Monetary Policy and Commodity Markets: Unconventional Versus Conventional Impact and the Role of Economic Uncertainty

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Abstract

This study explores the impact of both conventional and unconventional monetary policies in the US and the Euro area on the mean and volatility of certain commodity prices. The analysis considers the prices of eight commodities, i.e. oil, natural gas, gold, silver, aluminium, copper, platinum, and nickel, while the methodology employs the EGARCH-X modelling approach. The empirical findings clearly document that (i) the direction of the impact of both conventional and unconventional monetary policy on commodity returns and commodity volatility is similar and (ii) the impact from unconventional monetary policy on both commodity returns and volatility is relatively more pronounced, while these findings hold valid, irrespective of the geographical region and commodity type. Further investigation of the disparity on the size of the impact through the prism of economic uncertainty reveals that unconventional monetary policy has a stronger effect on economic uncertainty, thereby offering an indirect channel of monetary policy transmission on commodity markets.

Keywords: Conventional monetary policy; Unconventional monetary policy; Commodity returns; Mean and conditional volatility; Economic uncertainty.

JEL Classification: E52; E58; G10; G11

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1. Introduction

Commodity prices have a rather crucial role to play in shaping the dynamics of global economic activity. In fact, fluctuations in commodity prices appear to be key drivers of economic growth, affecting numerous aspects of the economy. In this regard, identifying and investigating drivers of commodity prices – especially during periods of unprecedented hikes – appears to be a rather crucial task that has drawn the attention of both researchers and investors in financial markets. More particularly, among the various drivers of prices in a number of commodity markets are: (i) convenience yields (Gibson and Schwartz, 1990; Gospodinov and Ng, 2013), (ii) exchange rates (Chen et al., 2010), (iii) interest rates (Frankel, 2008; Schwartz, 1997), (iv) money supply (Frankel, 1985; Dorfman and Lastrapes, 1996), as well as (v), monetary policy uncertainty (Rosa, 2014; Gospodinov and Jamali, 2015). In turn, several studies argue that commodity prices could act as early indicators of the future path of the economy, as they are continually auctioned in standardized markets with efficient information (Marquis and Cunningham, 1990; Cody and Mills, 1991).

With reference to monetary policy decision making and its impact on commodity prices, studies provide solid evidence that rising commodity prices are usually attributed to loose monetary policy decisions and persistently low interest rates (see, *inter alia*, Hamilton, 2009). Therefore, it is becoming increasingly important to comprehend the extent to which accommodative monetary policy affects developments in commodity prices. Nonetheless, most existing studies pertaining to the relation between monetary policy and commodity prices focus predominantly on conventional monetary policy (see, Lastrapes and Selgis, 2001; Leeper and Zha, 2003; Barksy and Kilian, 2004; Frankel, 2008; Mallick and Sousa, 2012; Rosa, 2014; Hammoudeh et al., 2015; Gospodinov and Jamali, 2015). By contrast, the existing relevant literature has rather neglected the effects stemming from unconventional monetary policy. By contrast, studies that consider unconventional monetary policy typically relate to the impact of the latter on: (i) bond yields (Neely, 2015; Baur and Neely, 2014; Bowman et al., 2015), (ii) exchange rates and stock prices (Bowman et al., 2015), (iii) global monetary and liquidity conditions (Korniyenko and Loukoianova, 2015), (iv) asset prices spillovers and capital flows (Chen et al., 2014), as well as (v), output (Gambacorta et al., 2014).

In turn, the objective of this study is to investigate the impact of both types of monetary policy on certain commodity markets (i.e., returns and volatility) and to identify potential differences that could shed additional light upon (i) the impact of monetary policy decision making on commodity markets and (ii) the response from monetary policy authorities to developments in commodity markets. Our motivation predicates upon authors such as Gilchrist and Zakrajsek (2013) and Bruno and Shin (2015) who explain that unconventional monetary policies may affect perceived risks and alter the risk-bearing capacity of market participants. Put differently, to the effect that we may achieve the objectives of the study we not merely focus on the impact of different policies on commodity markets but also, we try to assess these differences by further considering both market uncertainty and the "risk-taking" transmission channel of monetary policy (see, Borio and Zhu, 2012). Within this framework of analysis, the type of monetary policy that has the more pronounced impact on economic uncertainty, is also the type of policy that affects commodity markets the most, via the risk-taking transmission channel.

With these in mind, this study considers eight commodities, namely, oil, natural gas, gold, silver, aluminium, copper, platinum, and nickel, and two geographical regions, that is, the US and the Euro area, for a sample period which, overall, spans between 1989Q1 and 2016Q4. The two regions were selected on the grounds that monetary policy decisions from them tend to have a strong impact on many macroeconomic variables, asset prices and financial conditions (including credit/lending conditions) since they constitute a significant share of monetary actions around the globe. This differentiation is corroborated by the fact that money markets in the eurozone area are highly fragmented vis-à-vis those in the US (Potter and Smets, 2019).

In turn, for each region, we distinguish between the period of just-conventional policy and the period where both conventional and unconventional policies were in effect. As far as the US is concerned, unconventional monetary policy was brought into service in 2008Q4; that is, following the outbreak of the Global Financial Crisis (GFC). In Europe, unconventional monetary policy gained much prominence following the onset of the European sovereign debt crisis; that is during 2009Q4.

We then develop an EGARCH-X model, which facilitates: (i) the investigation of monetary policy impact on both the mean and volatility measures, (ii) the detection of potential asymmetric effects of monetary policy, as well as (iii), the inclusion of exogenous factors in the analysis. Conventional monetary policy is approximated by the FFR and the EONIA rate in the US and the Euro area, respectively; while unconventional, is approximated by short-term shadow rates following the work of Krippner (2015) and Wu and Xia (2016). The fact that we utilize two distinct variables in order to capture unconventional monetary policy further implies that, in this study, we consider the impact of each type of policy on commodities separately. In other words, in each region we isolate the relevant impact by distinguishing between a period of conventional policy implementation and a period of unconventional policy implementation. The latter is mainly driven by the fact that in both geographical regions, unconventional monetary policy emerged in a period when conventional policy measures were mired in the zero lower bound (ZLB) deadlock.

The main findings regarding this initial part of our study indicate that although the effect of both conventional and unconventional monetary policies on commodities is in the same direction; the impact (in terms of magnitude) stemming from unconventional monetary policy on both commodity returns and commodity volatility is considerably stronger. In fact, these findings hold, irrespective of geographical region and commodity type.

In turn, as mentioned earlier in this study, in order to shed light on the difference in the magnitude of the impact between conventional and unconventional monetary policies we bring economic uncertainty into service. Given that existing literature (i) strongly considers the link between commodity markets and economic uncertainty and (ii) has taken interest on whether commodities can be a safe haven (or not) during periods of economic turbulence (see for instance, Choudhry et al., 2015), assessing the impact of both types of monetary policy on economic uncertainty could help explain the stronger impact of unconventional monetary policy.

