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SHORT AND LONG-TERM CAUSALITY RELATIONS BETWEEN BROAD MONEY AND CRUDE OIL, EXCHANGE RATE, COMMODITY OPTION VOLATILITIES

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ABSTRACT

Purpose- The purpose of the study is to examine the dynamics linking broad money (M3) growth and crude oil volatility, euro/dollar volatility, commodity option volatility for the case of the US.
Methodology- Causality analysis depending on Vector Error Correction (VEC) models is employed to estimate the relationship between broad money (M3) growth and crude oil volatility, euro/dollar volatility, commodity option volatility for the case of the US.
Findings- Causality analysis results stresses that the balance sheet size of FED increase the uncertainties commodity and currency markets and thus volatility in euro/dollar and spot oil price and commodity options can be raised in the long-term. Both instantaneous causality and Granger causality indicate that money demand behavior of US economic agents are not affected from the commodity option, euro/dollar and crude oil volatilities both in short- and long-run.
Conclusion- Our empirical analysis implies that monetary aggregate targeting policy of FED can not be negatively mitigated by commodity option volatility, euro/dollar volatility, crude oil volatility indices. For further studies and analysis, we suggest the clarification of channels between monetary policy stance and financial instruments traded in commodity and currency markets.

Keywords: Causality analysis, crude oil volatility, exchange rate volatility, commodity option volatility, monetary policy.
JEL Codes: E44, E50, F41

1. INTRODUCTION

The US sub-prime mortgage crisis has led to plunging property and asset prices and thus a slowdown in the US economy. The negative impacts of the crisis also spread the economic and financial markets of other economies and volatility of asset prices increased. Following the 2008-2009 Global financial crisis, monetary policy authority in the US, namely the FED have implemented quantitative easing policies to stimulate the global economic activity and curb volatility in financial markets by affecting expectations positively. In the quantitative easing policy process, the economic agents have watched the growth of FED's balance sheet along with the interest rate decisions of the monetary policy authority. Accordingly, empirical models analyzing the role of monetary stance on macroeconomic and financial situation can use broad money as an indicator of monetary policy. Because monetary aggregates can be evaluated as a more important indicator than short-term interest rates in the quantitative easing process, we employ broad money (M3) growth as an indicator of monetary policy in this study. On the other hand, a rise in the volatility of global financial markets can be influence the dynamics of the financial markets of the US and thus lead to financial instability that FED should highly consider. Additionally, changes in spot and derivative prices of commodities and Euro/Dollar exchange rates can have important consequences the US foreign trade. Because the US is a major oil exporter and there is significant role of petrodollars in the financial system of the US, changes in oil and other commodity prices can also have consequences on the monetary aggregates of the US through financial channel.

Accordingly, we study the possible impacts broad money (M3) growth in the US on the volatility of exchange rates, oil price and stock market and vice versa. We explore the possibility of cointegration among broad money growth and commodity option volatility, euro/dollar volatility, crude oil volatility indices. Hereby, we perform causality analysis based on the Vector Error Correction (VEC) model with monthly data from 2010:03 to 2017:08. Because causality analysis is implemented on the basis of Vector Autoregression (VAR), performing causality analysis upon VEC model is The major contribution of this study. Within this empirical framework, the aim of this study is twofold: (i) to interpret whether changes in the balance sheet size of the FED may lead to considerable amount of changes in the indices of commodity option, euro/dollar and crude oil volatility (ii) to examine whether crude oil volatility, euro/dollar volatility and Chicago Boards option volatility indices may have considerable consequences of the monetary policy stance in the US. The main hypothesis of this paper is to test whether money demand in the US can be under the influence of the volatility in global financial markets and broad money can be used as policy instrument to curb the volatility in global financial markets.

The rest of the paper is organized as follows. Section two reviews the previous relevant literature analyzing the dynamics of broad money and volatility. In Section three data and methodology are presented and additionally, the estimation results are examined and evaluated. Finally, Section four concludes and discusses some policy implications.

