23. BÖLÜM / CHAPTER 23

COMMODITY PRICE UNCERTAINTY AND OUTPUT GROWTH: SVAR-GARCH-M MODEL

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DOI: 10.26650/B/SS10.2021.013.23

ABSTRACT

The actual demand and supply as well as the stock amount in commodity markets both affect the supply and demand expectations of investors. The future supply and demand expectations and uncertainty are influential with respect to the pricing in the commodity market. Since expectations and uncertainties in the commodity market can affect macroeconomic variables directly or indirectly, fluctuations in prices are crucial for policymakers and market practitioners. Changes or variations in financial markets may be seen as basic factors for commodity prices within globalizing economies and up-and-coming financial products. The effect of the changes in commodity prices that affect economic activity through various channels or transmission mechanisms varies between importing and exporting as well as between developed and developing countries. In this study, the effect of the commodity price uncertainty on output growth is examined within the context of the bivariate structural vector autoregression with a generalized autoregressive conditional heteroscedasticity in-mean error structure.

Keywords: Crude oil price index, Output growth, SVAR-GARCH-M model

1. Introduction

Commodities, defined as merchandize, have several subgroups, including precious metals (gold, silver, etc.), industrial metals (iron, steel, etc.), agricultural products (wheat, cotton, etc.), and energy products (oil, natural gas, etc.), and can be utilized using different investment methods. Since oil and oil products, which are the primary sources of energy consumption and are traded in high volumes, have turned into investment instruments, the positive and negative shocks that represent the crude oil price fluctuations depending on instability of supply or demand in the market have an impact on financial markets and macroeconomic variables. The uneven distribution of energy resources, which determine the level of development of the countries by driving socioeconomic development and which are the basic inputs of economies, aggravates energy dependence. When seen as supply or demand shocks, the changes in oil prices may lead to a vicious cycle (Tang et al., 2010). Uncertainty stemming from increased volatility in the oil market may result in an increased dependence of the countries that seek to maintain their economic development and attain their industrialization goals on oil, which, in turn, may pave the way for consumers' and producers' changing their consumption and investment decisions, as well as for the potential reallocation of the sources, affecting the economic structure. Oil prices, characterized with uncertainties, tend to be endogenous under macroeconomic conditions (Barsky and Kilian, 2004).

The factors for the determination of oil prices may be in the form of demand-side (economic growth, financial crises, taxes, speculations, etc.), supply-side (OPEC policies and supply production capacity, R&D and production/drilling costs, etc.), and political and geographical factors (embargoes, political risks, non-homogeneous reserve distribution, etc.). Since oil production is a long and costly process, short-term increases in demand cannot be responded to with increases in supply that have the same rate, and the supply elasticity of oil is lower in terms of elasticity of supply and demand. Owing to the inelastic nature of oil prices, increases in demand or decreases in supply can cause prices to increase. Since it is difficult for oil-importing countries to lower their oil consumption in response to increased oil prices, this leads to inelastic oil demand curve in the short-term, and when prices increase because of exchange rates, low level output occurs with high-cost input. In addition, the oil-importing countries are faced with an outflow of foreign currency in connection with increases in oil prices, which, in turn, results in foreign deficit and increased demand for foreign exchange. Increases in oil prices disturb the balance of payments of oil-importing countries and lead to increased inflation by making imported goods more expensive and exported goods cheaper (Güngör et al., 2016).

The impact of shocks on the output growth varies depending on the source of the shock. Changes in oil prices affect the output in industrial production, which is the driving force of real growth, and decrease the efficiency of labor and capital, as described in real business-cycle models. According to the supply-side effect, increases in the prices of oil, which is one of the basic inputs of production, directly push up production costs and indirectly affect the costs of delivery of goods and services, thereby lowering the output and efficiency of production and resulting in an indirect decrease in labor supply. Assuming that price escalation is temporary, borrowing made in an effort to maintain the consumption level increases the equilibrium real interest rate. Decreases in the production output and increases in the real interest rate have an impact on the real monetary balances and cost-push inflation and adversely affect profitability ratios and investment decisions. Further, the aforementioned decreases and increases lead to decreases in capacity utilization rates and gross domestic product (GDP) (Brown and Yücel, 2002). The hikes in oil prices in oil-importing countries may result in current account deficits or twin deficits. The dispersion hypothesis accounts for the impact of fluctuation in oil prices on real activities (Lilien, 1982). Changes in oil prices affect resource allocation among sectors. The changes in oil prices may lead to sectoral imbalance by lowering the consumption of the energy-driven goods, and the energy-intensive sector may contract and the energy-efficient sector may expand, depending on changes in demand. The costly nature of the cross-sectoral redistribution attributable to shifts in demand paves the way for decreases in value added (Barsky and Killian, 2004). Adjustment costs may increase because of capital stock or sectoral imbalances. Since the firms that change their energy-output, capital-output, and labor-output ratios in the long term keep their production technologies embedded in their capital equipment, they extend the adjustment period for changing the capital stock because of price increases, and economic organization is interrupted. Further, since increases in oil prices lead to increased sectoral imbalance, decision-making processes are hampered and coordination problems emerge. In addition, in cases where technology is embedded in capital, the volatility in oil prices creates uncertainty, resulting in postponed investments, decreased investment incentives, and reduced confidence in the continuity of firms as well as in the investors, all of which weakens the economy (Brown et al., 2003).