To elaborate, we investigate the hypothesis that the more pronounced impact of unconventional monetary policy on commodities might be attributed to the fact that, by default, unconventional monetary policy is exercised during periods of economic uncertainty, whereupon, the respective efforts from the monetary policy authority could (i.e., in line with the risk-taking channel of monetary policy) result in economic agents assuming greater levels of risk. Subsequently, we capture economic uncertainty in the US using the measures developed by Baker et al. (2012) and Jurado et al. (2015). For the Euro Area we consider the volatility of the Euro Stoxx 50 index (i.e., in the spirit of Belke and Kronen, 2017). In order to examine the impact of both types of policy on economic uncertainty we make use of the continuously updated (CU) generalized methods of moments (GMM) estimator (i.e., in the spirit of Hansen et al., 1996).

The results in relation to this second part of our study convey that both in the US and the Eurozone unconventional monetary policy has a stronger impact on economic uncertainty. The latter confirms our prior assumption that unconventional policy measures have a more pronounced impact on the risk-taking transmission mechanism of monetary policy, compared to respective measures of conventional policy. It follows that, during periods of economic uncertainty, the commodity markets under study should not necessarily constitute a safe haven, vis-à-vis other financial investments.

In this regard, the contribution of the study is twofold. First, to the best of our knowledge, our study adds to existing relevant literature by considering the effects of unconventional monetary policy on commodity prices (i.e., mean and volatility). Second, we provide new evidence considering the role of uncertainty in commodities markets. The rest of this paper is structured as follows. Section 2 discusses relevant literature. Section 3 explains the data and the empirical methods. Section 4 presents the empirical results and Section 5 concludes the study.

2. Literature review

Given that the focal point of this study is the investigation of the impact of different types of monetary policy on specific commodity markets considering economic uncertainty, this section purports to provide a concise exposition of all the relevant strands that form the basis of our analysis. Although not exhaustive, the literature presented in this section conveys important information on issues pertaining to three main areas; namely, conventional and unconventional monetary policy, as well as, economic policy uncertainty.

2.1 Conventional Monetary Policy

As mentioned earlier, most relevant existing studies concentrate on the relationship between conventional monetary policy and commodity prices. What is more, empirical studies within this literature cover a variety of commodity markets. For example, Frankel (1986) applies the Dornbusch (1976) model on agricultural commodities to show that monetary policy is a key driver of food prices. Along a similar vein, Barsky and Kilian (2001) put their emphasis on oil and opine that commodities do rise when real interest rates are very low. In particular, the decline in real interest rates is expected to lead to higher commodity prices via (i) the supply side channel (i.e., plummeting cost of holding inventories), (ii) investors turning to futures contracts (i.e., increased demand for commodities), as well as (iii), increases in the demand for capital goods which utilise such commodities as inputs (see, Arango et al., 2008).

Recent empirical studies that confirm this inverse relationship between real interest rates and commodity prices include Caballero et al. (2008), Frankel (2008), Lo (2008), Swaray (2008), Taylor (2009), Anzuini et al. (2010), Florez (2010), Roache and Rossi (2010), Mallick and Sousa (2012). On a parallel note, Kilian and Vega (2011) find that energy prices are predetermined with respect to monetary policy news.

Nonetheless, the empirical literature has yet to reach a consensus. For example, Hammoudeh et al. (2015) concentrating on sectoral commodity prices including non-fuel commodity prices, food prices, beverage prices, prices of agricultural raw materials, prices of metals and prices of fuel energy report that monetary policy contractions lead to instantaneous increases in the commodity price index, which they attribute to (i) aggregation bias, (ii) higher expected inflation and speculation, (iii) high production costs, and (iv) overshooting. Within a relevant strand of existing literature, Rosa (2014) carries out an event study in order to examine the effects of anticipated and unanticipated monetary policy and reports that energy prices respond negatively to low target rate surprises and unanticipated asset prices purchases.

Furthermore, authors such as Lombardi et al. (2010) do not find any link between interest rates and commodity prices. In addition, Klotz et al. (2014) investigating the Chinese markets do not find any causality between real interest rates and international commodity prices.

It should also be emphasized that the current literature has rather neglected the investigation of the dispersion of commodity prices (and returns) despite the growing popularity of conditional volatility methods. Within this scarce strand, Hammoudeh and Yuan (2008) employ GARCH models to provide evidence that higher interest rates reduce volatility in commodity markets.

2.2 Unconventional Monetary Policy

Drawing form international practice, when nominal interest rates are brought down to zero (i.e., to the Zero Lower Bound constraint), or when a country's monetary transmission mechanism is severely weakened due to loss of confidence in the market, or lack of liquidity, then, additional monetary stimulus can be generated only through unconventional measures (see, *inter alia*, Bini Smaghi, 2009). As we show below, existing literature has extensively investigated the impact of unconventional monetary policy on various macroeconomic and financial variables. Nonetheless, existing literature has rather neglected commodity markets.

Starting with studies that concentrate on unconventional monetary policy and economic activity following the global financial crisis (GFC) of 2007-09, Gertler and Karadi (2011) employ a monetary DSGE model to study the effects of unconventional monetary policy measures to control a simulated financial crisis. In addition, Gambacorta et al. (2014) report a positive impact on economic activity and consumer prices across a set of different countries that adopted such measures. What is more, Joyce et al. (2012) conclude that while unconventional monetary policy has an effect on the economy, there is ambiguity with regard to the size and duration of the effect and the channels through which it works.

Other studies concentrate on the effect of unconventional monetary policy on financial conditions. For instance, Neely (2005) reports that unconventional policy can reduce international long-term bond yields and the spot value of the dollar even at the zero bound. Similarly, Borrallo et al. (2016) show that quantitative easing announcements lead to sovereign yield and exchange rate fluctuations. Furthermore, Rogers et al. (2014) find that unconventional monetary policy is effective in easing financial conditions when policy rates are at the zero-lower bound. Moreover, Bowman et al. (2015) document that the effect of monetary policy shocks are significant, especially for local-currency sovereign yields, but the size and the persistence of the effect may be country-specific. On a parallel note, Baur and Neely (2014) find that the signaling effect is greater for countries in which yields respond more to conventional US monetary policy surprises, and that the portfolio balance effect is stronger for other countries.

Furthermore, considering specific geographical regions for which analogous studies have been conducted, authors such Ahmed and Zlate (2014), Chen et al. (2016), Tillmann (2016), Ahmed et al. (2017), Anaya et al. (2017) have investigated international spillovers of US unconventional monetary policy, while Chen et al. (2012) and Rogers et al. (2014) provide relevant evidence for the Bank of England and the Bank of Japan. As far as the Eurozone is concerned, a number of studies have employed changes in the size of the ECB's balance sheet to measure monetary policy directly (Gambacorta et al., 2014; Haldane et al., 2016; Boeckx et al., 2017). What is more, Gambetti and Musso (2017) examine specific components of unconventional monetary policy in the Eurozone, such as the implementation of the asset purchasing program (APP).

It should also be noted that in our study we refer to the short-term shadow rate suggested by Krippner (2015) as unconventional monetary policy in the U.S, while the corresponding measure of unconventional monetary policy in Europe is the short-term shadow rate of Wu and Xia (2016).