2. LITERATURE REVIEW

In order to attain the targets of monetary policy, maintaining financial stability has been recognized as an important issue by monetary policy authorities. More precisely, it is assumed that financial asset prices can transmit to consumer prices through the changes in commodity prices and exchange rates. Thus, researchers have given a crucial role to determine the variations in financial markets and the interactions between financial variables in terms of monetary policy conduction. Based upon a dynamic model, Turhan et al. (2014) compared the correlations between oil prices and exchange rates of G20 members. Their empirical evidence confirmed that a strengthening negative correlation between oil price and exchange rate in the last decade existed where policy shifts such as US' invasion of Iraq in 2003 and the 2008 global financial crisis were the main reasons. Additionally, they underlined the benefits in risk diversification and inflation targeting due to the new relationship. Brahmasrene et al. (2014) analyzed the causality between crude oil prices and exchange rates where they implemented variance decomposition and impulse response analysis. Their empirical results indicated that the exchange rates Granger-caused crude oil prices in the short run while the crude oil prices Granger-caused the exchange rates in the long run. They showed that the impact of extreme price volatility in June 2008 on exchange rates was significant. Moreover, they stressed that exchange rate shock had a significant negative impact on crude oil prices. The study of de Truchis and Keddad (2016), analyzing risk comovements between the crude oil market and U.S. dollar exchange rates, focused on the volatility dependence by means of both fractional cointegration and copula techniques. Their cointegration results concluded in favor of long-run independence for the Canadian and Japanese exchange rates while few evidence of long-run dependence was found for the European and British exchange rates. Additionally, they found increasing linkages just before the 2008 market collapse and more recently, in the aftermath of the European debt crisis. In a similar attempt, Hussain et al. (2017) focused on 12 Asian countries where the co-movements of oil price and exchange rate at different time scale were determined. Their results supported the co-movements of oil prices and exchange rate and a weak negative cross-correlation between oil price and exchange rate. Based upon a threshold VEC model, Kanjilal and Ghosh (2017) investigated the dynamics of crude oil and gold price after the global financial crisis in 2008. They found an asymmetric and non-linear relationship between oil and gold prices whereas regime shifts also have an effect and thus the relationship does not remain constant during the entire period of their study. The effects of commodity volatilities can also be extended by conventional spillover analysis. For instance, Nazlioglu et al. (2015) examined the volatility transmission between oil prices and financial stress by means of the volatility spillover test. A long-run volatility dominance was found and the volatility spillover causality test supported evidence on risk transfer from oil prices to financial stress before the crisis and from financial stress to oil prices after the crisis. Ahmadi et al. (2016) extended the analysis by the inclusion of agricultural and metal commodities. By applying a Structural VAR model and basing on impulse response functions, they revealed that the response of volatility of a commodity to an oil price shock differed significantly depending on the underlying cause of the shock. A recent study focusing on intraday relationship between oil and exchange rate volatility was performed by Jawadi et al. (2016). They researched the dynamics of oil price volatility by examining interactions between the oil market and the US dollar/euro exchange rate. Their results suggested that a negative relationship between the US dollar/euro and oil returns existed and a volatility spillover from the US exchange market to the oil market was evident.

