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ECB Monetary Policy and Commodity Prices

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Abstract:
We analyze the impact of the ECB monetary policies on global aggregate and sectoral commodity prices using monthly data from January 2001 till August 2019. We employ a SVAR model and assess separately period of conventional monetary policy before global financial crisis (GFC) and unconventional monetary policy during post-crisis period. Our key results indicate that contractionary monetary policy shocks have positive effects on the aggregate and sectoral commodity prices during both conventional and unconvetional monetary policy periods. The effect is statistically significant for aggregate commodity prices during post-crisis period. In terms of sectoral impact, the effect is statistically significant for food prices in both periods and for fuel prices during post-crisis period; other commodities display positive but statistically insignificant responses. Further, we demonstrate that the impact of the ECB monetary policy on commodity prices increased remarkably after the GFC. Our results also suggest that the effect of the ECB monetary policy on commodity prices does not transmit directly through market demand and supply expectations channel, but rather through the exchange rate channel that influences the European market demand directly.

JEL: C54, E43, E58, F31, G15, Q02
Keywords: European Central Bank, commodity prices, short-term interest rates, unconventional monetary policy, Structural Vector Autoregressive model, exchange rates

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1. Introduction and motivation

Inclusion of dynamics in commodity prices into monetary policy decisions has attracted attention of researchers and policy makers in recent decades despite that commodity prices are likely subject to substantial (and idiosyncratic) shocks with no fundamental macroeconomic implications (Angel, 1992; Bernanke et al., 1997). The seminal theoretical framework of Frankel (1986) demonstrated overshooting of agriculture and food prices with respect to monetary policy contraction and initiated further discussions and empirical analyses on the nexus between monetary policy and commodity prices (Angel, 1992; Hua, 1998; Frankel, 2008; Belke et al., 2014; Beckmann et al., 2014; Ratti and Vespignani, 2015; Hammoudeh et al., 2015).[1] The two main strands of related empirical research aim at (i) analyzing effects of country-specific (US and Chinese) monetary policy shocks on global commodity prices (Frankel, 2008; Akram, 2009; Belke et al., 2014; Klotz et al., 2014; Hammoudeh et al., 2015; among others), and (ii) assessing impact of global liquidity on commodity prices (Belke et al., 2010; Brana et al., 2012; Belke et al., 2013; Beckmann et al., 2014; Ratti and Vespignani, 2015). In both strands of the research, majority of results supports Frankel's (1986, 2008) overshooting theory, where expansionary monetary policy (decrease in interest rates and increase in liquidity) affects positively the global commodity prices. Despite of the research outlined above, to the best of our knowledge, the nexus has not been investigated with respect to the monetary policy of the European Central Bank (ECB).

This is surprising given the following evidence. First, according to the International Merchandise Trade Statistics Section (IMTSS) of the United Nations Statistics Division's (UNSD) on the global commodity trade data, the combined euro area members are the world's largest commodity importers: they accounted for 23.6% of world commodity imports in 2018, considerably higher percentage than individual proportions of other major commodity importers as the US (13.3%) and China (11.4%).[2] Hence, the largest proportion of world commodity imports by the euro area countries creates ample potential for transfer of the ECB monetary policy on commodity prices. Second, the first observation

[1] The rationale behind the overshooting framework of Frankel (1986) can be summarized as follows. Positive monetary policy shock is represented by an exogenous increase in the central bank interest rate that corresponds to contractionary monetary policy causing bond prices to fall, and bond yields to rise. For investors, a commodity or a bond can be seen as instruments in which to store wealth, and portfolio can be created from both instruments. The expected return of a commodity is its expected price rise. Portfolio arbitrage theory usually asserts that moves in the expected return of one instrument lead to moves in the expected returns of other instruments. Hence, departing from an equilibrium situation, if the expected return of bond (yield) increases, the expected return of one unit of commodity must increase too. Investors will divest commodity if its return is not big enough, until the current price of a commodity declines and its expected return increases. In other words, for a given expected price of a commodity in the future, commodity prices have to fall today after an increase in the bond rate (yield) triggered by the central bank's increase of the interest rate. The above "arbitrage condition that must hold in the commodity markets" is at the core of the effect of monetary policy on commodity prices as argued by Frankel (1986).

[2] The updated data is available on: https://unstats.un.org/unsd/trade/data/tables.asp#monthly

is underlined by the empirical evidence showing that during recent years the ECB monetary policy exhibits substantial spillover effects on output, price levels and exchange rates of non-euro area countries (Kucharcukova et al., 2016; Potjagailo, 2017; Hajek and Horvath, 2018) as well as on financial markets and oil prices (Hatsma et al., 2016; Dieppe et al., 2018). Therefore, it is sensible to hypothesize that monetary policy innovations in the euro area should have impacts on global trade aspects, especially on commodity prices. Third, the previous empirical literature mainly concentrated on responses of aggregate commodity price index to policy shocks – exceptions are the works of Frankel (2008), Hammoudeh et at., (2015) and Klotz et al. (2014) who found heterogeneous results for group commodity prices. In this light and considering the heterogeneity and volatility differences in the data of group commodity prices, we believe that analysis of individual commodity impacts is necessary for optimal and proper policy decision-making.

In his further development of the theoretical framework, Frankel (2008) proposes to add commodity prices to the list of variables that central banks monitor, regardless of their regime and target. From this perspective, the outcomes of our research are relevant for the ECB inflation targeting measures, as well as for policy decisions that involve foreign trade, exchange rate and real economy effects. Moreover, the distinction of conventional and unconventional monetary measures in our analysis is essential source of information for the debate related to efficiency of the ECB unconventional measures (see McMahon et al., 2018 or Ambler and Rumler, 2019, among others).

Based on the above motivation, we investigate effects of the ECB monetary policy on global aggregate and sectoral commodity prices. We analyze two separate periods: (i) conventional monetary policy period starting from full circulation of euro until the Global Financial Crisis (GFC) in 2008 (2001M01 – 2008M07), and (ii) unconventional monetary policy period starting from the end of GFC till the end of our sample (2009M04 – 2019M08). We employ the Structural Vector Autoregressions (SVAR) model to capture the effects of the ECB monetary policy innovations (proxied by short-term interest rates) on aggregate as well as sector commodity prices, namely food, fuel, metals, agricultural raw material and beverage prices. The results of Johansen (1988) co-integration test show the existence of long-run relationship between the non-stationary variables in all models for both periods.

Our key results indicate that contractionary monetary policy shocks have positive effects on the aggregate and sectoral commodity prices during both conventional and unconvetional monetary policy periods. The effect is statistically significant for aggregate commodity prices during post-crisis period. In terms of sectoral impact, the effect is statistically significant for food prices in both periods and for fuel prices during post-crisis period; other commodities display positive but statistically insignificant responses. Further, we show that appreciation of euro has immediate positive effect on commodity prices. Our findings are in contrast with the results of Frankel (1986, 2008), Hammoudeh et al., (2015) and Belke et al., (2014), where contractionary US monetary policy has negative effect on commodity prices. We believe that our results can be explained by exchange rate differences, where appreciation of euro causes euro priced commodities to be relatively cheap and induces their demand increase in the euro area. In other words, the rise in short-term interest rates is associated with appreciation of euro and increases the domestic demand for commodities traded in other currencies, which results in commodities' price increase.

The novelty of our research and contribution to the literature are threefold. First, to the best our knowledge, our empirical study is the first assessment of the effects of both conventional and unconventional ECB monetary policy on aggregate and sectoral commodity prices. Second, we demonstrate that the impact of the ECB monetary policies on commodity prices increased remarkably after the GFC, indicating the effectiveness of unconventional monetary policy tools on real economy in comparison to conventional tools. Third, our findings suggest that the effect of the ECB monetary policy on commodity prices transmits through the exchange rate channel that influences the European market demand directly.

The remainder of this paper is organized as follows. Section 2 reviews related theoretical and empirical literature. Sections 3 and 4 present the methodology and data, respectively. We bring and discuss empirical results in Section 5. Finally, Section 6 concludes.

2. Literature Review

International literature is abundant with research concerning macroeconomic and spillover effects of both conventional and unconventional monetary policies on economic activities (Schenkelberg and Watzka, 2013; Meinusch and Tillmann, 2016), price levels (Sims, 1992; Bernanke et al. 2005; Ono, 2017; Michaelis and Watzka, 2017), asset prices (Bernanke and Gertler, 2000; Mishkin, 2001; Rigobon and Sack, 2004; Miyakoshi et al., 2017) and bank performances (Mamatzakis and Bermpei, 2016; Borio et al., 2017 and etc.). Despite the theoretical studies analyzing linkage between monetary policy and commodity prices initiated since 90s (Frankel, 1986; Angel, 1992), the empirical studies have more recent history (Frankel, 2008; Beckmann et al. 2014; Hammoudeh et al. 2015). In this section, we demonstrate the theoretical and empirical approaches to the nexus between monetary policy and commodity prices.

Frankel (1986) developed theoretical explanation for overshooting of commodity prices, drawing on the Dornbusch's (1976) famous exchange rate overshooting theory. The assumption of the Frankel's (1986) theory is based on the fix price stickiness of manufactured goods and services, while commodities traded in fast-moving auction markets have flexible prices, which respond instantaneously to the macroeconomic shocks. Therefore, change in the monetary policy creates more than proportionate price effects on commodity prices, and as a result commodity prices overshoot their new long-run equilibrium. In addition to these, in debates of Angel (1992) and Browne and Cronin (2007) there have been argued that commodity prices are useful information in formulating the monetary policy also because they enter the production process at early stages and therefore have impact on general prices like producer or consumer price indices. In other words, changes in monetary policy that affects general price indices also have impacts on commodity prices. In his further theoretical framework Frankel (2008) explained the relationship between real interest rates and commodity prices in more detailed manner, where higher interest rates decrease the demand for storable commodities and increase the supply through three different channels: "(1) by increasing the incentive for extraction today rather than tomorrow (think of the rates at which oil is pumped, zinc is mined, forests logged, or livestock herds culled); (2) by decreasing firms' desire to carry inventories (think of oil inventories held in tanks); (3) by encouraging speculators to shift out of commodity contracts (especially spot contracts) and into treasury bills" (Frankel, 2008. p. 295). Moreover, Bessler (1984), Pindyck and Rotemberg (1990), Angel (1992) and Hua (1998) do not neglect the effects of monetary policies on commodity price changes, but the argument whether the causality is from monetary policy to commodity prices or vice versa requires empirical testing.

