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Effects of U.S. Macroeconomic Shocks on International Commodity Prices: Emphasis on Price and Exchange Rate Pass-through Effects

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Abstract
Using a structural VAR with block exogeneity, diagonality and identifying restrictions, this paper analyzes: first, the macroeconomic linkages among the oil price, U.S. output, interest rate, money supply, general price level and exchange rate; and second, the relationships of the macroeconomic variables with the price indices of ten international nonfuel commodity groups. By assuming the block exogeneity of U.S. macroeconomic variables with respect to the international nonfuel commodity prices, the paper discusses how exogenous oil/macroeconomic shocks affect the international commodity prices. It finally explores which oil/macroeconomic shocks are important in explaining the variations in international commodity prices. The results show that the sources of major fluctuations in the international commodities differ greatly by commodity. Soft and hard commodity prices such as those of ‘seafood’, ‘industrial metals’, and ‘gold’ seem to be strongly affected by the financial factor. Moreover, for some commodities, price fluctuations are more affected by the financial factor than by the real factor, supporting the view of “financialization” of commodities. Those commodities include ‘vegetable oils and protein meals’, ‘meat’, ‘seafood’, and ‘industrial metals’. The financial factor is also an important source of fluctuations in the oil prices. Oil price shocks have effects on the volatilities of interest rates, money supply, and general price level instantly, as well as on the exchange rate instead of the general price two years after the shock. Over the whole forecasting horizon, the degree of exchange rate pass-through is low on the general price level but is positive and high on oil and nonfuel international commodity prices.

Key words: Commodity Price, Structural VAR, Block Exogeneity, Diagonality.

JEL Classification: F3, Q4

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1. Introduction

Oil prices and many other international commodity prices have fluctuated substantially during the recent years. For example, it took only 5 months for the price of the WTI oil to plummet from about $150 a barrel in summer 2008 to about $32 at the end of the second half of that year. On the other hand, the same oil price quickly reversed course, again climbed up steadily and reached more than $75 a barrel on the New York Mercantile Exchange (NYMEX) during 2009. It then surged to $110 in the first quarter of 2011. The oil price as well as other commodity prices went on a roller-coaster ride in response to economic, financial and geopolitical shocks.

The accelerating commodity prices have brought concerns of slower economic activity and higher inflation to the world economies, a decidedly unpleasant combination that is known as “stagflation.” Being a feedstock and a transportation fuel, crude oil is probably the most important variable among the commodity class in terms of economic and financial impacts (see Hammoudeh and Bhar, 2011). Anecdotal data has shown a clear tendency for oil-price spikes to precede economic recessions as was the case in the 1973, 1981, 1991 and 2008 recessions.

There is a large body of literature that has studied the relationships between macroeconomic variables and oil prices but this paper adds more value to this literature by considering the oil/macroeconomic impacts on ten international commodity prices. First in the oil/macroeconomic literature, there is the classical supply-side effect that relates increases in oil prices to reductions in potential output due to reduced availability of a basic factor of production. For example, Hamilton (1983) made a significant contribution to the literature by extending the analysis to show that all except one of the post-WWII recessions were preceded by rising oil prices. Currently, Hamilton (2009) is still of the opinion that recent high oil prices had partly caused the 2008 recession.[2] In addition, other business cycle variables could not consistently account for the recessions like the oil price. Second, an increase in oil prices deteriorates the terms of trade for oil-importing countries, widening their current account deficits and weakening their currencies. Third, rising oil prices would lead to increased money demand (Mork, 1994), thus affecting the real balances. Fourth, a rise in oil prices would generate inflation by increasing the general price level.[3]

In examining the relationship between real oil price and US macroeconomic performance, Kilian (2009) identifies the global economic shocks that help decompose the real price of oil into four components. These components include: political oil supply shocks, other oil supply shock, aggregate shock to the demand for industrial commodities, and oil market-specific demand shocks. He then examines the impacts of these oil shocks on U.S. macroeconomic variables such as GDP growth and inflation. One of his findings suggests that the oil shocks are not equal in the sense that the aggregate demand shock and/or oil market demand shock are responsible for the major increases in oil prices since 1970s. Disruptions of crude oil production play a less important role. Political oil supply shocks cause a decline in real GDP only in the long run, while other oil supply shocks cause the same effect only in the short run. All in all domestic shocks, such as real GDP shock and inflation shock, have similar impact on U.S. macroeconomic performance; still this relative impact varies significantly over time. These results have strong bearing on the design of macroeconomic policies to deal with impacts of higher oil prices.

Kim and Roubini (2000) constructed a seven-variable VAR that includes U.S. short-term interest rate, monetary aggregate, CPI, industrial production, world oil price, US federal funds rate and exchange rate (foreign/$)) for the G-7 countries and identified the structural shocks by imposing nonrecursive short-run overidentifying restrictions. Their objective was to solve the puzzles that exist in the monetary economics such as the liquidity puzzle (an increase in interest rate to a monetary shock), the price puzzle (an increase in the general price level to an interest rate shock), the exchange rate puzzle (a depreciation of domestic currency to domestic interest rate shock) and forward discount bias puzzle (persistent appreciation of domestic currency to a domestic interest rate shock).[4] Based upon

[2] See “Oil prices and the economic recession of 2007-08,” http://www.voxeu.org/index.php?q=node/3664

[3] Brown and Yücel (2002) summarized six transmission channels through which oil price shocks affect macroeconomic activity.

[4] According to the uncovered interest parity condition, a positive domestic interest rate shock should lead to a persistent depreciation of the domestic currency over time after the instant appreciation.

their model, Kim and Roubini (2000) were able to resolve those puzzles and also emphasized the importance of the oil price in the macroeconomic system.

Cologni and Manera (2008) constructed a six-variable cointegrated VAR (oil price, exchange rate, consumer price index, GDP, interest rate and money supply) for the G-7 countries and identified the structural shocks by imposing both short-run restrictions and long-run restrictions (linear restrictions on cointegrating vectors). They found the instantaneous, temporary effect of an oil price shock on prices for those G-7 countries.

Anzuini, Lombardi and Pagano (2010) tried to estimate the effect of U.S. monetary shocks on the commodity prices. Using the monthly data of U.S. interest rate, money supply, CPI, industrial production, commodity price index, and oil price and by imposing a short-run identifying restrictions, they measured the effect of U.S. monetary policy shocks that are identified in the interest rate equation on the commodity price. They find that the monetary policy shocks, defined as a 100 basis point reduction in the Federal funds rate, have positive effects on the commodity price in the short run. They also measure the effect of U.S. monetary policy shocks on the individual commodity prices. However, their approach has some problems. They replace one commodity price with other commodity price in the VAR system, and reestimate the model to measure the effect of U.S. monetary shocks. In this case other shocks are no longer unique, so the U.S. monetary policy shocks are different.

Lastrapes (2006) showed how the U.S. commodity prices responded to U.S. productivity and monetary shocks by assuming block exogeneity and diagonality. Lastrapes (2006) found that positive U.S. productivity shocks have negative effects on U.S. commodity prices, while positive U.S. monetary shocks have positive effects on those prices, though the price responses across commodities are not uniform.

This paper closely follows Kim and Roubini (2000), Cologni and Manera (2008) and Lastrapes (2006) in several respects. Specifically, econometrically this paper follows the Lastrapes (2006) approach with block exogeneity and diagonality assumptions. In term of the choice of macroeconomic variables, this paper closely follows Kim and Roubini (2000) and Cologni and Manera (2008). Still, the paper differs from those studies in several ways. First, while Kim and Roubini (2000) and Cologni and Manera (2008) mostly impose short-run identifying restrictions to identify structural shocks, we impose long-run identifying restrictions. Second, while their objective is to analyze the effect of macroeconomic shocks on other macroeconomic variables, our main objective is to analyze how differently US macroeconomic shocks, together with the oil price shock, affect the international commodity prices. We construct the ten different nonfuel international commodity price indices and analyze the effects of US macroeconomic shocks on the international commodity prices.The paper is organized as follows. In section 2, we briefly discuss the empirical methods. In section 3, we present the empirical findings. Section 4 concludes.

2. The Model and its Identification

2.1. Estimation

Let $\Delta z_t = \begin{pmatrix} \Delta z_{1t} \\ \Delta z_{2t} \end{pmatrix}$ be an n-dimensional vector stochastic process, where z_{1t} is an $n_1 \times 1$ vector of macroeconomic variables, z_{2t} is an $n_2 \times 1$ vector of international non-fuel commodity prices, and $n = n_1 + n_2$. The variable set z_{1t} includes the oil price (*OIL*), U.S. output (*Y*), U.S. 3-month T-bill rate (*I*), U.S. money supply (*M*), U.S. general price level (*P*), and U.S. nominal effective exchange rate ($/foreign)(*S*) ($n_1 = 6$), while set z_{2t} contains different types of international nonfuel commodity prices as presented in Table 1 ($n_2 = 10$).

Assume that this process is generated by the dynamic linear model:

$$A_0 \Delta z_t = A_1 \Delta z_{t-1} + \cdots + A_p \Delta z_{t-p} + u_t, \quad (1)$$

where $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$ is a white noise vector process and $E u_t u_t' = I$. The parameters of interest in equation (1) can be recovered from the (reduced-form) VAR representation of Δz_t, given a sample of observations and a set of identifying restrictions.

The moving-average representation of the structural model is:

$$\Delta z_t = \left(A_0 - A_1 L - \cdots - A_p L^p\right)^{-1} u_t = \left(D_0 - D_1 L + D_2 L^2 + \cdots\right) u_t = D(L) u_t \quad (2)$$

The series of coefficient matrices $\{D_k\}$, $k = 0, ..., \infty$, is absolutely summable, and each of the coefficient matrices D_k can be partitioned as:

$$D_k = \begin{pmatrix} D_{11}^k & D_{12}^k \\ D_{21}^k & D_{22}^k \end{pmatrix}. \quad (3)$$

where *k* denotes the number of lags for the coefficient matrix *D* that goes from *k*=0 for contemporaneous to infinity periods. In the partition, each matrix $D_{i,j}^k$ has the dimension $n_i \times n_j$, *i*, *j* = 1, 2, where n_i refers to the aggregate oil/macroeconomic partition and n_j to the international nonfuel commodity partition. Thus, the partitioned matrices conform to the aggregate oil/macroeconomic variable sub-vector and the international nonfuel commodity-price sub-vector.