There have been several contributions to the literature examining the relationship between monetary policy and commodity price volatilities. Especially, the renewed interest in oil price and USD relationships has been stimulated by suggestive comovements on these markets, particularly since the beginning of 2000. The empirical effort by Bachmeier (2008) can be seen as one of the major contributions in that extent which provided evidence on the role played by monetary policy in the transmission of oil shocks to the US economy. He showed that there was no relationship between the reaction of individual stock prices to oil shocks and to monetary policy shocks and concluded that systematic monetary policy was not as effective as suggested in some previous studies. On the other hand, Bashar et al. (2013) provided evidence for a relationship between oil price uncertainty and macroeconomy in the context of Canada. They proposed a Structural VAR model where oil price uncertainty makes a major contribution to overall variations in the output level. Furthermore, their study also showed that higher oil price uncertainty significantly decreased both output and price levels, resembling an adverse demand shock. Consequently, they demonstrated that the Central Bank of Canada reacted with an expansionary monetary policy to oil price uncertainty shocks. Examining the impact of monetary policy on the exchange rate, Kohlscheen (2014) investigated the impact of monetary policy shocks on the exchange rates of Brazil, Mexico and Chile. In the paper, it is argued that it was difficult to attribute the stronger version of the exchange rate puzzle to fiscal dominance while the lack of empirical backing for the predictions of standard open economy models persisted irrespective of whether the US Dollar or effective exchange rates were used. Most recently, Sun et al. (2017) investigated the cross-correlations between the US monetary policy, US dollar index and WTI crude oil market. The importance of the study is that they examined the effect through multifractal detrended cross-correlation analysis approach. There was clear evidence that the US monetary policy operations had influences on the cross-correlated behavior of US dollar index and crude oil market.

3. DATA AND METHODOLOGY

VAR-type models have been widely used in the economic literature for the analysis of international transmission mechanism of monetary policy and its spillover effects since the study of Sims (1980). Determining unit root properties is an important factor which leads to a possible search of cointegration between the variables under investigation. In this respect, VEC models can be used as a major tool to expose the causality relations linking the dynamics of the economic variables to each other. In this study, we use VEC modeling with monthly data from 2010:03 to 2017:08 to analyze the relationship between the indices of crude oil volatility, euro/dollar volatility, option volatility and broad money for the case of USA. Therefore, the effects of monetary policy decisions of FED on commodity, currency and financial markets are examined along with the role of those markets on the monetary policy stance in the US. For the analysis, the statistical database of Federal Reserve Bank of St. Louis, OECD and Yahoo Finance were used and the following variables were obtained: broad money index (M3); $m3_t$, crude oil volatility index; ovx_t, euro/dollar volatility index; evz_t, Chicago Boards option volatility index; $cboe_t$. All series are in logarithms and J-MuLTi software is used to carry out the empirical exercise.

3.1. VEC Model

The base framework of VEC model is based on Vector Autoregression (VAR) model, while the $\mathrm{VAR}(p)$ model with deterministic terms and exogenous variables is written as below;

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + B_0 x_t + \ldots + B_q x_{t-q} + CD_t + u_t \tag{1}$$

where the vector of endogenous variables with K elements is represented by $y_t = (y_{1t}, \ldots, y_{Kt})'$. $x_t = (x_{1t}, \ldots, x_{Mt})'$ refers to a vector containing the exogenous variables. The A_i, B_j and C are the parameter matrices of the $\mathrm{VAR}(p)$ model. u_t denotes to an unobservable white noise process with positive covariance matrix E($u_t u_t'$)=Σ_u (JMulTi 4.23 Help System). If there exist cointegration among the variables under investigation, VEC model are estimated. In this respect, VEC model excluding the exogenous variables can be expressed as below;

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t \tag{2}$$

In equation (2), Πy_{t-1} is $I(0)$ and it refers to the long-term part containing $I(1)$ variables since Δy_t do not have stochastic trends assuming that all variables can be at most $I(1)$. $\Pi = \alpha\beta'$ is a product of $(K \times r)$ matrices with $\mathrm{rk}(\Pi) = r$, thus α and β have $\mathrm{rk}(\alpha) = \mathrm{rk}(\beta) = r$. $\beta' y_{t-1}$ is expressed by premultiplying $\Pi y_{t-1} = \alpha\beta' y_{t-1}(\alpha'\alpha)^{-1}\alpha'$, therefore there exist $r = \mathrm{rk}(\Pi)$ linearly independent cointegrating relations among the components of y_t. The rank of Π denotes the cointegrating rank of the system and β refers to a cointegration matrix. The weights attached to the cointegrating relations in the equations of the model are included in α -loading matrix. In this study, the rank of the system can be specified using the Johansen test as represented (Lütkepohl, 2007a, p.92).

