast error variance decompositions (FEVD) of different variables over different forecasting horizons (in quarters). It displays percentages of the variance of the error made in forecasting a variable at a given horizon due to the five specific shocks. The shocks are denoted by the associated variables.

Fig. 6 shows that commodity prices, especially oil prices, account for an increasing share of output fluctuations over the forecast horizon. The share attributable to oil price shocks increases to about 55% while the share attributable to food prices increases to 5% in the medium run and beyond. Interestingly, the share of output fluctuations attributable to oil price shocks is substantially larger than the combined share attributable to shocks to real interest rates and the real exchange rate. In the short run, a major share of output fluctuations is accounted for by output shocks, which could be seen as an indication of the low explanatory power of the other shocks in the short run.

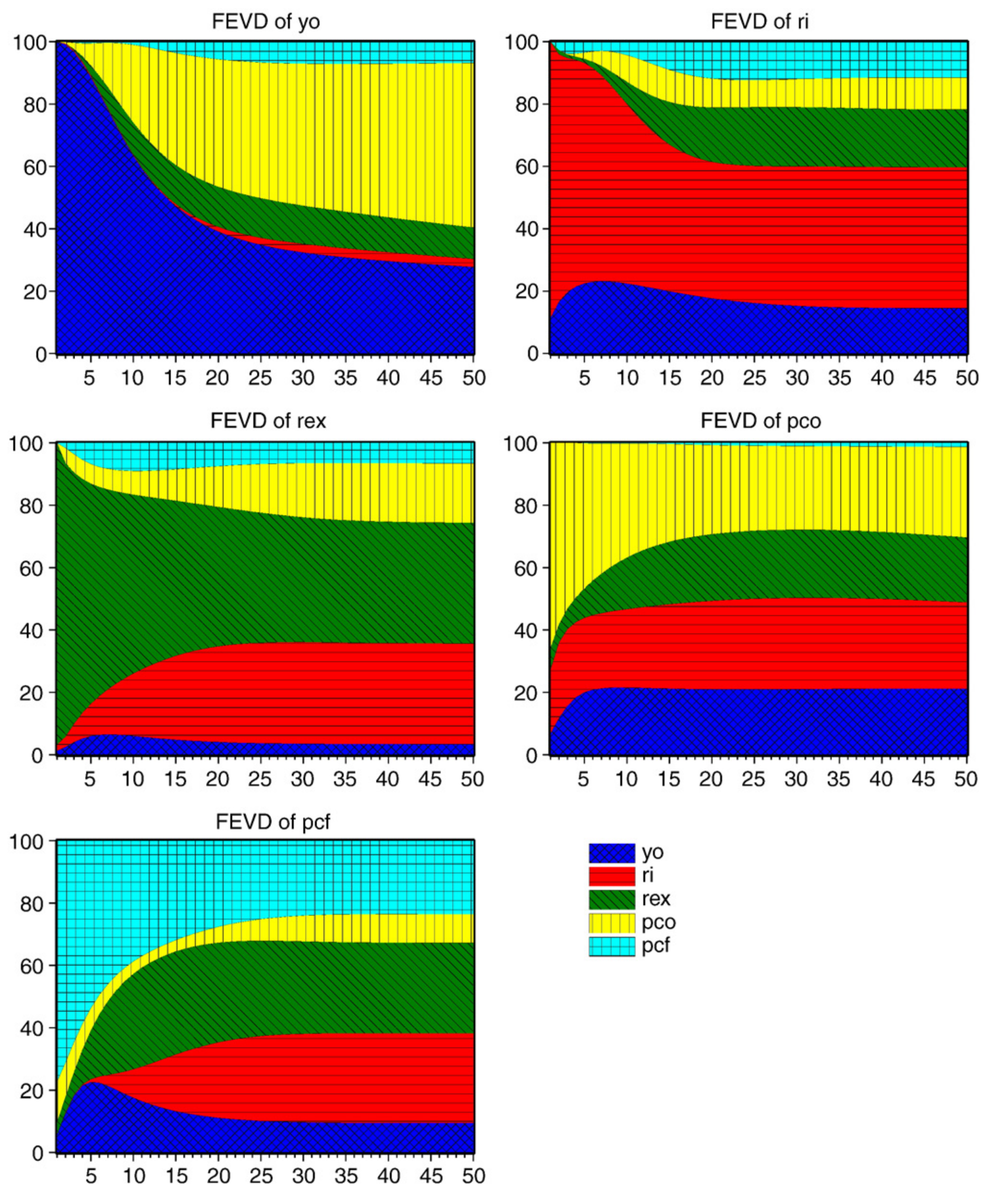

Fig. 6. Forecast error variance decompositions based on the VAR model with food prices over different horizons (*x*-axis).