Increases in oil prices pave the way for income (welfare) transfer, defined as the transfer of purchasing power from oil-exporting countries to oil-importing ones. Since the transfer of money from oil-importing countries to oil-exporting ones is continuous, this may lead to unfair income distribution. The differences between oil buying and selling prices have different effects on oil-importing and oil-exporting countries from a commercial perspective. The changes that

occur depending on exchange rates and markets are assessed as the domestic utilization rate and the import-export rate and may have different effects on exchange rates based on the utilization rate. Oil and oil products affect consumption patterns depending on supply and demand and are traded using foreign currencies, and therefore, potential variations in oil prices can directly affect foreign exchange rates and impinge on economic stability and international competitiveness of countries. Owing to the inelastic nature of oil prices, decreases in energy supply adversely affect the macroeconomic structure of oil-importing countries while decreases in oil demand create negative effects on the macroeconomic structure of oil-exporting countries. Since oil-importing countries rely on oil for their export and public revenues, declining oil prices have adverse effects on economic activity and domestic demand while rising oil prices push up the purchasing power and aggregate demand (Brown et al., 2003). In countries where economic diversity is low and oil is the most important source of income and economic growth is driven by oil exports, increases in oil prices lead to increased expenditure and oil-based public revenues. National currencies may be overvalued, resulting in the loss of competitiveness in non-oil sectors (Orsam, 2014). Excessive dependence on a single economic activity results in unstable growth because of the declining expenditure and emerging public deficits due to decreasing prices. To eliminate instability, capital investments should be shifted toward non-oil sectors (Hamdi-Sbia, 2013).

Changes in oil prices have structural effects on the economy because of the dependence on oil. In determining the role of oil price increases based on supply and demand, oil price and output growth are examined through general equilibrium models and different structural shocks. Rasche and Tatom (1981), Darby (1982), Santini (1985), and Gisser and Goodwin (1986) reported that increases in oil prices decrease production and increase inflation. Hamilton (1983) showed that economic stagnation is correlated with fluctuations in oil prices, noting that the changes in prices in the pre-1980 period had asymmetric effects on the economy, whereas the declining oil prices in the post-1980 period had no foreseen effect on the macroeconomic performance. Burbridge and Harrison (1984) emphasized that increases in oil lead to decreases in industrial production. Mork (1989) demonstrated a negative correlation between oil prices and economic growth. Ferderer (1996) argued that increases in oil prices create income transfer from oil-importing countries to oil-exporting ones, thereby decreasing real income and adversely affecting domestic demand and investments in oil-importing countries. Jones and Leiby (1996) demonstrated that when oil prices increase, economic activity declines, but when oil prices decrease, the same level of increase cannot be attained. Hooker (1996) reported that increases in oil prices result in losses in economic growth and welfare increases in the oil-importing countries.

Hamilton (2003) upheld that there is a non-linear correlation between the fluctuation in oil prices and output growth. Huang et al. (2005) stressed that changes in oil prices are influential over economic activities. Kilian (2008) proposed a three-variable, endogenous model for oil prices in the context of the relationship between oil and GDP and studied the driving forces of different price increases. Fukunaga et al. (2009) demonstrated that the effect of the changes in oil prices on the level of industrial production is lower. Farzanegan and Markwardt (2010) reported that increases in oil prices result in significant decrease in GDP and positive price shocks in oil prices have a greater influence on GDP than negative shocks. Gronwald et al. (2009) found that increases in oil prices have negative effects on macroeconomic variables. Hamilton (2011) indicated that decreases in oil prices have no effect in compliance with the reallocation effect while oil price shocks have non-linear effects on the real GDP. Ghalayini (2011) reported no causal relationship between oil prices and economic growth rate and demonstrated a negative relationship between increases in oil prices and economic growth for oil-importing countries while the opposite applies to oil-exporting countries. Öksüzler and İpek (2011) showed that oil prices have one-way effects on growth. Aydın and Acar (2011) observed that the direct effects of oil price shocks on macroeconomic variables are negative, adding that oil price shocks affect the economy not only directly but also indirectly. Zhang and Chen (2011) demonstrated that although oil prices have positive effects on stock exchange returns, these effects are low. Akıncı et al. (2012) reported that increases in oil prices trigger economic growth in their countries while price increases have negative effects on the growth process in importing countries. Hamdi-Sbia (2013) maintained that oil is the primary source of economic growth in oil-exporting countries and any increase in oil prices leads to increases in public expenditure and, therefore, oil-based public revenues. Gubler and Hertweck (2013) showed that commodity price shocks are the driving forces of macroeconomic fluctuations. Ju et al. (2014) emphasized that oil price shocks may have adverse effects on GDP and exchange rates, but positive impact on inflation and greater shocks in oil prices may have effects on exports and imports.

