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Commodity prices, interest rates and the dollar

by

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Commodity prices, interest rates and the dollar

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Abstract

We investigate whether a decline in real interest rates and the US dollar contribute to higher commodity prices, and whether commodity prices tend to display overshooting behavior in response to changes in especially real interest rates. We analyze the behavior of a broad range of real commodity prices, i.e. 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 a reduction in real interest rates. Moreover, we find that oil prices as well as metal prices tend to display overshooting behavior in response to interest rate changes. The evidence also suggests that a decline in the dollar leads to a surge in commodity prices. Shocks to interest rates and the dollar are found to account for substantial shares of fluctuations in the commodity prices.

Key words: Commodity prices, interest rates, exchange rates, VAR models.

JEL codes: E37, E47, Q17, Q43.

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

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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; see e.g. IMF (2008) and Krichene (2008).[1] World economic growth, with substantial contribution from the growth of emerging economies, has also been relatively high over a number of years. 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 and higher demand for agricultural commodities in order to substitute biofuel 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 (1976)'s model; see Frankel (1986) and Frankel (2006). We also examine the possible contribution of world economic growth and of possible spillover-effects from energy prices, specifically from crude oil prices to prices of other commodities.

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). There, 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 increase, adjusted for carrying costs and possible risk premium. Thus, in response to a fall in interest rates, current commodity prices must rise more 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).

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 their dollar price and/or a fall in their

[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.

foreign currency prices to ensure the same price when measured in dollars. Moreover, as many commodities are priced in dollars in international markets, a fall in the value of the dollar may raise the purchasing power and commodity demand of foreign consumers, while reducing the returns of foreign commodity suppliers and potentially their supplies. The price impact of shifts in demand and supply of commodities may be particularly large if the demand or supply of commodities are 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 partly or wholly outweigh each other. 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 the real expenditures of agents and thereby make them reduce their demand for all goods and services. Therefore, whether an increase in the price 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 the increase in different commodity prices have fueled each other, in particular, whether one can ascribe increases in prices of e.g. food 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. 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, shocks that increase 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 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 possible 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.

We base our empirical analysis on five-variable vector autoregressive (VAR) models for four commodity prices: real oil prices in US dollars, aggregate price indices of food, metals and industrial goods. 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 enable us to examine dynamic interactions between the financial and real macroeconomic variables and the commodity prices. We assess the relative contributions of the 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 lower real interest rates lead to higher real commodity prices. Moreover, commodity prices specifically oil prices and metal prices tend to display overshooting behavior in response to interest rate shocks, while food prices and prices of industrial goods tend to respond gradually. A fall in the value of the dollar tends to cause higher commodity prices. We also find that interest rates and exchange rate shocks account for most of the fluctuations in commodity prices at all horizons. The contribution of real interest rates relative to the real exchange rate depends on the commodity price considered.

The paper is organized as follows. The next section briefly outlines common arguments for the relationships between commodity prices, real interest rates and the dollar. Section 3 presents 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 very much 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:

$$E_t pc_{t+1} - pc_t = i \; + s(i), \tag{1}$$

where $E_t pc_{t+1} - pc_t$ is the expected revaluation of a commodity over a period, measured by the expected price increase from period t to $t+1$, given available information at time t. On the right hand side, "i" is the nominal interest rate while $s(i)$ represents the storage costs of commodities 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).

Condition (1) states that revaluation gains from a commodity holding, net of storage costs, should equal the nominal interest rate. This no-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.[2] 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 people 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 the carrying costs also increase the inventory demand for commodities and thereby their prices. 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 the bond markets; cf. Hotelling (1931). The lower supply of commodities would contribute to raising their prices. Finally, lower interest rates may also 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 owing to e.g. higher money supply. This may be because prices of manufactured goods, which tend to be sticky, make general inflation less responsive to shifts in the money supply in the short run. Thus, real interest rates may also fall with nominal interest rates. Expected commodity prices on the other hand may only rise in proportion to the accompanying rise in money supply, as implied by monetary theory. In order to ensure no-arbitrage, current commodity prices may therefore increase more than their expected price. Their rise must be sufficient to ensure that the expected rise in commodity prices, $E_t pc_{t+1} - pc_t$, equals the nominal interest rate and carrying costs.

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 log of the 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

[2] 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 values and thereby current commodity prices.

foreign currency. If a commodity is mainly priced in dollars, as is the case for crude oil, its price in foreign currencies can be derived from equation (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. This may contribute to a higher dollar price of the commodity.

Equation (2) may also be interpreted as the law of one price for commodities that are traded and priced abroad as well as in the US. Commodities of a given kind are relatively homogenous and internationally tradable goods. Hence, for such goods, equation (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 the foreign commodity. 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. It follows that a reduction in 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. A VAR model, after an appropriate identification of shocks, would allow us to examine the response of commodity prices to unanticipated shocks particularly to interest rates and the dollar exchange rate, and vice versa, while taking into account the dynamic interaction between commodity prices and macroeconomic variables.

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

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

where $\varepsilon_t \sim (0,\, \Sigma_\varepsilon)$. A is a $k \times k$ invertible matrix of structural coefficients, which may model contemporaneous relationships among the variables in z, while A_is $(i = 1, 2, ..., p)$ are $k \times k$ matrices modeling dynamic interaction 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 (3) with the inverse of A, A^{-1}:

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

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

4 Empirical analysis

4.1 Model specification

We formulate VAR models for the following five seasonally adjusted aggregate variables in logs: *yo*, *ri*, *rex*, *pco* and *pcxo*, where *pcxo* = *pcf*, *pcm* or *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, the financial variables and the commodity prices. *ri* denotes 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. *pco* is the real price per barrel of crude oil in dollars while *pcxo* is the real price index of a commodity exclusive crude oil. The commodity price exclusive oil price is interchangeably the real prices of food (*pcf*), metals (*pcm*) and raw materials (exclusive oil) for industrial purposes (*pci*). 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.

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.

As we are primarily interested in estimating parameters that describe the system's dynamics, we formulate the VAR models in levels to allow implicitly for cointegration between possibly integrated variables. 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. 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.

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
Akaike Information Criterion	1	1	1
Final Prediction Error	2	2	2
Schwarz Criterion	1	1	1

Note: See e.g. Lütkepohl, H. and M. Krätzig (2004) for details.