Shocks to food prices account for a somewhat larger share of real interest rate fluctuations than oil price shocks; see column 2 of Fig. 6. One possible explanation could be the relatively higher share of food prices relative to fuel prices in consumer prices, which are the main determinant of interest rate setting in OECD countries that have adopted flexible inflation targeting regimes over the sample period. Such regimes take into account output fluctuations when targeting inflation. This may also explain the relatively large contributions of real exchange rate shocks and output shocks to real interest rate fluctuations. The contribution of real exchange rate shocks to interest rate fluctuations could be due to exchange rate pass-through to consumer prices. The share of real exchange rate shocks increases over time and becomes quite substantial in the long run.

Fluctuations in the real exchange rate are mostly due to shocks to the real exchange rate and the real interest rate; see row 2. The other shocks do not contribute notably to real exchange rate fluctuations, especially in the short run. This is consistent with the exchange rate disconnect puzzle and the empirical evidence suggesting that apart from own shocks, real exchange rates largely move in response to interest rate changes; see e.g. Alquist and Chinn (2008) and the references therein. We note that oil price shocks account for a larger share of real exchange rate fluctuations than food price shocks. This could be due to the relatively larger importance of oil prices to current accounts and other determinants of real exchange rates relative to that of food prices.

We find that fluctuations in commodity prices are mainly driven by shocks to the real interest rate and the real exchange rate. The second and third rows of Fig. 6 show that shocks to the real interest rate and the real exchange rate account for a relatively large share of commodity price fluctuations at all horizons. Specifically, the real interest rate shocks account for more than 20% of fluctuations in oil prices and food prices. The contribution of real exchange rate shocks to oil price fluctuations is somewhat lower than 20%, but higher to food price fluctuations. Output shocks account for a relatively large share of oil price fluctuations at all horizons, but for a smaller share of food price fluctuations than of oil price fluctuations, in general.

Forecast error variance decompositions based on the VAR models with industrial goods prices and metal prices are largely consistent with those based on the VAR model with food prices; see Figs. 11 and 12 in Appendix B.2. These figures also suggest that the real interest rate and the real exchange rate account for large shares of the fluctuations in commodity prices.

Notable differences relative to the forecast error variance decomposition based on the VAR model with food prices, are that in the case of the VAR model with metal prices, real interest rates shocks accounts for a larger share of oil price movements, i.e. about 30%, somewhat at the expense of real exchange rate shocks. Real exchange rate shocks account for a relatively small share of metal price fluctuations than of food price fluctuations and prices of industrial raw materials.

6. Conclusions

We have investigated the empirical relationship between commodity prices, real interest rates and the dollar exchange rate. The analysis is based on structural VAR models with different commodity prices, in addition to a proxy for world output fluctuations, the real interest rates and the dollar real exchange rate.

Our evidence suggests that shocks to the real interest rate and the dollar real exchange rate contribute significantly to movements in commodity prices. We find that commodity prices rise when the real interest rates fall and when the real value of the dollar depreciates. In the former case, real oil prices as well as real prices of industrial raw materials tend to display overshooting behavior in response to shocks to real interest rates. In comparison, real prices of food and metals display delayed response to interest rate shocks. Thus, we find mixed evidence of overshooting behavior in response to interest rate shocks.

We have also found that shocks to real interest rates and the real exchange rate account for substantial shares of fluctuations in commodity prices at all horizons. Shocks to output account for notable shares of fluctuations in oil prices and metal prices, but to a lesser extent to fluctuations in food prices and prices of industrial raw materials. Shocks to oil prices account for a relatively large share of output fluctuations. This is in contrast with the shocks to the other commodity prices which contribute relatively little to output fluctuations.