Finally, our empirical attempt is also close to the strand of the empirical literature on the transmission of monetary policy shocks (Christiano et al., (1999). Within this field, several studies explore how the monetary transmission mechanism has evolved over time, such as Boivin and Giannoni (2006), Canova and Gambetti (2009) and Boivin et al. (2010).

2.3 Economic Uncertainty

There is a wealth of literature regarding the relationship between uncertainty and commodity markets. Indicatively we quote: Andreasson et al. (2016) - who report (i) negative correlations between commodity futures markets and a policy uncertainty index and (ii) that although energy commodities are influenced by policy uncertainty, gold and coffee appear to Granger-cause the relevant index, Joëts et al. (2017) - who show that during turbulent times (i) precious metals constitute indeed a safe-haven and (ii) both food and industrial commodities are affected by the level of macroeconomic uncertainty, as well as, Zhang and Broadstock (2018) - who find that connectedness in commodity markets has become considerably stronger following the GFC 2007-09.

By contrast, very few studies have particularly investigated the impact of monetary policy on commodities via economic uncertainty, a link which is strongly considered by our study. Considering this indirect channel of monetary policy, Gospodinov and Jamali (2015) study the effect of uncertainty associated with monetary policy on commodity prices to show that uncertainty associated with negative monetary policy shocks (i.e., a fall in the target rate by more than expected), leads to a fall in the future prices of some energy and metal commodities, while the uncertainty associated with a positive monetary policy shock, leads to differing effects across commodity groups and business cycles.

Turning to the question of how to appropriately measure economic uncertainty our empirical strategy is based on a set of US-based uncertainty measures that have been proposed in the literature on uncertainty shocks. More specifically, as far the US are concerned, the uncertainty measures are the factor-based estimates of macroeconomic uncertainty by Jurado et al. (2015) and the economic policy uncertainty index constructed by Baker et al. (2012). For the case of the Eurozone, the measure of uncertainty was that of the volatility of the Euro Stoxx50, measured as the standard deviation over time, with the results obtained from Belke and Kronen (2017). Notably, our empirical approach is close to the strand of macroeconomic empirical research that focuses exclusively on the question of how movements in uncertainty affect economic activity.

Rather than using one specific observable variable to proxy for uncertainty, Jurado et al. (2015) estimate uncertainty as a set of factors that are common to different individual measures of uncertainty. Accordingly, they consider a large set of economic time series, and pay specific attention to separating unforecastable from forecastable components in each series, as it is only unforecastable variations that should be related to uncertainty. To this end, they use forecasting models with a large set of predictors. Based on the forecasting errors that result, stochastic volatility models are used to compute the uncertainty in each time series. Uncertainty is then estimated as the common, latent ‘uncertainty factor’ across these individual series, using principal component methodologies. Based on our data availability in relevance to interest rates, the analysis makes use of their quarterly measure of firm-level uncertainty, constructed, from firm-level profit growth, normalized by sales. In addition, the analysis uses the economic policy uncertainty (EPU) index constructed by Baker et al. (2012). This index is built on the following components: the frequency of newspaper references to economic policy uncertainty, the number of federal tax code provisions set to expire, and the extent of forecaster disagreement over future inflation and government purchases. The updated versions of the two indices are provided directly by the authors to whom we express our gratitude.

Relevant studies have shown that economic uncertainty (i) negatively affects economic activity (see, *inter alia*, Alexopoulos and Cohen, 2009; Bachmann and Bayer, 2011; Knotek and Khan, 2011; Baker et al., 2012; Jurado et al., 2015), (ii) positively affects stock market volatility (see, for instance, Arnold and Vrugt, 2008; Bernal et al., 2014; Liu and Zhang, 2015), (iii) negatively affects investment and productivity (see, Pástor and Veronesi, 2013; Chau et al., 2014; Gulen and Ion, 2016, among others).

3. Data and Empirical Methods

3.1 Data

The analysis makes use of daily data on oil, natural gas, gold, silver, aluminium, copper, platinum and nickel prices. The analysis focuses on non-agricultural commodities, while the selection of commodities from energy, metals and precious metals markets is justified by the fact that they are that are good representatives of the global commodity markets, while have emerged as desirable asset classes for international portfolio diversification. Given their importance for such diversification purposes, their close association and volatility with financial cycles signifies their importance for capital flows and the real economy (Arouri and Nguyen, 2010; Daskalaki and Skiadopoulos, 2011; Hammoudeh and Araújo-Santos, 2012), thus intensifying high volatility and contagion effects (Lee et al., 2007; Markwat et al., 2009).

Data, obtained from Datastream, on oil, natural gas, gold, silver, aluminium and copper span the period 1990-2016, while those on platinum span the period -12/01/2005-2016, and those on nickel span the period 28/04/2005-2016. It also employs conventional monetary policy measures by using the Federal Funds Rate for the US over the period 1990-2008:q3, while it uses conventional monetary policy measures of the overnight EONIA rate for the Eurozone area, spanning the period 2001-2008. EONIA is an interbank and not a policy rate. The primary reason we follow this approach is that whilst the central bank moved the policy rate in discrete steps, by signaling information about the future path of the policy rate, the central bank could steer interbank rates, reflecting all currently available information about the future direction of the policy rate.

Unconventional monetary policy in the US spans the period 2008:q4 to 2016, while that in the Eurozone covers the period 2009 to 2016. The key indicator of the US unconventional monetary policy is the short-term shadow rate suggested by Krippner (2015), while the corresponding indicator for the European unconventional monetary policy is the short-term shadow rate suggested by Wu and Xia (2016). Damjanovic and Masten (2016) document that this shadow rate makes a significant difference for estimating the effects of unconventional monetary policy shocks in the case of the Eurozone. The Krippner measure obtains the expected path of the actual short rate and its long-run expectation from a shadow/ZLB Gaussian affine term structure model of the yield curve and then integrate the difference between those quantities over the horizon from zero to infinity.

In zero lower bounds (ZLB) periods, short rate expectations initially include a period of zero, followed by a non-zero path that converges to the long-run expectation, while in non-ZLB periods the expected path of the short rate is entirely non-zero as it converges to the long-run expectation. The Wu-Xia measure uses a simple factor-augmented vector autoregression (FAVAR) through which the shadow interest rate is calculated. The estimates provide a tool for measuring the effects of monetary policy at the ZLB. Both rates have displayed considerable movements during the zero lower bound time span. This shadow rate is the interest rate at the short-term end of the shadow yield curve. Both shadow rates are derived from market bond rates since based on the assumption of efficient markets, bond rates reflect all currently available information about the future size of the balance sheet. Data on commodity prices and conventional monetary policy rates were obtained from Datastream, while those for the shadow policy rates from the sites of the corresponding authors. All commodity prices data are expressed in logarithms. Table 1 provides certain summary statistics.