In the last two decades, there were several studies testing the commodity price overshooting model empirically. By employing the bivariate regression analyses on US annual data 1950-2005, Frankel (2008) found that commodity prices overshoot significantly with respect to the changes in real interest rates. In particular, he found that since 1950 three major commodity price indices, which are Commodity Resource Board, Moody's and Dow Jones, exhibit negative and robust relationship with real interest rates. Specifically, 11 out of 23 individual commodity prices have statistically significant inverse relationship with real interest rates. Akram (2009) used a structural VAR model with the quarterly US data covering the period 1990-2007 to analyze the effects of real interest rates on different commodity prices. He found that the commodity prices rise when the real interest rates fall. Moreover, real oil and industrial raw material prices show overshooting behavior in response to the real interest rate shocks, while real food and metal prices show delayed response. Further, both broad commodity price indices and all their components react positively to US expansionary monetary policy shocks in but with small direct effects (Anzuini et al., 2013). The similar effects as those in the above-mentioned studies were found also by Belke et al. (2014) who, over the period 1970-2008, proxied the policy rate with quarterly data of the three-month treasury bill rates of 19 developed economies (the United States, the Euro Area, Japan, the United Kingdom, Canada, Korea, Australia, Switzerland, Sweden, Norway, and Denmark). Existing international literature investigated mostly the effects of US interest rates on international commodity price indices, while Klotz et al. (2014) and Sun et al. (2019) analyzed the nexus for China's policy rates and did not find significant evidence for causal relationship.

Apart from the investigations of US and China policy rates, there are significant number of empirical researches interested in the impacts of global liquidity on commodity prices (Belke et al. 2010; Brana et al. 2012; Belke et al. 2013; Belke et al. 2014; Beckmann et al. 2014; Ratti and Vespignani, 2015). For the determination of global liquidity Belke et al. (2013) used broad range of nominal monetary aggregates M2 for US and Japan, M3 and M4 for Euro Area and other emerging economies covering the quarterly period from 1980 to 2011. They analyzed the nexus between global liquidity, food and aggregate commodity price indices by using the cointegrated VAR model and found significant long-run positive relationship. That intuitively, when central banks of all major economies running the expansionary monetary policy to enhance or stabilize their economies, causing a rise in global liquidity that results with commodity and food price increases. The similar results found in Beckmann et al. (2014), where they used monthly data for the same countries and monetary aggregates and employed Markov-switching vector error correction model (MS-VECM) for the period of 1980:01-2012:06. In order to sustain with monthly data, they used industrial production as a measure of output rather than GDP, and besides finding long-run significant positive relationship, here the commodity prices respond more quickly to global liquidity shocks as compared to consumer prices, which favors the overshooting hypothesis. Interestingly, in the investigation of Ratti and Vespignani (2015) positive liquidity shocks of BRIC (i.e. Brazil, Russian, Indian and Chinese M2) countries were larger than the shocks of G3 (US, EU and Japanese M2) for most of the individual commodity price indices. The impacts of BRICS liquidity shocks were larger in energy prices, mineral and metal prices, and raw material prices, while effects on precious metal prices were larger instead in G3 liquidity for the same monthly data over the period of 1999-2012.

Hammoudeh et al. (2015) compared the effects of US conventional monetary interventions on broad and sector commodity price indices to the unconventional QE policy interventions. By employing Structural VAR (SVAR) model, the research displays the negative response on aggregate and sector commodity prices (with some variations) to innovations in federal fund rates in both conventional and unconventional monetary policy periods. Here, in difference with conventional policy period measured from 1957 to 2008, as a policy proxy they substituted M2 growth rate with the central bank reserves growth rate, and federal funds rate with the interest rate spread (the difference between long-term and short-term interest rates) for unconventional policy period measured from April 2008. The interest rate variable used for capturing the unconventional period varies among the researchers due to the zero lower bond (ZLB), where some studies relied on interest rate spread (Hammoudeh et al., 2015; Chen et.al., 2016; Hanabusa, 2017) while others (Hafemann and Tillmann, 2017; Hajek and Horvath, 2018; Gajewski et al. 2019) preferred to use shadow policy rates introduced either by Wu and Xia (2016) or by Krippner (2013).

As the last strand of the reviewed literature lacks analysis of the impact of the ECB monetary policy on commodity prices, we aim to put forth such evidence in our work.

3. Methodology

Our goal is to evaluate dynamic responses of non-policy variables due to unexpected shocks in the policy variables while exploiting the rich dynamic relationships among variables. Following the works of Hammoudeh et al. (2015), Sousa (2010), Cover and Mallick (2012) and Afonso and Sousa (2012), for our empirical assessment we employ Structural Vector Autoregressions (SVAR) model developed by Sims (1980), which has become a common practice for researchers to analyze the effects of monetary policy shocks on the real economy. We do not employ the Vector Error Correction model (VEC) of Engle and Granger (1987) that would require differencing our data and result in potential loss of information. In this sense, we follow the early work of Phillips and Durlauf (1986), Stock (1987), West (1988), Sims et al. (1990) and Toda and Yamamoto (1995) who developed analytical framework and showed that differencing is not needed if data series are non-stationary but cointegrated; this is indeed our case as we show in Section 4. Such approach yields consistent estimates and potential finite sample bias becomes small (if any) as our interest primarily lies in obtaining impulse response functions of the short-term (monthly) effects. This is in accord with the analysis of cointegrated non-stationary price variables of Fanchon and Wendel (1992) who show that VAR monthly price forecasts over nearly five-year horizon exhibit the lowest mean square errors along with better forecasting performance over first seven months when compared to the VEC model. Further effective use of the SVAR approach in estimating monetary policy shocks was demonstrated by Akram (2009) and Dungey and Fry (2009).

To analyze the effects of the ECB monetary policy on commodity prices we estimate the following SVAR;

$$\boldsymbol{\Gamma}(\mathbf{L})\,\boldsymbol{X_t} = \boldsymbol{\Gamma_0}\,\boldsymbol{X_t} + \boldsymbol{\Gamma_1}\boldsymbol{X_{t-1}} + \boldsymbol{\Gamma_2}\boldsymbol{X_2} + \ldots\ldots\ldots = \mathbf{C} + \boldsymbol{\varepsilon_t} \tag{1}$$

where $\varepsilon_t \,|X_s$, s < t~N ($\underline{0}$, Λ), and Γ(L) is a matrix polynomial in the lag operator L, n is a number of variables in the system, and ε_t is the vector of shocks of economic fundamentals that span the space of innovations of X_t, and therefore the reduced form can be estimated as;

$$\boldsymbol{\Gamma_0^{-1}\Gamma(L)\, X_t \;= B\,(L)\, X_t \;=\; \alpha \;+\; \upsilon_t \sim N(0, \textstyle\sum)} \tag{2}$$

where $\sum = \Gamma_0^{-1}\,\Lambda\,(\Gamma_0^{-1})'$, and $\upsilon_t = \Gamma_0^{-1}\varepsilon_t$ is the vector of the VAR innovations.
The characterization of monetary policy in the model is:

$$\boldsymbol{i_t = f(\Omega_t) + \varepsilon_t^i} \tag{3}$$

where the central bank policy rate $\boldsymbol{i_t}$ depends on f linear function of Ω_t information set and ε_t^i interest rate shock.

For the identification restrictions in the Γ_0 matrix, we decided to separate X_t into three groups, similarly as Christiano et al. (2005), Sousa (2010) and Hammoudeh et al. (2015) as $X_t = [X_{1t}, \boldsymbol{i}_t, X_{2t}]'$. The groups are, (I) X_{1t}, subset of n_1 variables that do not respond contemporaneously to the policy shocks; (II) $\boldsymbol{i}_t$, monetary policy instrument; and (III) subset of n_2 variables, X_{2t}, which respond contemporaneously to the policy shocks. Therefore, the structural shocks are identified by imposing the restrictions on contemporaneous matrix Γ_0:

$$\Gamma_0 = \begin{bmatrix} \underbrace{\gamma_{11}}_{n_1\times n_1} & \underbrace{0}_{n_1\times 1} & \underbrace{0}_{n_1\times n_2} \\ \underbrace{\gamma_{21}}_{1\times n_1} & \underbrace{\gamma_{22}}_{1\times 1} & \underbrace{0}_{1\times n_2} \\ \underbrace{\gamma_{31}}_{n_2\times n_1} & \underbrace{\gamma_{32}}_{n_2\times 1} & \underbrace{\gamma_{33}}_{n_2\times n_2} \end{bmatrix} \tag{4}$$

Specific variables corresponding to the above recursive assumptions are: the set of variables X_{2t}, consists of monetary aggregate growth rate, exchange rate and commodity price index which respond contemporaneously to policy shocks; industrial production and price level respond with lag and constitute set X_{1t}. Therefore, the vector of endogenous variables can be ordered in the following Structural Decomposition order as;

$$X_t = [\text{Industrial Production}_t, CPI_t, \text{Interest Rates}_t, M2\,Growth_t, \text{Exchange Rates}_t, \text{Commodity Price}_t]'.$$

The variable ordering in the above model is similar to that in Hammoudeh et al. (2015) as they used monthly data for the estimation of unconventional monetary policy period and we employ monthly data for both periods. According to our variable ordering, commodity prices are assumed to respond contemporaneously to all shocks of preceding variables, and CPI responds faster than industrial production to the interest rate shocks with a certain lag. The optimal lag lengths are chosen based on the several information criteria.

4. Data

For our empirical analysis we use the monthly data covering the period from January 2001 to August 2019. Despite that euro was launched on January 1, 1999, we do not employ the data before 2001, because euro is fully in circulation only from 2001; our approach is similar to that of Hajek and Horvath (2018). Due to the structural break associated with Global Financial Crisis (GFC) in 2008, we divided our analysis into two parts: (i) pre-crisis period: covering the effects of conventional monetary policy shocks 2001M01 - 2008M07 and (ii) post-crisis period: capturing the effects of unconventional monetary policy 2009M04 – 2019M08. The division is also in line with the theoretical mechanism of overshooting and going back to equilibrium, albeit from a medium-term perspective when the real interest rate goes back to equilibrium in the post-crisis period.

