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Summary

This study investigates the effects of oil price shocks on volatility of selected agricultural and metal commodities. To achieve this goal, we decompose an oil price shock to its underlying components, including macroeconomics and oil specific shocks. The applied methodology is the structural vector autoregressive (SVAR) model and the time span is from April 1983 to December 2013. The investigation is divided into two subsamples, before and after 2006 for agricultures taking into account the 2006-2008 food crisis, and before and after 2008 for metals considering the recent global financial crisis. The validity of time divisions is confirmed by historical decomposition accomplishment. We find that, based on impulse response functions, the response of volatility of each commodity to an oil price shock differs significantly depending on the underlying cause of the shock for the both pre and post-crisis periods. moreover, according to variance decomposition the explanatory power of oil shocks becomes stronger after the crisis. The different responses of commodities are described in detail by investigating market characteristics in each period.

Keywords: Metals, Commodities, Volatility, Oil Price

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Abstract

This study investigates the effects of oil price shocks on volatility of selected agricultural and metal commodities. To achieve this goal, we decompose an oil price shock to its underlying components, including macroeconomics and oil specific shocks. The applied methodology is the structural vector autoregressive (SVAR) model and the time span is from April 1983 to December 2013. The investigation is divided into two subsamples, before and after 2006 for agricultures taking into account the 2006-2008 food crisis, and before and after 2008 for metals considering the recent global financial crisis. The validity of time divisions is confirmed by historical decomposition accomplishment. We find that, based on impulse response functions, the response of volatility of each commodity to an oil price shock differs significantly depending on the underlying cause of the shock for the both pre and post-crisis periods. moreover, according to variance decomposition the explanatory power of oil shocks becomes stronger after the crisis. The different responses of commodities are described in detail by investigating market characteristics in each period.

1 Introduction

In recent years the linkages between oil prices and non-energy commodities prices, including agricultures and metals have increased. This is the result of two main reasons, the substitution of fossil fuels by biofuels as well as the hedge strategies against inflation caused by higher oil prices, (see, Ji and Fan [2012]). The linkage channels between oil and commodity prices are not identical for agricultures and metals. This linkage between agricultures and oil can potentially be explained via three main channels. First, when the increases in the price of oil resulted from a better global economic activity, demand for food increased as well, since the higher income level of emerging economies altered the food consumption pattern. Some authors such as Hochman et al. [2012] and Baumeister and Peersman [2013] assert that this is the most important channel through which oil price shocks affect agricultural commodities. Second, an increase in the price of oil resulting from any kind of shock might trigger demand for biofuels. This increases demand and, consequently, the price of corn, soybeans and other substitute and complementary crops. Furthermore, the increase in production of ethanol after May 2006 caused an additional increase in corn demand for ethanol production, which might have led to a closer link between energy and corn prices. This affects the price of other agricultural products as well, since corn competes with those commodities for fertilizer, scarce water and land sources (Baumeister and Peersman [2013]). The third channel of linkage is that an increase in the price of oil raises the production cost of agricultures, including transportation costs and fertilizers prices, which lead to higher agricultural production prices.

The potential linkage channels between oil and metal prices are rather different from those of agricultures. First, when better economic activity raises global oil demand and enhances oil price, it also increases demand for industrial metals such as copper and silver, as an input to the economy. Second, when oil price increases, the general price level of commodities rises (see, Hunt [2006] and Hooker [2002]). This inflationary effect of oil price is the most important channel of effect on gold price. Third, according to Hammoudeh and Yuan [2008] higher commodity prices resulting from an oil price shock lead to a tightening in monetary policy that enhances the interest rates. The authors argue that the rise in interest rates in interest rates impacts on commodity returns and volatility through multiple macroeconomic channels. For instance, changes in interest rates affect the building construction industry which uses copper and silver heavily, among other metals, and they impact consumer demand for durable goods, which use industrial metals in their manufacturing processes. Fourth, an increase in the price of oil boosts metal prices via the transportation and production costs. However, the question that arises is why after an oil price shock, volatility in commodity markets rises while both commodity and input prices are increasing, despite the fact that an increase in commodity prices is usually good news for producers. This is well described by FAO [2012] for agricultural commodities. It is argued that although price increases are good news for producers, the input prices of oil-based fertilizers, in particular, can increase more quickly than the output prices, which makes producers lose rather than gain benefit. On the other side, there are transport and storage restrictions as well as lack of access to inputs and credit, which prevent producers from investing properly on higher prices. This is a more serious problem for poor food producers, as for them price volatility means uncertainty and higher risk, which prevent enough investments to increase food production and to reduce vulnerability. As a result of these problems, most developing countries experienced a low level of supply response to the high prices of 2007-2008, which led to higher volatility in agricultural market. It is well documented in the relevant literature that an increase of commodity prices is bad news for commodity market consumers and consequently increases the volatility in these markets (see, Carpantier [2010]). Nevertheless, in this study we depart from the previous investigations and we assert that not all oil price shocks identically effect volatility of commodity prices, and the responses of volatility to the oil price shocks depend on the driver behind each shock.

Among the existing literature on this issue, a number of studies focus on the area of volatility spillover between commodity and energy markets using the bivariate or multivariate GARCH-type models, while a number of studies examine the relation between oil and commodity prices applying the cointegration and the Granger causality procedures as well as VAR and structural VAR models to examine this relationship. The relevant literature will be described in details in the next section. The majority of these studies apply the conventional approaches in which commodity prices respond to exogenous changes in oil price. Kilian [2009a] states that these approaches are not completely satisfying as the price of oil is endogenous, and it is driven by its fundamental factors, including demand and supply, and each shock has a different effect on the real price of oil and hence on the economy. Kilian [2009a] performs a structural decomposition of the real price of oil into three components, including oil supply shocks, shocks to global demand for all industrial commodities and other oil-specific demand shocks. Using a structural VAR approach the author analyzed the effects of these shocks on the U.S. GDP and found that the effects depend on the cause of the shocks. Subsequently, Kilian and Park [2009] consider the endogeneity of oil price with respect to the same decomposition and analyze their effects on the U.S. stock market. They obtained the same conclusion for the stock market as the one Kilian [2009a] had obtained for the U.S. GDP. Subsequently, Kilian and Murphy [2014] identify shocks to speculative demand for oil from oil-specific demand shocks in the previous model. This shock is proposed to capture the shifts in oil price caused by higher demand in response to the uncertainty of future oil supply.

Among studies on the linkage between oil and commodity prices, Wang et al. [2014] analyzed the effect of oil price shocks on agricultural prices employing a structural VAR framework. They found that the amount, duration and signs of responses of agricultural prices to an oil price shock differ depending on the reason behind the shock.

The aim of this study is to extend the literature by investigating the effects of different oil-related shocks on the volatility of selected agricultural and metal commodities. The analysis is based on a structural VAR model, which relates oil price to its driving factors, namely oil supply shock, global demand shock and speculative demand shock.
First, we use real daily futures returns for commodities from April 1983 to December 2013, to measure the conditional volatilities applying the GARCH approach. Then, we convert the obtained volatility series to monthly data to use within the structural VAR model.
We apply the data of global oil production as a proxy for global supply, the global real activity index proposed by Kilian [2009a] to quantify the global oil demand and the above-ground oil inventory level to quantify speculative demand in the oil market. Following Baumeister and Peersman [2013] that state that the relationship between oil and agricultural commodity prices had fundamentally changed since May 2006, and in order to take into account the 2006-2008 food crisis, we divide the agricultural data time span into two subsamples, from April 1983 to April 2006 (pre-crisis period) and from May 2006 to December 2013 (post-crisis period). Moreover, to take into account the role of the 2008 global financial crisis for the analysis of metals, we divide its relevant data time span into two subsamples, from April 1983 to December 2007 (pre-crisis period) and from January 2008 to December 2013 (post-crisis period). In order to check for the validity of this time span division, we perform a historical decomposition analysis, to estimate the individual contribution of each shock to the dynamics of volatilities. The historical decomposition demonstrates the relative importance of the shocks in explaining volatility movements, therefore the explanatory power of each individual shock would be observable before and after the crises.