[Table 1, about here]

The early stages of our analysis involve computing a number of unit root test statistics for each one of the variables considered. The DF-GLS test (Elliott et al., 1996), the KPSS test (Kwiatkowski et al., 1992; it tests the null of stationarity in levels), and the Ng-Perron test (Ng and Perron, 2001-with both a constant and a time trend) results are reported in Table 2. They strongly document that all the variables considered turn out to be stationary only in their first differences.

[Table 2, about here]

On a final note, economic uncertainty in the US is approximated by two different measures; that is, the economic policy uncertainty (EPU) index developed by Baker et al. (2012) and the macroeconomic uncertainty index developed by Jurado et al. (2015). In line with Belke and Kronen (2017) for the Euro Area we consider the volatility of the Euro Stoxx 50 index.

3.2 Empirical Methods

The analysis comprises two stages. First, we investigate the impact of both types of monetary policies on the commodity markets that we include in our study, while in turn, we examine the impact of those policies on economic uncertainty.

In this regard, we begin with the mean-variance modelling approach, i.e., the EGARCH-X methodology (Hansen and Lunde, 2011), which retains the properties of the EGARCH model recommended by Nelson (1991) in capturing asymmetries in volatility clustering and the leverage effect observed across asset markets, while also extending the model to include any other potential drivers of commodity prices in the X vector of control variables.

$$rc_t = \alpha_0 + \beta \sum_{i=0}^{p} \Delta i_{t-1} + \sum_{i=1}^{q} b_i \, rc_{t-i} + \varepsilon_t \qquad (1)$$

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$$h_t = \omega + \alpha\, \varepsilon_{t-1} + \gamma\, (|\varepsilon_{t-1}| - E|\varepsilon_{t-1}|) + \theta\, h_{t-1} + \varphi \sum_{i=0} \Delta i_{t-1} \tag{2}$$

where rc_{it} proxies commodity returns, and i proxies the monetary policy rate. The mean equation (1) is well described as an autoregressive-X (AR-X) model, i.e., an AR model augmented by any control variables X_t. The conditional volatility equation (2) describes a type of EGARCH-X modelling approach. In both equations, the policy interest rate is allowed to play an explicit role in influencing both the mean and the volatility of commodity returns. To point out the merit of the employed methodology, the analysis uses the EGARCH modelling approach since it explicitly considers the presence of potential asymmetric responses (supporting the leverage effect), as well as differential financial risks depending on the direction of price change movements. Thus, EGARCH family models have been shown to be superior vis-a-vis other competing asymmetric conditional variances (Alexander, 2009). Furthermore, the case of the EGARCH-X model includes extra information on certain important factors, such as interest rates, via the conditional volatility (Connor and Linton, 2001; Hwang, 2001).

Next, the returns for each commodity is modeled by an ARMA (p,q) process as follows:

$$\phi(L)rc_t = \mu_0 + \theta(L)\mu_t, t = 1, \dots T \tag{3}$$

where μ_t is a constant term; L is the lag operator; $\phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \dots - \phi_p L^p$ and $\theta(L) = 1 - \theta_1 L - \theta_2 L^2 - \dots - \theta_q L^q$ are polynomials of p autoregressive terms and q moving average terms, respectively with ϕ and θ unknown parameters. The error term, μ_t, is free of autocorrelation, but exhibits conditional heteroscedasticity.

Table 3 displays the results of the ARMA model specifications for the returns with respect to each commodity (along with those of the Ljung-Box autocorrelation tests that select the correct ARMA model), as well as the corresponding tests for ARCH effects. As the results indicate, the presence of autoregressive conditional heteroskedasiticty (i.e., volatility clustering) recommends us to proceed with the estimation of the multivariate E-GARCH-X model.

[Table 3, about here]

The second stage of our analysis relates to the investigation of the relationship between different types of monetary policies and economic uncertainty. To avoid potential endogeneity problems, this part of the analysis makes use of the generalized method of moments (GMM) estimators and more specifically the continuously updated (CU) GMM estimator, suggested by Hansen et al. (1996), whose estimates are independent of any normalization applied to the data. This method suggests that the continuous-updating GMM estimator has a smaller bias than the standard two-step GMM estimator.

The estimates are based on the following modelling equations:

$$EPU_t = a_0 + a_1\, CMP_t + u_t \quad (4)$$

$$EPU_t = b_0 + b_1\, UCMP_t + v_t \quad (5)$$

where EPU is the economic policy uncertainty index, CMP denotes the conventional monetary policy interest rates and UCMP is the unconventional/shadow policy interest rates. Finally, u and v denote the error terms.

4. Empirical Results and Discussion

This section sets out the results from our modeling approach. Within the context of our analysis, we are mainly interested on the impact of monetary policy, both conventional and unconventional, on the returns in specific commodity markets, as well as on their conditional volatility. In this regard, the analysis focuses on the relevant estimates reported in Tables 4 to 7. In particular, the results in relation to the US conventional and unconventional monetary policy are presented in Tables 4 and 5, whereas those for the Euro area in Tables 6 and 7 below. In addition, results pertaining to the link between monetary policy and economic uncertainty is given by Table 8 later in the study.

[Tables 4 to 7, about here]

4.1 The Sign of the Impact

Prominent among our results is that both conventional and unconventional monetary policies have a negative and statistically significant impact on commodity returns. In point of fact, this is true regardless of the geographical region or commodity under investigation. The values of the relevant estimates can be found in the results pertaining to the mean equation of the model that is included in each one of the Tables 4 to 7 and for each commodity separately. For instance, considering conventional monetary policy in the US, Table 4 indicates that the coefficients for Oil, Natural gas, and Gold are -0.026, -0.032, and -0.036 for Gold, respectively.

These findings are in line with existing studies. Drawing from existing relevant literature, we quote Frankel (2006) who argues that high real commodity prices are typically associated with a loose monetary policy regime and Hammoudeh et al. (2015) who provide evidence that monetary contraction under both types of monetary policy has a negative impact on both metal and energy commodity prices. More recently, Jawadi et al. (2017) argue that economic expansion (i.e., as the latter is promoted within the framework of unconventional monetary policy) might make investors turn to commodities markets; thereby, leading to rising commodity prices.

Turning to the conditional variance equation, we dwell upon two main points. First, there is a positive impact of both conventional and unconventional monetary policies on commodity conditional volatility, which is statistically significant and true across all commodities under investigation and for both geographical regions. In line with the example provided above, the relevant values in Table 4 – which refers to the US conventional monetary policy, indicate an estimate of 0.032 for Oil, 0.038 for Natural Gas, 0.039 for Gold, and so on. Second, the gamma (γ) coefficient is always negative and statistically significant, which practically implies that there is a leverage effect, in the sense that, negative shocks tend to generate more volatility on commodity returns vis-a-vis positive shocks. This finding is particularly insightful, given that we have already identified a significant negative influence in the mean equation of the model; that is, the influence stemming from monetary policy.

From the standpoint of monetary policy, the aforementioned analysis implies that higher interest rates will negatively affect commodity returns and positively affect commodity conditional volatility. Furthermore, in the presence of asymmetric volatility (i.e., a negative γ coefficient) the findings further imply that the negative impact stemming from contractionary policy (i.e., an increase in interest rates) will have a more pronounced impact on commodity volatility compared to expansionary policy (i.e., a decrease in interest rates).