All variables in the analysis are expressed in natural logarithms, except for interest rates. The economic activity and inflation indicator in X_{1t} elements are chosen based on industrial production index and consumer price index obtained from the ECB; the same data are used by Hammoudeh et al. (2015), Klotz et al. (2014), Ratti and Vespignani, (2015), Belke et al. (2014), Beckmann et al. (2014), and Anzuini et al. (2013).[3] The industrial production index of EU19 countries and harmonized index of consumer prices (HICP) of the euro area are seasonally adjusted data.

With the exception of the monetary policy instruments ($\boldsymbol{i}_t$), all other variables are identical for both conventional and unconventional policy periods. The ECB's major tool of monetary policy prior to GFC was interest rate. Similarly, as Potjagailo (2017), Akram (2009) or Sousa (2010), for the pre-crisis period we employ the euro area three-month interest rate from the ECB database that is a representative short-term interest rate and benchmark rate for euro area money market. However, after the GFC and due to the ZLB the ECB introduces unconventional monetary policy measures. Therefore, for post-crisis period we use the short-term shadow policy rate designed by Wu and Xia (2016) and that was used as a policy tool proxy in recent analyses (Hafemann and Tillmann, 2017; Hajek and Horvath, 2018; Galariotis et al., 2018).[4]

[3] European Central Bank, Statistical Data Warehouse:
https://sdw.ecb.europa.eu/home.do;jsessionid=50F29F9952C346B9B74C34E96412B1E0
[4] The updated shadow rates are available on the website of Cynthia Wu:
https://sites.google.com/view/jingcynthiawu/shadow-rates?authuser=0

In the set of X_{2t} elements we employ seasonally adjusted monetary aggregate (M2) growth as a liquidity variable, and nominal exchange rate of 19 trade partner currencies against euro; both data are from the ECB. The exchange rate variable is defined as monthly average of trade partner currencies against euro (e.g. XXX/EUR); increase of exchange rate is associated with appreciation of euro. The broad commodity price index and sectoral commodity indices are in constant prices, not seasonally adjusted and are sourced from International Monetary Fund (IMF).[5] We transformed the commodity data to the seasonally adjusted data by the method of STL Decomposition. The broad price index and group of commodity price indices are: (1) all commodity price index; (2) Food price index which includes cereal, vegetable oils, meat, seafood, sugar, and other food (apple (non-citrus fruit), bananas, chickpea, fishmeal; (3) beverage price index: coffee, tea, and cocoa; (4) agricultural raw materials price index: timber, cotton, wool, rubber, and hides price indices; (5) all metals price index: gold, silver, palladium, platinum, aluminum, cobalt, copper, iron ore, lead, molybdenum, nickel, tin, uranium and zinc price indices and (6) fuel price index: crude oil (petroleum), natural gas, coal price and propane indices. We replaced commodity price variable with all above commodity group price indices to see the effects separately.

The dummy variable captures the effects of large variation in commodity prices (see in Figures 3A-6A, Appendix) and exchange rates for the period of 2014M09-2016M06 (post-crisis analysis) due to the sharp decrease in crude oil prices. For our robustness checks, we employed interest rate spread data from ECB, obtained from the difference between short-term interest rates and 10-year government bond yields. Further, we use an alternative short-term shadow rates calculated by the method of Krippner (2013) that are available from the Reserve Bank of New Zealand.[6]

5. Empirical Results

5.1 The pre-crisis period: effects of conventional monetary policy on commodity prices

In this section, we initially show results for unit-root and cointegration tests together with optimal lag length selection criteria. Then, we provide results for the impacts of conventional monetary policy shocks on aggregate (broad) commodity price index and on sectoral commodity price indices separately.

[5] The IMF Primary Commodity Prices are downloadable from: https://www.imf.org/en/Research/commodity-prices
[6] The Reserve Bank of New Zealand updates the shadow rates for US, Japan, Euro Area and UK at the following link https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures

5.1.1 Unit root test, Co-integration test and Lag Selection Criteria

We used two standard unit root test techniques to test for stationarity of variables in the model covering the period 2001M01-2008M07. Results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are displayed in Table 1A (Appendix). The Null Hypothesis (H_0) in the both tests indicates existence of the unit root. Hence, rejection of H_0 implies that the series in the model are stationary. We observe that all series to be used for the pre-crisis period analysis are non-stationary in their levels (with or without intercept), except M2 growth rate variable, where H_0 hypothesis is rejected. Whether to transform the variables to stationary form or not, we need to test further the long-run relationship between variables.

In order to assess the existence of long-run relationship between variables in our model, we employed Johansen (1988) co-integration test. The H_0 hypothesis in the test is “no co-integration”, meaning the non-existence of long-run relationship between the variables in the model. The outcome of the co-integration test gives us information whether non-stationary variables can be jointly used in a VAR model.

Table 1

Johansen co-integration test results: Conventional monetary policy period (Pre-crisis period)

		Trace			**Maximum Eigenvalue**		
Dependent **Variable**	Eigenvalue	Trace Statistic	0.05 Critical Value	Probability	Max-Eigen Statistic	0.05 Critical Value	Probability
Log(Commod_All)	0.5185*	141.40*	107.35*	0.0001*	64.32*	43.42*	0.0001*
Log(Commod_Agri_Raw)	0.5022*	132.75*	107.35*	0.0004*	61.38*	43.42*	0.0002*
Log(Commod_Beverage)	0.5400*	139.30*	107.35*	0.0001*	68.27*	43.42*	0.0000*
Log(Commod_Food)	0.5224*	158.60*	107.35*	0.0000*	65.05*	43.42*	0.0001*
	0.3408**	93.55**	79.34**	0.0029**	36.68	37.16	0.0567
	0.2601***	56.87***	55.25***	0.0357***	26.52	30.81	0.1534
Log(Commod_Metals)	0.5347*	146.20*	107.35*	0.0000*	67.33*	43.42*	0.0000*
Log(Commod_Fuel)	0.5295*	144.81*	107.35*	0.0000*	66.36*	43.42*	0.0000*

Note: The existence of co-integration linear combinations is marked by stars: *none, **at most 1 equation, ***at most 2 equations. The optimal lag 1 is selected based on Schwarz information criterion (SC).

In the Table 1, we displayed only those results, which reject the H_0 hypothesis under 1 and 5% significance levels. Except in the commodity food model, there is at least one linear combination in other models that has long-run co-integration. In other words, Trace statistics shows at least three co-integration linear combinations in commodity food model, while Maximum Eigenvalue reflected two. To sum up, the results of Johansen co-integration test reflect long-term relationship between the non-stationary variables of all six regressions.

Table 2

Unrestricted VAR lag selection criteria: Conventional monetary policy period (Pre-crisis period)

Dependent Variable	LR	FPE	AIC	SC	HQ
Log(Commod_All)	2	1	1	1	1
Log(Commod_Agri_Raw)	1	1	1	1	1
Log(Commod_Beverage)	3	1	1	1	1
Log(Commod_Food)	2	2	2	1	1
Log(Commod_Metals)	1	1	1	1	1
Log(Commod_Fuel)	2	1	1	1	1

Note: LR: sequential modified Likelihood-Ratio test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Moreover, the optimal lag one is selected based on the formal lag criterion in the below Table 3 for each commodity model. Except for the LR information criterion, the other lag order selection criteria (FPE, AIC, SC and HQ) suggests maximum optimal lag length of one.

5.1.2 Impulse-Response Functions for the Pre-Crisis Period

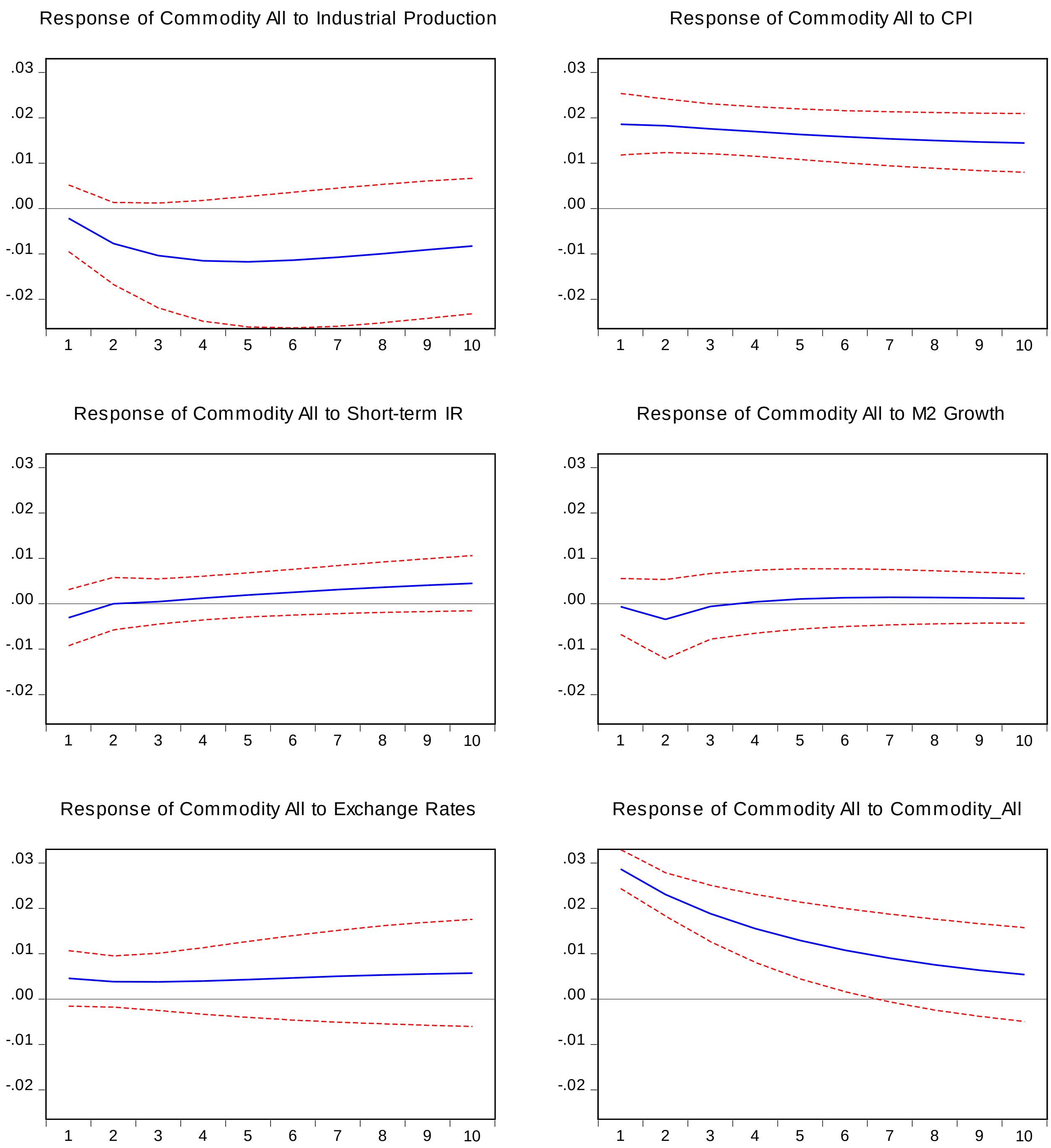
Impulse-response functions are useful tool for analyzing the interactions between variables and their reactions to the policy shocks. They demonstrate the reaction of one standard deviation shock occurring in a variable to other variables or to itself. In our analysis, we first display and discuss the responses of aggregate commodity prices to the innovations in all variables of the model (Fig. 1). Further, we discuss the responses of group commodity price indices to the innovations in short-term interest rates (Fig. 2). The impulse-response function is represented as blue line, while the red dashed lines with ±2 standard deviation error bands show the 5% significance level.