To the best of our knowledge, this is the first study that considers the endogeneity of oil prices in order to assess the effects of oil shocks on volatility of commodity prices, and the first which distinguishes the impacts of oil factors, including supply and speculative shocks from the impacts of macroeconomic factors. We use the measure of volatility rather than price, as the growing role of commodities in financial markets and of financialization in commodity markets has increased the importance of volatility in these markets. The results of this study provide advantages for investors in terms of hedge strategies and risk management to lower the risk of investment during oil price shocks.

This article is structured as follows. Section 2 provides a review of the literature. Section 3 describes the data. Section 4 presents the applied econometrics methodology. Section 5 reports the empirical results and discussion. Section 6 shows a robustness check. The conclusion is provided in section 7.

2 Literature review

There is a vast number of studies that examine the relationship between oil and non-energy commodity markets. In what follows we describe the existing literature and we provide the contribution of this study.

The first group of studies examines the relationship between oil and commodity markets using cointegration and error correction, VAR and structural VAR models. Among studies related to the agriculture-oil nexus, Campiche et al. [2007] apply a Johansen cointegration test during the 2003-2007 period, and reveal no cointegration between agricultures and oil during the 2003-2005 period, however corn and soybean are cointegrated with oil during the 2006-2007 time period. Hammoudeh et al. [2010] use the ARDL model during the 2005-2008 period, and indicate that the grain price is significantly affected by the price of oil and other grain prices. Saghaian [2010] applies the Johansen cointegration and VECM procedure during the 1996-2008 period, and finds that oil and agricultures are cointegrated and causality runs from oil to agricultural prices. Serra et al. [2010] use a smooth transition VEC model and Generalized impulse response functions in the US from 2005 to 2007, and confirm that a shock to oil and corn prices causes a change in ethanol price. Nazlioglu and Soytas [2012] use the Toda-Yamamoto causality procedure and Generalized impulse response function during the 1994-2010 period, and reveal that the Turkish agricultural prices do not significantly react to oil price and exchange rate shocks. Nazlioglu and Soytas [2012] use the Pedroni panel cointegration test during the time 1980-2010 period, and show that oil price significantly affects agricultural prices. Esmaeili and Shokoohi [2011] apply a principal component analysis between 1961-2005, and find that oil price affects the food production index. Cha and Bae [2011] employ a structural VAR model with sign restriction in the US during the 1986-2008 period, and show that an increase in oil price raises the demand for corn as well as its price. Ciaian and Kancs [2011] apply the Johansen cointegration test during the 1994-2008 period, and reveal that energy prices affect prices for agricultural commodities and that the interdependencies between the energy and food markets are increasing over time. Reboredo [2012] uses copulas approach during the 1998-2011 period, and finds weak oil-food dependences and no extreme market dependence. Liu [2014] applies the ARDL cointegration test, the Granger causality model and the Generalized forecast error decomposition. He finds that there is no strong long-run equilibrium relationship between oil and agricultural volatility indices.

Furthermore, among studies related to metals-oil markets nexus, Hammoudeh et al. [2009] use the Toda Yamamoto causality procedure during the 2003-

2007 period, and find that oil price does not Granger cause the precious metals prices in Turkey. Sari et al. [2010] apply the Johansen-Juselius, the ARDL cointegration approaches and the generalized impulse response functions between 1999 and 2007. They confirm the positive responses of gold, silver and platinum to oil price increases. Zhang and Wei [2010] apply the Engle-Granger cointegration and the VECM procedure during the 2000-2008 period, and reveal that the oil price Granger causes the gold price, but not vice versa.

In a new generation of studies, following Kilian [2009a]'s structural VAR model based on oil price decomposition methodology, Qiu et al. [2012] use the structural VAR model to decompose supply-demand structural shock effects on corn and fuels prices. The fuels prices include oil, ethanol and gasoline during the 1994-2010 period. The results reveal that fuels market shocks do not spillover into the corn market, however the fundamental market factors of corn are the main drivers of corn prices. Applying the same methodology Wang et al. [2014] use the structural VAR model to decompose oil price shocks during the 1980-2012 period. Their findings show that the responses of agricultural commodity prices to an oil price shock depend on drivers behind the shock. Moreover, they find that oil market shocks have stronger effects on agricultural commodity price variations after the food crisis in 2006-2008 than the period before.

The second group of studies examines volatility spillover between non-energy commodities and oil markets employing the univariate and multivariate GARCH-type models. In this context, Hammoudeh and Yuan (2008) apply the univariate GARCH-type models during the 1990-2006 in favor of the impact of oil price on return, and find strong evidence in favor of the impact of oil price on return and volatility of silver, weak evidence of effect on volatility of gold and no effect on copper. Choi and Hammoudeh [2010] use a DCC-GARCH model during the 1990-2006 period, and find an increasing correlation between oil and industrial commodities since the 2003 Iraq war but decreasing correlations with the S&P 500 index. Du et al. [2011] use stochastic volatility models to oil, corn and wheat prices in 1998-2009, and confirm volatility spillover among oil, corn and wheat after the fall of 2006. Serra [2011] uses the semi-parametric GARCH model with data in 2000-2008. He considers price links between oil, ethanol and sugar in Brazil and finds strong volatility links between them. Ji and Fan [2012] use the EGARCH model over the 2006-2010 period and consider the US dollar index as an exogenous shock. They divide the sample into before and after the 2008 financial crisis and find that the oil market has significant volatility spillover effects on non-energy commodity markets and that the influence of the US dollar index on commodity markets has weakened since the 2008 crisis. Nazlioglu et al. [2013] apply newly developed causality in the variance test on the period from 1986 to 2011. Based on impulse response functions they show that in the post 2006 food crisis oil market volatility is transmitted to agricultural markets, with the exception of sugar, while there was no risk of transmission in the pre-food crisis period. Gardebroek and Hernandez [2013] use the VAR-GARCH approach during the 2000-2008 period. The results show a higher correlation between ethanol and corn markets particularly after 2006, and significant volatility spillover from corn to ethanol price but not the converse. However they do not find major cross market volatility effects running from oil to corn. Wu and Li [2013] analyze volatility spillovers in China's oil, corn and ethanol markets during the 2003-2012 period, employing the univariate EGARCH and the BEKK-MVGARCH models. The results indicate a higher interaction among oil, corn and fuel ethanol markets after September 2008. Liu [2014] investigates cross-correlations between oil and agricultural commodity markets in 1994-2012, using a de-trended cross-correlations statistical analysis, and provides that volatility cross-correlations are highly significant. And finally Mensi et al. [2014] apply the VAR-BEKK-GARCH and the VARDCC-GARCH models, and find evidence in favor of significant linkages between energy and cereal markets. Moreover, the OPEC news announcements are found to exert influence on oil markets and on oil-cereal relationships.

In this study we extend the above described literature examining the effects of oil price shocks on the volatility of commodity prices from a different point of view. We distinguish the impacts of oil specific factors, including oil supply and speculative demand shocks from the macroeconomic factor. Moreover, we consider the measure of volatility rather than the price of commodities, in order to provide a perspective of risk in commodity markets during different oil price shocks.

3 Data description

We use real daily futures closing prices for commodities. First we obtain nominal three months ahead futures prices for metals, including copper, gold and silver traded on NYMEX, nominal one months ahead futures prices for agricultures, including coffee traded on NYBOT, corn, soybean, sugar and wheat traded on CBOT, and WTI crude oil traded on NYMEX. Then, nominal prices are divided to the U.S. CPI (2010=100) obtained from the WDI to achieve real prices. The real prices are converted to log returns by means of $R_t = \log(\frac{P_t}{P_{t-1}})$, where R_t is the corresponding return and P_t is the corresponding price series.

All the return series have a Kurtosis statistic greater than three. Therefore the series contain fat tails and have a negative skewness statistic suggesting the presence of a left fat tail, expect for coffee and sugar that show a right tail. Moreover the Jarque-Bera statistics indicate non-linearity for all return series at the 1% level of significance.