The results of misspecification tests in Table 2 suggest that the three models are adequately characterized. In particular, the null hypotheses of no autocorrelation up to order 5 and no heteroscedasticity are not rejected at the 5% level of significance. Moreover, the null hypotheses of normally distributed errors are not rejected for all of the equations except the equations for the real interest rate in two of the VAR models. In the latter case, the normality assumption is rejected, and explains the rejection of the joint test for normality for the VAR models with food prices and metal prices at the standard levels of significance.

Table 2: Diagnostics for the three VAR(2) models

Tests	VAR(2) with *pcf*	VAR(2) with *pcm*	VAR(2) with *pci*
AR 1–5 F(125,142)	1.056 [0.376]	1.197 [0.149]	1.363 [0.037]
Hetero F(300, 308)	0.898 [0.824]	0.772 [0.988]	0.829 [0.940]
Normality $\chi^2(2)$	23.692 [0.009]	19.872 [0.031]	16.669 [0.080]

Note: see Godfrey (1978), White (1980) and Doornik and Hansen (1994) for test details. p -values are presented in square brackets.

To identify the shocks, we order the variables, and thereby the corresponding shocks, as noted above, i.e. (yo, ri, rex, pco, $pcxo$)$'$. This implies that,

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

where $\varepsilon_{pcxo} = \varepsilon_{pcf}$, ε_{pcm} or ε_{pci}. The "$*$" entries in the matrix represent unrestricted parameter values. The zeros suggest that the associated fundamental shock does not contemporaneously affect the corresponding endogenous variable. Specifically, the first row in the B matrix implies that 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 suggests 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 or 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 a remedy for 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.

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.[3] Given the rejection of the normality assumption and our 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 and commodity prices. The results also support an overshooting response of some commodity prices, specifically of oil prices and metal prices, to real interest rate shocks. The results of shocks to industrial production (yo) and oil prices are consistent with a large number of studies based on VAR models.

In the following, we present the results for the VAR models with food prices (pcf) in detail, and briefly comment on notable differences in results based on the other two VAR

[3] We employ the bootstrap method suggested by Hall (1992). The number of bootstrap replications is set to 1800, though it does not matter much if one uses fewer replications.

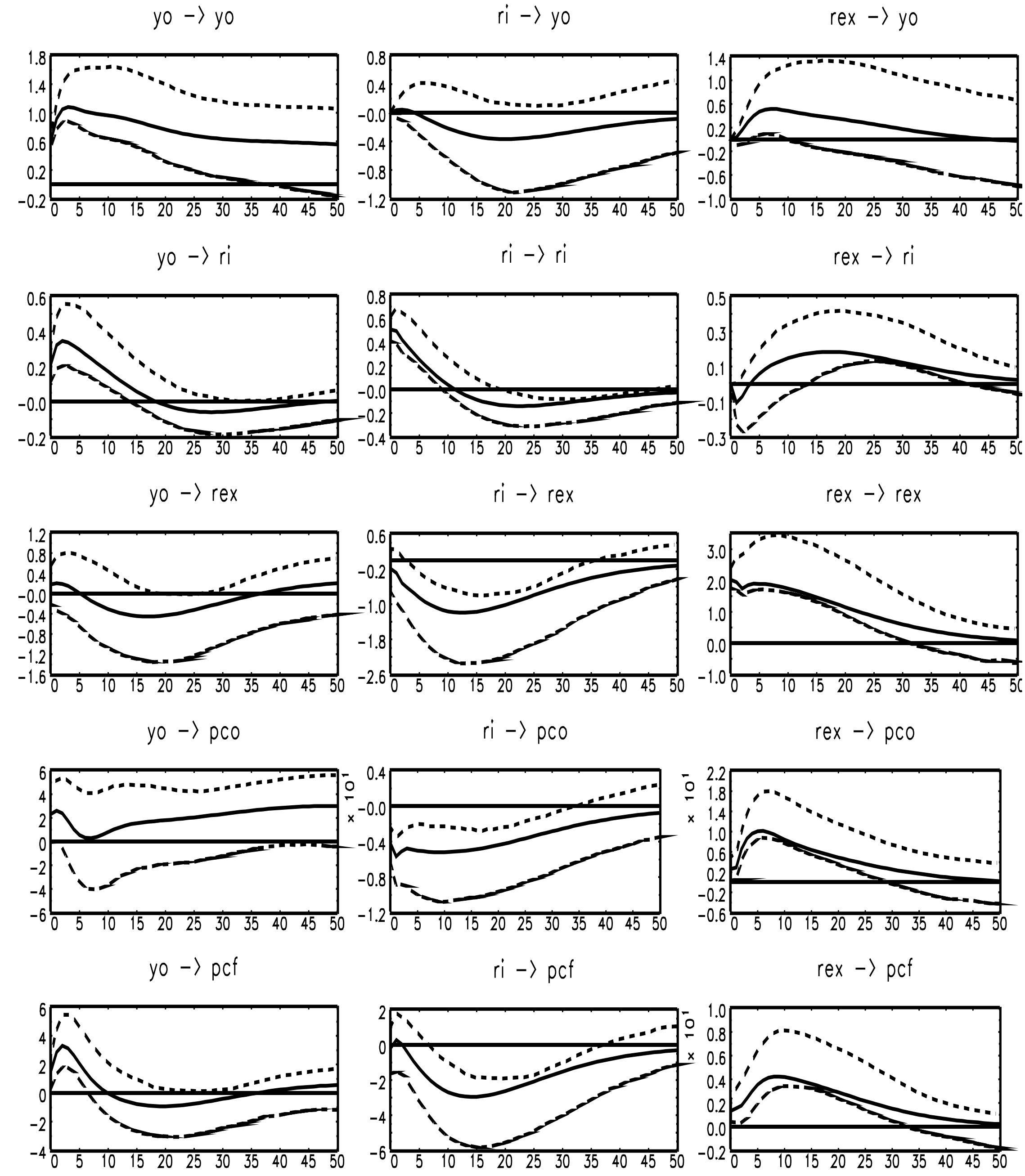

Figure 1: For VAR model with food prices, impulse responses (in %) to one standard error shocks to output (first column), interest rate and real exchange rate shocks, respectively (dashed lines: 95% confidence intervals). Quarters on the horizontal axis, here and elsewhere.

models. The latter results are presented in detail in Appendix B.2.