In the first row, one standard deviation of a positive shock in industrial production decreases the aggregate commodity prices with statistical insignificance during all ten months period, while CPI innovations have statistically significant increasing effect during all periods. The increasing effect of CPI innovations reflects the sensitivity of global commodity prices to the macroeconomic innovations in Eurozone economies. When it comes to the policy instrument and M2 growth in the second row, they both show insignificant feedback for all periods, where short-term interest rates have decreasing impact in the first two periods but then becomes increasing for the rest of period. Apparently adverse to the interest rates, M2 aggregate has price reducing effect in the first two periods, but increases the prices after the third period.[7]

[7] It seems that commodity prices react inversely to expansionary monetary policy, which is not in line with previous studies of Frankel (2008), Hammoudeh et al. (2015) and Belke et al. (2014) who found negative effects of US short-term interest rates on commodity prices.

Figure 1

Impulse response functions to all positive macroeconomic shocks during pre-crisis period: aggregate commodity prices.

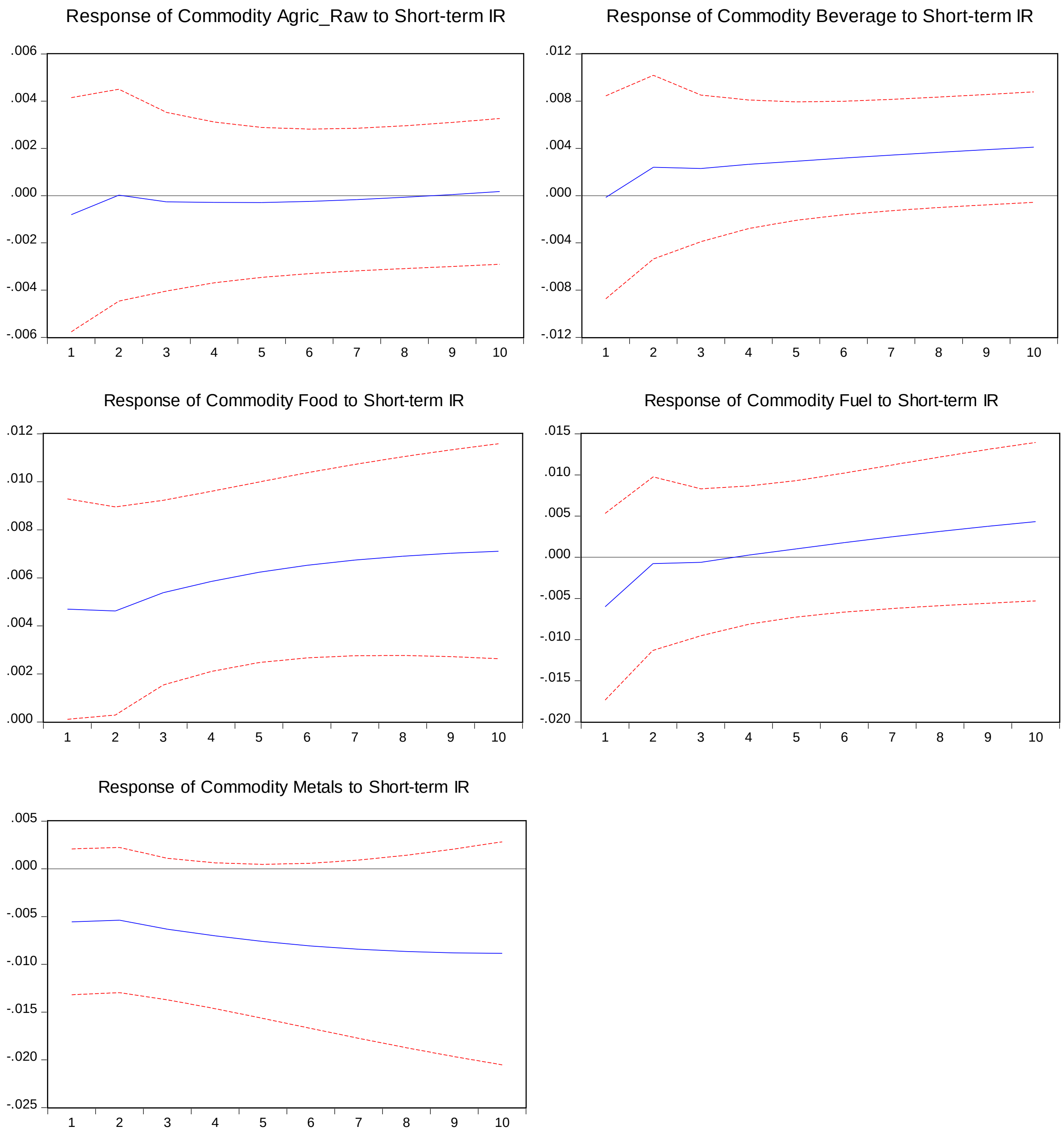


Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

The price increasing effect of interest rates is also observed in the group commodity prices, except for metal prices (Fig. 2). The response of food prices to the short-term interest rate shocks appears persistent and statistically significant after the second period with stable 0.5% effect. Food prices also display similar responses to euro appreciation after second period as in Figure 1A (Appendix). However, other group commodity prices demonstrate statistically insignificant responses.

Figure 2

Impulse response functions to positive interest rate shock during pre-crisis period: sectoral commodity prices.



Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

Despite of the statistically insignificant responses of policy instrument in our estimation output (except in food prices), we believe that the reason for this relationship is driven by differences in currencies in which commodities are traded. We observe that the positive exchange rate shock (appreciation of euro) has price increasing effect on aggregate and group commodity prices (Fig. 1A). In other words, the appreciation of euro which is associated with contractionary monetary policy, has price increasing impact on aggregate commodity prices. Stronger euro means that commodities priced in other currencies become cheaper and demand for relatively cheaper commodities in European market priced in euro increases, pushing commodity prices up. It is also reflected in the effects of M2 growth, where positive shock in liquidity (expansionary policy) leads to the depreciation of euro currency and has negative impact on aggregate and other group commodity prices.

5.2 The post-crisis period: effects of unconventional monetary policy on commodity prices

Following the empirical steps in the section 5.1, in this section, we firstly discuss the results of unit-root and co-integration tests along with the lag selection criteria, and then display the outcomes of impulse response functions for the shocks in unconventional monetary policy on commodity prices covering the period 2009:04 - 2019:08.

Table 3

Johansen co-integration test results: Unconventional monetary policy period (Post-crisis period)

		Trace			**Maximum Eigenvalue**		
Dependent **Variable**	Eigenvalue	Trace Statistic	0.05 Critical Value	Probability	Max-Eigen Statistic	0.05 Critical Value	Probability
Log(Commod_All)	0.4854*	162.92*	95.75*	0.0000*	81.06*	40.08*	0.0000*
	0.3077**	81.86**	69.82**	0.0040**	44.87**	33.88**	0.0017**
Log(Commod_Agri_Raw)	0.4743*	149.11*	95.75*	0.0000*	78.44*	40.08*	0.0000*
	0.2331**	0.67**	69.82**	0.0427**	32.39	33.88	0.0745
Log(Commod_Beverage)	0.4802*	164.49*	117.71*	0.0000*	79.82*	44.50*	0.0000*
Log(Commod_Food)	0.4821*	149.07*	95.75*	0.0000*	80.27*	40.08*	0.0000*
Log(Commod_Metals)	0.4925*	153.25*	95.75*	0.0000*	82.74*	40.08*	0.0000*
	0.2300**	70.51**	69.82**	0.0440**	31.88	33.88	0.0849
Log(Commod_Fuel)	0.4805*	166.02*	95.75*	0.0000*	79.90*	40.08*	0.0000*
	0.3259**	86.12**	69.82**	0.0015**	48.12**	33.88**	0.0006**

Note: The existence of co-integration linear combinations is marked by stars: *none, **at most 1 equation, ***at most 2 equations. The optimal lag 1 is selected based on Schwarz information criterion (SC).

Table 4

Unrestricted VAR lag selection criteria: Unconventional monetary policy period (Post-crisis period)

Dependent Variable	LR	FPE	AIC	SC	HQ
Log(Commod_All)	7	1	1	1	1
Log(Commod_Agri_Raw)	2	2	2	1	1
Log(Commod_Beverage)	2	1	1	1	1
Log(Commod_Food)	2	1	2	1	1
Log(Commod_Metals)	7	1	1	1	1
Log(Commod_Fuel)	2	1	1	1	1

Note: LR: sequential modified Likelihood-Ratio test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Similar to the pre-crisis period variables, the results of unit-root tests in the Table 2A (Appendix) demonstrates the non-stationarity of variables in their levels with an exception of ΔLog (M2) variable. This brings us to look for the existence of long-term relationship between the variables of six separate equations by using Johansen co-integration test. The outcome of the co-integration test in Table 3, shows the existence of co-integration in all six models associated with dependent variables in the table. In particular, the models which analyzing the variables of food and metal prices have only one cointegration vector, while other four models have two. In other words, there is at least one linear combination in all models of non-stationary data that has long-run equilibrium. For all of the models we select optimal lag one based on the results of several lag selection criteria in Table 4.