The residual diagnostics tests suggest existence of an ARCH effect for all returns at the 1% level of significance; thus the returns of metals suffer from heteroskedasticity, up to one lag, and according to the Ljung-Box Q-test for residuals, there are enough evidences for presence of serial correlation up to 10 lags. In order to check for stationary properties of series we apply the Augmented Dickey and Fuller (1979) (ADF) and the Phillips and Perron(1988) unit root tests. According to both tests the level of commodity prices contain unit roots and their returns are stationary. The description of returns are shown in table 1. According to the above described specifications the returns of commodities are suitable for applying the GARCH approach to measure volatility. The GARCH estimations are shown in table 2.

In the next step, we convert the obtained volatility series to monthly data, to investigate the effects of different oil price shocks on volatility of selected commodities. The applied data for the crude oil market include the percent change in global crude oil production, a measure of global real economic activity, the change in above ground oil inventory and the change in the real price of oil. Following Kilian and Murphy [2014] we use inventory data to quantify speculation in the oil market. The relevant data for global crude oil production is obtained from the Monthly Energy Review of the Energy Information Administration (EIA). Data for global real activity, introduced by Kilian [2009a] is based on data for global dry cargo shipping rates, as a new measure of global business cycle. It is stationary by construction and and it is available on a monthly basis since the early 1970s.. This measure captures shifts in the global use of industrial commodities. Furthermore, due to the lack of data on global crude oil inventories, following Kilian and Lee [2013] and Kilian and Murphy [2014] we apply a proxy for global crude oil inventories, which is the ratio of OECD petroleum stocks over the U.S. petroleum stocks. Those data are obtained from the Energy Information Administration (EIA).

The time span is from April 1983 to December 2013, which is based on data availability for all series. This has the advantage of covering the 1997 Asian financial crisis, the 2006-2008 food crisis, the 2008 stock market crash, the 2008 global financial crisis and the 2008 and 2012 oil price shocks.

4 Methodology

We estimate the effects of oil shocks on volatility of commodities within the framework of SVAR.

To achieve this goal, first we calculate the conditional volatility of commodities within a GARCH framework developed by Bollerslev [1986]:

$$y_t = \beta' x_t + \varepsilon_t \quad (1)$$

$\varepsilon_t = z_t\sqrt{h_t}, \quad \varepsilon_t \sim N(0, \sqrt{h_t}), \quad z_t \sim i.i.d.N(0,1)$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i h_{t-j} \tag{2}$$

Where ε_{t-i}^2 denotes the ARCH term and h_{t-i} denotes the GARCH term. We select the appropriate models based on the ARCH test, serial correlation and the Akaike Information Criteria (AIC). Accordingly, the chosen model for corn, soybean, sugar and wheat is the AR(1)-GARCH(1,1) model and the chosen model for coffee, copper, gold and silver is the AR(1)-GARCH(2,1) model. The parameters should satisfy $\alpha_0 > 0,\ \sum_{i=1}^{p} \alpha_i \geq 0\ and\ \sum_{i=1}^{q} \beta_i \geq 0$, to guarantee the non-negative conditional variance. Bollerslev [1986] shows that the necessary and sufficient condition for the second order stationarity of the GARCH(p,q) model is $\sum_{i=1}^{p} \alpha_i + \sum_{i=1}^{q} \beta_i < 1$, which is satisfied for all estimations of this study. The results of the variance equation of the GARCH model, the second moment condition and the relevant diagnostic tests are shown in table 2.

In the next step, we convert the daily volatility series to monthly, in order to investigate the effects of different oil price shocks on volatility of commodities. A structural vector autoregressive (SVAR) model is used to investigate the time-varying impact response of volatility of different commodities to different oil market shocks, namely, oil supply shock, global demand shock and speculative demand shock. The analysis is based on a dynamic simultaneous equation model in the form of a structural VAR as follows.

$$A_0 y_t = \alpha + \sum_{i=1}^{12} A_i y_{t-i} + \varepsilon_t \tag{3}$$

Where y_t is the vector of endogenous variables including the percent change in global crude oil production, a measure of global real economic activity, the change in global crude oil inventories above the ground, the change in the real price of crude oil and volatility of the commodity that is under study. ε_t is the vector of structural shocks that is assumed to be unconditionally homoscedastic, and its variance-covariance matrix is normalized such that $E(\varepsilon_t \varepsilon_t') = \Sigma_u = I$. The first shock, the oil supply shock, is the shock to the global production of crude oil. The Second shock, the global demand shock, is the shock to consumption demand for crude oil and other industrial commodities. The third shock captures the changes in speculative demand for oil in response to increased uncertainty about future oil supply shortfalls. The fourth shock is residual shock that captures other oil market shocks that are not captured by the first three shocks, like weather shocks. Finally, the last shock is the shock to volatility of each commodity.

4.1 Identification

The reduced-form of representation of equation 3 is given by

$$y_t = A_0^{-1}\alpha + \sum_{i=1}^{12} B_i y_{t-i} + e_t \qquad (4)$$

where $B_i = A_0^{-1}A_i$ and $e_t = A_0^{-1}\varepsilon_t$, the vector of residuals, are estimated from the reduced form VAR model (4). The elements of A_0^{-1} can be obtained from

$$\Sigma_e = E(e_t e_t') = A_0^{-1}\Sigma_\varepsilon A_0^{-1'},$$

if the number of unknown parameters of A_0^{-1} is not larger than the number of equations. Therefore in order to uniquely identify the elements of A_0^{-1} we need to impose some restrictions on it. Following Kilian [2009a] we employ short-term recursive exclusive restrictions.

$$\begin{pmatrix} e_{1t}^{\Delta global\ oil\ production} \\ e_{2t}^{global\ real\ activity} \\ e_{3t}^{\Delta global\ oil\ inventory} \\ e_{4t}^{\Delta real\ price\ of\ oil} \\ e_{5t}^{volatility} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{global\ demand\ shock} \\ \varepsilon_{3t}^{speculative\ shock} \\ \varepsilon_{4t}^{residual\ shock} \\ \varepsilon_{5t}^{volatility\ shock} \end{pmatrix}$$

There are five assumptions that are discussed in the following.
First, we assume that, within a month, crude oil supply responds only to the oil supply shocks among all the shocks in the model. This assumption is made based on the high production adjustment cost and the fact that the price elasticity of crude oil supply in the short-term is extremely low, due to the long-lead time and capital intensive nature of production projects (Kilian [2009a] and Mu and Ye [2011]).
Second, the increases in the real price of oil driven by shocks to the speculative demand for oil and other residual shocks to the oil market do not affect global economic activity within the same month of the shock. This restriction is consistent with the sluggishness of global real economic activity(Kilian [2009a]).
The third assumption is that within a month the level of above ground oil inventories is affected by oil supply shocks, global demand shocks and oil speculative demand shocks. The last assumption is that any shock that is specific to the commodity market may affect the oil market variables only with the delay of at least one month. While volatility of price of each commodity is allowed to respond to oil market shocks in the same month. This assumption corresponds to the four exclusion restrictions in the last column of the matrix A_0^{-1}, and is implied by the standard approach of treating innovations to the price of oil as predetermined with respect to the economy (Kilian and Park [2009], Lee and Ni [2002]).

In order to take into account the role of the food crisis for the analysis of agricultural commodities, we follow Baumeister and Peersman [2013] by dividing the whole sample into two subsamples: $1983:4-2006:4$ (pre-crisis period) and $2006:5-2013:12$ (post-crisis period). And to take into account the role of the financial crisis, for the analysis of metals, we divide the whole sample into two subsamples: $1983:4-2007:12$ (pre-crisis period) and $2008:1-2013:12$ (post-crisis period). In order to check for the validity of this time span division, we perform a historical decomposition analysis, to estimate the individual contribution of each shock to the dynamics of volatility. Historical decomposition is a very strong econometric tool that enables us to analyze the cumulative effect of structural shocks on volatility of commodities. Historical decomposition methodology is applied to analyze the observed series of the endogenous variables in terms of the structural shocks and the evolution of the exogenous variables. The strength of this tool is that it takes the series of structural shocks that evolve through time rather than assuming that structural shocks are one time shocks. This allows us to make a judgement over what has actually happened to the series of interest in the sample period.