4.2 The Size of the Impact

Having identified the significant influence stemming from monetary policy towards the commodity market, we then turn to issues relating to the size of the relevant impact. The latter might also be insightful with regard to identifying potential differences between conventional and unconventional monetary policies.

To begin with a general observation, a quick look at the *a* coefficient in the variance equation (i.e., in all Tables 4 to 7) illustrates that the latter is always statistically significant, which practically implies that the size of the shock is a crucial driver that contributes to volatility (i.e., irrespective of whether the shock is negative or positive in the first place).

Turning to a more detailed exposition of the results, it is worth emphasizing the ensuing disparities between conventional and unconventional monetary policy. It would be instructive at this point to note that these disparities hold regardless of the geographical region and commodity under investigation. In this respect, starting with the mean equation of the model, we note that the value of the coefficient regarding the impact of the US conventional monetary policy on oil returns (Table 4) is equal to -0.026, with the respective value for unconventional monetary policy (Table 5) being equal to -0.071. It follows that, unconventional monetary policy has a rather more pronounced negative impact on oil returns. In fact, the same is true when we also consider all other commodities in our sample; that is, negative shocks on commodity returns that stem from unconventional policy are systematically stronger.

Furthermore, the findings appear to be qualitatively similar when we concentrate on the variance equation of the model. As can be evidenced in Table 4, the effect of conventional monetary policy on oil volatility is equal to 0.032, while the respective effect originating in unconventional policy decisions (Table 5) is 0.085. A closer look at Tables 4 to 7 reveal that this pattern is repeating itself across all commodities included in our study. In addition, the respective values for the γ coefficient in Tables 4 and 5 are -0.078 and -0.089, indicating that the leverage effect is again more pronounced in the case of unconventional monetary policy. It should be noted, however, that the difference between the two values is not very large and this is true irrespective of the geographical region or commodity under investigation. Given though that the γ coefficient practically captures the presence of asymmetric volatility in the model, we focus on the sign and the statistical significance of this coefficient, rather than on its size. At the very least, what this finding signifies is that both types of monetary policy entail asymmetric effects.

On a final note, understandably, the stronger impact of unconventional policy described above, takes place in a different period of time, whereupon nominal conventional monetary policy rates oscillate around the zero lower bound (ZLB) and in this regard, the comparison is not really instantaneous. Nonetheless, these findings are suggestive of the fact that commodities appear to have a stronger link to unconventional monetary policy.

4.3 The Role of Economic Uncertainty

In order to shed additional light to the previously reported finding pertaining to the different size of the impact, we focus on the relationship between each type of monetary policy and economic uncertainty. The reasoning behind this choice is to come up with at least one indicator (i.e., economic uncertainty) that helps explain this difference. To put it simply, if unconventional monetary policy has a stronger impact on economic uncertainty compared to conventional monetary policy, then, it should also have a stronger impact on commodity markets, given the important role of economic uncertainty for developments in commodity markets in general. Results are reported in Table 8:

[Table 8, about here]

The findings clearly document that in both the US and the Eurozone and also, across all economic uncertainty measures, unconventional monetary policy seems to exert a stronger effect on economic uncertainty, thus, providing evidence that justifies its stronger effect on commodity returns and volatility. The results of this part of the empirical analysis point towards the broader impact of unconventional monetary policy on market participants' risk attitude and uncertainty.

4.4 Policy Implications

In order to provide an insightful summary of the results presented above, we highlight the relevant policy implications. To begin with, it would be instructive to note that our findings pertain not only to studies that investigate the impact of monetary policy decisions on commodity markets, but also to studies that examine the response from monetary policy to developments in commodity markets per se.

As far as the first strand is concerned, authors such as Jawadi et al. (2017) underscore the transmission mechanism of monetary policy through commodity markets. Among other things, Jawadi et al. (2017) report that unconventional monetary policy measures might lead to economic agents taking on more risk via rebalancing their portfolios (i.e., by directing their capital toward commodity markets). Put differently, Central Banks appear to stimulate risk-taking behavior by implementing unconventional monetary policies, thereby increasing economic uncertainty. Our findings apparently confirm this argument by highlighting the strong impact of unconventional monetary policy both on economic uncertainty and on the commodity markets of interest. What is more, this narrative is closely related to the "risk-taking" transmission channel of monetary policy (see, Dell'Ariccia et al., 2017; Delis et al., 2017). That is, periods of very low interest rates could be accompanied by increased levels of risk-taking in the banking sector; a fact that increases uncertainty instead of receding it. Despite that, according to this definition, the risk-taking channel appears at first glance to be more relevant to conventional monetary policy measures, it might also be reinforced by the unconventional monetary policy transmission mechanism explained in Jawadi et al. (2017). In this regard, our study provides corroborative evidence that the risk-taking channel might in fact be more pronounced in the light of unconventional monetary policy. It follows that decision makers should consider the effects on risk-taking behavior when adopting unconventional monetary policy measures.

With regard to the second relevant strand, authors such as Filardo et al. (2018) highlight the importance for monetary authorities to identify the source of the shock in commodity markets. In particular, Filardo et al. (2018) in line with well-established relevant literature (see, inter alia, Kilian, 2009) distinguish between demand-side and supply-side shocks and argue that effective monetary policy should ideally distinguish between the two. Put differently, if the objective is to subdue inflationary pressures in commodity markets then, identifying the source of inflation is key so that neither output nor economic stability are adversely affected. In turn, the findings of our study imply that depending on the type of policy adopted by the Central Bank, the identification of the source of the shock becomes even more crucial. On a final note in relation to the above, despite the differences in the size of the impact between conventional and unconventional policies, we should not lose sight of the fact that not all commodity markets behave in a similar manner. For example, Hammoudeh et al. (2015) provide evidence that food commodities respond quite differently from energy or other commodities to monetary policy developments.

In retrospect, the findings of our study imply that policy recommendations should strongly consider the pronounced effect of unconventional monetary policy on certain commodity markets, vis-à-vis conventional monetary policy.

5. Conclusion

Existing studies have identified monetary policy decision making as a key driver of commodity prices (i.e., and returns). However, the investigation of volatility in commodity markets in the light of unconventional monetary policy decision making has rather been neglected by the existing literature. In this study, we investigated the impact of both conventional and unconventional monetary policy on eight commodities, namely, oil, natural gas, gold, silver, aluminium, copper, platinum, and nickel, considering two geographical regions, that is, the US and the Euro area.

For each geographical region, we further identified two distinct time intervals separated by some break that denotes a crisis event. In particular, following the unconventional monetary policy measures that were adopted in the US in the light of the GFC of 2007-09, we distinguished between the pre-unconventional policy period, 1989-2008:Q3, and the period 2008:Q4-2016, which encompasses the relevant unconventional policy measures. The respective time intervals for the Euro area were 2001-2008 (i.e., a relatively tranquil period for the area) and 2009-2016 (i.e., following the European sovereign debt crisis and the relevant decisions made by the European Commission and the ECB).