5.2.1 Impulse-Response Functions for the Post-Crisis period

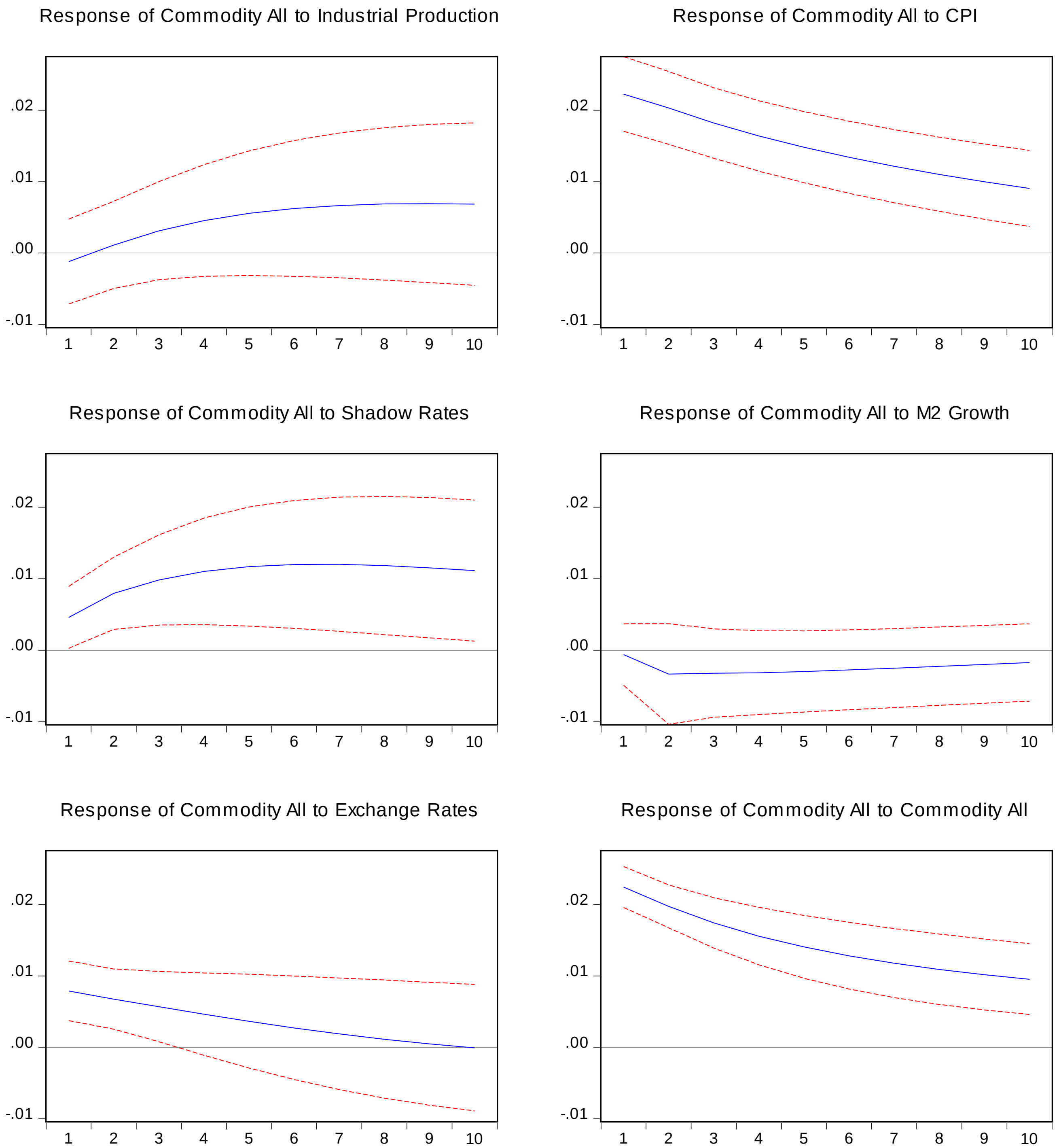
In this section, as in the section 5.1.2, we displayed the impulse-responses of aggregate commodity prices to structural shocks in all macroeconomic variables in the model (Fig. 3) and responses of group commodity prices to short-term shadow policy shocks only (Fig. 4).

Starting with policy instrument, the positive shock in short-term shadow policy rate has an immediate price increasing impact on aggregate commodity prices, and effect is rising after the second period till the fifth and becomes stable until the end of the displayed horizon. Similar to the pre-crisis period, but here with statistically significant effect, contractionary monetary policy shock has contemporary positive impact on commodity prices, showing that the increase in interest rates resulting in immediate 0.5% rise in commodity prices. The policy channel results are in contrast with the findings of Hammoudeh et al. (2015) for the unconventional policy period as well. This relationship is also supported by liquidity channel, where commodity prices responded negatively to the growth rate of

M2, implying that the contractionary policy shock causes commodity prices to rise. However, in both pre-crisis and post-crisis periods, liquidity channel reveals insignificant and negative pattern.

Figure 3

Impulse response functions to all positive macroeconomic shocks during post-crisis period: aggregate commodity prices.

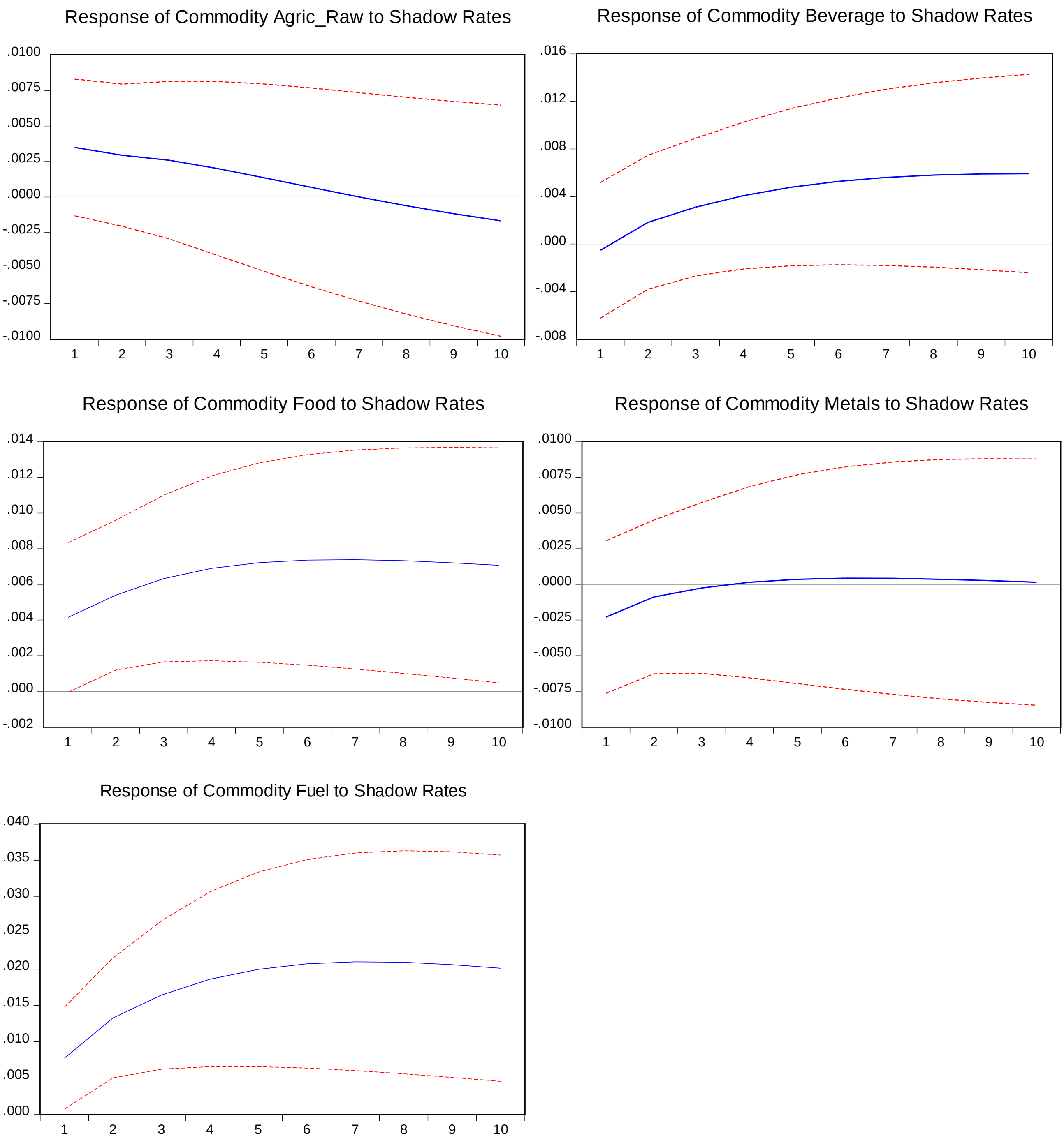


Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

The immediate responses to the exchange rate shocks of aggregate commodity prices are positive (from 0.5% to 1%) during four periods and then vanishes until the end of the period with staying in the positive impact area. Additionally, the impact of exchange rate appreciation is price increasing, contemporaneous and statistically significant on food, fuel, metals and agricultural raw material prices (Figure 2A, Appendix).

Figure 4

Impulse response functions to positive interest rate shock during post-crisis period: sectoral commodity prices.



Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

Like in the pre-crisis period, even with more robust results, we rely on the causes of the combination of interest rate, liquidity and exchange rate channels. Namely, an increase in interest rates (contractionary shock) causes to the appreciation of euro that attracts the relatively cheap commodities to Eurozone and resulting to the increase in commodity prices. The sensitivity of commodity prices to Eurozone CPI reflects similar significant and immediate positive effect as in the pre-crisis period with the same magnitude of 2%, while industrial production exhibits positive but statistically insignificant feedback.