The impulse responses of the VAR model with food prices which are presented in Figure 1 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 effect on food prices is statistically significant in the short run while the effect on oil prices is numerically significant over all horizons, though statistically insignificant. 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. The positive correlation between real interest rates and commodity prices lends support to the argument that the relationship between real interest rates and commodity prices is shock dependent. This suggests that the demand effect of higher yo dominates the discounting effect of higher real interest rates on the present value of commodity prices. The effect on the real exchange rate is ambiguous and statistically insignificant.

A shock to real interest rates depresses economic growth 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 the real exchange rate.

In contrast, oil prices (pco) fall immediately and thereafter increase gradually, consistent with Frankel (1986)'s overshooting model for commodity prices. Food prices (pcf) 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 5–6 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.

Figure 2 presents the impulse responses for shocks to oil and food prices. It is seen that a shock to oil prices depresses economic growth over a relatively long time period in a statistically significant manner; cf. 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

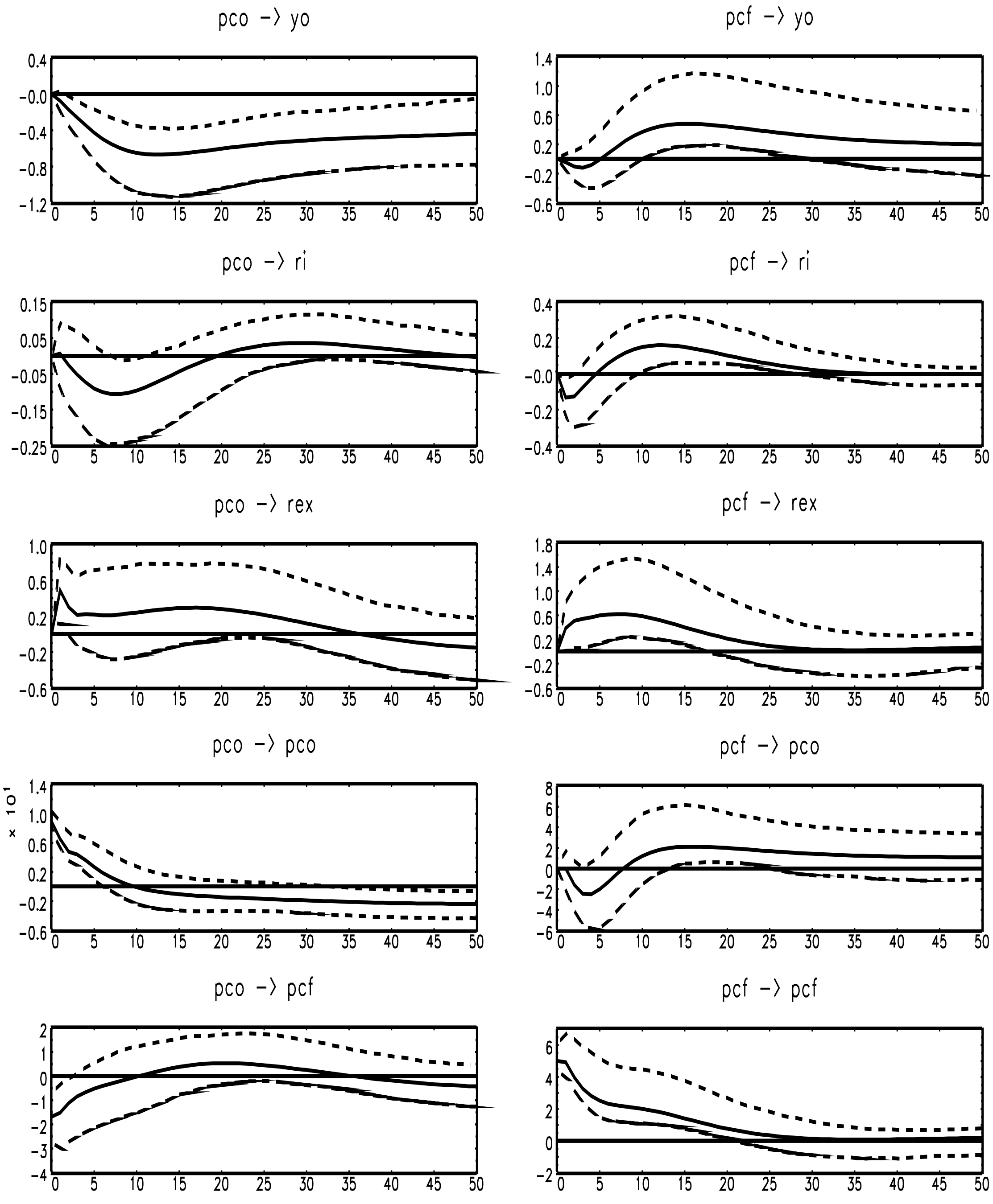

Figure 2: For VAR model with food prices, impulse responses (in %) to one standard error shocks to oil prices (first column) and food prices, respectively (dashed lines: 95% confidence intervals).

medium run. The positive oil price shock lowers food prices in the short run. A possible interpretation is that demand for food goods falls due to the reduction in economic growth 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 biofuel production.

The second column of Figure 2 shows that a shock to food prices depreciates the real exchange rate in the short and medium run. The activity level and oil prices increase over time and hence also the real interest rate.

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 Figures 4–7 in Appendix B.1. One notable difference relative to the latter model is that metal prices overshoot their long run values in response to the shock to interest rates. The impulse response of metal prices resembles that of oil prices, except that metal prices respond more strongly than oil prices.

Regarding the response to commodity price shocks, Figure 7 shows that prices of industrial raw materials (pci) do not respond to the shock to oil prices in the short run, which contrasts with the response of food and metal prices. It is possible that expenditure and substitution effects outweigh each other in this case. Another difference, especially relative to the VAR model with food prices, is that the interest rate increases more and faster in response to the shock to prices of industrial goods.

5.2 Forecast error variance decomposition of shocks

In the following, we investigate contributions of different structural shocks to inducing fluctuations in the different variables. Figure 3 shows forecast error variance decompositions 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, which are denoted by the associated variables.