$$y_t = D_t + x \tag{3}$$

where y_t refers to a K-dimensional vector containing observable variables. $D_t = \mu_0 + \mu_1 t$ expresses the deterministic part with a linear trend term, while x_t is accepted as is a stochastic process having a Vector Autoregression

(VAR) representation. Based on the framework of (2), the pair of hypothesis below can be tested to specify the cointegrating rank of the model (Lütkepohl, 2007a, p.112).

$$\mathrm{H}_0(r_0): \mathrm{rk}(\Pi) = r_0 \text{ versus } \mathrm{H}_1(r_0): \mathrm{rk}(\Pi) > r_0,\ r_0 = 0, ..., K-1 \quad (4)$$

The causality concept proposed by Granger (1969) states that y_{1t} is to be causal for a time series variable y_{2t} if y_{1t} helps to improve the forecasts of y_{2t}. According to the causality concept proposed by Granger (1969), y_{1t} is to be causal for a time series variable y_{2t} if the former helps to improve the forecasts of the latter. Based on the representation of $\mathrm{VAR}(p)$ in matrix forms as in (5), the null hypothesis that y_{1t} is not Granger-casual for y_{2t} is tested by $\alpha_{21,i} = 0,$ $i = 1, 2, ..., p.$ Thus, y_{1t} / y_{2t} is not Granger-causal for y_{2t} / y_{1t} if its lags do not appear in the y_{2t} / y_{1t} equation. (JMulTi 4.23 Help System).

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \sum_{i=1}^{p+2} \begin{bmatrix} \alpha_{11,i} & \alpha_{12,i} \\ \alpha_{21,i} & \alpha_{22,i} \end{bmatrix} \begin{bmatrix} y_{1,t-i} \\ y_{2,t-i} \end{bmatrix} + CD_t + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (5)$$

On the other hand, Granger-causality analysis can be performed based on the framework of the VEC model.

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \alpha\beta' \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \sum_{i=1}^{p-1} \begin{bmatrix} \gamma_{11,i} & \gamma_{12,i} \\ \gamma_{21,i} & \gamma_{22,i} \end{bmatrix} \begin{bmatrix} \Delta y_{1,t-i} \\ \Delta y_{2,t-i} \end{bmatrix} + u_t \quad (6)$$

where $\alpha_{12,i} = 0,\ i = 1, 2, ..., p$ is equivalent to $\gamma_{12,i} = 0 (i = 1, ..., p-1)$ and the element in the upper right-hand corner of $\alpha\beta'$ is equal to zero. If it is assumed that $r = 1$, a and β are (2×1) vectors and $\alpha\beta' = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \begin{bmatrix} \beta_1 & \beta_2 \end{bmatrix} = \begin{bmatrix} \alpha_1\beta_1 & \alpha_1\beta_2 \\ \alpha_2\beta_1 & \alpha_2\beta_2 \end{bmatrix}$, the conditions $\alpha_1\beta_2 = 0$ is checked along with the $\gamma_{12,i} = 0$ condition. a and β have rank one, thus there must be Granger-causality in at least one direction (Lütkepohl, 2007a, p.146).

If the value of y_{1t} in the forecast period helps to improve the forecasts of y_{2t}, y_{1t} can be accepted as instantaneously causal for y_{2t}. Conversely, y_{1t} is accepted to be instantaneously non-causal for y_{2t} when the condition in (7) holds.

$$y_{2,t+1|\Omega_t} = y_{2,t+1|\Omega_t \cup y_{1,t+1}} \quad (7)$$

In equation (7), Ω_t contains all the set of all the relevant information in the universe and $\cup$ refers to the union. $y_{1t} /$ y_{2t} can be accepted as instantaneously causal for y_{2t} / y_{1t}, if and only if u_{1t} and u_{2t} are correlated (Lütkepohl, 2007a, p. 147).