The impact of shadow policy shocks on sectoral commodity prices in Fig. 4 reflects contemporaneous and persistent effects on food and fuel prices. They both show an immediate and price increasing responses rising until the fifth period, which then stabilizes as in the response of aggregate commodity prices. The outcomes in food and fuel prices are also similar to the results of Hammoudeh et al. (2015). The magnitude of shock on fuel prices are higher than others, that is with immediate 1% response and rises to 2% in latter periods after the third. However, other group commodities display statistically insignificant effects. Finally, results of the policy shocks based on the alternative short-term shadow rates calculated by the method of Krippner (2013) display in general same impact as those using the Wu and Xia (2016) shadow policy rates; results are not reported but available upon request.

Generally speaking, a positive (contractionary) monetary policy shock in both conventional and unconventional policy periods have price increasing impact on aggregate and sectoral commodity prices. The impact of short-term policy rates is statistically significant especially during unconventional policy period, which could be due to the growing influence of the ECB policy decisions and euro area trade on global economy as well as on global commodity prices.

6. Conclusion

We analyzed the impact of the ECB monetary policies on global aggregate and sectoral commodity prices. In a SVAR model, we employed monthly data and covered separately the period before GFC and afterwards to capture the effects of conventional and unconventional monetary policies. We used three-month short-term interest rates as a monetary policy instrument for the conventional policy period, while short-term shadow policy rates from Wu and Xia (2016) are used for unconventional policy period due to the ZLB. We analyzed not only the effects of interest rate shocks on aggregate commodity price indices, but we also assessed individual responses of each sector commodity price index, covering commodities of food, fuel, beverage, metals and agricultural raw materials.

Our empirical findings indicate that contractionary monetary policy shocks have price increasing effects on the aggregate commodity prices during both conventional and unconventional monetary policy periods. Although the pattern of the impact in both periods is similar, it is statistically insignificant during the conventional policy period. The aggregate commodity prices responded contemporaneously and positively to the positive interest rate shocks during the post-crisis period. Moreover, contractionary policy shocks also have price increasing effect on sectoral commodity prices. During the pre-crisis period, only commodity food prices exhibit statistically significant response to the policy shocks but other commodities do not. However, during post-crisis period both food and fuel prices show contemporaneous and positive responses to the contractionary policy shocks. Other three commodities (metals, agricultural raw materials and beverages) display mainly positive but statistically insignificant results. The effect of positive liquidity shocks (M2) are negative in all models but they are also statistically insignificant.

Outcomes of our empirical study for food and fuel prices are consistent with results of Hammoudeh et al., (2015), but for aggregate commodity prices are in contrast with results of Frankel (1986, 2008), Belke et al., (2014) and Hammoudeh et al., (2015), where contractionary US monetary policy has negative effect on commodity prices. To the best of our knowledge, the relationship has not been investigated for the ECB's policy interventions yet. Hence, our results are not directly comparable anyway. Divergence of inferences might stem from a sensible cause, though. Since the EU is the largest importer of world commodities, we believe that the positive effects of the ECB both conventional and unconventional monetary policies on aggregate and sectoral commodity prices are driven by the exchange rate differences. We found that appreciation of euro has immediate and positive effect on commodity prices in both periods, which causes euro priced commodities to be relatively cheap and demanded in European market. In other words, the rise in short-term interest rates is linked with euro appreciation and increases the domestic demand for commodities traded in different currencies, which results in immediate price increase in commodities.

Our main contribution to the literature on monetary policy and commodities is threefold. First, it is the first empirical study assessing the effects of both ECB's conventional and unconventional monetary policy shocks on aggregate and sectoral commodity prices. Second, we demonstrate that the impact of the ECB monetary policies on commodity prices increased remarkably after the GFC, indicating the effectiveness of unconventional monetary policy tools on real economy in comparison to conventional tools. Third, our results suggest that the effect of the ECB monetary policy on commodity prices transmits through the exchange rate channel, which influences the European market demand directly.

We believe that the monetary policy authority should consider the inverse effects of interest rate policy decisions on global commodity prices transmitted through the exchange rates. It is also a valuable information source in designing and implementing inflation targeting policies, where expansionary monetary policy (or contractionary) would have weak inflationary (or deflationary) effect on overall prices due to the expensive (or cheap) commodities. Specifically speaking, decision-making during the time of the unconventional policy measures use should entail immediate commodity price effects that are caused mainly by food and fuel prices.

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APPENDIX

Table 1A

Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root (PP) tests: Pre-crisis period

TESTS	**Augmented Dickey-Fuller**		**Phillips-Perron**	
	None (Levels)	Intercept (Levels)	None (Levels)	Intercept (Levels)
Variable	**t-Statistic**	**t-Statistic**	**t-Statistic**	**t-Statistic**
Log (Industrial Production)	1.363586	-0.156334	1.470769	-0.315507
Log (CPI)	12.48272	1.649952	12.48272	1.431532
Log (Short-term Rate)	-0.163661	-1.217762	-0.162022	-0.867554
ΔLog (M2)	-1.513532	-8.896516*	-2.083536*	-9.146200*
Log (Exchange Rate)	1.498862	-1.104629	1.700126	-0.743922
Log (Commod_All)	3.304581	2.031448	3.149393	1.861192
Log (Commod_Agricul_Raw)	1.956517	0.022855	1.926092	0.001496
Log (Commod_Beverage)	2.510890	0.360967	2.510890	0.357193
Log (Commod_Food)	3.238980	1.668174	2.880876	1.473782
Log (Commod_Metal)	2.863171	0.347382	2.594245	0.239491
Log (Commod_Fuel)	2.117792	1.079886	2.190698	1.131860

Note: ADF and PP test critical values with intercept (and none): 1% level -3.504727 (-2.590910)
5% level -2.893956 (-1.944445)
10% level -2.584126 (-1.614392)

Table 2A

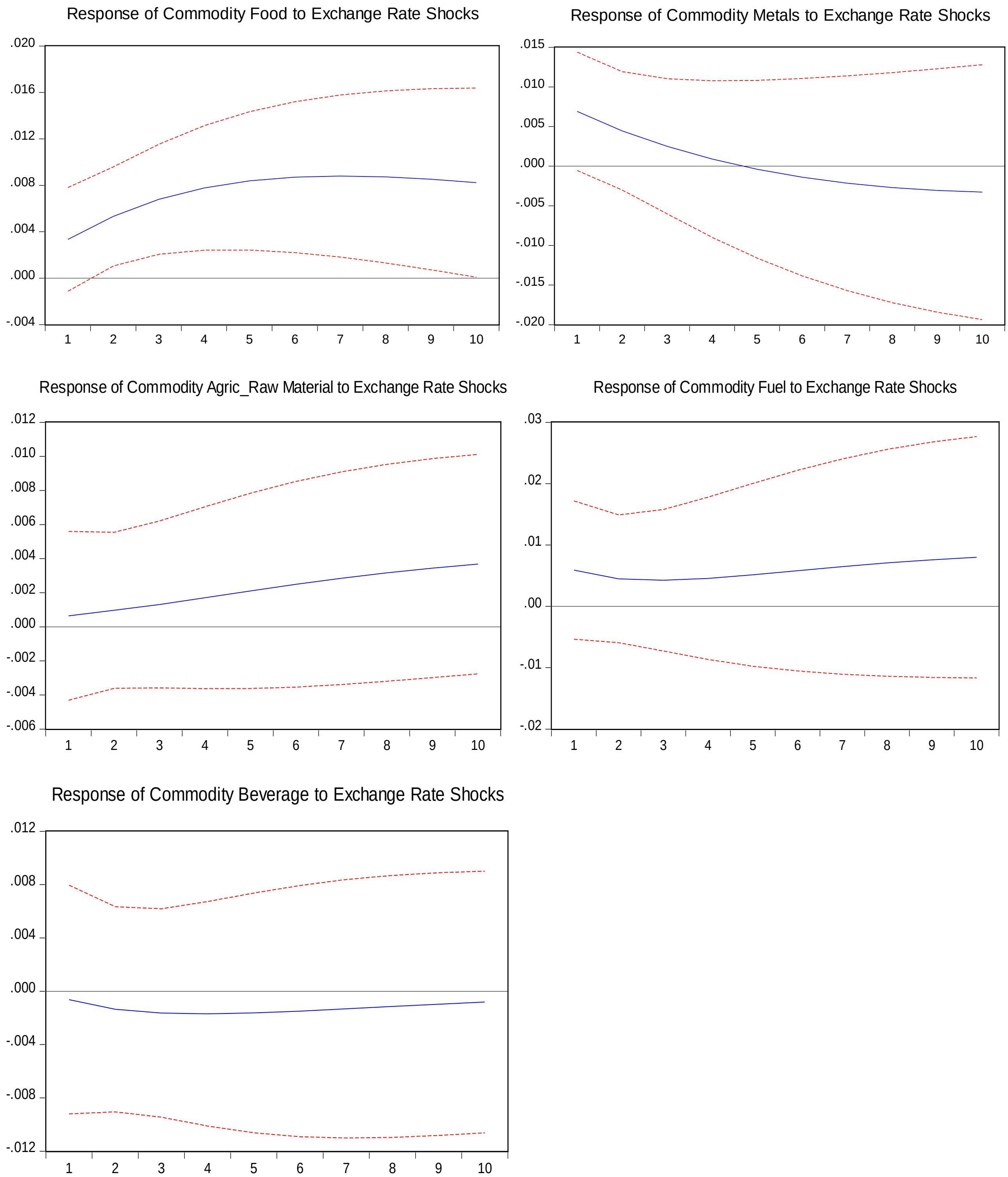
Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root (PP) tests: Post-crisis period

TESTS	**Augmented Dickey-Fuller**		**Phillips-Perron**	
	None (Levels)	Intercept (Levels)	None (Levels)	Intercept (Levels)
Variable	**t-Statistic**	**t-Statistic**	**t-Statistic**	**t-Statistic**
Log (Industrial Production)	1.441895	-2.123089	1.529376	-2.558148
Log (CPI)	4.541748	-1.777641	6.094650	-1.805517
Log (Shadow Rate)	2.194218	0.813555	2.626937	1.169422
ΔLog (M2)	-0.195014	-8.372919*	-3.647011*	-9.076918*
Log (Exchange Rate)	-0.666815	-2.360395	-0.681075	-2.135183
Log (Commod_All)	-0.117022	-1.297093	0.108714	-1.520193
Log (Commod_Agricul_Raw)	-0.155053	-1.612915	0.071123	-1.881027
Log (Commod_Beverage)	-0.302490	-1.552179	-0.222477	-1.587794
Log (Commod_Food)	0.067227	-1.823610	0.195345	-1.859290
Log (Commod_Metals)	0.469196	-1.948479	0.705603	-2.277368
Log (Commod_Fuel)	-0.266441	-1.305743	-0.099951	-1.355957