Figure 3 shows that commodity prices account for an increasing share of output fluctuations over the forecast horizon. The share attributable to oil price shocks increases to about 20% 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 share attributable to real interest rates and the real ex-

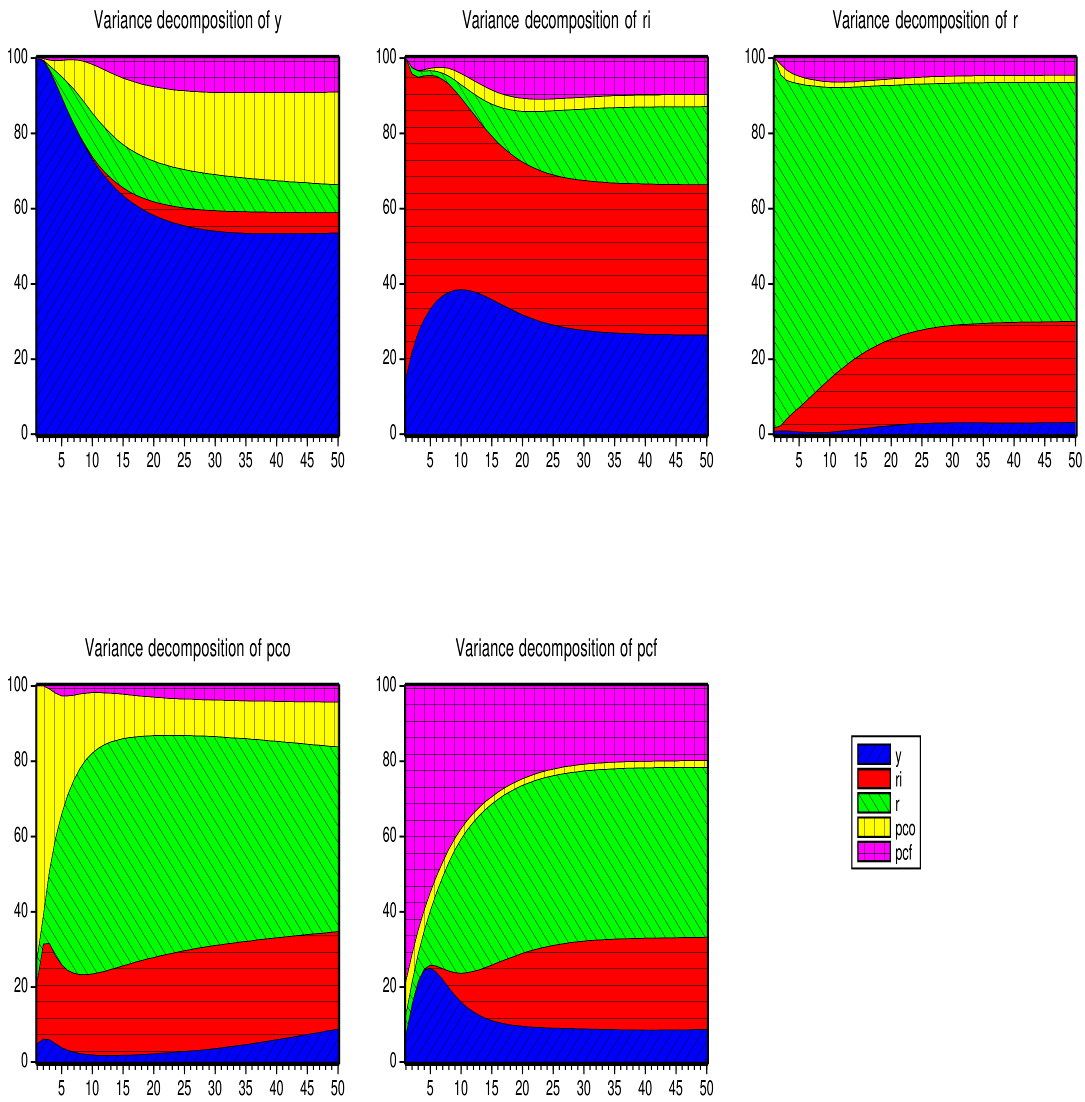

Figure 3: Forecast error variance decompositions based on the VAR model with food prices over different horizons (x-axis). Note: y $=yo$ and r $=$ *rex*.

change rate in output fluctuations. A substantial 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.

Shocks to food prices seem to account for a larger share of real interest rate fluctuations than oil price shocks; see column 2 of Figure 3. 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 a large number of OECD countries which have adopted inflation targeting regimes over the sample period. This may also explain the relatively large contribution of output shocks to the real interest rate fluctuations. The share of shocks to the real exchange rate increases over time and becomes quite substantial in the long run.

Fluctuations in the real exchange rate are almost entirely due to shocks to the real exchange rate and the real interest rate; see column 3. The other shocks do not contribute notably to real exchange rate fluctuations. This is consistent with the exchange rate disconnect puzzle and the empirical evidence suggesting that apart from own shocks, the real exchange rate largely moves in response to interest rate changes; see e.g. Alquist and Chinn (2008) and the references therein. We note that shocks to food prices account for a larger share of real exchange rate fluctuations than oil price shocks. A possible explanation is that the real exchange rate is defined by consumer price indices, where food prices play a relatively larger role than fuel prices, at least directly.

We find that fluctuations in commodity prices are mainly driven by shocks to the real interest rate and the real exchange rate. The second row of Figure 3 shows 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 around 20% of the fluctuations in oil prices and food prices. The contribution of the real exchange rate shocks is much higher, above 50%. Output shocks account for a relatively small share of the commodity price fluctuations, but for a higher share of food price fluctuations than oil price fluctuations.

It is also worth noting that oil price shocks account for a relatively small share of oil price fluctuations. In contrast, shocks to food prices account for a relatively larger share of food price fluctuations.

Forecast error variance decompositions based on the VAR models with metal prices and industrial goods prices are largely consistent with those based on the VAR model with food prices; see Figures 8 and 9 in Appendix B.2. They also suggest that the real interest rate and the real exchange rate account for most 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 exchange rate shocks accounts for a larger share of oil price movements, i.e. about 60%, somewhat at the expense of real interest rate shocks. Real exchange rate shocks account for a somewhat smaller share of metal price fluctuations (close to 40%) than of food price fluctuations.

In the case of the model with industrial goods prices, however, real interest rate shocks account for a substantially larger share of oil price fluctuations than in the other two models. This is mainly at the expense of the contribution of shocks to the real exchange rate. Real interest rate shocks contribute to about 50% of fluctuations in oil prices and industrial goods prices.

We also note from Figure 9 that oil price shocks account for a larger share of output fluctuations than in the other two models; their contribution is about 30%. The real exchange rate also admits relatively larger contribution from shocks to industrial goods prices as well as from real interest rates.

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 metal prices tend to display overshooting behavior in response to shocks to the real interest rates. In comparison, real prices of food and industrial goods display delayed response to the interest rate shocks. Thus, we find mixed evidence of overshooting behavior in response to interest rate shocks.