Following Blanchard and Quah (1989), we note that infinite-horizon restrictions both for the z_1 and z_2 sub-systems are sufficient to identify the dynamics of the full system. The long-run shock multipliers of the levels are:

$$\lim_{k\to\infty} \frac{\partial z_{t+k}}{\partial u_t} = D(1) = \begin{pmatrix} \sum_{i=0}^{\infty} D_{11}^i & \sum_{i=0}^{\infty} D_{12}^i \\ \sum_{i=0}^{\infty} D_{21}^i & \sum_{i=0}^{\infty} D_{22}^i \end{pmatrix} = \begin{pmatrix} \tilde{D}_{11} & \tilde{D}_{12} \\ \tilde{D}_{21} & \tilde{D}_{22} \end{pmatrix}, \quad (4)$$

where $\tilde{D}_{11}$ contains the long-run shock multipliers from the z_1 sub-system, and $\tilde{D}_{22}$ contains the long-run shock multipliers from the z_2 sub-system.

The grand objective is to discern how the endogenous variables (z_t) respond over time to the exogenous structural shocks (u_t). To realize this objective, we impose two sets of restrictions on the relations among the variables. The first set of restrictions is that the individual international nonfuel commodity prices are mutually independent after conditioning on the aggregate oil/macroeconomic variables (diagonality). It means that the correlations across the nonfuel commodity prices are fully accounted for through their joint dependence on the aggregate variables in sub-system z_1. This implies that common macroeconomic variables move the nonfuel commodity prices together or there is a herding behavior that characterizes those price comovements due to common oil/macroeconomic influences. Lucas (1973), for example, assumed that relative price shocks are independently drawn from a common distribution. Pindyck and Rotemberg (1990) attribute commodity price co-movements to common macroeconomic factors and herding behavior. If nonfuel commodity prices are mainly affected by oil price shocks, other macroeconomic shocks and their own shocks, then diagonality should be a reasonable assumption. The second set of restrictions entails that the aggregate oil/macroeconomic sub-system is independent of the individual nonfuel commodity prices (block exogeneity).[5] That is, we assume the international commodity prices, other than the oil price, are of negligible impact on the system in comparison to the oil/macroeconomic variables. In the context of equation (4), the first set of restrictions implies that $\tilde{D}_{22}$ is diagonal, while the second set implies that $\tilde{D}_{12} = 0$. Then equation (4) for the long-run shock multiplier can now be re-expressed as

$$\lim_{k\to\infty} \frac{\partial z_{t+k}}{\partial u_t} = D(1) = \begin{pmatrix} \sum_{i=0}^{\infty} D_{11}^i & 0 \\ \sum_{i=0}^{\infty} D_{21}^i & \sum_{i=0}^{\infty} D_{22}^i \end{pmatrix} = \begin{pmatrix} \tilde{D}_{11} & 0 \\ \tilde{D}_{21} & \tilde{D}_{22} \end{pmatrix}. \quad (5)$$

2.2. Identification

While the diagonality and block exogeneity restrictions solve the estimation problem, they are not sufficient to identify the economic structure.[6] The entire system can fully be identified by the restrictions on the aggregate oil/macroeconomic system only (i.e., restrictions on $\tilde{D}_{11}$ in equation (5)). To identify the economic structure, we impose the long-run identifying restrictions on the aggregate variables that include the oil price (*OIL*), U.S. output (*Y*), U.S. 3-month T-bill rate (*I*), U.S. money supply (*M*), U.S. price level (*P*), and

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[5] For more details on diagonality, block exogeneity and estimation procedures, see Lastrapes (2006).

[6] Block exogeneity and diagonality assumptions make estimation feasible, especially when the number of the international commodity prices is large. In our paper, we analyzed the effects of different aggregate shocks on ten different international non fuel commodity group price indices. If we are to analyze all the international commodity prices (64 categories) reported by the IMF, we cannot do it without those assumptions, due to a lack of degrees of freedom.

U.S. nominal effective exchange rate ($/foreign) (*S*) (that is, six oil and macroeconomic variables). We select a long-run recursive identification scheme and order the exogenous variables first.

Following Huh (2005), we assume that the oil price has a long-run effect on all U.S. economic variables so that the oil price is ordered first in the macro sub-system. This ordering is also justified by the disentangling of oil supply shocks from aggregated and oil demand shocks by Killian (2009). Regarding the justification of the ordering between the macroeconomic variables *Y*, *I*, *M*, *P* and *S*, we follow conventional economic theory. We first assume that output is supply-determined and that money is neutral in the long-run. We also note that interest rate is not affected by the nominal money supply because there will be no change in real money supply due to proportional rise in the price level in the long-run. A classical theory predicts that there will be a proportional change in the price level due to a percentage change in the money supply in the long-run. Finally, we assume that, while the price shock affects the exchange rate in the long-run as in the purchasing power parity, exchange rate shock have limited effect on the price level in the long-run. Therefore, the long-run ordering in the oil/macroeconomic system is *OIL* → *Y* → *I* → *M* → *P* → *S* and we assume that the long-run multiplier $\tilde{D}_{11}$ in equation (5) is a lower triangular matrix.

Our next question concerns how those oil/macroeconomic shocks will affect the fluctuations of international nonfuel commodity prices. Interpretation of the effects of those aggregate shocks on the international nonfuel commodity prices requires more caution. As an illustration, let cp_t be an international nonfuel commodity price at time *t*, o_t the oil price, y_t the U.S. output i_t the interest rate, M_t the money supply, p_t the U.S. price level and s_t the nominal effective exchange rate ($/foreign). Also, let α_t be the oil shock, β_t the output shock, γ_t the interest rate shock, δ_t the money supply shocks, ε_t the price shocks, ϕ_t the exchange rate shocks and η_{it} the *i*-th commodity-specific shock at time t. Then the contemporaneous effects of the oil/macroeconomic variables on the *i*-th international nonfuel commodity price at *t+k* due to the specific shocks α_t, β_t, γ_t, δ_t, ε_t and ϕ_t that occur at *t* can be expressed as follows:

$$\begin{aligned} cp_{i,t+k} &= f_i(o_{t+k}, y_{t+k}, i_{t+k}, m_{t+k}, p_{t+k}, s_{t+k}) + \eta_{i,t+k} \\ &= f_i\big[o_{t+k}(\alpha_t), y_{t+k}(\alpha_t, \beta_t), \\ &\quad i_{t+k}(\alpha_t, \beta_t, \gamma_t), m_{t+k}(\alpha_t, \beta_t, \gamma_t, \delta_t), \\ &\quad p_{t+k}(\alpha_t, \beta_t, \gamma_t, \delta_t, \varepsilon_t) \\ &\quad + s_{t+k}(\alpha_t, \beta_t, \gamma_t, \delta_t, \varepsilon_t, \phi_t)\big] + \eta_{i,t+k} \end{aligned} \tag{6}$$

For example, when there is an oil shock, its long-run effects on the aggregate variables and on the international nonfuel commodity prices will be:

$$\begin{aligned} \lim_{k\to\infty} \frac{\partial cp_{i,t+k}}{\partial \alpha_t} &= \frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial o_{t+k}}\frac{\partial o_{t+k}}{\partial \alpha_t} \\ &+ \frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial y_{t+k}}\frac{\partial y_{t+k}}{\partial \alpha_t} + \\ &\frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial i_{t+k}}\frac{\partial i_{t+k}}{\partial \alpha_t} + \\ &\frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial m_{t+k}}\frac{\partial m_{t+k}}{\partial \alpha_t} + \\ &\frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial p_{t+k}}\frac{\partial p_{t+k}}{\partial \alpha_t} + \\ &\frac{\partial cp_{i,t+k}}{\partial f_i}\frac{\partial f_i}{\partial s_{t+k}}\frac{\partial s_{t+k}}{\partial \alpha_t} \gtrless 0 \; (7) \end{aligned} \tag{7}$$

The sign of responses of the international nonfuel commodity prices *i*, $cp_{i,t+k}$, to a specific shock depends on the relative magnitudes and the signs of the responses of the oil/macroeconomic variables to the different shocks. Therefore, in this paper we let the data determine the long-run effects of the oil/macroeconomic shocks on the ten international nonfuel commodity prices.

3. Estimation Results

3.1. Data and model specification

We obtained monthly U.S. macroeconomic data on industrial production, 3-month T-bill rate, money supply (*M1*), nominal effective exchange rate and the consumer price index from the database of the Federal Reserve Bank of St. Louis. Short-term interest rates are more responsive to sudden policy changes. They are herein proxied by the three-month US Treasury bill rate instead of the federal funds rate (*FFR*) because *FFR* is characterized by jumps as a result of large swings in its short-term cycles or transitory components relative to its long-term trend or permanent component (Hammoudeh and Bhar, 2010).[7] Investors also consider the T-bill rate as a measure of the quality of the Fed's performance as it signals to Wall Street whether the Fed is behind the curve or not. Bernanke and Blinder (1992) find that this interest rate is the most significant exogenous variable that represents the actions of monetary policy.

The nominal exchange rate is the trade weighted exchange index (broad) and is converted into ($/foreign). We created index data for eight out of the ten international nonfuel commodity group price indices, namely, cereal, vegetable oil and protein meal, meat, seafood, sugar, beverage, agricultural raw material and industrial metal by sourcing the series and their weighs from the IMF. The detailed components in each category is summarize in the Table 1.[8] The oil price is the average of Dated Brent, West Texas Intermediate (WTI) and Dubai spot prices and is also obtained from the IMF. This composite oil price covers most of the oil grades produced in the world. This is important due to the recent changes in the spread between WTI and Brent. The remaining two nonfuel commodity prices, namely gold and silver, are obtained from the London Bullion Market Association (LBMA).

Due to the availability constraint on the starting dates of the data on international commodity prices from the IMF, the sample period spans 1980:1-2010:12, which includes 372 monthly observations. Still, this 30-year sample period is meaningful because it includes: the 1980, 1985, 1998 and 2008 oil shocks; the 1981-1983, 1991, 2001, 1998 and 2008 recessions; the 1994 Mexican debt crisis; the 1997 Asian crisis; and the three Gulf wars. We also include monthly dummies to account for the seasonal variations both in the macroeconomic variables and in the commodity prices.

Both the Dickey-Fuller and Phillip-Perron unit-root test results show that each series has a unit root so that the moving average of the process can be estimated from a system in first-differences.[9] After accounting for the monthly dummies as control variables and including the 12 first-differenced lagged variables, there are 275 degrees of freedom in each equation of the oil/macro VAR, and 257 degrees of freedom in each equation of international nonfuel commodity prices.[10]

Of course, we may consider including all the international commodity prices in one VAR system and allowing for cross-effects among international commodity prices and oil/U.S. macroeconomic variables. In this case, given the sample periods of 1980:1-2010:12 (372) and 16 variables (6 oil/U.S. data and 10 international commodity price data), and given that we include 11 seasonal dummies, a constant term, and 12 differenced lagged variable, the degree of freedom becomes 168 (372 (observations) - 12(lags)*16(variables) - 11(seasonal dummies) - 1(constant term)). In this case, we lose a lot of degrees of freedom. Also, in a structural VAR, imposing a identifying restriction is also an important issue. There are some stylized facts about the relationship among macroeconomic/oil variables, but imposing restriction on the relationship between U.S./oil variables and individual international commodity prices is a difficult issue. Also, imposing the relation among the international commodity prices leaves another difficult task. So, identifying the U.S./oil variables in one hand (block exogeneity assumption) and assuming that international commodity prices are independent after controlling for macroeconomic/oil effects (diagonality assumption) seem our best strategy.