Note: ADF and PP test critical values with intercept (and none): 1% level -3.504727 (-2.590910)
5% level -2.893956 (-1.944445)
10% level -2.584126 (-1.614392)

Figure 1A

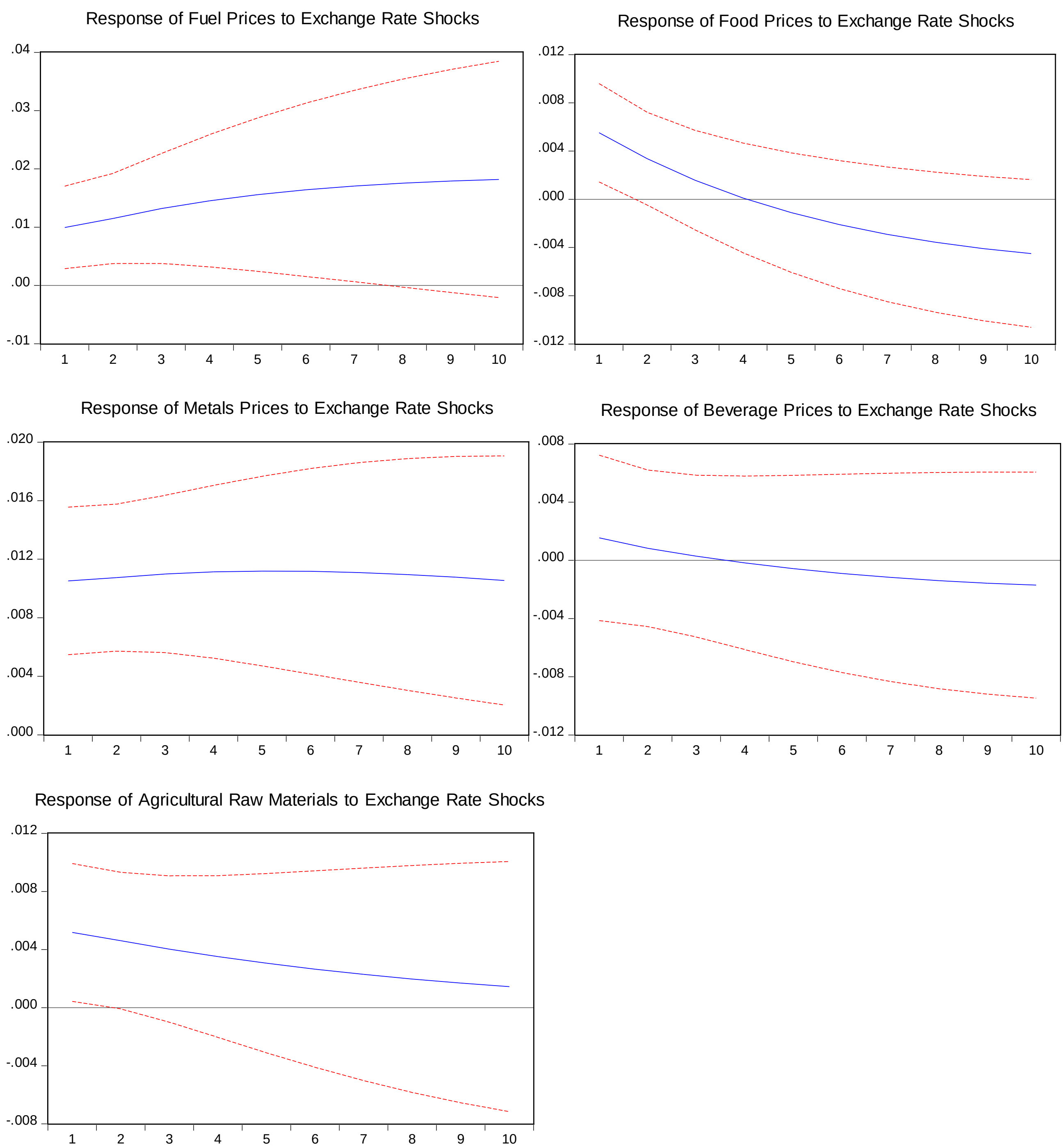
Impulse response functions to positive exchange rate shock during pre-crisis period: sectoral commodity prices.



Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

Figure 2A

Impulse response functions to positive exchange rate shock during post-crisis period: sectoral commodity prices.



Note: blue line – average response; red dashed lines – error bands of ±2 standard deviation (5% significance level).

Figure 3A

Graphical presentation of model variables during pre-crisis period: 2001M01 – 2008M07

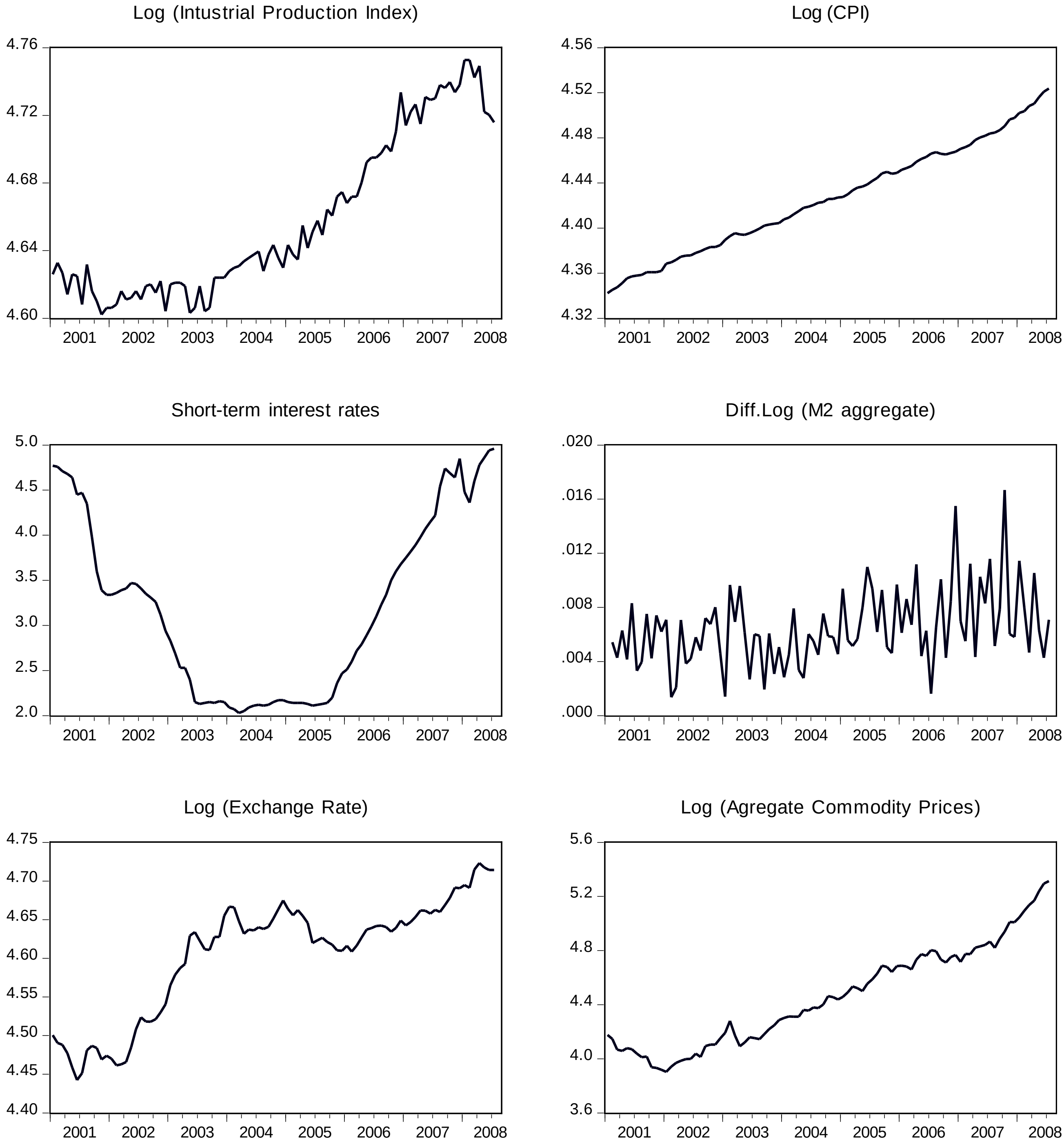


Figure 4A

Graphical presentation of group commodity prices during pre-crisis period: 2001M01 – 2008M07