We have also found that real interest rates and the real exchange rate account for substantial shares of fluctuations in commodity prices at all horizons. The converse is not found to be the case, as movements in the real interest rate and real exchange rate are affected relatively little by shocks to commodity prices. This is in contrast with output fluctuations which are affected substantially by oil price shocks.

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Appendix: Data

- CPI: The US consumer price index; Source: OECD_MEI; code: USA.CPALTT01.IXOB.Q.
- PCF: The Economist's world commodity price index for food in USD, deflated by the US CPI; Source ECOWIN and OECD_MEI.
- PCI: The Economist's world commodity price index for industrial inputs exclusive food and agricultural products, in USD, deflated by the US CPI; Source ECOWIN and OECD_MEI.
- PCM: The Economist's world commodity price index for industrial metals in USD, deflated by the US CPI; Source ECOWIN and OECD_MEI.
- PCO: Brent Blend crude oil price in USD, deflated by the US CPI; code: IMF-IFS.
- REX: Effective real exchange rate for the US. Source: OECD_MEI; code: USA.CCRETT01.IXOB.Q.

- ri: The US federal funds rate, in percent per annum. Source: IMF-IFS; code: Q.11160B..ZF....
- YO: OECD Industrial production; Source: OECD_MEI; code: OTO.PRINTO01.IXOBSA.Q.

Appendix B.1: Identified impulse responses

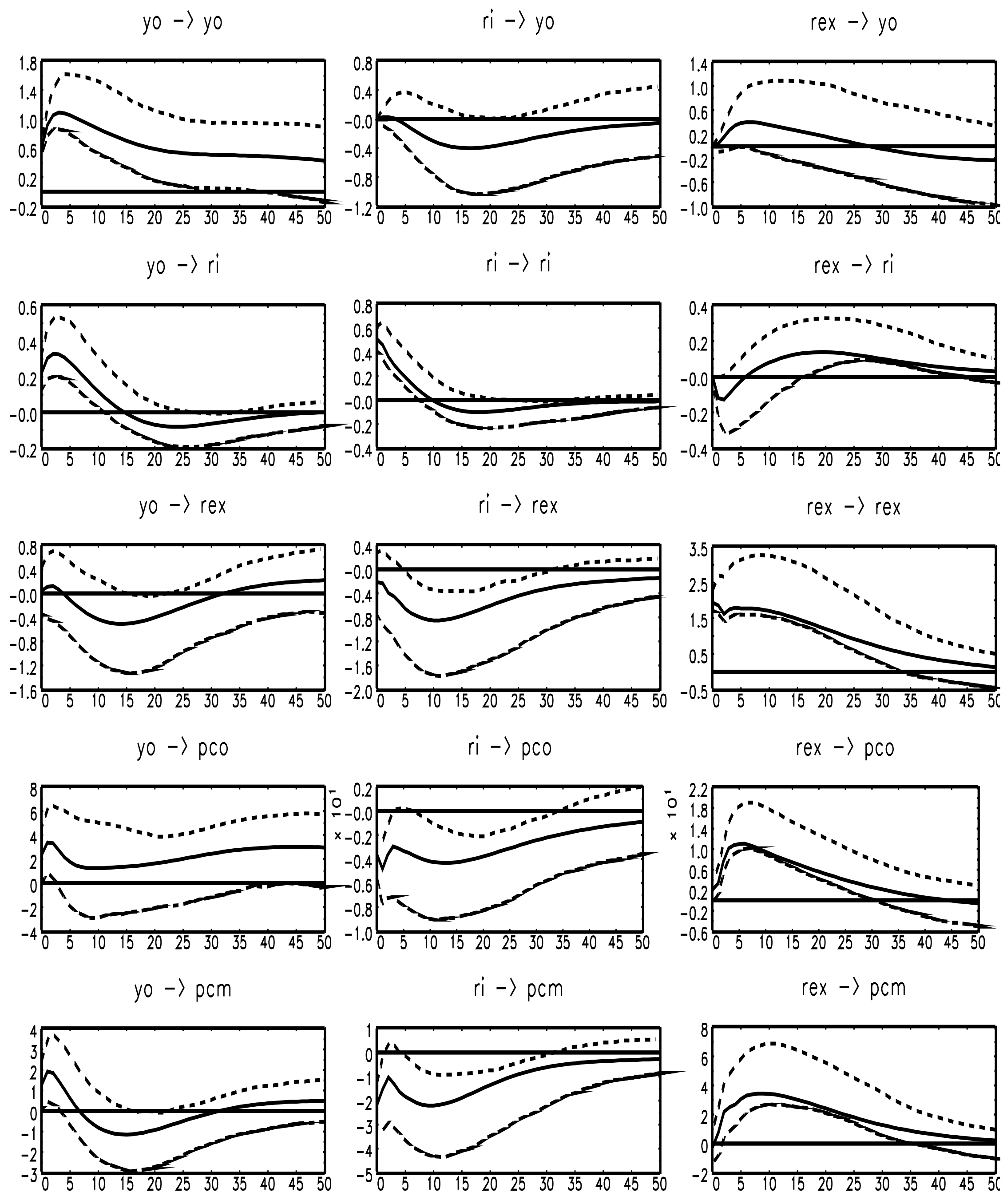

Figure 4: For VAR model with metal prices, impulse responses (in %) to one standard error shocks output (first column), interest rate and real exchange rate shocks, respectively (dashed lines: 95% confidence intervals).