3.2. Empirical Data and Analysis

3.2.1 Empirical Data

In order to select an appropriate form of time series model, we firstly implement commonly used unit root test. Implementation of Augmented Dickey–Fuller (ADF) test is conducted by following the Pantula principle.[1] The lag orders of the ADF tests are suggested by the Akaike Info Creation (AIC).

Table 1: Augmented Dickey–Fuller Test Results

Variables	ADF Test Statistic	Number of Lagged Differences
$cboe_t$ (c)	-2.91	1
$\Delta cboe_t$	-5.85	6
evz_t (c)	-2.33	1
Δevz_t	-12.39	0
ovx_t (c)	-2.36	0
Δovx_t	-9.32	0
$m3_t$ (c,t)	-1.54	1
$\Delta m3_t$ (c)	-7.16	0
Notes: The 1% critical values for the ADF test with constant (c) and no terms are -3.43 and -2.56, respectively. The critical values of the ADF test are obtained from Davidson and McKinnon (1993).		

Table 1 show that all the series are $I(1)$ at levels and stationary at first differences. Thus, we explore cointegrating relations among the variables of the model ($cboe_t, evz_t, ovx_t, m3_t$). In this respect, we apply the Johansen cointegration test based on the VEC model framework presented in empirical analysis section to consider a deterministic trend term in the data generation process. The ordering of the variables in the model is as $cboe_t, evz_t, ovx_t, m3_t$, reflecting our assumption that there are high interactions between broad money and commodity option, euro/dollar, crude oil volatilities.

Table 2: Johansen Cointegration Test Results based on the VEC model

Series: $cboe_t, evz_t, ovx_t, m3_t$ **No. of Included Lags (Levels):** 2			
Null Hypothesis	**Test Value**	**%95 Critical Value**	**%99 Critical Value**
$r=0$	75.31	63.66	70.91
$r=1$	37.49	42.77	48.87
$r=2$	13.14	25.73	30.67

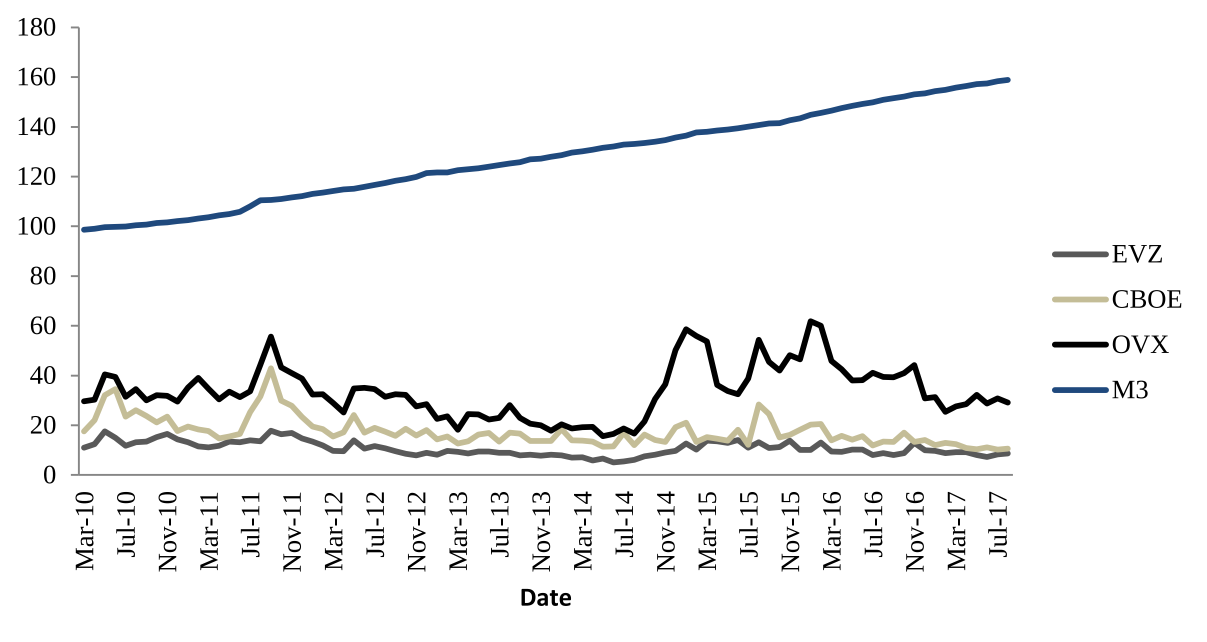
Table 2 indicates that there is cointegration of the first order; in this respect, VEC model is estimated for the vector $y_t = (cboe_t, evz_t, ovx_t, m3_t)'$. Within this model framework, we perform causality analysis between to make inferences about the dynamics of financial markets, monetary policy stance and money demand of US. More specifically, we aim to test the instantaneous and Granger causality relationships among commodity option volatility, euro/dollar volatility, crude oil volatility and broad money (M3) indices.