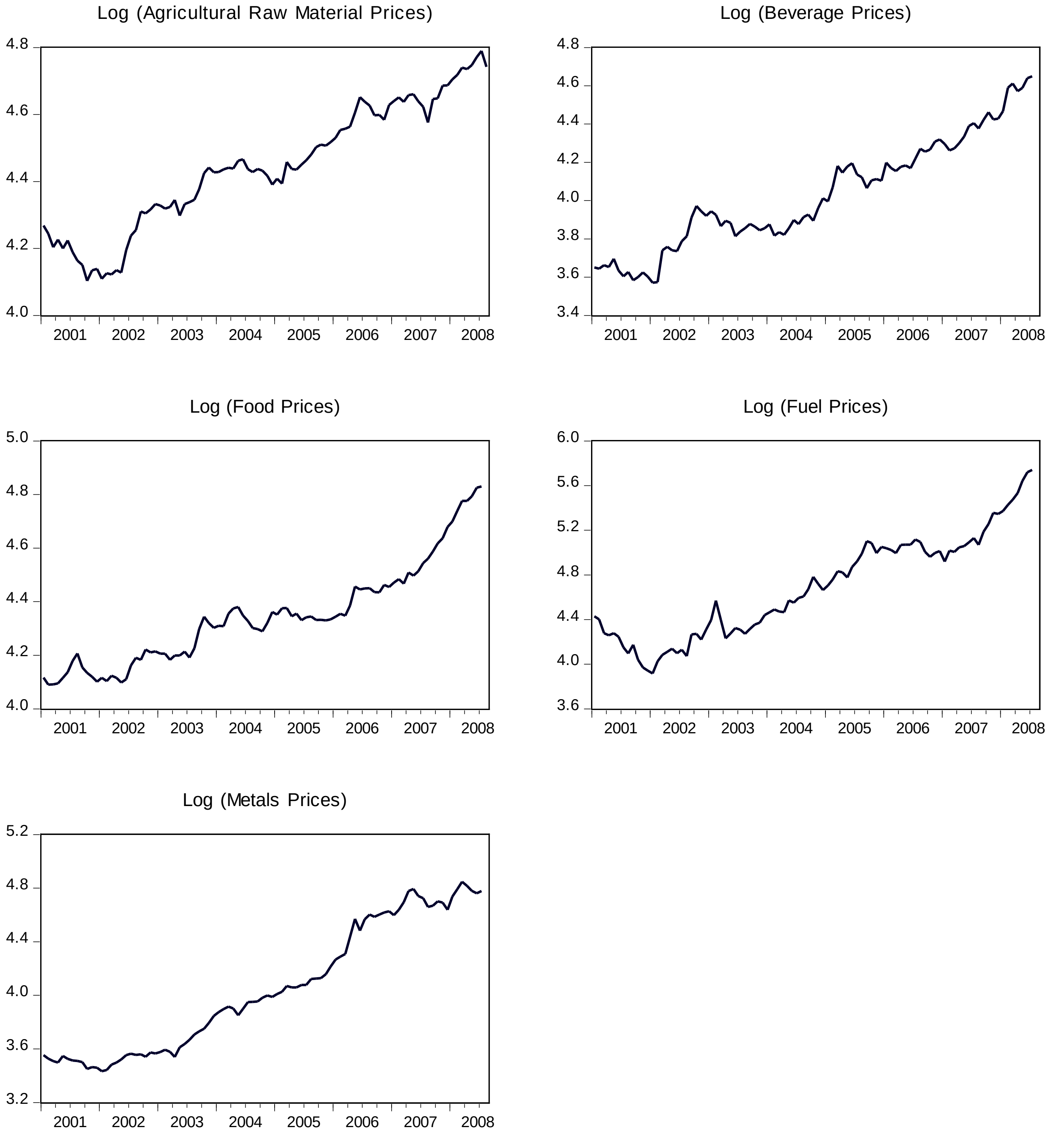


Figure 5A

Graphical presentation of model variables during post-crisis period: 2009M04 – 2019M08

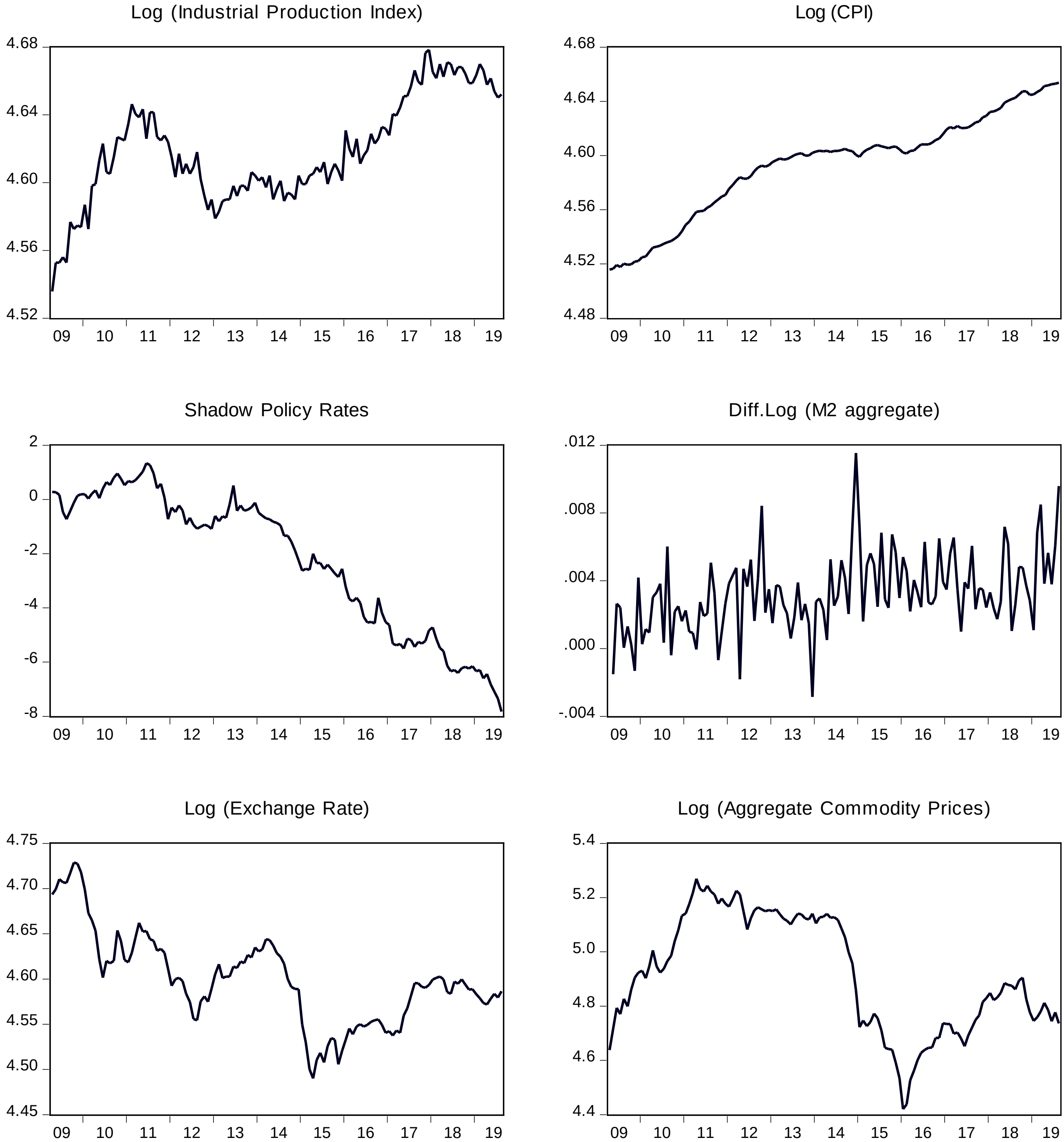
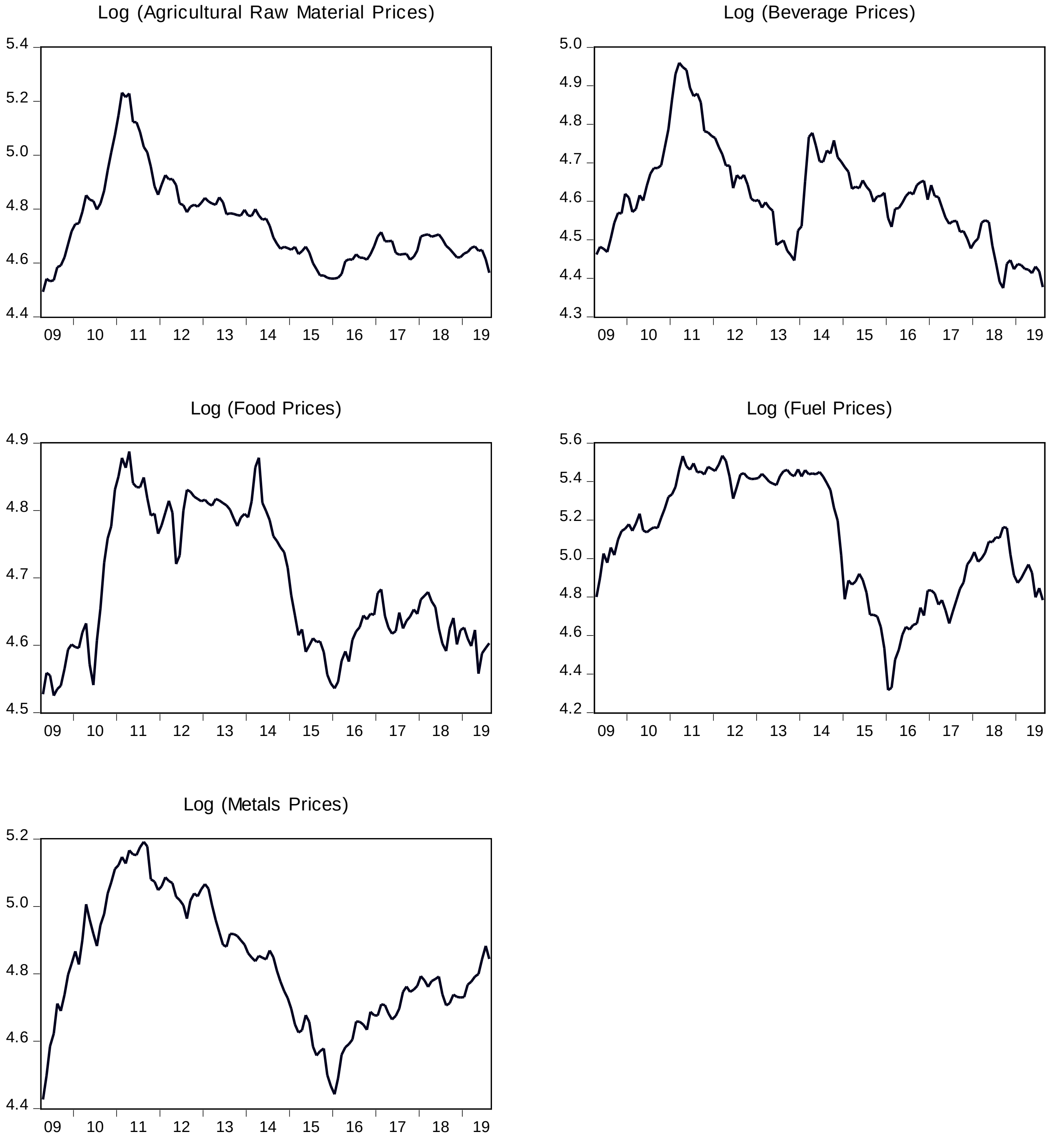


Figure 6A

Graphical presentation of group commodity prices during pre-crisis period: 2009M04 – 2019M08



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