Our analysis sheds light on the recent fluctuations in commodity prices. The analysis suggests that the recent surge in commodity prices may be attributed to relatively low real interest rates and weak dollar. Moreover, the analysis suggests that the current fall in a broad range of commodity prices after the commodity price boom, and the accompanying relatively low real interest rates can be attributed to weak economic activity.

Our analysis implies that shocks to the US real interest rates, proxying world real interest rates, and in the value of dollar may be useful indicator of movements in commodity prices. Moreover, commodity prices may overshoot their long run values in response to real interest rate shocks. Such overshooting response should be taken into account when devising monetary and/or fiscal policy response to a rise or a fall in commodity prices. For example, linear interest rate response to commodity price movements by monetary authorities can have destabilizing effects on an economy, because of the overshooting behavior of commodity prices. Furthermore, the large share of output fluctuations attributable to oil price shocks found in our analysis suggests that oil prices are a key driving force and a useful indicator of the prospects for world economic activity.

Our analysis has been based on linear VAR models. An interesting extension of the analysis presented here would be to include non-linear variants of the VAR models as in Kyrtsou (2008).

Acknowledgements

I would like to thank especially two anonymous referees and the editors for useful comments. I am also thankful to Christian Kascha, Luca Sala, Robert Vigfusson, Fakhir Zaman, several colleagues at Norges Bank and participants at the workshop “Commodity prices: drivers and economic impacts”, organized jointly by Bank of England and European Central Bank in 2009, for useful comments and discussions.

Appendix A. Data

- CPI: The US consumer price index; Source: OECD_MEI; Series: USA.CPALTT01.IXOB.Q.
- PCFN: The Economist's world commodity price index for food in USD. Source ECOWIN; Series: ew:com20805.
- PCIN: The Economist's world commodity price index for industrial inputs exclusive food and agricultural products, in USD; Source ECOWIN; Series: ew:com20815.
- PCMN: The Economist's world commodity price index for industrial metals in USD. Source ECOWIN; Series: ew:com20820.
- PCON: Brent Blend crude oil price in USD. Source OECD_EO; Series: Q.WLD.WPBRENT.
- REX: Effective real exchange rate for the US. Source: OECD_MEI; Series: USA.CCRETT01.IXOB.Q.
- ri: The US 1-month LIBOR rate, in percent per annum. Source: IMF-IFS; Series: Q.11160LDCZF...
- YO: OECD Industrial production; Source: OECD_MEI; Series: OTO.PRINTO01.IXOBSA.Q.