5 estimation results

The results of historical decomposition of each commodity's volatility show that the role of some oil price shocks in explaining the dynamics of volatilities increases considerably after a specific time. This time is the mid 2006 for most agricultural commodities and around 2007-2008 for metals. This confirms the time division taking into account food crisis for agricultures and global financial crisis for metals. Figures 1 and 2 represent the results of historical decomposition for some commodities.[1]

[Figure 1 and 2 here]

We analyze the effects of three oil related shocks, namely, oil supply shock, global demand shock and speculative demand shock on volatility of commodities prices in the agricultural and metal markets[2]. The results are presented in the form of impulse responses and variance decompositions. The latter represents the share of variations in volatility of each commodity resulting from each structural shock.

Figures 3a and 3b show the impulse responses of different agricultural products to different oil related shocks for the time periods before and after May

[1] To save space, the results of historical decomposition are shown only for corn and silver as examples and the remaining results are available from the authors upon request.

[2] The contribution of the residual shock is not included because it is difficult to interpret this shock economically. Also, this shock does not play an important role in determining the real price of oil as documented by Kilian and Murphy [2014]

2006, respectively. Moreover the responses of metals to different oil shocks are shown in figures 4a and 4b, for the time periods before and after January 2008.
From the impulse responses one realizes that the responses of volatility of all commodities to an oil price shock differ depending on the underlying cause of the shock. Furthermore the responses differ in the pre-crisis and post-crisis periods.
According to the variance decomposition of volatility of all commodities in tables 3 and 4 the explanatory power of oil shocks to all volatility variations becomes stronger after the crisis corresponding to their market. This can be seen also from impulse responses in figures 3a, 3b, 4a and 4b.

[Figure 3 here] [Figure 4 here] [Table 3 and 4 here]

The estimation results are analyzed in more details in the following. Our findings are consistent with the view that the link between oil and agricultural commodity markets has been stronger since 2006 (see Kristoufek et al. [2012], Nazlioglu [2011], Nazlioglu et al. [2013] and Reboredo, 2011).

5.1 Agricultural commodities

Figures 3a and 3b show the responses of agricultural commodities volatility to the structural shocks underlying the price of oil, for the periods before and after May 2006.
After May 2006 the responses of volatility of agricultural products, in figure 3b, seem to be greater than in the period before the break, as shown in figure 3a. The results from variance decomposition in table 3 confirm this finding. This result is not surprising given the increase in production of ethanol after May 2006 that implies an additional increase in demand for corn. This also affects the price of other agricultural products since corn competes with other agricultural commodities for fertilizer, scarce water and land resources (Baumeister and Peersman [2013]).
As the impulse responses in figures 4a and 4b show, the volatility of each product responds differently to each of the structural shocks to oil price. This leads us to investigate how each product reacts to each oil market structural shock.

An increase in the real price of oil due to a positive global demand shock, the second rows of figures 3a and 3b, decreases volatility of corn for both pre and post break periods, increases volatility of soybeans significantly only before the break with a delay of about one year, makes a short-lived small increase in volatility of wheat only after the break, makes an increase in volatility of sugar only after the break with a four-month delay and leads to a short-lived significant increase in volatility of coffee only after the break as well. When the increase in oil price is triggered by an economic activity growth, there are two conflicting types of expectations. First, we expect a decline in volatility of crops given a positive shock to economic activity and hence a demand side effect on commodity markets, if there is enough inventory. Second, we expect an increase in volatility of crops given that higher oil price leads to higher commodity prices, and given that this is bad news for commodity markets, which according to the literature (e.g. Hammoudeh and Yuan [2008], Carpantier [2010] and Chkili et al. [2014]) leads to an increase in volatility in these markets as an inverse leverage effect. Nevertheless, our results indicate that the effects of this shock are mixed and are more in favor of increasing volatility. The reason of these reactions can be summarized as follows. This shock leads to a demand-side effect in commodity markets. Hence, it makes an increase in human consumption demand for all crops and an increase in demand for meat, which leads to a higher demand for some of these crops, as animal feed. Moreover, this shock leads to a higher demand for biofuels and therefore higher demand for corn, soybeans, wheat and sugar as inputs to biofuels production. On the other side, it is difficult for farmers to respond quickly to the fluctuations of the market. For instance, it takes four years for coffee and five to six years for sugar plants to produce fruits. Consequently this demand surplus reduces their inventory level, and enhances their price volatility. The only exception is corn that has shown a calmer and less volatile market resulting from increasing oil price due to global demand shock. Given that the demand and the net return of producing corn is higher than wheat and soybeans (Antonakakis and Filis [2013], Baumeister and Peersman [2013] and Hart [2005]), and given that these three crops can be produced in the same land, after a positive global demand shock there might be a supply shift in favor of corn. This decreases the inventory level of two other crops in order to smooth consumption, which increases their volatility even in a good economy period (IIF [2011], Roberts and Schlenker [2010] and Pietola et al. [2010]). Thus, the decline in volatility of corn is due to a better economy combined with a fundamental equilibrium in its market. After the 2006 break, since the demand for these crops was higher than the period before (Hochman et al. [2012] and Baumeister and Peersman [2013]) it is not surprising to see that the global demand shock had a stronger effect on the crops volatility.

In the third rows of figures 3a and 3b we see the responses to a speculative demand shock. It is noteworthy to mention that a speculative demand shock occurs as a result of possibility of uncertainty in the oil market, such as predicting conflicts in oil exporting countries, low level of oil inventories, and misspecification of oil prices in financial markets, which all lead to predicting a surge in future oil prices. Hence, when oil price increases resulting from a speculative demand shock, our expectations are as follows.
First, it increases the demand for biofuel and therefore acts like a positive demand shock for corn, soybean, sugar and wheat, as inputs to biofuel production. We expect a decrease in volatility of these markets, if there are enough inventory levels. Second, an inverse leverage effect is expected, as

earlier in this section. However, our results show a short-lived increase in volatility of corn, soybeans and sugar after the break, and no statistically significant response of volatility of wheat for the both pre and post break periods. This can be explained by the fact that an increase in demand for these crops after this shock is not as high as in the case of a global demand shock. Given that ethanol is mostly produced by corn and biodiesel by soybeans and sugar, and given that after the 2006 break demand for biofuel is higher than before, the increase in demand for biofuel leads to an increase in the price of the input crops, and the inverse leverage effect dominates. Finally, the first rows of figures 3a and 3b show the responses to an oil price increase due to a negative oil supply shock. This shock also makes expectations in two opposite channels of effects on agricultural markets, as we described above. Our results show that a negative oil supply shock does not have a statistically significant effect on volatility of corn and wheat for both periods before and after the 2006 break, it makes a short-lived small increase in soybean volatility only after the break, makes a longer-lived increase in volatility of coffee only after the break with five months of delay, and lastly it decreases volatility of sugar before the break and increases its volatility after the break. This could be evidence that this shock did not matter much for the volatility of these crops before 2006. However with the increasing role of biofuels after 2006 its effect became significant, as the higher oil price leads to a higher demand for biofuel inputs production after 2006.

5.2 Metals

In this section we analyze how the structural shocks driving the price of oil affect the volatility of gold, silver and copper. Gold is a precious metal and its demand is mostly for investment to hedge against inflationary effects of economic shocks (Narayan et al. [2010]). Demand for copper mirrors manufacturing and economic growth. And silver has a dual nature, being a precious metal as well as having multiple applications in industry and medicine.

Table 4 presents the share of each structural oil related shock in the variation of metals volatility in the form of variance decomposition, based on the structural VAR model responses. These results indicate that the responses of metals to oil related shocks are larger after the 2008 financial crisis than before.

Figures 4a and 4b show the responses of metals volatility to different oil price shocks for the time periods before and after the 2008 financial crisis.