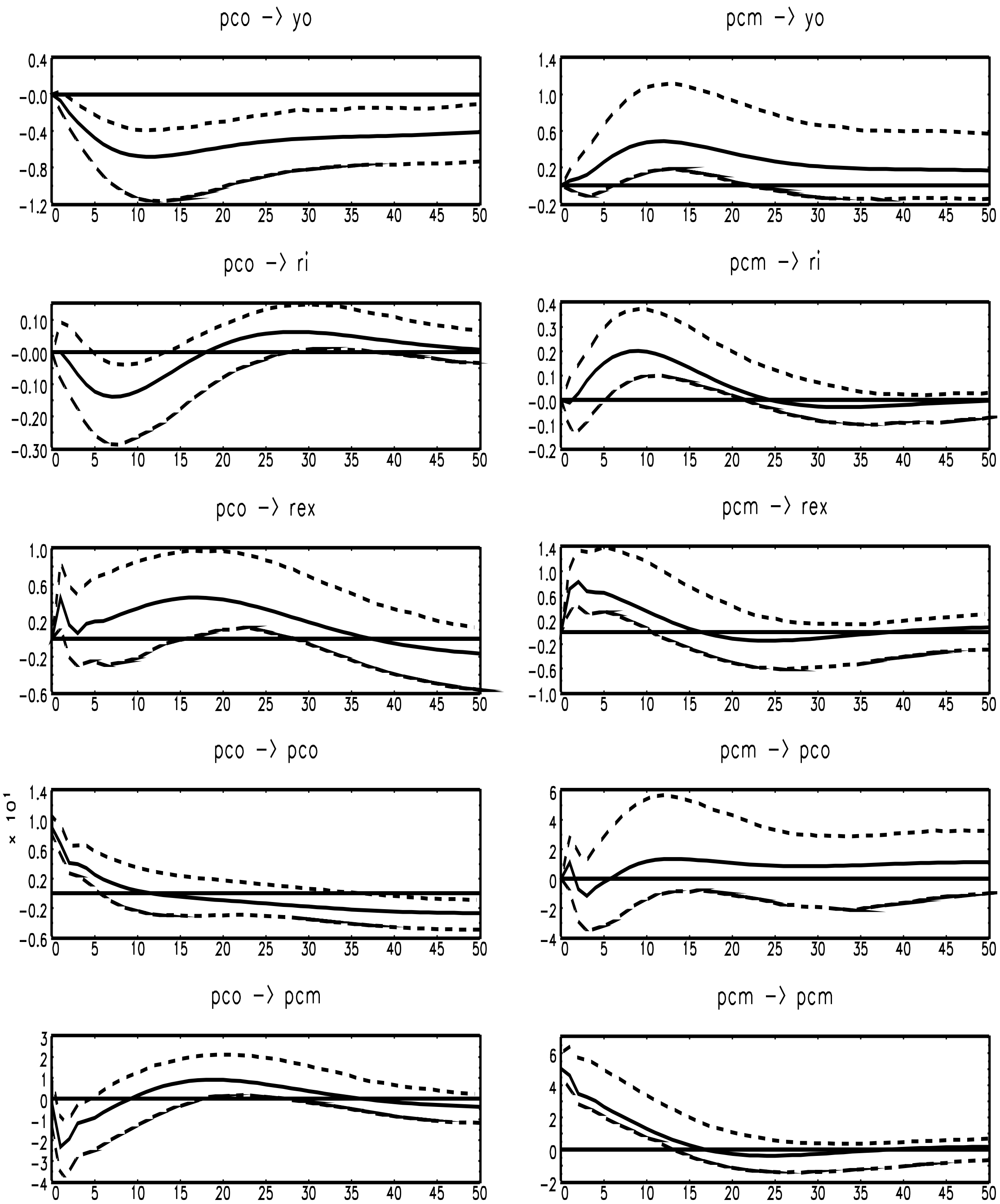

Figure 5: For VAR model with metal prices, impulse responses (in %) to one standard error shocks to oil prices and food prices, respectively (dashed lines: 95% confidence intervals).

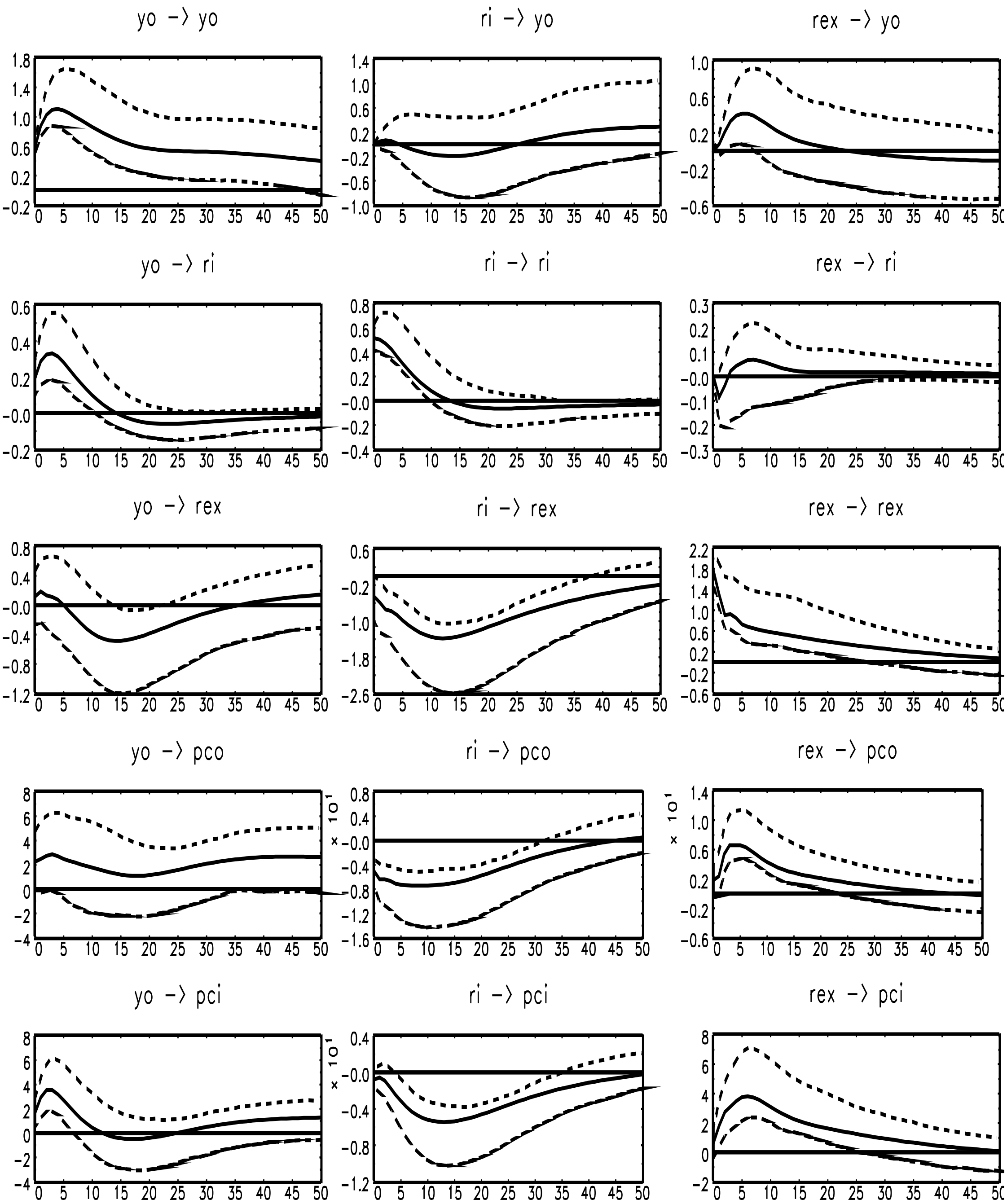

Figure 6: For VAR model with industrial input prices, impulse responses (in %) to one standard error shocks output (first column), interest rate and real exchange rate shocks, respectively (dashed lines: 95% confidence intervals).