Appendix B.1. Impulse responses

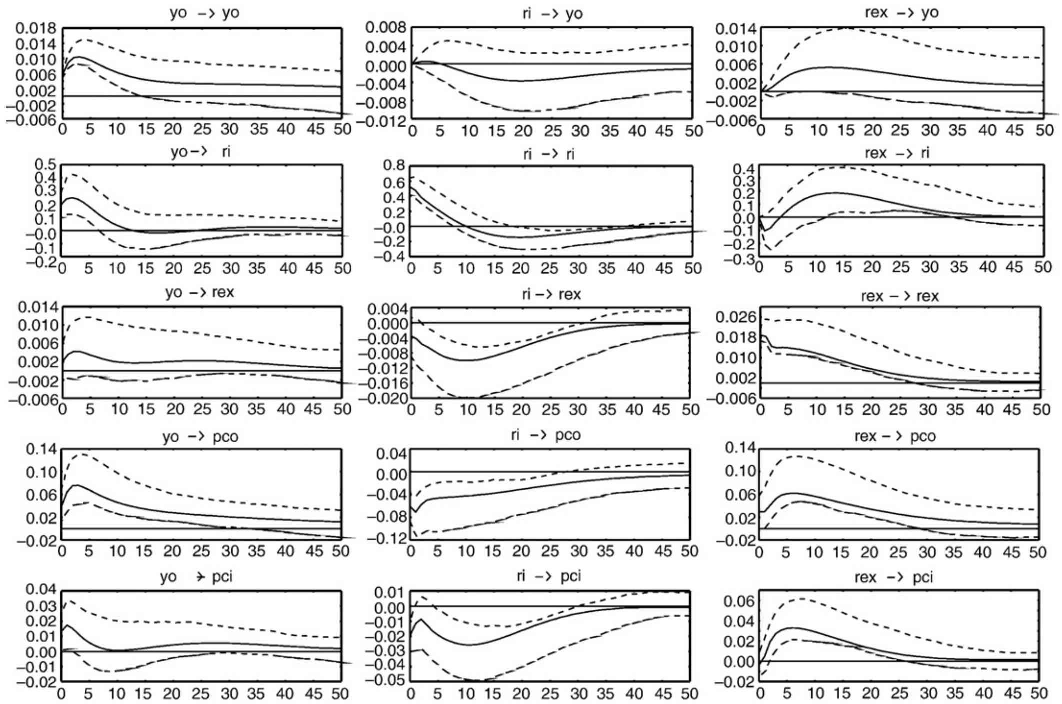

Fig. 7. For VAR model with industrial input prices, impulse responses to one standard error shocks to output, interest rate and real exchange rate, in the three columns respectively (dashed lines: 95% confidence intervals).

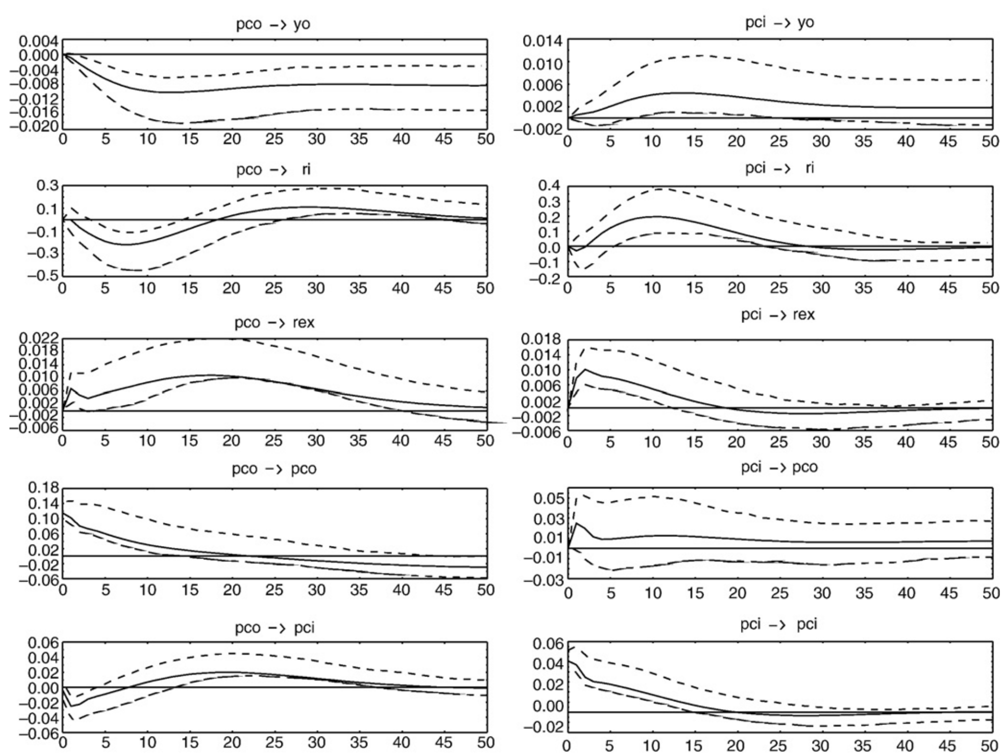

Fig. 8. For VAR model with industrial input prices, impulse responses to one standard error shocks to oil prices and industrial input prices, in the two columns respectively (dashed lines: 95% confidence intervals).