The first rows of figures 4a and 4b show the responses of metals volatility to an oil supply shock for the pre-crisis and post-crisis periods, respectively. The results indicate that the responses to oil supply shocks are not statistically significant for all three metals. The insignificant responses hold for both the pre- and post-crisis periods.

The second rows of figures 4a and 4b represent that all the three metals respond positively to a positive global demand shock before the crisis, while after the crisis this shock decreases their volatility. When the increase in the price of oil is due to a positive global demand shock, the consumption demand for metals increases, as they are inputs for the economy, which increases their prices as well. However, the surprising question is why does this shock affect the volatility of metals in a totally different way before and after the 2008 crisis. This can be explained as below. Along with persistent rapid increase in consumption demand for commodities, their investment demand has also been rising from 2000 to 2008. According to Christian [2009], during that time period the returns available on stocks and bonds were no longer attractive, and volatility of returns in these asset groups was rising. Moreover, at the same time some academic and market-related research publications asserted that commodities compete with stocks and bonds effectively over time in terms of investment, which led the investment demand for metals to increase both physically and financially. It is well known that well-informed and rational commodity investors should add liquidity to the commodity derivatives market, buying when prices are low and selling when prices are high, they should help to clear the market (IIF [2011]). Nevertheless, ill-informed investors exhibiting herding behavior could add to price volatility (Mayer [2009]), which has happened to metal markets, and increased volatility in those markets before the 2008 crisis. This herding behavior decreased after 2008. The other factor that affects the different volatility responses to a positive global demand shock before and after the 2008 is that, the supply of base metals has responded to rising demand slowly due to slow development in mining capacity and rising energy costs. But the presence of inventory and the smoother increase in demand, after the crisis, have declined the gap between demand and supply and reduced volatility in metal markets. The results confirm the view that after the 2008 crisis investment interest decreased in commodities and it became more supply/demand fundamentals-based (see for instance Narayan et al. [2010]).

The third rows of figures 4a and 4b show the responses of metals volatility to the oil price increase derived by speculative demand for oil.
Before the 2008 break, the speculative demand shock for oil did not significantly affect the volatility in gold, silver and copper markets. After the break, this shock significantly affects only the volatility of silver. It decreases the volatility in the silver market for about 8 months, this decline being statistically significant for the first 4 months. This can be explained by the very high increase in demand for silver for the production of solar panels relative to the pre-2008 period. Since 2008, considering the enormous increase in production of solar panels to be used in solar as an alternative source of energy[3], an increase in the price of oil after this shock would increase the

[3] In 2000, only 1 million ounces of silver were used in PV fabrication and by 2008 this

industrial demand of silver. But given that the very slow response of supply of silver[4] leads to a decline in silver inventory the decline in silver volatility is short-lived. Furthermore, we find that the responses of volatility of copper to this shock are not statistically significant for the both pre and post-crisis periods. This could be due to the fact that copper is mainly industrial and very sensitive to business cycles, and that the speculative demand shock for oil does not significantly affect the real economic activity in the short run, consequently it does not affect the copper market (Hammoudeh et al. [2009], Hammoudeh et al. [2010]).

6 Robustness check

6.1 Alternative volatility measurement

In order to check the robustness of the results we apply realized volatility as an alternative measurement of volatility within the same structural VAR model. The results confirm that the signs of volatility's responses mainly remain robust to oil related impulses.[5]

6.2 Alternative model and proxies for oil related shocks

As the second robustness check, we employ the unrestricted VAR model to assess the effect of structural shocks on the price of oil on the volatility of each commodity. We perform this by estimating the VAR model

$$\begin{pmatrix} u_{it} \\ vol_{jt} \end{pmatrix} \sim VAR(p) \tag{5}$$

where $u_{it}, \quad i = 1, 2, 3$ denotes the structural shocks to the oil market including oil supply, global demand and oil speculative demand shocks. The time series for oil market structural shocks are derived from the estimation of the structural VAR model for crude oil market developed by Kilian and Murphy [2014], and $vol_{jt}, \quad j = 1, 2, ..., 8$ denotes the time series for the volatility of each commodity under this study.

The responses mainly remain robust with those from the structural VAR model estimated in the previous section. As the global demand shock is the most important source of effect on volatilities, we represent the impulse responses related to this shock. The related graphs are shown in figure 5a for agricultural commodities and in figure 5b for metal commodities.

had increased to 19 million and then increased again to 64.5 million ounces in 2013. (Berry [2014])

[4]see Opdyke [2014] and `www.silver-coin-investor.com/silver-supply.html`

[5]These graphs are not included in the appendix due to the limitation on length of the paper, however they are available upon request from the authors.

7 conclusion

In this paper, we analyze the effects of oil price shocks on selected agricultural and metal commodities price volatility. The sample data is from 1983:04 to 2013:12. To account for the food crisis for the analysis of agricultural commodities, the sample is divided into before and after the 2006 food crisis subsamples. And to take into account the role of financial crisis, for the analysis of metals, we divide the whole sample into before and after the 2008 financial crisis subsamples.

Our analysis makes two contributions to the literature. First, we decompose the oil price shock to its driving components, oil supply shock, global demand shock and oil speculative demand shock, which is very important to understand how volatility in commodity markets responds to oil market shocks. Second, we investigate each selected commodity market characteristics to better understand the channels through which oil price shocks affect commodity markets.

The implication of the results on the effect of oil related shocks on commodities price volatility, whether in terms of the direction and duration of the effects over different time spans, or the evolution of the effects before and after the food and financial crises, are important to all beneficiaries of investigations in commodity markets. The underlying beneficiaries include policymakers, industrial manufacturers, crops producers and financial traders. According to our results it is proper for them to consider that: a) The responses of volatility of commodities to an oil price shock significantly differ depending on the underlying cause of the shock for the both pre and post-crisis periods. b) The explanatory power of oil shocks to the variations of volatility of all commodities becomes stronger after the crisis. c) For the both pre and post-2006 crisis, global demand and speculative demand for oil, significantly affect volatility of crops in contrast with very small role of oil supply shock. d) Before 2008 in all three metals volatility increases in response to a global demand shock while after the break they all decrease in volatility in response to the same shock. e) Volatilities of metals respond totally different to oil supply and speculative demand shocks in each period.

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	Data description			Diagnostics		ADF	P-P	ADF	P-P
Commodity	Skewness	Kurtosis	Jarque-Bera	ARCH	Serial correlation	Levels		Returns	
				F-stat	Q-stat	t-stat		t-stat	
Coffee	0.04184	11.06076	21097.74	182.45***	2.080**	-2.90	-2.91	-88.58***	-88.58***
Corn	-16.065	32.11544	278574.8	6.83***	2.53***	-2.89	-2.96	-85.61***	-85.59***
Soybean	-0.9628	13.18267	34867.58	27.79***	3.29***	-2.55	-2.55	-85.84***	-85.87***
Sugar	0.04309	9.649809	10365.88	64.88***	2.75***	-3.13	-3.08	-65.61***	-90.52***
Wheat	-0.61641	13.96244	32716.69	18.79***	2.470**	-3.25	-3.25	-87.83***	-87.85***
Copper	-0.32016	8.094391	8583.30	369.15***	7.07***	-2.21	-2.34	-94.94***	-94.84***
Gold	-0.19928	9.946727	15763.40	152.32***	2.46***	-1.68	-1.63	-89.87***	-89.92***
Silver	-0.72619	9.937221	16355.51	237.74***	2.94***	-2.72	-2.73	-90.30***	-90.37***

Notes: ***,**,* indicate statistical significance at the 1%, 5% and 10/ levels, respectively.
ADF decotes Augmented Dickey Fuller unit root test.
P-P denotes Phillips Perron unit root test.