Figure 1 shows the historical development of international commodity prices. It seems that these commodity prices generally show stable and somewhat downward movement until late 1998, and then its trend had reversed course since 1999 until July 2008. After the sharp drops in the international commodity prices during the global financial crisis (from October to December 2008), prices show a rising trend.

Table 2 shows the descriptive statistics for the log-differenced macroeconomic and commodity variables, except that the 3-month T-bill rate is differenced in level. Therefore, the values approximately measure the percentage

[7] We also tried the federal funds rate, but the T bill rate has more significant relationships with the macroeconomic variables.

[8] The weight in each commodity price index is based on the weight provided by the IMF (http://www.imf.org/external/np/res/commod/comp.pdf).

[9] The results of the unit root tests are available on request.

[10] The oil industry is huge and has a pervasive impact on the U.S. economy, while other industries can be thought of as "relatively small." So block exogeneity should be a reasonable assumption. In fact, any regression analysis that focuses on the effects of other macroeconomic variables on the commodity prices implicitly assumes block exogeneity because they consider the macroeconomic variables as explanatory variables.

changes in the relevant variables. As displayed in Table 2, the oil price commands the highest volatility among all the variables as evident by the values for the standard error (standard deviation). This is consistent with the results of earlier research on commodities (Hammoudeh et al. (2009) and Plourde and Watkins (1998)). The mean of the monthly log-differenced oil price is 0.0023 (or 0.23%), the minimum was -0.3163 (or exactly -27.1%) (on October 2008, the height of the 2008 Great Recession), and the maximum was 0.4594 (or 58.3%) (on August 1990, the invasion of Kuwait by Iraq).[11]

3.2. Impulse responses

Figure 2 reports the accumulated responses which are the responses of each of the levels of the macro variables to own and other structural shocks. This figure also includes one-standard error band for each response, generated from a Monte Carlo integration simulation with 1,000 replications. In response to own oil shocks, the oil price rises by 4.6% instantaneously (k=1 month) and then stabilizes at 7.5% in the long-run (k=61 months), and the response is statistically significant. Furthermore, the U.S. output falls by 0.12% because of an increase in the oil cost in the long run, although statistically not significant. There is a statistically significant rise in interest rate due to the oil shock in the short run. The money supply, which is statistically significantly, falls by 1.33% in the long run due to the oil shock. There is a short-run rise and a long-run fall in the general price level due to the oil price shock, though those responses are not statistically significant. The short-run rise in the price level may be due to a rise in the oil price, while the long-run fall may due to a fall in the output in response to the oil price shock. Based on the responses of the macroeconomic variables to the oil price shock, the oil price shock can be thought of as a negative supply shock.

The U.S. Output shocks cause the interest rate to rise, and money supply and exchange rate ($/) to fall in the long-run. The U.S. price level, even though statistically insignificant, rises in the long-run as a result of the output shocks. Based on the responses of the macroeconomic variables, especially of U.S. price level, to the output shocks, these shocks can be viewed as positive U.S. output demand shocks, making aggregate demand policies pertinent to output growth.

In response to the U.S. interest rate shock, the oil price would fall in the short-run while the U.S. output would rise in the short-run and then falls 26 months after the shock but the response is statistically insignificant. At the instant of the shock, the interest rate rises by 0.22% point while the oil price falls by 2.3%. Thus, the short-run rise in the output to an interest rate shock may mainly come from a fall in the oil price. On the other hand, money supply would fall by 0.71% in the long-run, suggesting that the monetary policy is reinforcing the interest rate shock. There is also a statistically significant fall in the U.S. price level in the short run and in the long run due to the contractionary impact of the shock. The U.S. exchange rate ($/foreign), though not statistically significant, would generally fall (appreciation of U.S. dollar) both in the short-run and in the long-run largely due to increased foreign investments in dollar-denominated securities. Thus, there seems to be little evidence of a price puzzle and an exchange rate puzzle in our study as was discussed in Kim and Roubini (2000). Papers that impose short-run identifying restrictions view interest rate shock as the money supply shocks because they regard interest rate equation as the policy reaction function. In this matter, they call it a money supply shock, Our paper imposes a long restriction and assumes that interest rate is affect only by oil price and U.S. industrial production in the long run. So, in this matter, we call it “interest rate policy shock” that is different from money supply shock. In 1980s, the U.S. abolished monetary targeting and moved toward interest rate targeting.

Therefore, based on the responses of the macro variables to the interest rate shock, this shock can be thought of as an interest rate policy shock such as increasing the discount rate, engaging in open market operations or increasing the interest rate on banks’ excess reserves at the Fed.

There also seems to be little evidence of a liquidity puzzle to money supply shocks. Interest rate would fall in the short-run in response to the money supply shock, but the response is not statistically significant. Moreover, the oil price would rise in response to the money supply shock and the increase in liquidity. Additionally, there are rises in both the U.S. price level and the ($/foreign) exchange rate (depreciation of the US dollar) due to the shock, which all are consistent with conventional economic theory, but the responses are not statistically significant. Our

[11] The numbers in the parentheses show the exact percentage change calculations of the log-differenced data, i.e., (exp (*)-1) where * denotes a log-differenced value.

paper imposes a long restriction and assumes that interest rate is affect only by oil price, U.S. industrial production, and interest rate in the long run. So, in this matter, we call it "money supply shock" that can be thought of as a positive monetary policy shock such as a quantitative easing or a liquidity shock.[12] We observe that the U.S. government currently adopting both interest rate policy and monetary policy. Given that the current nominal effective interest rate approaches close to zero, only way to boost the economy in the monetary authority side is to ease the money. So, distinguishing money supply shock from interest policy shock is a sensible way of identifying different policy shock from monetary authority side.

The general price shocks would have positive and statistically significant impacts on the oil price, output and interest rate in the short run. In response to such price shocks, money supply would fall in the short run, mainly due to a rise in the interest rate and the policy response of money supply to inflation, while the U.S. exchange rate would appreciate (a fall in exchange rate ($/foreign)) in the long run in response to a general price shock. Appreciation in the U.S. dollar is somewhat in contrast with our prediction. According to the PPP, a rise in the domestic price level would lead to a depreciation of domestic currency in the long-run. There will however be an appreciation of U.S. dollar only when the foreign price level responds more than the U.S. price level does to the U.S. price shocks. Based on the responses of the macro variables, the general price shock can be considered as an inflation shock such as an import-inflation or a demand pull inflation shock.

Finally, the exchange rate shocks that lead to a depreciation of U.S. dollar would have positive impacts on the U.S. output in the short run. Interest rate and price level would also rise in the short-run, but the response is not statistically significant. Three months after the exchange rate shock, the exchange rate rises (depreciates) by 1.92%. On the other hand, the U.S. price level rises by only 0.02% three months after the shock, indicating a low degree of exchange rate pass-through effect. Over the whole forecasting horizon, the degree of exchange rate pass-through on the U.S. price level is low. The literature on exchange rate pass-through to price finds a low effect, as well. In their review, Goldberg and Knetter (1997) find that the degree of pass-through to international prices over one year is typically small. The oil price, also not statistically significant, would generally rise in response to an exchange rate shock in the short run. Three months after this shock, the oil price would rise by 1.15% showing high degree of exchange rate pass-through on oil price. Based on the responses of the macro variables, the exchange rate shock can be thought of as a foreign financial shock. U.S. dollar is a base currency and U.S. government has less incentive to intervene in the foreign exchange market. An example of foreign financial shock that is specific to foreign exchange market shock would be the depreciation of U.S. dollar resulting from the negotiation with major exporting countries such as China. Another example of foreign financial shock that leads to a depreciation of U.S. dollar would be encroaching uncertainty or concerns on the future of the U.S. economy or concerns on the future of non-U.S. economy, such as Eurozone.

Figures 3-8 show the responses of international nonfuel commodity prices to different macro shocks. These figures also include one-standard price error band (in blue) and exchange rate error band (in red) as in Figure 2 for each response to analyze the general price and exchange rate pass-through effects on the international nonfuel commodity prices.

The definitions of commodity prices are provided in Table 1. Most of nonfuel commodity prices analyzed show positive but varying responses to oil shocks, implying that these oil shocks such as oil demand (e.g., economic booms) or oil supply shocks (e.g., geopolitics, natural disasters, etc) would basically move all commodity prices up. In the long run, the oil shocks would raise the price of 'silver' by 1.91%, followed by 'sugar' up1.85%, 'cereal' up 1.39%, 'industrial metal' up 1.27%,'gold' up 1.01%,'vegetable oils and protein meals' up 0.48%, 'meat' up 0.43%, 'seafood' up 0.38%, 'beverage' up 0.33%. Silver is known to be much more volatile than gold because of its use as an industrial commodity (Sari et al, 2009). Moreover, oil, silver and gold are considered resource currencies, inflation hedges and safe havens during rising risk types. There should also be no surprise in the relatively high responses of industrial metals prices to oil shocks because these metals are highly energy-intensive, and like oil they are good financial plays on the value of the dollar and the level of inflation. The high response of sugar to oil price shocks is somewhat surprising, given the responses of the

[12] The jury is still out on the effectiveness of QE. See Roche (2011).

other soft commodities. The high response of this commodity is probably due to having inelastic demand. Therefore, the impact of the oil price shocks on precious and industrial metals is positive and significant but is less significant on food prices (with the exception of prices of sugar and cereal). Finally, the 'agricultural raw materials' price index would rise in the short run and fall 25 months after the shock. These materials are volatile because they are sensitive do divergent world demand and countries' export and import policies in the short- and long-run.

The responses of the nonfuel commodity prices to the U.S. output shocks would differ by sector, rising in some sectors while declining in others. In the long run, the prices of 'cereal' and 'beverage' would rise by 1.12% and 0.85%, respectively, in response to those output shocks. On the other hand, the prices of 'vegetable oils and protein meals' would drop by -0.20%, 'meat' by -1.53%, 'seafood' by -0.94%, 'sugar' by -2.08%, 'agricultural raw material' by -0.95%, 'industrial metal' by -1.70%, 'gold' by -3.34%, and 'silver' by -1.54% in the long-run in response to the U.S. output shocks. There seem to be two opposite driving forces affecting the international commodity prices coming from the U.S. output shocks. A U.S. output demand shock would lead to an increase in the U.S. general price level, and could also lead to a rise in the international commodity prices. On the other hand, an appreciation of U.S. dollar in response to a U.S. output shock may lower the international commodity prices. However in general, exchange rate effects seem to dominate the price level effects in affecting the international commodity prices, when those effects are originated from the U.S. output shocks.