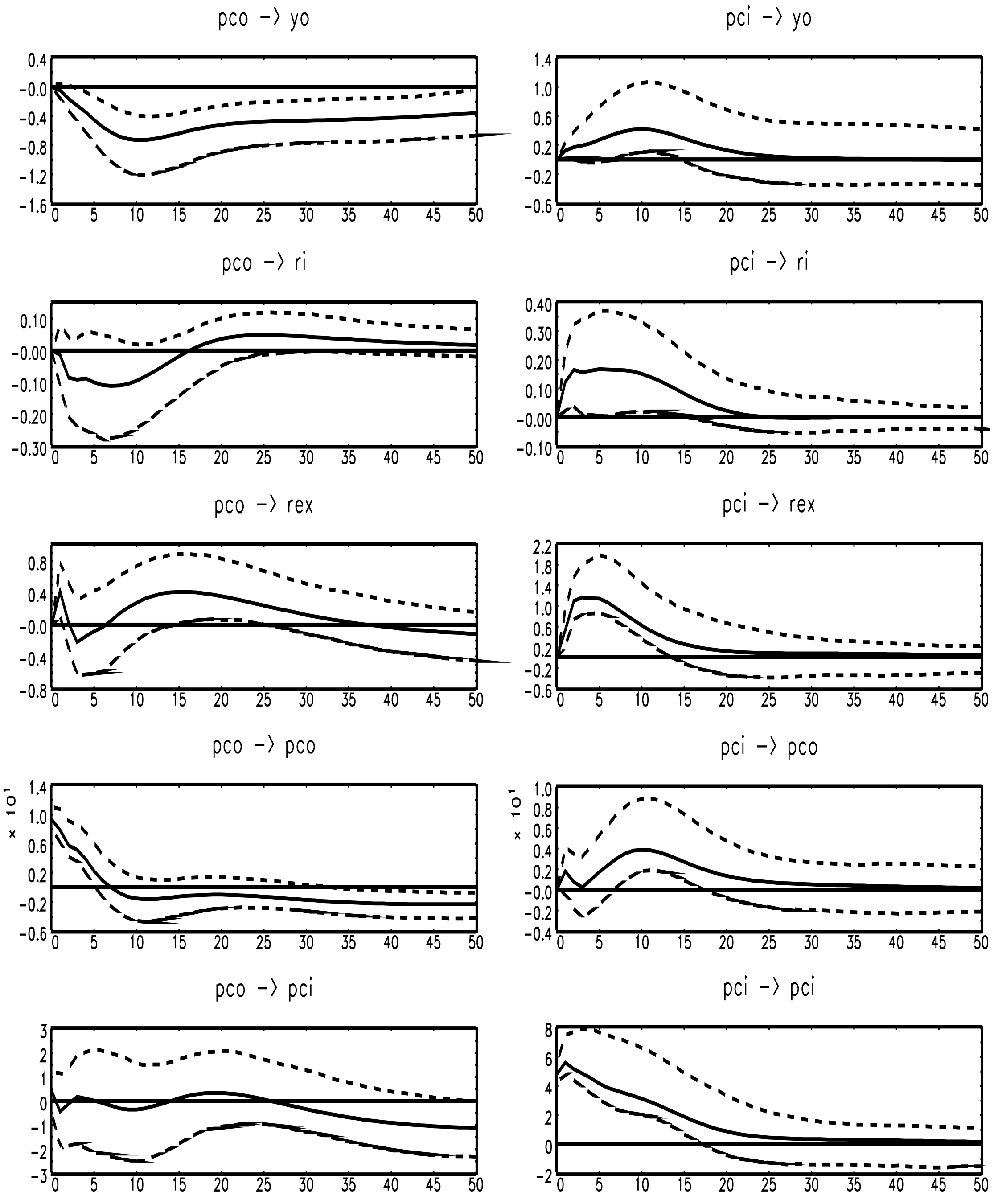

Figure 7: For VAR model with industrial input prices, impulse responses (in %) to one standard error shocks to oil prices and industrial input prices, respectively (dashed lines: 95% confidence intervals).