Table 1: Data description

AR(1)-GARCH(p,q)	Variance equation			Information criteria	Diagnostic tests	
Commodities	$\alpha_1 + \alpha_2$	$\beta_1 + \beta_2$	Second Moment Condition	AIC	ARCH	Serial correlation
					F-stat	Q-stat
Coffee	0.039	0.9599	0.9998	-49.757	0.835	15.35
Corn	0.081	0.9127	0.9940	-56.654	0.429	12.22
Soybean	0.068	0.9234	0.9914	-58.105	1.973	23.00
Sugar	0.033	0.9656	0.9995	-48.650	2.052	26.28
Wheat						
Copper	0.036	0.9633	0.9998	-57.567	4.211**	15.172
Gold	0.030	0.9695	0.9999	-64.738	4.168**	16,187
Silver	0.032	0.9645	0.9966	-53.761	0.032	19.169

Notes: AIC denotes Akaike Information Criterion. ***, ** and * denote statistically significant at the 1%, 5% and 10% levels

Table 2: GARCH model estimations

	Before Crisis					After Crisis				
	supply shock	global demand shock	speculative shock	residual shocks	volatility shocks	supply shock	global demand shock	speculative shock	residual shocks	volatility shocks
Corn	4.20	7.29	5.28	3.86	79.36	6.93	10.35	15.13	18.54	49.045
Soy	6.37	16.11	2.26	6.47	68.79	13.27	21.00	14.15	17.61	33.96
Wheat	8.36	6.02	1.88	3.15	80.59	16.02	15.65	8.87	33.99	25.4
Sugar	4.57	6.04	7.70	21.75	59.94	12.10	54.79	6.45	7.01	19.65
Coffee	3.60	4.42	10.18	4.81	76.99	36.10	26.61	3.66	10.46	23.17

Table 3: Variance decomposition of volatility of crops based on the estimation of model 3

	Before Crisis					After Crisis				
	supply shock	global demand shock	speculative shock	residual shocks	volatility shocks	supply shock	global demand shock	speculative shock	residual shocks	volatility shocks
Gold	4.35	3.88	8.18	6.14	77.45	19.06	20.05	11.69	25.42	23.78
Silver	3.88	11.50	7.01	4.1	73.51	40.25	25.89	11.57	5.81	16.48
Copper	5.63	5.96	2.41	12.28	73.73	19.98	27.52	11.21	23.04	18.24

Table 4: Variance decomposition of volatility of metals based on the estimation of model 3

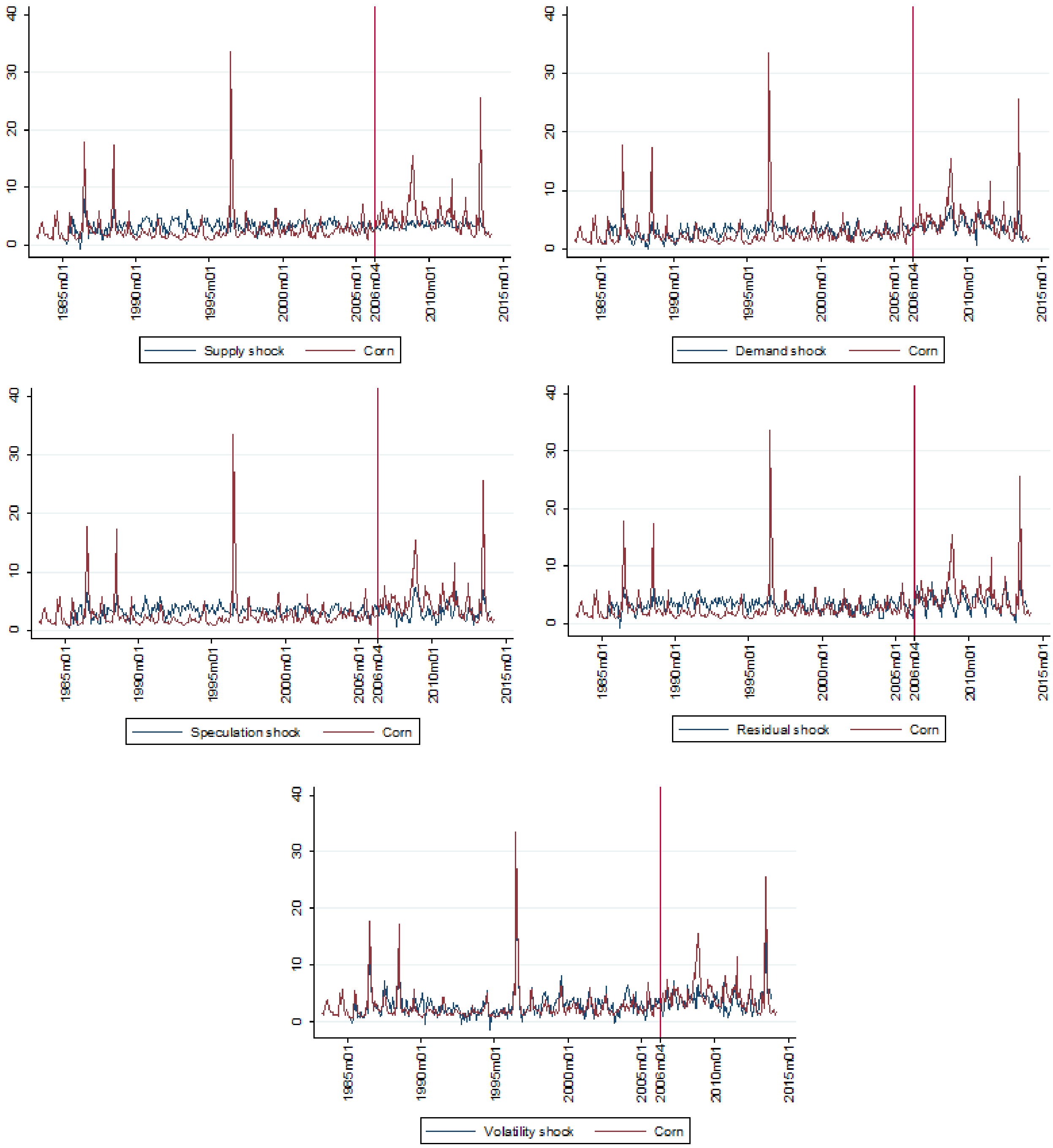

Figure 1: Historical decomposition of volatility of the price of Corn 1983:04-2013:12