The responses of the nonfuel commodity prices to U.S. interest rate shocks also differ by sector. In the long-run, 'sugar' goes up by 1.56%, followed by 'industrial metal' which increases by 0.92% and 'cereal' by 0.5% in response to the U.S. interest rate shocks. On the other hand, prices of 'agricultural raw material' would drop by -1.08%, 'seafood' by -0.8%, 'beverages' by -0.69%, 'gold' by -0.56%, 'meat' by -0.33%, 'vegetable oils and protein meals' by -0.23% and 'silver' by -0.09% in the long-run in response to the U.S. interest rate shocks. It is interesting to find that some soft commodities are much more negatively sensitive to interest rates shocks than hard commodities. Moreover, in response to the U.S. interest rate shocks, the U.S. price level would fall and the U.S. dollar would appreciate. Thus, the drops in most of the international commodity prices are consistent with expectations on the price and exchange rate pass-through effects. One possible explanation of rises in the international commodity prices in response to the U.S. interest rate shock would be that U.S. interest rate shock may have asymmetric effects on the commodity prices that may not be captured in the U.S. price level.

From Figure 2, one can see that the U.S. output rises in the short-run, and the U.S. price level falls in both the short-run and the long-run. It is also possible that some commodity prices for specific sectors may actually rise.

As is the case in the oil price shocks, all the nonfuel commodity prices analyzed show positive but varying responses to the U.S. money supply shocks. In the long-run, the monetary shocks would raise the prices of 'seafood' by 2.48%, 'industrial metal' by 1.68%, 'agricultural raw material' by 1.66%, 'meat' by 1.14%, 'gold' by 0.99%, 'silver' by 0.75%, 'sugar' by 0.72%, 'beverage' by 0.54%, 'vegetable oils and protein meals' by 0.33% and 'cereal' by 0.03%. We should note that these increases are generally less than those generated by the oil price shocks.

At the instant of the U.S. price shock, all the non-fuel international commodity except cereal show positive responses, fuelled by rising overall inflation. In the long-run, however, most of nonfuel international commodity prices would fall in response to the U.S. price shock ('sugar' by -4.57%, 'silver' by -4.07%, 'gold' by -2.70%, 'cereal' by -2.21%, 'vegetable oils and protein meals' by -2.10%, 'industrial metal' by -2.09%, 'seafood' by -1.46%, 'agricultural raw material' by -0.75% and 'meat' by -0.72%. Only the 'beverages' price rises in response to the price shock in the long-run.

Generally, nonfuel international commodity prices show positive responses to U.S. exchange rate shocks both in the short-run and in the long-run, indicating a significant exchange rate pass-through effect. Some of these commodities face commercial policies' barriers, subject to trade negations including limits on exports and imports, and currency controls. The long-run response of exchange rate to its own exchange rate shock is 2.03%. The long-run responses of international commodity prices to the exchange rate shocks are: 'industrial metals' up 2.13%, 'vegetable oils and protein meals' 1.91%, 'gold' 1.61%, 'cereal' 1.4%, 'meat' 1.17%, 'seafood' 0.80%, 'silver' 0.73% and 'agricultural raw materials' 0.37%. Only the 'beverages' price shows negative response to U.S. exchange rate shock (-1.19% in the long run). This result demonstrates that soft commodities can be more sensitive to exchange rate shocks more than industrial commodities and precious metals. The financial media which concentrates on oil, gold, silver and copper should also be aware of this finding.

3.3. Variance Decomposition

Table 3 reports the results of the variance decomposition of commodity prices for *k* =1 (at instant of shocks), *k* = 13 (12 months or 1 year after the shocks), and *k* =25 (24 months or 2 years after the shocks).

Besides the sensitivity to own commodity-specific shocks, the results show that the major sources of fluctuations in the international commodity prices differ greatly by commodity at the instant period (*k*=1). For example, the oil shocks explain about 2.64% of the variations in the 'agricultural raw material' price, and 2.95% in the 'industrial metal' price. However, the oil shocks have a little (less than 1%) impact on other international commodity prices at the instant period.

The U.S output shocks share in the variations of the price of 'vegetable oils and protein meals' 4.06%, followed by sugar' 2.58%, 'seafood' 2.05%, 'gold' prices 1.56% and 'cereal' is 1.46% at the instant period. The U.S. interest rate shocks have only a small explanation of the variations in the 'sugar' price. The U.S. money supply shock have some explanatory power on the price variations of 'seafood' (1.69%), 'industrial metal' (1.46%), 'gold' (3.30%) and 'silver' (1.99%). The U.S. general price shocks have some instant impacts on the variations in prices of 'industrial metal' (5.39%), 'gold' (1.18%), and 'silver' (1.81%). The U.S. exchange rate shocks instantly affect price variations of 'vegetable oils and protein meals' (2.72%), 'seafood' (10.05%), 'beverage' (1.91), 'industrial metal' (5.29%), 'gold' (10.64%), and 'silver' (3.53%) at the instant period.

Two years after the shock, the relative importance of own commodity-specific shocks declines and that of macroeconomic shocks rises. Besides its own shock, the 'cereal' price variations are mainly affected by the general price shocks (4.31%), followed by the exchange rate shocks (4.10%), oil price shocks (3.49%) and output shocks (2.90%) at k=25 (2 years after the shock). The 'vegetable oils and protein meals' price fluctuations are mainly affected by the exchange rate shocks (10.91%), followed by the effect of the price shocks (6.40%). It is possible that commodity group is impacted by divergent world demand and limits on its exports and imports and this may explain its highest sensitivity to the exchange rate shocks. "Meat' prices are mainly affected by the output shocks (7.28%), followed by the money supply shock (4.65%), the exchange rate shock (3.94%) and interest rate shock (2.99%). 'Seafood' price variations are strongly affected by the money supply shocks (15.69%), then by the exchange rate shocks (7.21%), price shocks (5.63%) and oil price shocks (2.93%). Seafood production has fewer linkages with the overall economy than meat which is strongly affected by the output demand shock.

Besides its own shock, the 'sugar' price has its variations mainly explained by the price shocks (15.95%), interest rate shocks (4.92%), output shocks (2.48%), money supply shocks (2.13%) and oil price shock (1.56%) at k=25. Sugar is a more basic commodity in household consumption than meat and seafood and also has fewer substitutes. This probably explains the highest importance of the price shocks on its price. 'Agricultural raw materials' prices are affected by the price shock (9.52%), money supply shocks (6.27%), oil price shocks (5.05%), interest rate shocks (2.99%) and output shocks (1.85%).

'Industrial metals' prices are greatly affected by exchange rate shock (13.91%) and partly affected by price shock (6.01%), interest rate shock (5.05%), money supply shock (4.03%), oil shock (3.23%) and output shock (1.17%). Many industrial commodities are priced in dollar and this may have to do with their highest sensitivity to the exchange rate. 'Gold' price volatility is significantly affected by output shock (24.46%) and price shock (15.88%) and partly affected by exchange rate shock (7.75%), money supply shock (4.27%), interest rate shock (3.19%), and oil price shock (1.48%) at k=25. Finally, 'silver' price fluctuations are explained considerably by the price shocks (21.26%), and are partly explained by the oil price shocks (2.74%), money supply shocks (2.73%), exchange rate shocks (1.85%) and output shocks (1.68%). Gold and silver have monetary value, priced in dollar and can be considered as resource currencies. They are an inflation hedge and safe havens during inflation and dollar depreciation. It's interesting to note here that gold is also significantly influenced by the output demand shock.

Table 4 reports the variance decomposition of the commodity prices by real and economic factors. Here we define a real factor as the sum of oil price shock, output shock and general price shocks. The financial factor is defined to be the sum of interest rate shock, money supply shock and exchange rate shock. Some variations of the commodity prices seem to be affected greatly by the financial factor including the price variations of 'seafood' (23.95%), industrial metal (22.99%) and gold (15.21%). Moreover, for some commodities, their price volatilities are affected more by the financial factor than by the real factor. Those commodities include 'seafood' (23.95% for the financial factor vs. 9.67% for the real factor), 'industrial metals' (22.99% vs. 10.41%), 'meat' (11.58% vs. 8.60%) and 'vegetable oils and protein meals' (i.e., 10.44% vs. 8.64%).

So far, we have analyzed how macroeconomic shocks affect the international commodity price variations. The result shows that the magnitudes and the sources of fluctuations differ by the international commodity price. Table 5 reports the results of the variance decomposition of macroeconomic variables for the k =1 (at instant of shocks), k = 13 (12 months or 1 year after the shocks), and k =25 (24 months or 2 years after the shocks). Focusing on the oil price in relation to its own shock and other macroeconomic shocks, the result shows that oil price variation is greatly explained by the U.S general price shock (25.37%), U.S. money supply shock (12.67%), and U.S. interest rate shock (12.06%), in addition to its own shock, and is partly explained by the U.S. output shock (2.19%) at k=1. We can also categorize the different oil price shocks as the own shock (oil price shock), the real sector shock (sum of the output shock and price shock), and the financial sector shock (sum of the interest rate shock, money supply shock, and exchange rate shock). At k=1, the relative importance of the real sector and financial shocks are 27.56% and 25.15%, respectively, emphasizing relative importance of the financial effects on the oil price variations.

Oil price shocks have instant effects on the variations of interest rates (3.44%), money supply (12.86%), and general price level (6.33%) at k =1. They also have significant effects on interest rate (9.99%), money supply (30.35%), and exchange rate (3.42%) at k=25 (2 years after the shock).

4. Conclusion

This paper analyzes how oil price and other U.S. macroeconomic variables, including output, interest rate, money supply, general price level and exchange rate, are endogenously related, and how the exogenous macro shocks affect other macro variables. It also examines how the exogenous macro shocks affect ten international (non-fuel) commodity prices and price indices. It finally explores which oil/macroeconomic shocks are more important in explaining the variations in the commodity prices.

The main results also reveal that the oil price shock are negative oil supply shocks (e.g., geopolitics, natural disasters), the U.S. output shocks are output demand shocks (e.g., recovery and booms in business cycle), the interest rate shocks are interest rate policy shocks (e.g., increases in discount rate or rate on bank excess reserves at the Fed), the monetary shocks are expansionary monetary policy shocks (e.g., quantitative easing through securities purchases), the general price shocks are inflation shocks (e.g., import inflation and demand pull inflation) and exchange rate shocks through dollar depreciation (e.g., trade negotiations, uncertainty, debt crises and fiscal default). Most of the results of the various macroeconomic shocks follow conventional economic theories; there seems to be little evidence of a liquidity puzzle, interest rate puzzle or price puzzle as indicated by Kim and Roubini (2000).

The oil/macroeconomic results demonstrate that the financial factor (sum of interest rate, money supply and exchange rate shocks) is an important source of fluctuations in oil prices. Oil is now considered a financial asset. The oil price shocks have *instant* effects on the variations of the money supply (12.86%), followed by the price level (6.33%) and the interest rates (3.44%). However, these oil shocks have significant effects on money supply (30.35%), interest rate (9.99%) and exchange rate (3.42%), two years after the shock.