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

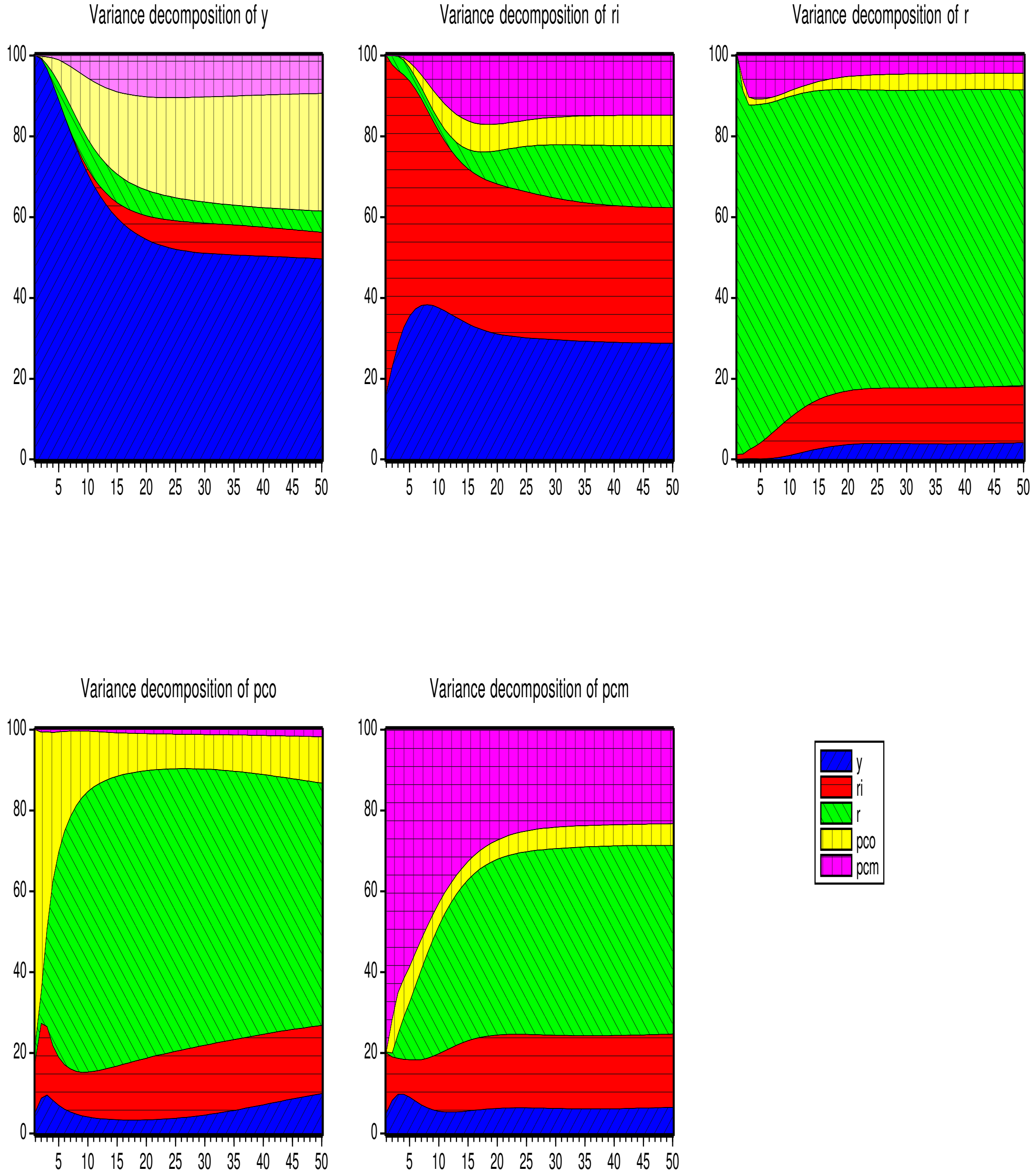

Figure 8: FEVD based on the VAR model with metal prices over different horizons in quarters(x-axis). Note: y $=yo$ and r $=rex$.

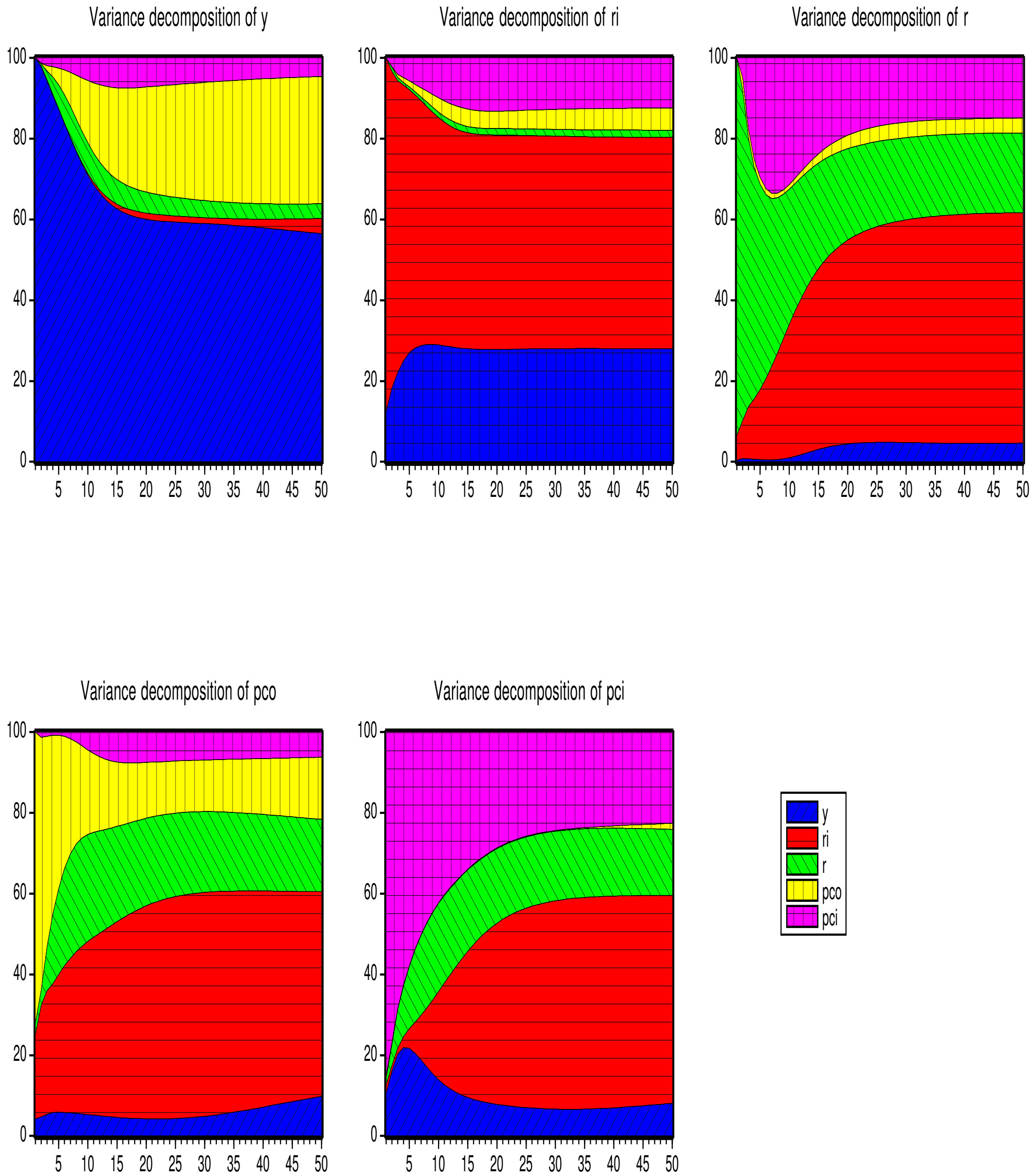

Figure 9: FEVD based on the VAR model with industrial goods prices over different horizons in quarters (x-axis). Note: y $= yo$ and r $= rex$.

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