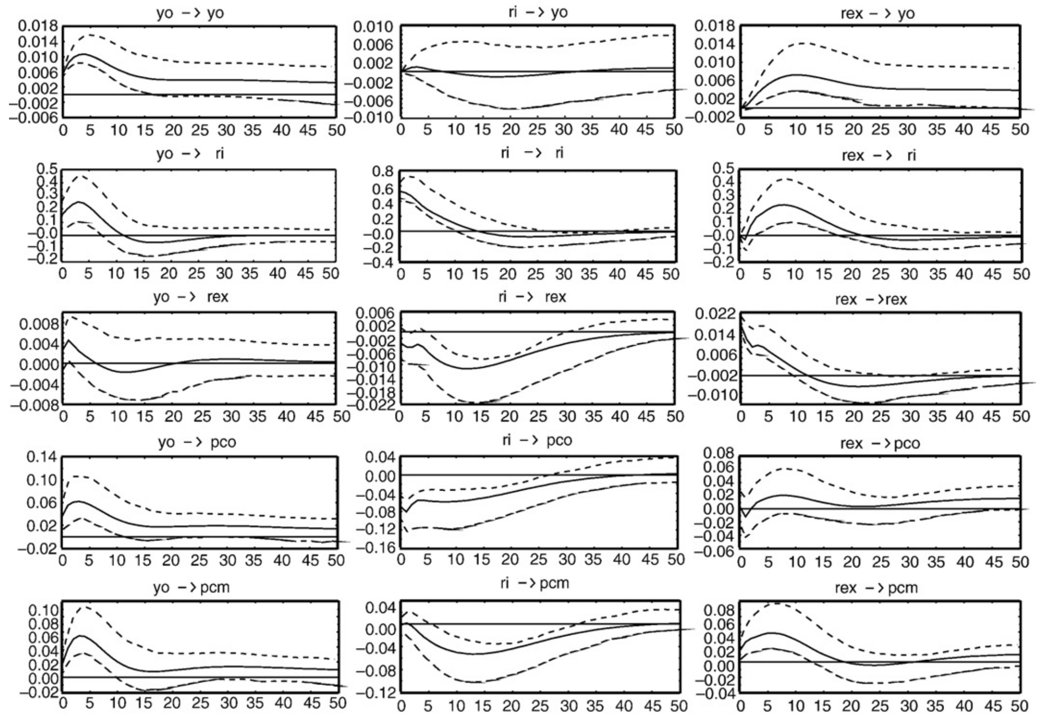

Fig. 9. For VAR model with metal prices, impulse responses to one standard error shocks to output, interest rate and real exchange rate, in the three columns respectively (dashed lines: 95% confidence intervals).

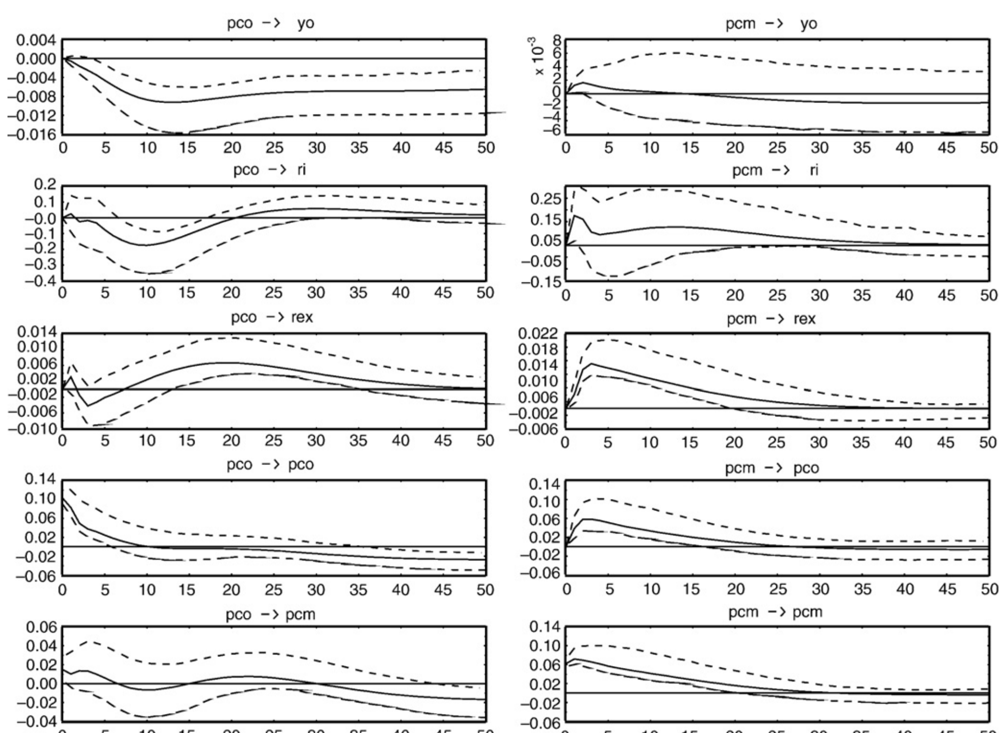

Fig. 10. For VAR model with metal prices, impulse responses to one standard error shocks to oil prices and metal prices, in the two columns respectively (dashed lines: 95% confidence intervals).