The international commodity results show that the sources of major fluctuations in the international commodity prices differ strongly by commodity. Two years after the shock, an exchange rate shock in the form of dollar.

depreciation has more pronounced effects on the variations of certain soft and hard commodity group price indexes including those of 'industrial metals', 'vegetable oils and protein meals', 'gold' and 'seafood', in this sequence of relative importance. This result confirms that precious metals are safe havens in response to weak paper currencies. But it also adds that certain soft commodities can also be safe harbors during currency depreciations.

The U.S. general price shocks are also important sources of fluctuations in the price of 'silver', sequentially followed by prices of 'sugar', 'gold', 'agricultural raw material', and 'industrial metals'. The importance of general inflation on prices of commodities considerably outweighs that of currency depreciation. On the other hand, the money supply shocks affect significantly prices of international soft commodities such as 'seafood' and 'agricultural raw material.' The relative importance of money supply is less than that of general inflation in terms of both commodity depth and width.

The U.S. interest rate shocks have an effect on the international commodity prices of 'sugar', followed by 'industrial metals', 'gold' and 'meat' in this row. As can be seen, the interest rate's relative importance is much less than that of the general price level, exchange rate and money supply. The U.S. output shocks strongly affect the price variations of 'gold,' followed by 'meat' and 'beverages.' Interestingly, the relative impact of output shocks on gold outweighs that of the general price and the exchange rate. Nowadays, mass media tells us that the variation in the price of gold may be mainly due to a variation in value of the U.S. dollar and the global inflation. However, our result shows that the more important cause of price variation in gold is due to the variation in U.S. economy. Finally, the oil shocks have relatively moderate impacts on the prices of both hard and soft commodities, including 'agricultural raw material,' followed by 'cereal,' 'industrial metal,' and 'seafood.' Sensitivity of seafood prices is perhaps due to diesel used in fueling fishing vehicles. The result points out that oil price shocks could have greater impacts on soft than hard commodities for certain commodities. The impact of oil prices on food inflation is moderate, perhaps due to the volatile nature of food prices.

Some commodity prices seem to be affected strongly by the financial factor, such as prices of 'seafood,' 'industrial metal' and 'gold', two years after the shock. Moreover, for some commodities, price variations are more affected by the financial factor than by the real factor. Those commodities include 'seafood' (financial factor 23.95% vs. real factor 9.67%), followed by 'industrial metals' (22.99% 10.41%), 'meat' (11.58% vs. 8.60%) and 'vegetable oils and protein meals' (10.44% vs. 8.64%).

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Table 1: Definitions of International Commodity Prices

Notation	Index Composition (Data Source)
1. Cereal	Wheat, Maize, Rice, Barley (IMF)
2. Vegetable oil and protein meal	Soybeans, Soybean meal, Soybean oil, Palm oil, Fishmeal, Sunflower/Safflower oil, Olive oil, Groundnuts (IMF)
3. Meat	Beef, Lamb, Swine Meat, Poultry (IMF)
4. Seafood	Fish, Shrimp (IMF)
5. Sugar	Free market, EU, US (IMF)
6. Beverage	Coffee, Cocoa beans, Tea (IMF)
7. Agricultural raw material	Timber, Cotton, Wool, Rubber, Hides (IMF)
8. Industrial metal	Copper, Aluminum, Iron ore, Tin, Nickel, Zinc, Lead, Uranium (IMF)
9. Gold	Monthly average P.M. price (The London Bullion Market Association: LBMA)
10. Silver	Monthly average price (LBMA)

Notes: The weights in each commodity price index are based on the weights provided by the IMF. Avalable onhttp://www.imf.org/external/np/res/commod/comp.pdf.

Table 2: Descriptive Statistics

Variables	Mean	Standard Deviation	Minimum	Maximum
OIL	0.0023	0.0829	-0.3163	0.4594
Y	0.0017	0.007	-0.0404	0.0212
I	-0.032	0.5186	-4.62	2.61
M	0.0042	0.0157	-0.0363	0.0755
P	0.0028	0.0035	-0.0193	0.0151
S($/)	0.0007	0.0182	-0.0647	0.0539
Cereal	0.0017	0.0431	-0.2166	0.174
V. Oil & P. Meal	0.0019	0.046	-0.2148	0.2376
Meat	0.0007	0.0457	-0.2199	0.1646
Seafood	-0.0002	0.0484	-0.183	0.1667
Sugar	0.0008	0.0818	-0.2719	0.3739
Beverage	0.0000	0.0496	-0.1617	0.265
Ag. Raw Mat.	0.0017	0.0322	-0.1616	0.0977
Ind. Metal	0.0027	0.0465	-0.2238	0.1521
Gold	0.0019	0.042	-0.1839	0.1829
Silver	-0.0008	0.0773	-0.5016	0.2772

Notes: the results are based on the log differenced variables, except that 3-month T-bill rate is differenced in level. The definitions of the commodity prices are given in Table 1. *OIL* is the oil price, *I* is the 3 month T bill rate, *M* is money supply, *P* is the general price index, and ***S*** is the $/foreign exchange index-Broad. Other variables are defined in Table 1.

Table 3: Variance Decomposition of Commodity Prices at Different Forecasting Horizons

Shocks / Responses	k	Own	*Oil*	*Y*	*I*	*M*	*P*	*S*
Cereal	1	98.19	0.15	1.46	0.21	0.00	0.00	0.00
	13	89.13	3.17	1.97	0.24	0.09	2.01	3.40
	25	84.43	3.49	2.90	0.72	0.05	4.31	4.10
Vegetable Oils & Protein Meals	1	92.44	0.12	4.06	0.03	0.10	0.50	2.74
	13	82.88	0.70	2.30	0.42	0.89	1.91	10.91
	25	80.92	0.66	1.58	0.27	0.45	6.40	9.72
Meat	1	98.84	0.11	0.09	0.85	0.08	0.01	0.02
	13	84.26	0.87	3.83	5.82	3.26	0.60	1.36
	25	79.83	0.94	7.28	2.99	4.65	0.38	3.94
Seafood	1	85.36	0.09	2.05	0.72	1.69	0.04	10.05
	13	71.98	2.96	2.00	0.87	9.13	0.50	12.56
	25	66.38	2.93	1.11	1.05	15.69	5.63	7.21
Sugar	1	95.60	0.01	2.58	1.80	0.01	0.00	0.00
	13	81.14	0.70	1.63	5.67	1.90	5.29	3.68
	25	70.36	1.56	2.48	4.92	2.13	15.95	2.60
Beverage	1	96.33	0.73	0.00	0.40	0.00	0.64	1.91
	13	85.44	0.92	5.38	0.26	1.03	3.13	3.85
	25	89.14	0.79	4.72	0.35	0.50	1.87	2.61
Agricultural Raw Materials	1	92.21	2.64	0.53	0.46	0.01	3.34	0.82
	13	71.34	9.35	2.97	1.93	1.51	7.99	4.91
	25	71.58	5.05	1.85	2.99	6.27	9.52	2.74
Industrial Metals	1	84.52	2.95	0.32	0.07	1.46	5.39	5.29
	13	69.51	3.32	0.96	3.39	1.33	3.35	18.14
	25	66.59	3.23	1.17	5.05	4.03	6.01	13.91
Gold	1	82.33	0.01	1.56	0.99	3.30	1.18	10.64
	13	64.39	1.12	11.18	4.72	3.00	5.25	10.33
	25	42.98	1.48	24.46	3.19	4.27	15.88	7.75
Silver	1	92.42	0.02	0.05	0.14	1.99	1.81	3.53
	13	83.98	1.41	0.87	0.66	1.90	7.79	3.38
	25	69.19	2.74	1.68	0.57	2.73	21.26	1.85

Notes: Notes. *OIL* is the oil price, *I* is the 3 month T bill rate, *M* is money supply, *P* is the general price index, and ***S*** is the $/foreign exchange index-Broad. Other variables are defined in Table 1.
Variance decomposition is read horizontally for each endogenous variable to sum up the variations to 100% over all the shocks.

Table 4: Variance Decomposition of Commodity Prices by Factors

	K	Own Factor	Real Factor	Financial Factor
Cereal	1	98.19	1.61	0.21
	13	89.13	7.15	3.73
	25	84.43	10.70	4.87
Vegetable Oils & Protein Meals	1	92.44	4.68	2.87
	13	82.88	4.91	12.22
	25	80.92	8.64	10.44
Meat	1	98.84	0.21	0.95
	13	84.26	5.30	10.44
	25	79.83	8.60	11.58
Seafood	1	85.36	2.18	12.46
	13	71.98	5.46	22.56
	25	66.38	9.67	23.95
Sugar	1	95.60	2.59	1.81
	13	81.14	7.62	11.25
	25	70.36	19.99	9.65
Beverage	1	96.33	1.37	2.31
	13	85.44	9.43	5.14
	25	89.14	7.38	3.46
Agricultural Raw Materials	1	92.21	6.51	1.29
	13	71.34	20.31	8.35
	25	71.58	16.42	12.00
Industrial Metals	1	84.52	8.66	6.82
	13	69.51	7.63	22.86
	25	66.59	10.41	22.99
Gold	1	82.33	2.75	14.93
	13	64.39	17.55	18.05
	25	42.98	41.82	15.21
Silver	1	92.42	1.88	5.66
	13	83.98	10.07	5.94
	25	69.19	25.68	5.15

Notes: Real factor includes oil price shocks, output shocks, and price shocks. Financial factor includes interest rate shocks, money supply shocks, and exchange rate shocks. Variance decomposition is read horizontally for each endogenous variable to sum the variations up to 100% over all the shocks.

Table 5: Variance Decomposition of Macro Variables at Different Forecasting Horizons

Shocks / Responses	**K**	***Oil***	***Y***	***I***	***M***	***P***	***S***
	1	47.28	2.19	12.06	12.67	25.37	0.42
Oil	13	65.64	0.55	8	5.74	19.6	0.47
	25	76.77	0.35	5.13	4.62	12.79	0.34
	1	0.61	81.16	0.07	0.01	12.87	5.29
Y	13	0.44	78.49	3.68	1.26	12.8	3.33
	25	0.57	88.82	2.83	0.83	5.48	1.47
	1	3.44	0.04	67.56	2.08	25.37	1.5
I	13	11.05	5.77	67.22	0.26	14.75	0.95
	25	9.99	16.06	64.51	0.14	8.69	0.61
	1	12.86	0.01	2.83	84.17	0	0.04
M	13	30.56	5.15	3.18	48.81	11.91	0.39
	25	30.35	8.67	8.7	45.17	6.94	0.19
	1	6.33	8.13	20.04	0.37	64.94	0.19
P	13	1.74	0.76	6.74	1.8	88.29	0.67
	25	0.92	0.61	2.97	2.18	92.88	0.42
	1	0.05	16.94	1.26	2.62	0	79.13
S	13	2.55	6.02	0.62	1.18	1.88	87.76
	25	3.42	8.35	0.54	2.73	7.34	77.63

Notes: Notes. *OIL* is the oil price, *I* is the 3 month T bill rate, *M* is money supply, *P* is the general price index, and ***S*** is the $/foreign exchange index-Broad. Other variables are defined in Table 1.
Variance decomposition is read horizontally for each endogenous variable to sum up to 100%.