In turn, conventional monetary policy was captured by the FFR and the EONIA in the US and the Euro area, respectively. We further proxied unconventional policy in the US utilizing the short-term shadow rate in the spirit of Krippner (2015) and the unconventional policy in the Euro area employing the respective shadow rate suggested by Wu and Xia (2016). In order to accomplish the objectives of this study, we also made use of an EGARCH-X model, which on one hand, allowed for the ascertainment of potential asymmetric effects of the impact of monetary policy, while on the other hand, it facilitated the inclusion of exogenous drivers in the analysis.

The main findings indicated that (i) the direction of the impact of both conventional and unconventional monetary policy on commodity returns and commodity volatility was similar and (ii) the impact from unconventional monetary policy on both commodity returns and commodity volatility was rather more pronounced. Most importantly, these findings held true, irrespective of the geographical region and commodity type.

In order to further investigate the different size of the impact we adopted a standard regression analysis framework from which we obtained continuously updated (CU) GMM estimators (i.e., in the spirit of Hansen et al., 1996) on the relationship between the two different types of monetary policy and the various economic policy uncertainty measures. The results documented that the impact of unconventional monetary policy on economic uncertainty is in fact stronger, compared to that of conventional monetary policy, suggesting that uncertainty, which has a key role in shaping dynamics in commodities markets, could provide one possible explanation (or channel) via which innovations in unconventional monetary policy have a stronger effect on commodity markets.

Potential avenues for future research might include other types of commodities as well, as such as agricultural commodities. Investigating whether certain types of commodities behave differently within the framework of this type of analysis might further facilitate efforts for a more effective monetary policy.

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Table 1. Summary statistics

Variables	Mean	SD	Min	Max	Skewness	Kurtosis	J-B	Obs
Oil	1.56	0.29	1.03	2.16	0.29	-1.36	690.6***	7,048
Natural gas	0.71	0.09	0.55	0.96	0.52	-0.79	1327.7***	7,048
Gold	2.72	0.26	2.40	3.28	0.71	-1.03	974.6***	7,048
Silver	0.91	0.30	0.55	1.69	0.77	-0.81	1094.3***	7,048
Aluminium	3.23	0.11	3.01	3.51	0.42	-0.50	842.7***	7,048
Copper	3.52	0.26	3.12	4.01	0.33	-1.40	953.1***	7,048
Platinum	2.92	0.24	2.52	3.36	-0.13	-1.45	874.2***	5,502
Nickel	4.27	0.16	3.92	4.73	0.45	0.12	795.8***	2,787
EONIA	2.12	0.04	2.02	2.16	-0.63	-0.94	1099.1***	4,175
Funds rate	3.38	2.67	8.97	10.7	0.28	-0.89	978.4***	7,048

Table 2. Unit root tests

Variables	GLS-ADF	KPSS	Ng-Perron			
			MZ_a	MZ_t	MSB	MPT
Oil	-1.59(4)	0.662(2)***	-3.44	-1.43	0.385	29.316
ΔOil	-5.83(3)***		-77.8***	-6.73***	0.067***	1.124***
Natural gas	-1.49(4)	0.594(3)***	-3.81	-1.52	0.368	25.931
ΔNatural gas	-6.35(3)***		-78.9***	-5.98***	0.052***	1.126***
Gold	-1.37(4)	0.681(2)***	-5.73	-1.49	0.413	28.709
ΔGold	-6.36(3)***		-82.4***	-7.16***	0.058***	1.166***
Silver	-1.47(4)	0.529(2)***	-6.72	-1.51	0.392	26.511
ΔSilver	-6.28(2)***		-72.1***	-6.85***	0.069***	1.108***
Aluminium	-1.52(3)	0.613(2)***	-5.28	-1.48	0.355	27.592
ΔAluminium	-5.84(1)***		-85.6***	-7.11***	0.072***	1.127***
Copper	-1.49(4)	0.499(3)***	-6.19	-1.62	0.329	28.416
ΔCopper	-5.46(2)***		-83.8***	-6.83***	0.067***	1.084***
Platinum	-1.56(3)	0.547(2)***	-6.45	-1.55	0.395	27.005
ΔPlatinum	-6.04(2)***		-91.4***	-6.59***	0.075***	1.136***
Nickel	-1.44(3)	0.677(2)***	-5.38	-1.46	0.361	28.714
ΔNickel	-5.86(1)***		-69.5***	-6.18***	0.049***	1.142***
Funds rate	-1.57(3)	0.536(3)***	-6.39	-1.52	0.408	29.805
ΔFunds rate	-5.66(1)***		-73.2***	-7.09***	0.073***	1.064***

Table 2 (continued)

Variables	GLS-ADF	KPSS	Ng-Perron			
			MZ_a	MZ_t	MSB	MPT
EONIA	-1.38(3)	0.519(2)***	-7.03	-1.43	0.374	28.773
ΔEONIA	-5.69(2)***		-84.6***	-6.58***	0.080***	1.177***
Krippner rate	-1.28(3)	0.602(2)***	-5.48	-1.58	0.352	28.639
ΔKrippner rate	-6.63(1)***		-79.2***	-6.26***	0.074***	1.149***
Wu-Xia rate	-1.35(2)	0.564(2)***	-5.92	-1.52	0.381	27.608
ΔWu-Xia rate	-7.19(1)***		-72.4***	-6.11***	0.065***	1.195***

Note: The test was run including both a constant and a linear trend. Figures in parentheses denote the lag length of the dependent variable used to obtain white noise residuals. This lag length was determined by the Akaike Information Criterion (AIC). The critical values for the Ng-Perron test at 10%, 5% and 1% are: -14.2,-17.3 and -23.8, respectively for MZ_a, -2.62, -2.91 and -3.42, respectively for MZ_t, 0.185, 0.168, 0.143, respectively for MSB, and 6.67, 5.48 and 4.030, respectively for MPT. ***: $p \leq 0.01$.

Table 3. ARMA models and ARCH tests for nominal returns

Commodity	Model	ARCH LM Test
Oil	ARMA (2, 0)	224.95***
	Q = 9.24 [0.34]	[0.00]
Natural gas	ARMA (1, 0)	272.45***
	Q = 7.37 [0.43]	[0.00]
Gold	ARMA (2, 0)	218.58***
	Q = 9.04 [0.36]	[0.00]
Silver	ARMA (2, 0)	198.61***
	Q = 9.84 [0.35]	[0.00]
Aluminium	ARMA (2, 0)	259.04***
	Q = 8.16 [0.36]	[0.00]
Copper	ARMA (2, 0)	198.62***
	Q = 10.16 [0.31]	[0.00]
Platinum	ARMA (1, 0)	249.58***
	Q = 8.19 [0.37]	[0.00]
Nickel	ARMA (2, 0)	267.82***
	Q = 8.35 [0.34]	[0.00]

Significance at the 1 percent level denoted by ***. Q is the Ljung-Box (1978) autocorrelation statistic, with the null hypothesis being the correct model. Figures in brackets denote p-values.