Appendix B.2. Forecast error variance decompositions (FEVD)

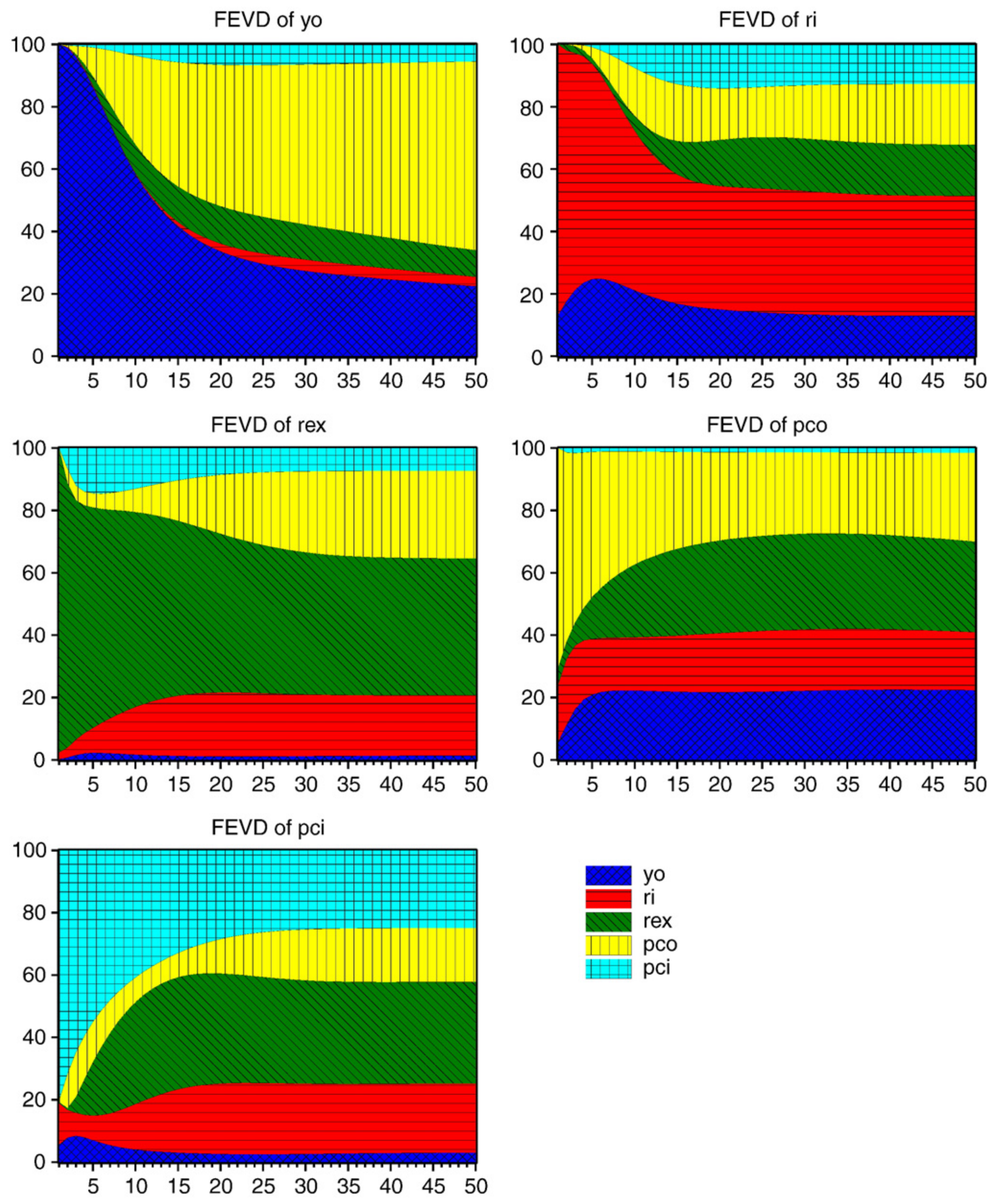

Fig. 11. FEVD based on the VAR model with industrial goods prices over different horizons in quarters (*x*-axis).