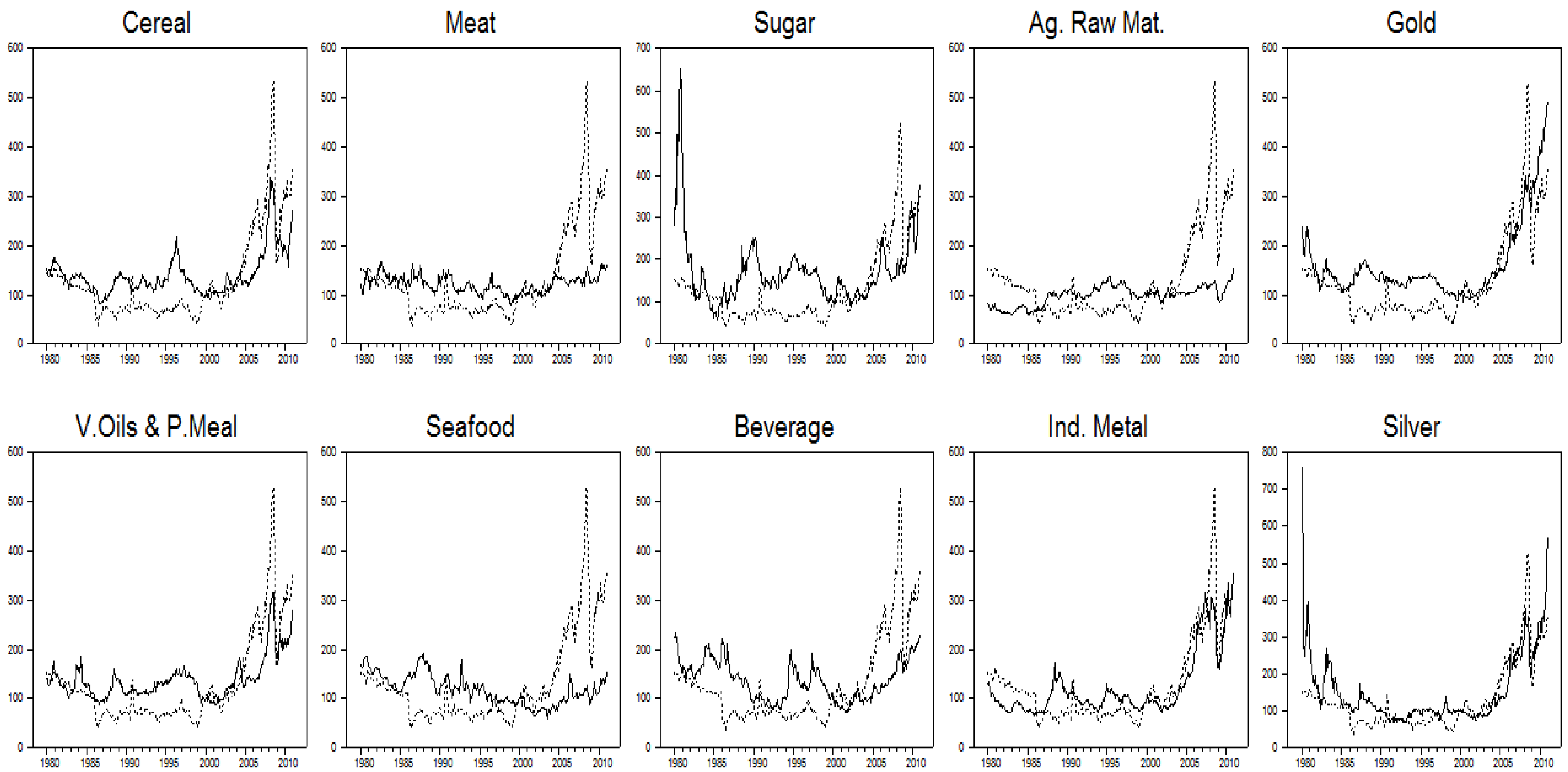

Figure 1. Trajectories of Oil and Nonfuel Commodity Prices and Price Indices (2000.1=100)

Note: Dotted curve shows petroleum price changes.

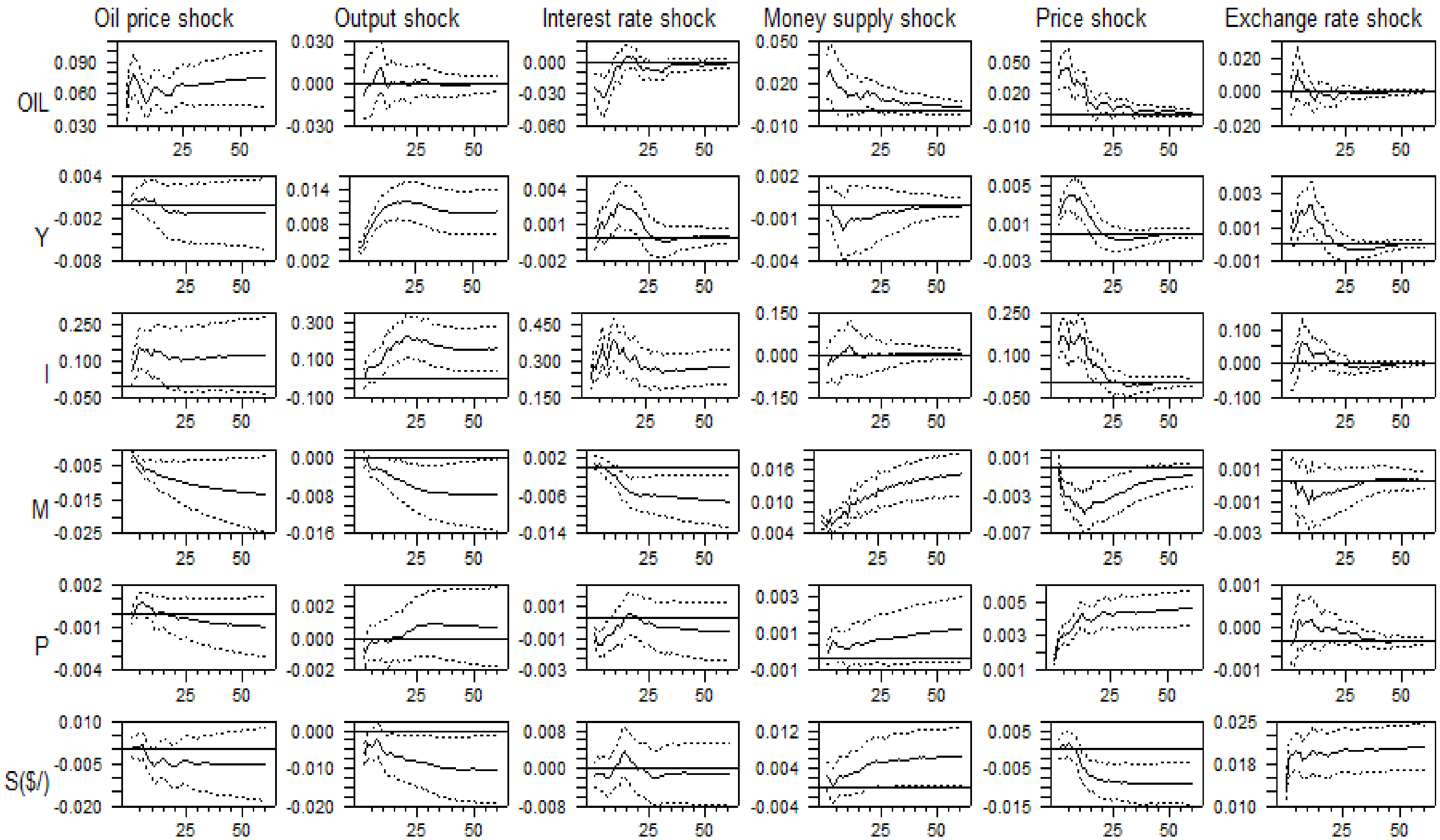

Figure 2. Responses of Aggregate Variables to Aggregate Shocks

Note: Solid curves show actual responses from estimations; dotted curves from simulations show standard error bands for each response.