Table 4. EGARCH-X estimates: The Fed funds rate-conventional monetary policy (1989- 2008:q3)

Variables/	Oil		Natural gas		Gold		Silver		Aluminium		Copper		Platinum		Nickel	
Equations	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Δi	-0.026^{b}	0.032^{b}	-0.032^{b}	0.038^{b}	-0.036^{b}	0.039^{b}	-0.034^{b}	0.037^{b}	-0.029^{c}	0.018^{c}	-0.041^{b}	0.032^{b}	-0.028^{c}	0.030^{b}	-0.032^{b}	0.034^{b}
	[0.05]	[0.05]	[0.04]	[0.04]	[0.04]	[0.03]	[0.04]	[0.03]	[0.06]	[0.07]	[0.04]	[0.03]	[0.07]	[0.04]	[0.05]	[0.05]
rc(-1)	0.672^{a}	-	0.626^{a}	-	0.627^{a}	-	0.581^{a}	-	0.528^{a}	-	0.579^{a}	-	0.539^{a}	-	0.588^{a}	-
	[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]	
rc(-2)	0.198^{a}	-		-	0.186^{a}	-	0.171^{a}	-	0.114^{a}	-	0.108^{a}	-	-	-	0.138^{a}	-
	[0.00]				[0.00]		[0.00]		[0.00]		[0.00]				[0.00]	
ω	-	0.047^{a}	-	0.067^{a}	-	0.059^{a}	-	0.053^{a}	-	0.039^{a}	-	0.059^{a}	-	0.055^{a}	-	0.062^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.01]		[0.00]		[0.00]		[0.00]
α	-	0.219^{a}	-	0.248^{a}	-	0.225^{a}	-	0.248^{a}	-	0.198^{a}	-	0.214^{a}	-	0.198^{a}	-	0.205^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
γ	-	-0.078^{b}	-	-0.088^{a}	-	-0.083^{a}	-	-0.092^{a}	-	-0.058^{a}	-	-0.063^{a}	-	-0.059^{a}	-	-0.065^{a}
		[0.04]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
θ	-	0.725^{a}	-	0.764^{a}	-	0.774^{a}	-	0.796^{a}	-	0.761^{a}	-	0.775^{a}	-	0.748^{a}	-	0.793^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
LL	-	2687.4	-	2874.8	-	2968.3	-	3196.1	-	2856.4	-	2916.5	-	2784.3	-	2874.5
Constant	0.0043	-	0.0034	-	0.0024	-	0.0015	-	0.0012	-	0.0017	-	0.0016	-	0.0023	-
	[0.41]		[0.45]		[0.48]		[0.59]		[0.75]		[0.71]		[0.69]		[0.65]	
No. of obs.	7048		7048		7048		7048		7048		7048		5502		2878	

LL denotes the estimated maximum likelihood function. Figures in brackets denote p-values. Lags for the policy rate both in the mean and the conditional volatility equations were determined through the Akaike criterion. c: p≤0.10; b: p≤0.05; a: p≤0.01.

Table 5. EGARCH-X estimates: The Fed funds rate-nonconventional monetary policy (2008q4- 2016)

ariables/	Oil		Natural gas		Gold		Silver		Aluminium		Copper		Platinum		Nickel	
Equations	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Δi	-0.071^{a}	0.085^{a}	-0.064^{a}	0.067^{a}	-0.103^{a}	0.093^{a}	-0.086^{a}	0.076^{a}	-0.053^{a}	0.039^{b}	-0.069^{a}	0.068^{a}	-0.051^{a}	0.056^{a}	-0.066^{a}	0.073^{a}
	[0.00]	[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.01]	[0.00]	[0.01]	[0.00]	[0.00]	[0.00]
rc(-1)	0.693^{a}	-	0.659^{a}	-	0.684^{a}	-	0.613^{a}	-	0.573^{a}	-	0.596^{a}	-	0.584^{a}	-	0.617^{a}	-
	[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]	
rc(-2)	0.219^{a}	-		-	0.203^{a}	-	0.192^{a}	-	0.122^{a}	-	0.119^{a}	-	-	-	0.154^{a}	-
	[0.00]				[0.00]		[0.00]		[0.00]		[0.00]				[0.00]	
ω	-	0.058^{a}	-	0.084^{a}	-	0.075^{a}	-	0.060^{a}	-	0.047^{a}	-	0.066^{a}	-	0.068^{a}	-	0.069^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
α	-	0.251^{a}	-	0.272^{a}	-	0.263^{a}	-	0.275^{a}	-	0.229^{a}	-	0.246^{a}	-	0.229^{a}	-	0.236^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
γ	-	-0.089^{b}	-	-0.096^{a}	-	-0.096^{a}	-	-0.098^{a}	-	-0.072^{a}	-	-0.077^{a}	-	-0.073^{a}	-	-0.078^{a}
		[0.02]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
θ	-	0.768^{a}	-	0.792^{a}	-	0.792^{a}	-	0.764^{a}	-	0.784^{a}	-	0.796^{a}	-	0.782^{a}	-	0.807^{a}
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
LL	-	2716.3	-	2946.5	-	2995.6	-	2965.4	-	2895.3	-	2983.2	-	2816.5	-	2973.1
Constant	0.0062	-	0.0042	-	0.0038	-	0.0035	-	0.0028	-	0.0032	-	0.0036	-	0.0044	-
	[0.23]		[0.29]		[0.30]		[0.38]		[0.42]		[0.31]		[0.37]		[0.28]	
No. of obs.	7048		7048		7048		7048		7048		7048		5502		2878	

Similar to those in Table 4. b: $p \leq 0.05$; a: $p \leq 0.01$

Table 6. EGARCH-X estimates: The EONIA rate-conventional monetary policy (2001- 2008)

ariables/	Oil		Natural gas		Gold		Silver		Aluminium		Copper		Platinum		Nickel	
Equations	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Δi	-0.021[c]	0.023[c]	-0.027[b]	0.030[b]	-0.031[b]	0.027[b]	-0.028[c]	0.028[b]	-0.022[c]	0.014[c]	-0.031[c]	0.026[c]	-0.021[c]	0.023[c]	-0.020[c]	0.026[c]
	[0.07]	[0.07]	[0.05]	[0.05]	[0.05]	[0.05]	[0.06]	[0.05]	[0.07]	[0.08]	[0.06]	[0.06]	[0.08]	[0.07]	[0.07]	[0.07]
rc(-1)	0.634[a]	-	0.619[a]	-	0.618[a]	-	0.559[a]	-	0.513[a]	-	0.526[a]	-	0.496[a]	-	0.534[a]	-
	[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]	
rc(-2)	0.166[a]	-		-	0.164[a]	-	0.158[a]	-	0.096[a]	-	0.085[a]	-	-	-	0.112[a]	-
	[0.00]				[0.00]		[0.00]		[0.01]		[0.01]				[0.00]	
ω	-	0.040[a]	-	0.062[a]	-	0.054[a]	-	0.046[a]	-	0.034[b]	-	0.047[a]	-	0.041[a]	-	0.049[a]
		[0.00]		[0.00]		[0.00]		[0.01]		[0.03]		[0.01]		[0.01]		[0.01]
											-				-	
α	-	0.205[a]	-	0.226[a]	-	0.207[a]	-	0.225[a]	-	0.164[a]		0.189[a]	-	0.163[a]		0.182[a]
		[0.00]		[0.00]		[0.00]		[0.00]		[0.01]		[0.00]		[0.00]		[0.00]
γ	-	-0.067[b]	-	-0.075[a]	-	-0.069[a]	-	-0.072[a]	-	-0.058[a]	-	-0.052[a]	-	-0.051[a]	-	-0.054[a]
		[0.05]		[0.00]		[0.00]		[0.00]		[0.00]		[0.01]		[0.00]		[0.00]
θ	-	0.702[a]	-	0.748[a]	-	0.738[a]	-	0.753[a]	-	0.729[a]	-	0.734[a]	-	0.716[a]	-	0.748[a]
		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]
LL	-	2326.8	-	2576.9	-	2627.9	-	2794.5	-	2533.8	-	2607.6	-	2490.2	-	2560.1
Constant	0.0031	-	0.0029	-	0.0022	-	0.0008	-	0.0006	-	0.0012	-	0.0011	-	0.0014	-
	[0.46]		[0.49]		[0.49]		[0.68]		[0.78]		[0.75]		[0.73]		[0.69]	
No. of obs.	7048		7048		7048		7048		7048		7084		5502		2878	