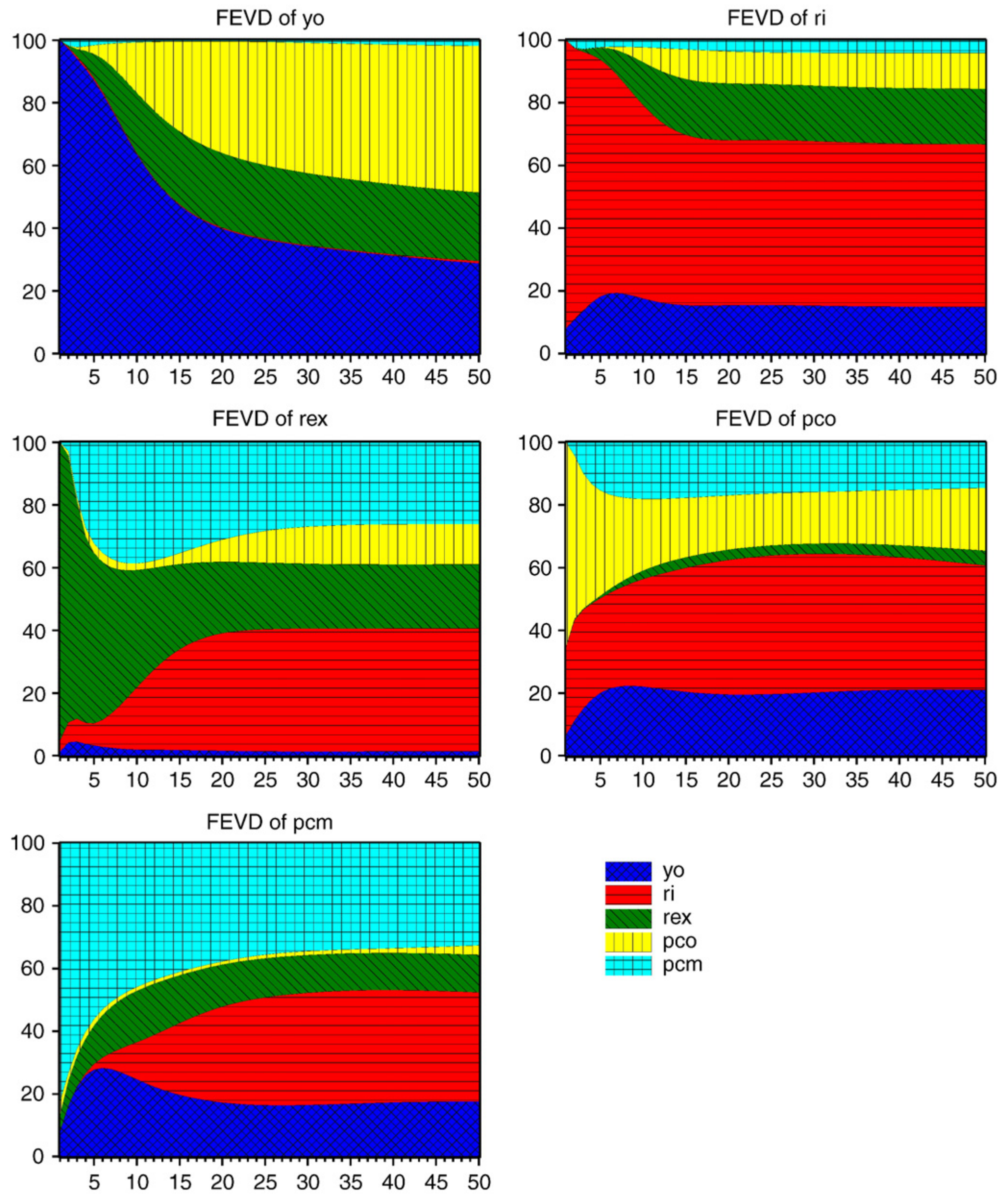

Fig. 12. FEVD based on the VAR model with metal prices over different horizons in quarters (*x*-axis).

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