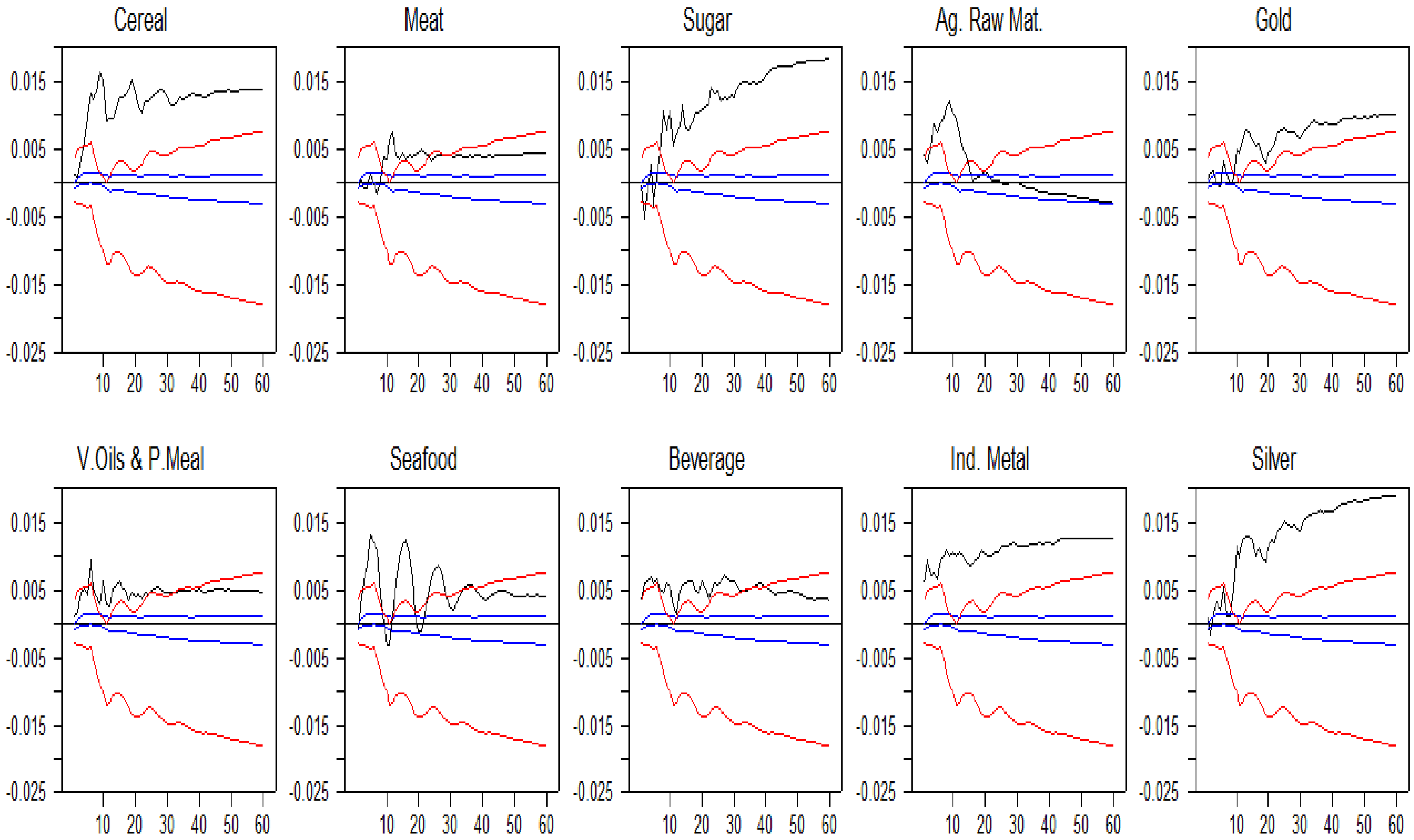

Figure 3. Responses of International Commodity Prices to Oil Shocks

Note: The blue lines are the US price error bands, while the red lines are the exchange rate error bands.

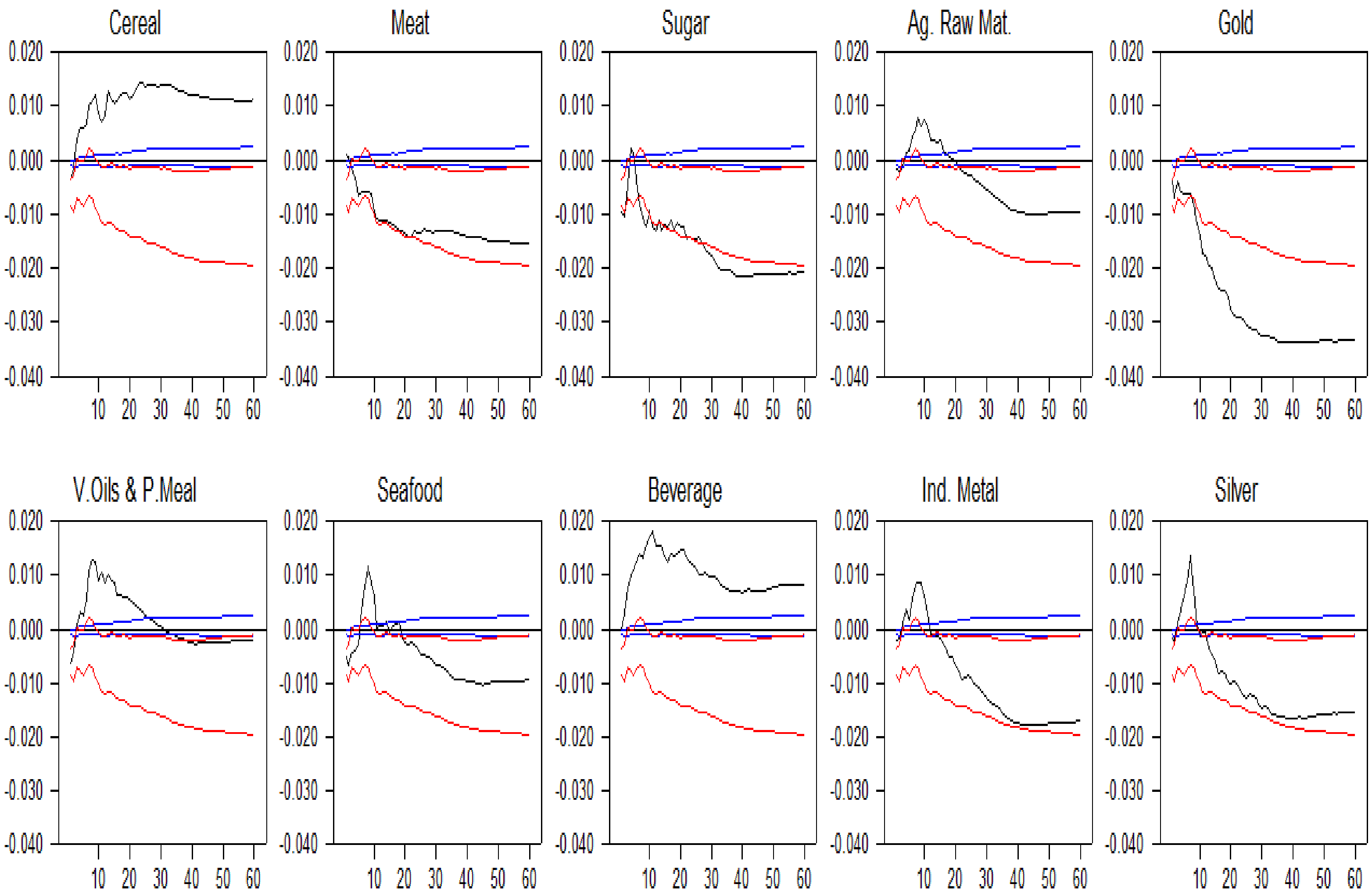

Figure 4. Responses of International Commodity Prices to U.S. Output Shocks

Note: The blue lines are the US price error bands, while the red lines are the exchange rate error bands.

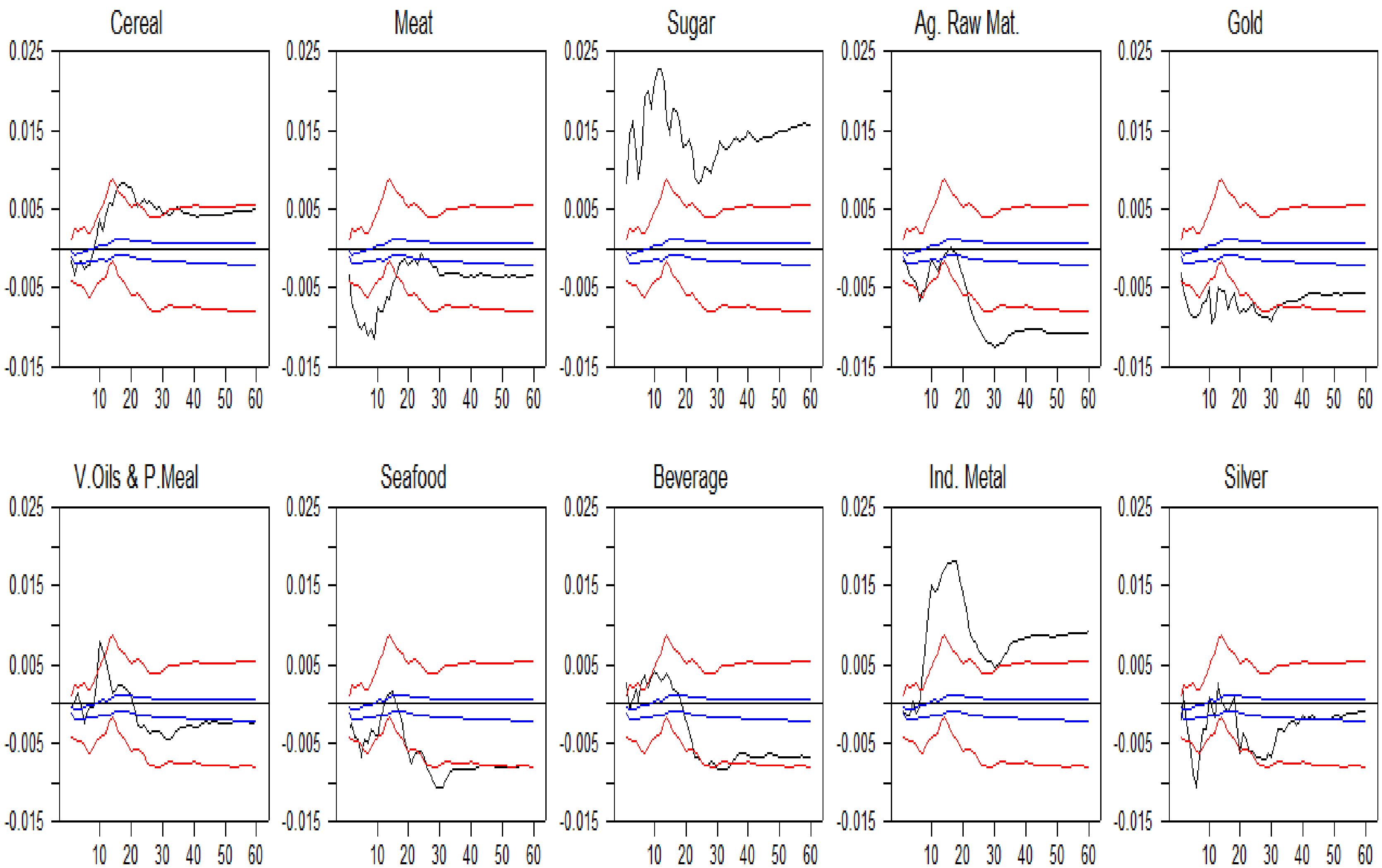

Figure 5. Responses of International Commodity Prices to U.S. Interest Rate Shocks

Note: The blue lines are US price error bands, while the red are the exchange rate error bands.