Similar to those in Table 4. b: $p \leq 0.05$; a: $p \leq 0.01$

Table 7. EGARCH-X estimates: The EONIA rate-nonconventional monetary policy (2009- 2016)

Variables/ Equations	Oil (1)	Oil (2)	Natural gas (1)	Natural gas (2)	Gold (1)	Gold (2)	Silver (1)	Silver (2)	Aluminium (1)	Aluminium (2)	Copper (1)	Copper (2)	Platinum (1)	Platinum (2)	Nickel (1)	Nickel (2)
Δi	-0.058^{a}	0.062^{a}	-0.048^{b}	0.053^{a}	-0.085^{a}	0.070^{a}	-0.063^{a}	0.063^{a}	-0.042^{a}	0.031^{b}	-0.055^{a}	0.052^{a}	-0.043^{a}	0.047^{a}	-0.053^{a}	0.056^{a}
	[0.00]	[0.00]	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.03]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
rc(-1)	0.671^{a}	-	0.623^{a}	-	0.639^{a}	-	0.587^{a}	-	0.537^{a}	-	0.561^{a}	-	0.542^{a}	-	0.589^{a}	-
	[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]		[0.00]	
rc(-2)	0.204^{a}	-		-	0.165^{a}	-	0.163^{a}	-	0.109^{a}	-	0.094^{a}	-	-	-	0.136^{a}	-
	[0.00]				[0.00]		[0.00]		[0.00]		[0.01]				[0.00]	
ω		0.051^{a}		0.065^{a}		0.058^{a}		0.048^{a}		0.042^{a}	-	0.057^{a}		0.062^{a}	-	0.060^{a}
	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.01]	-	[0.01]		[0.00]	-	[0.00]		[0.00]
											-				-	
α		0.235^{a}		0.249^{a}		0.235^{a}		0.247^{a}		0.206^{a}		0.218^{a}	-	0.205^{a}		0.201^{a}
	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.00]		[0.00]		[0.00]		[0.00]
γ		-0.068^{b}		-0.072^{a}		-0.064^{a}		-0.072^{a}		-0.059^{a}	-	-0.049^{a}	-	-0.054^{a}	-	-0.053^{a}
	-	[0.03]	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.00]		[0.01]		[0.01]		[0.01]
θ		0.744^{a}		0.728^{a}		0.741^{a}		0.741^{a}		0.742^{a}	-	0.753^{a}	-	0.747^{a}	-	0.689^{a}
	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.00]	-	[0.00]		[0.00]		[0.00]		[0.00]
LL	-	2608.5	-	2548.3	-	2573.4	-	2640.7	-	2705.6	-	2688.1	-	2605.2	-	2711.8
Constant	0.0041	-	0.0037		0.0032		0.0029		0.0023		0.0025	-	0.0030	-	0.0038	-
	[0.28]		[0.32]	-	[0.34]	-	[0.43]	-	[0.46]	-	[0.36]		[0.41]		[0.32]	
No. of obs.	7048		7048		7048		7048		7048		7048		5502		2878	

Similar to those in Table 4. b: p≤0.05; a: p≤0.01

Table 8. Economic policy uncertainty estimates

Variable	Coefficient	p-value
US-Jurado et al. Index (1990-2008:q3)		
constant	0.785*	0.07
CMP	0.057**	0.03
CMP(-1)	0.028*	0.06
Hansen J-statistic (overidentification test of all instruments): [0.68]		
LM test: [0.00], Wald test: [0.00]		
Instruments used: constant, CMP(-2), CMP(-3)		
US-Jurado et al. Index (2008:q4-2016)		
constant	0.516*	0.10
UCMP	0.086***	0.01
UCMP(-1)	0.054**	0.03
Hansen J-statistic (overidentification test of all instruments): [0.77]		
LM test: [0.00], Wald test: [0.00]		
Instruments used: constant, UCMP(-2), UCMP(-3)		
US-Baker et al. Index (1990-2008:q3)		
constant	0.629*	0.08

CMP	0.048**	0.05
CMP(-1)	0.017*	0.10

Hansen J-statistic (overidentification test of all instruments): [0.84]

LM test: [0.00], Wald test: [0.00]

Instruments used: constant, CMP(-2), CMP(-3), CMP(-4)

US-Baker et al. Index (2008:q4-2016)

constant	0.337	0.16
UCMP	0.094***	0.00
UCMP(-1)	0.059**	0.03

Hansen J-statistic (overidentification test of all instruments): [0.92]

LM test: [0.00], Wald test: [0.00]

Instruments used: constant, UCMP(-2), UCMP(-3)

Eurozone- Euro Stoxx50 Index (2001-2008)

constant	0.846*	0.06
CMP	0.052**	0.04
CMP(-1)	0.024*	0.08
CMP(-2)	0.015*	0.10

Hansen J-statistic (overidentification test of all instruments): [0.59]

LM test: [0.00], Wald test: [0.00]

Instruments used: constant, CMP(-3), CMP(-4)

Eurozone- Euro Stoxx50 Index (2009-2016)

constant	0.296	0.20
UCMP	0.091***	0.00
UCMP(-1)	0.064**	0.02
UCMP(-2)	0.033*	0.06

Hansen J-statistic (overidentification test of all instruments): [0.81]

LM test: [0.00], Wald test: [0.00]

Instruments used: constant, UCMP(-3), UCMP(-4)

The number of lags was determined through the Akaike criterion. Figures in brackets denote p-values. Hansen H-statistic denotes the test for the validity of instruments used. LM is the strength of identification test by Kleibergen and Paap (2006), Wald test is the test for weak instruments by Stock and Yogo (2005). *: $p \leq 0.10$; **: $p \leq 0.05$; ***: $p \leq 0.01$.