[1] The Pantula (1989) states that if a linear trend term is required in the test for the time series y_t, then a constant term is used in the test for Δy_t. If just a constant is required in the test for y_t, the test for Δy_t is to be implemented with no deterministic term (Lütkepohl, 2007b: 55).

3.2.2 Stylized Facts

After the 2008-2009 global financial crisis, unconventional monetary policies have been conducted by various countries' central banks to mitigate the fluctuations in financial markets and maintain financial stability. Particularly, quantitative easing policy implemented by the FED has also led to an increase in monetary aggregates. According to Figure 1, it is detected that growth of broad money (M3) has an increasing trend. Additionally, short-term interest rates have been used to control long-term interest rates influencing the variations in exchange rate and stock markets. Eliminating the negative consequences of volatility in oil prices has also been in the center of monetary policy formulation, despite the effect that oil prices emerge as a main factor affected by political risk.

Figure 1: Historical Data



In the context of political risk, 2014 is considered an important year. More specifically, it is observed that the political tension between Russia and the western world increased during that period. Because of the Russian-Ukrainian conflict, Russia annexed Crimea imposing financial and other sanctions by western world. At the same time, Russian banks are frozen out of western capital markets, depreciating Russian ruble against major currencies. As a result, developments in the Russian economy led to negative expectations about global economic activities. This process was accompanied by the historical declines in oil prices. In Figure 1, it is shown that oil volatility caused by the fall of oil prices raised from the mid of 2014. Furthermore, the spread between oil price volatility and CBOE-EVZ volatilities increased possibly due to the success of unconventional monetary policy implementations in US and Euro area.

3.2.1 Empirical Findings

Changes in the broad money can be recognized as an indicator of the changes in monetary policy stance along with policy interest rates. Quantitative easing policy of the FED is coming into prominence than that of the effects of short-term interest rates on macroeconomic and financial variables. Moreover, changes in broad money can have consequences on maintaining financial stability by causing fluctuations in financial markets.

Table 3: Granger Causality Tests' Results

Series: $cboe_t, evz_t, ovx_t, m3_t$ **No. of Included Lags (Levels):**1 $H_0 : m3_t$ **do not Granger-cause** $cboe_t, evz_t, ovx_t,$		**Series:** $cboe_t, evz_t, ovx_t, m3_t$ **No. of Included Lags (Levels):**1 $H_0 : cboe_t, evz_t, ovx_t$ **do not Granger-cause** $m3_t$	
Test Statistic	**p-value-** F	**Test Statistic**	**p-value-** χ
2.7551	0.0128	1.3030	0.2556