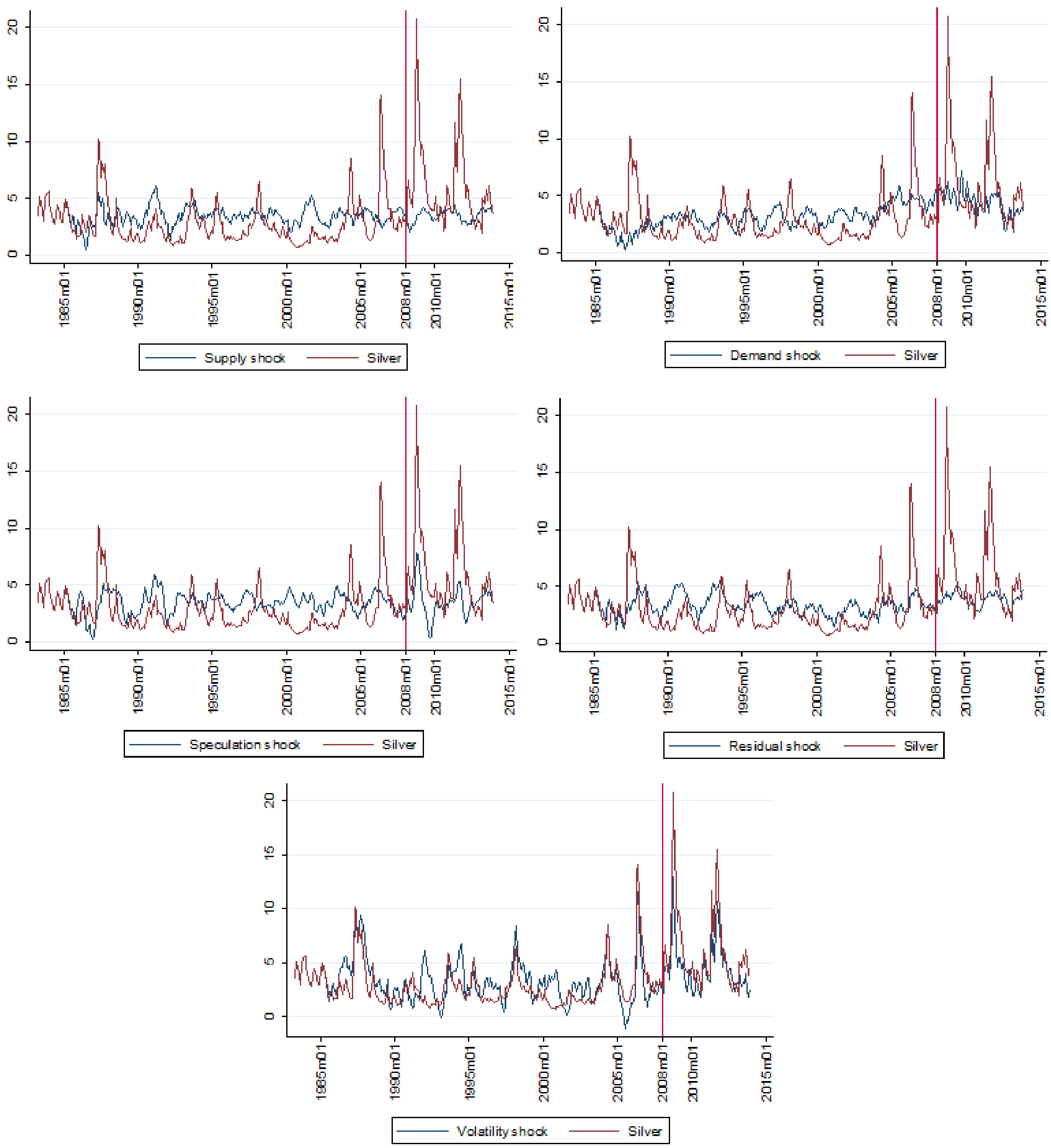

Figure 2: Historical decomposition of volatility of the price of Silver 1983:04-2013:12

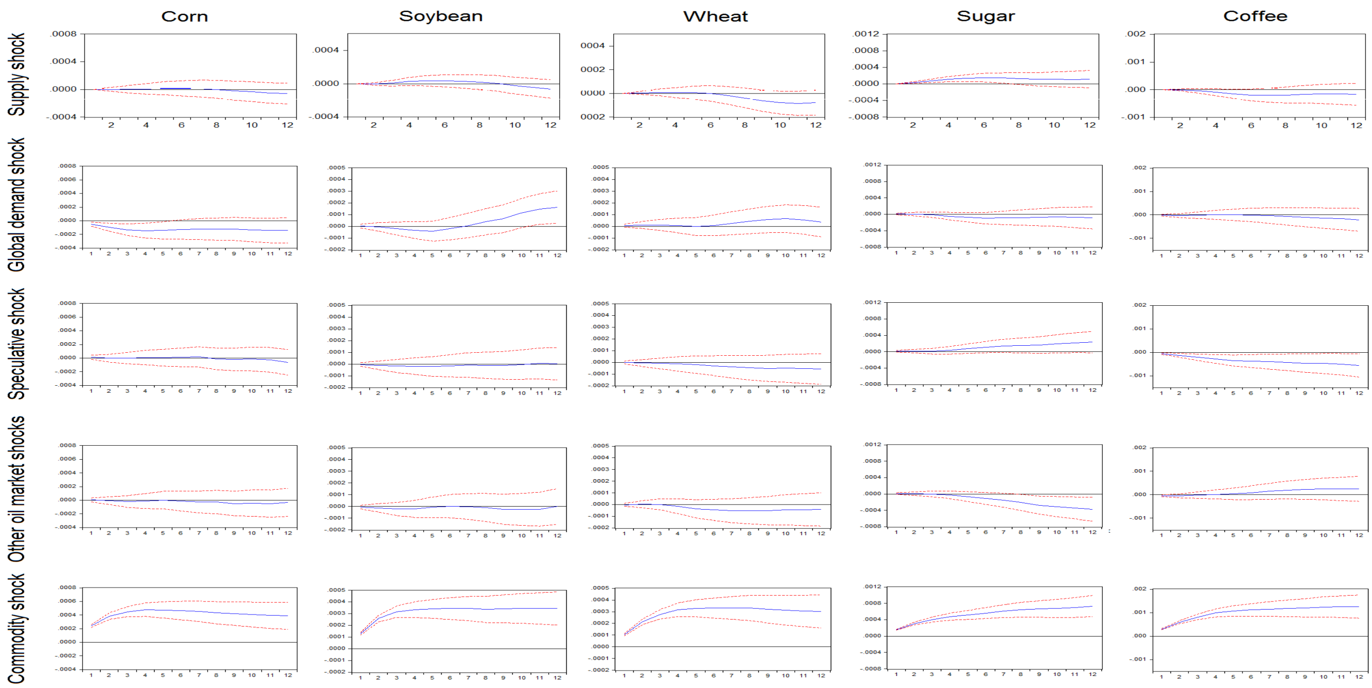

Figure 3a: Cumulative Responses of volatility of crops to the structural shocks in oil market for the time period of 1983:04-2006:04

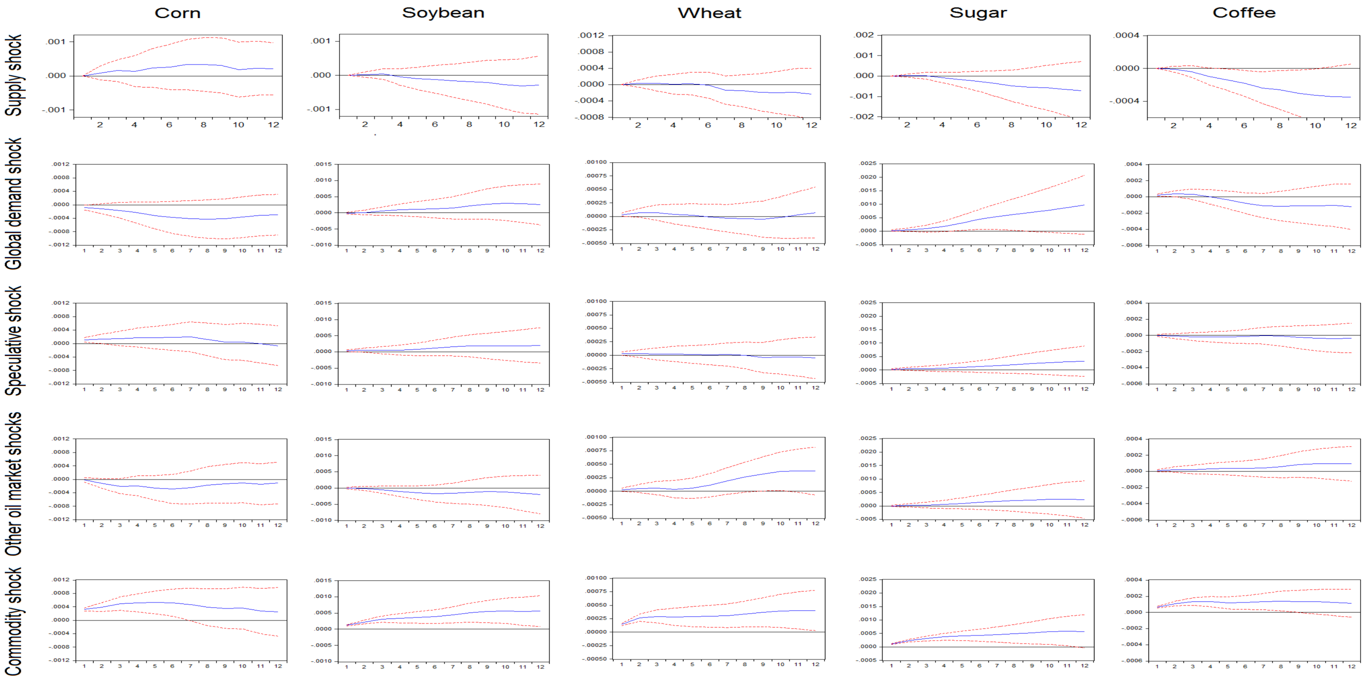

Figure 3b: Cumulative Responses of volatility of crops to the structural shocks in oil market for the time period of 2006:05-2014:02