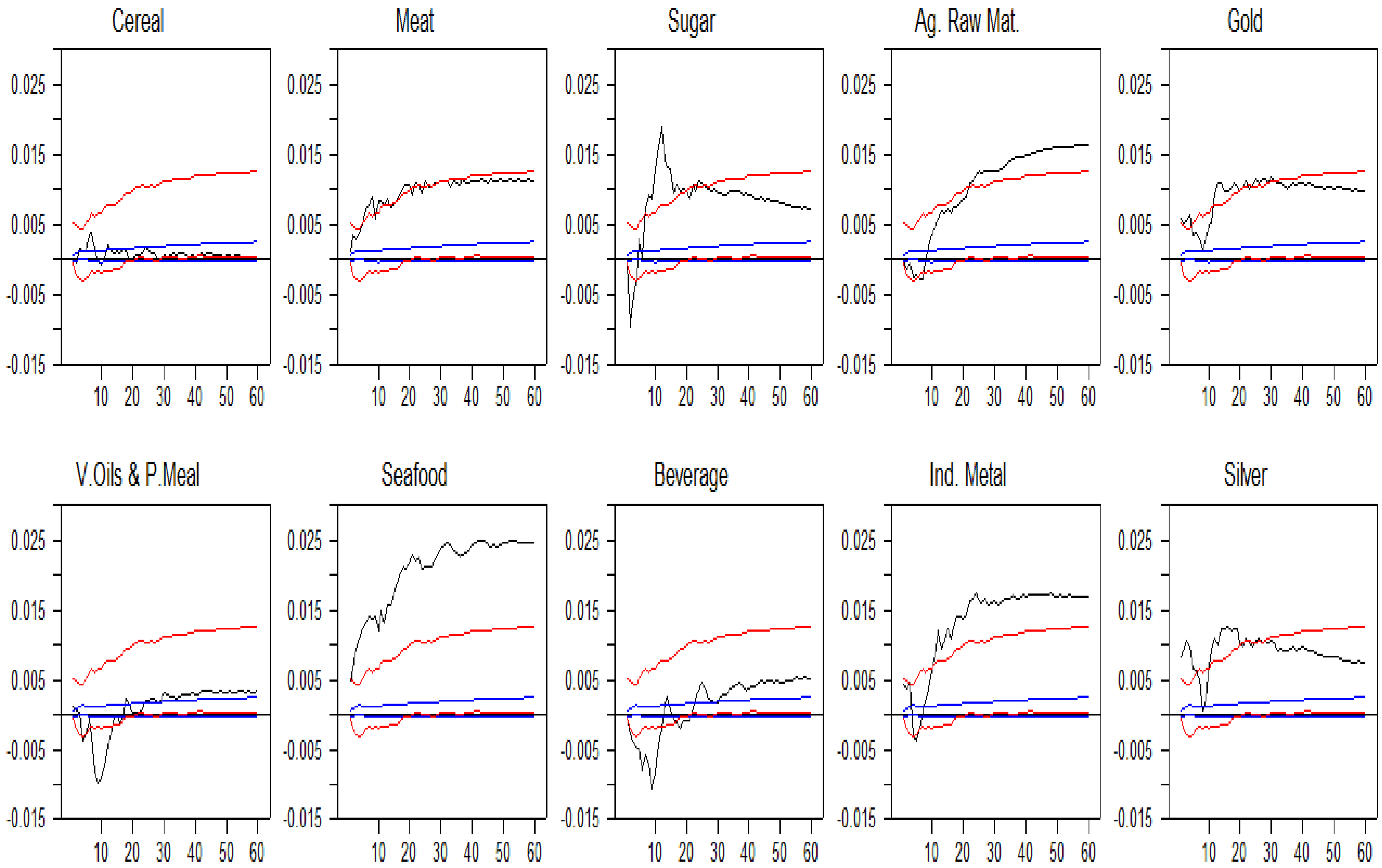

Figure 6. Responses of International Commodity Prices to U.S. Money Supply Shocks

Note: The blue lines are the US price error bands, and the red are the exchange rate error bands.

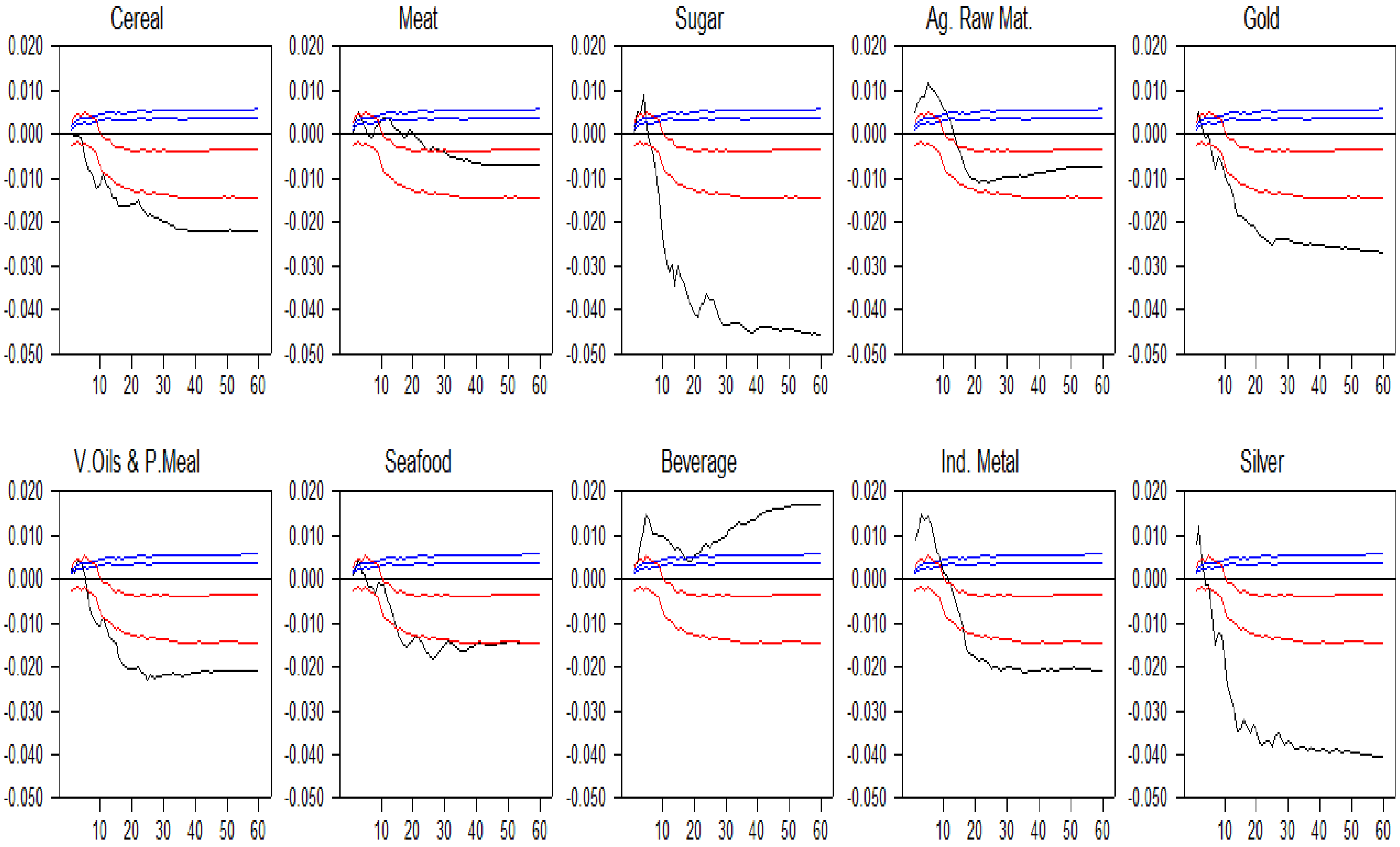

Figure 7. Responses of International Commodity Prices to U.S. Price Shocks

Note: The blue lines are the US price error bands, and the red are the exchange rate error bands.

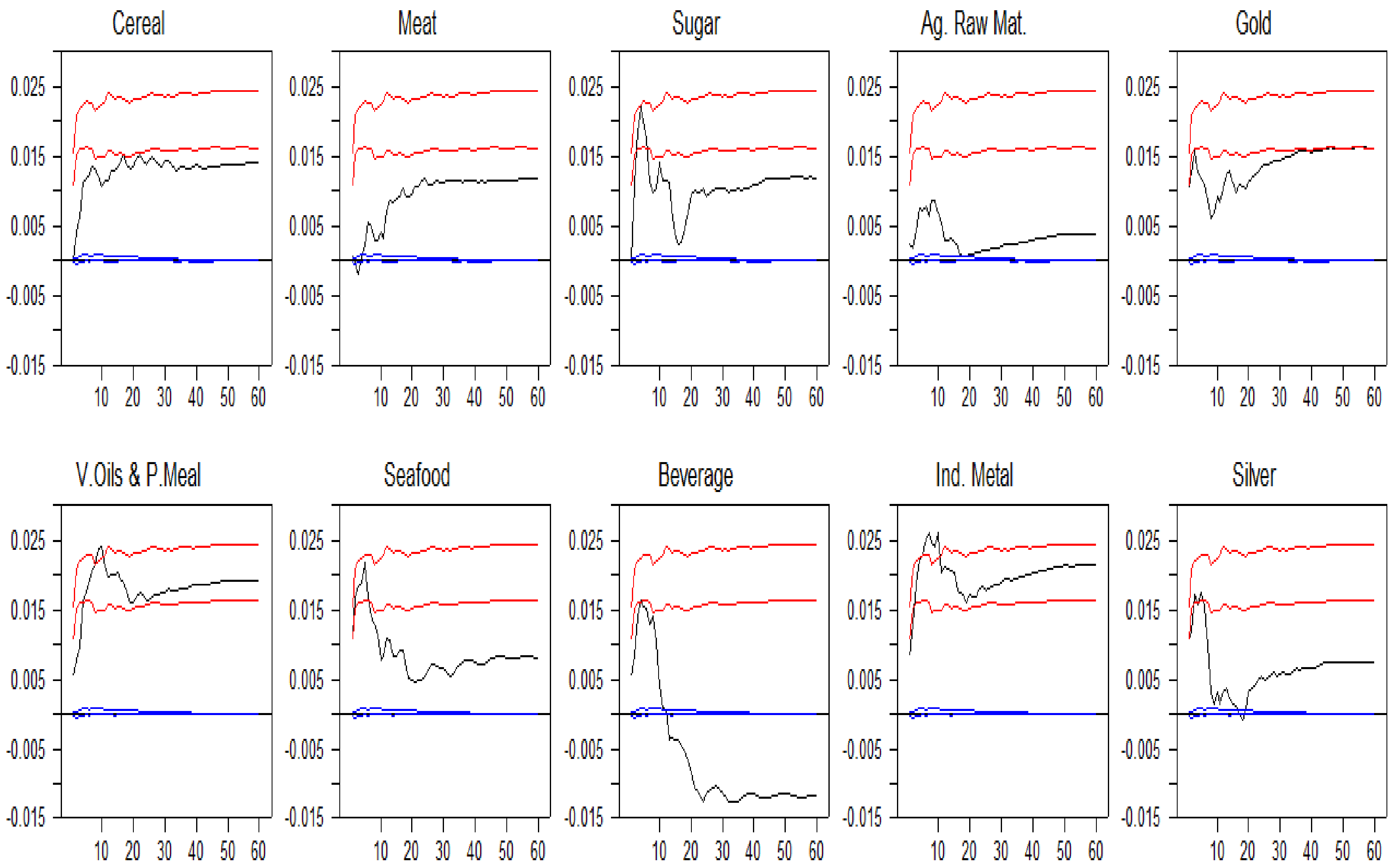

Figure 8. Responses of International Commodity Prices to U.S. Exchange Rate Shocks

Note: The blue lines are the US price error bands, while the red are exchange rate error bands.