Series: $cboe_t, evz_t, ovx_t, m3_t$ No. of Included Lags (Levels):1 H_0 : No instantaneous causality between $m3_t$ and $cboe_t, evz_t, ovx_t$		Series: $cboe_t, evz_t, ovx_t, m3_t$ No. of Included Lags (Levels):1 H_0 : No instantaneous causality between $cboe_t, evz_t, ovx_t$ and $m3_t$	
Test Statistic	**p-value-** F	**Test Statistic**	**p-value-** χ
3.3527	0.3404	3.3527	0.3404

We apply causality analysis based on VEC modeling and the results are presented in Table 3. According to Granger causality analysis, changes in M3 may have consequences on the volatility of commodity option, euro/dollar and crude oil. Conversely, we do not detect instantaneous causality between M3, commodity option, euro/dollar and crude oil. Therefore, it can be inferred that changes in the monetary stance of the FED and/or money demand shocks may have long-term impacts. Accordingly, changes in the balance sheet size of FED may affect the dynamics of the spot oil market. Secondly, it can be asserted that broad money (M3) of the USA can transmit to oil price volatility through changes in the aggregate supply and demand of world economy. Granger causality results also indicate that broad money demand is an important indicator influencing the variations in currency markets. We show that uncertainties in financial market (more specifically in euro/dollar volatility) increase and thus economic agents' interest in investing to US dollar or Euro is varying. More specifically, it can be evaluated that US dollar and Euro are alternatives to each other. As implied in Granger causality analysis, changes in the balance sheet size of FED increase the volatilities and uncertainties in commodity and currency markets; thus, the hedging behavior of the investors becomes stronger. This implication is supported by the results of the Granger causality analysis.

Instantaneous causality and Granger causality analysis are also performed to specify whether monetary policy stance of the FED and money demand behavior of US economic agents are under influence commodity option, euro/dollar and crude oil volatilities both in short- and long-run. Accordingly it can be exposed that the monetary policy implementation of the US cannot be conducted by the effects coming from financial markets. Macroeconomic factors such as inflation, current account balance and unemployment can be the major determinants of monetary policy stance, whereas FED aims to mitigate the commodity option, euro/dollar and crude oil volatilities by using its instruments. Causality analysis also reflects that M3 money multiplier and thus money demand behavior of economic agents in US are not affected by the fluctuations in those markets.

4. CONCLUSION

In this paper, we employ VEC modeling to analyze the relations between broad money (M3) growth and the indices of crude oil volatility, euro/dollar volatility and Chicago Boards option volatility with monthly data from 2010:03 to 2017:08. In this respect, we perform both instantaneous and Granger causality analysis to make interpretations in the short and long-term perspective.

According to instantaneous causality analysis; in the short-run, the dynamics of financial markets were not influenced by the monetary policy stance of the FED. However, Granger causality analysis results stress the role of broad money for crude oil volatility, euro/dollar volatility and option volatility in the long-run. The importance of the changes in the balance sheet size of FED is reflected, thus we can infer that possible monetary tightening policy in the foreseeable future can lead to major variations in financial markets. Despite there may exist asymmetries in the response of financial markets to monetary policy changes, causality analysis implies that financial stability can be negatively affected in the US triggering capital outflows. In line with Mundell–Fleming model, we can assume that raised interest rate may positively affect the expectations to US financial assets. Causality analysis also implies that factors leading to changes in the broad money demand should be explored. More specifically, changes in broad money of the US can be recognized as a factor inevitably influencing the dynamics of world economy through oil prices and the currency market.

Monetary policy authority can use its instruments to curb the volatility in financial markets to sustain financial stability. Our causality results validate this phenomenon for the US economy, whereas we find that there may exist any considerable impacts on broad money coming from commodity option, euro/dollar and crude oil markets in terms of volatility. More specifically, we can assert that variations in those markets are not perceived in the same direction by the FED and economic agents deciding on money demand.

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