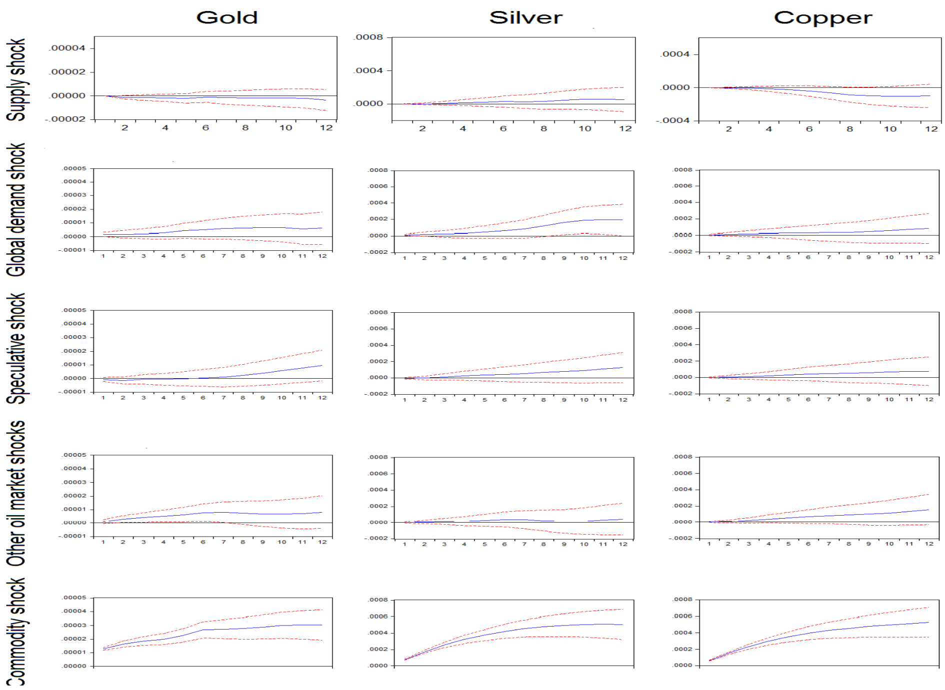

Figure 4a: Cumulative Responses of volatility of metals to the structural shocks in oil market for the time period of 1983:04-2007:12

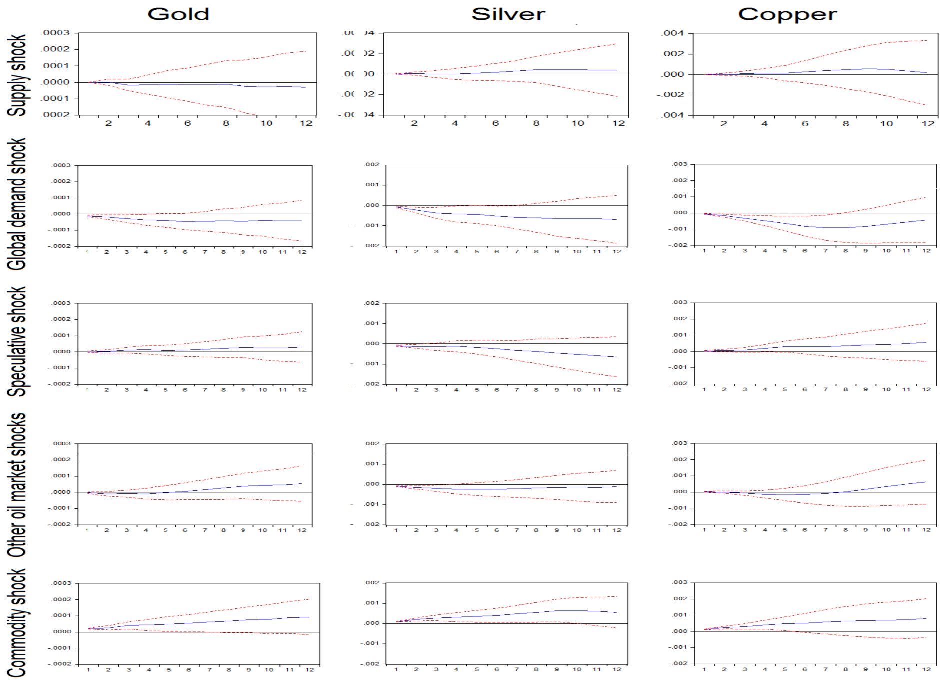

Figure 4b: Cumulative Responses of volatility of metals to the structural shocks in oil market for the time period of 2008:01-2014:02

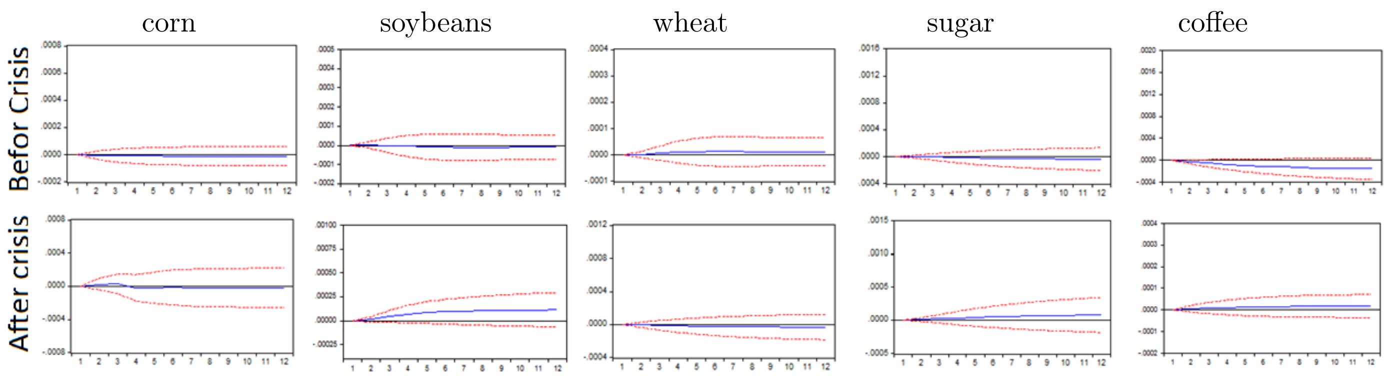

Figure 5a: Cumulative Responses of volatility of crops to global demand shock for the time period of 1983:04-2013:12

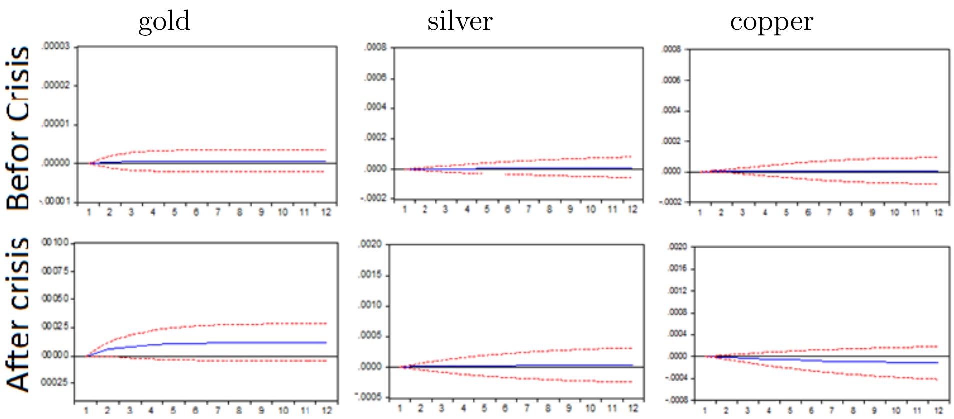

Figure 5b: Cumulative Responses of volatility of metals to global demand sock for the time period of 1983:04-2013:12

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