Deniz and Sümer (2015) indicated that increases in oil prices have positive influences on growth and foreign trade figures in oil-exporting countries. Ratti and Vespignani (2016) demonstrated that not only increases in oil prices but also the volatility in high oil prices affect monetary policy and undermine economic growth. Kim et al. (2017) showed that interest rate reactions differentiate over time and oil price shocks have increasingly become a more important source of volatility in interest rates. Han and Sever (2016) observed that excessive volatility in oil prices and exchange rate fluctuations during crises have adverse effects on

economic growth. Algan et al. (2017) reported that the industrial production index is adversely affected by increases in the volatility of oil prices. Lorusso and Pieroni (2018) indicated that aggregate demand shocks are important in accounting for changes in inflation and interest rates while demand shocks that are unique to the oil market have significant contributions to the fluctuations in GDP growth and unemployment rates. Sağlam and Güreşçi (2018) demonstrated that there is a positive correlation between changes in oil prices and selected macroeconomic indicators in the short term while oil shocks have permanent effects mostly on inflation and the least affected indicator is the oil prices in the long term. In addition, they noted that there is a continuous positive correlation between oil prices and real exchange rates while this does not apply to price inflation. Ahmed et al. (2019) showed that the shocks in oil prices have significant effects on economies of countries both in the short and long term. Nasir et al. (2019) demonstrated that economies react differently to oil shocks. Van Eyden et al. (2019) reported that the volatility in oil prices has significant effects on economic growth of countries and oil-producing countries are negatively affected by oil price uncertainty to a great extent. Yasmeen et al. (2019) emphasized that changes in oil prices have different effects on sectoral growths in the short and long terms.

To maintain economic development and attain industrialization goals, increasing energy costs create links between oil prices and output growth, particularly in the oil-importing developing countries. In the case that the resources required for the production activities that ensure increases in production rates for stable and sustainable growth are insufficient, intermediate inputs are imported. Uncertainties in the prices of oil, a raw material without any substitute, can impact macroeconomic indicators of oil-importing or oil-exporting developed or developing countries. Fluctuations in oil prices are of great importance, in terms of production and costs, for the import and export policies of Turkey, which uses oil both as a production input and final energy resource. In this study, the effects of shocks in crude oil (petroleum) price index on output growth in Turkey, an oil-importing developing country, are examined for the monthly periods of 1986:M01–2019:M06 using structural vector autoregression with a multivariate generalized autoregressive conditional heteroscedasticity in-mean (SVAR-GARCH-M) method.

2. Methodology

SVAR models are identified using exclusion restrictions on the structural shocks' impact effects, restrictions on the shocks' long-run effects or restrictions on the signs of the specific variables' responses to a shock. The VAR(p) model can be expressed as $y_t = v + A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t$ where $y_t = (y_{1t}, \dots, y_{Kt})'$ is a vector of observable variables,

the A_i are coefficient matrices, v is a constant term and the u_t are K -dimensional serially uncorrelated reduced form residuals with mean zero and nonsingular covariance matrix Σ_u . The structural residuals (ε_t), assumed to be instantaneously uncorrelated ($\varepsilon_t \sim (0, \Sigma_\varepsilon)$) where Σ_ε is a diagonal matrix, has zero mean and is serially uncorrelated. The structural residuals, where the matrix B , any matrix satisfying $\Sigma_u = B\Sigma_\varepsilon B'$, includes the instantaneous effects of the structural shocks on the observed variables, are obtained from the reduced form residuals

$$\varepsilon_t = B^{-1}u_t \quad (1)$$

by a linear transformation. Due to the fact that the structural innovations are not uniquely determined the restrictions made on or its inverse *just-identifies* the structural model and the structural shocks (Lütkepohl and Netsunajev, 2015). The variances of the reduced form and the structural innovations change over time when u_t is a heteroskedastic, and each regime is characterized with, $\Sigma_u(m)$, covariance matrix. When the corresponding covariance matrices are decomposed as

$$\Sigma_u(m) = B\Lambda_mB', \quad m = 2, \dots, M \quad (2)$$

with the matrices of variances of structural shocks in regime m relative to regime 1, $\Lambda_m = \text{diag}(\Lambda_{m1}, \dots, \Lambda_{mK})$, and the structural shocks are normalized to have unit variances in the first volatility regime (Λ_1), then the structural shocks, obtained in Equation (1), are instantaneously uncorrelated in all volatility regimes. The matrix of impact effects of the shocks, B , is (locally) uniquely determined by the decomposition in Equation (2) if for any subscripts $k, l \in \{1, \dots, K\}$, $k \neq l$ there is a $j \in \{2, \dots, M\}$ such that $\lambda_{jk} \neq \lambda_{jl}$ (Lanne et al., 2010). The statistical model becomes important in the identification procedure on SVARs with heteroscedasticity to obtain exact identification via changes in volatility and additional economic restrictions are imposed after the statistical identification is achieved (Lütkepohl and Netsunajev, 2015).

There are several approaches for modelling changes in volatility. This paper models the changes in volatility using a generalized autoregressive conditional heteroscedasticity (GARCH) process. The conditional covariance matrix of u_t (reduced form errors follow a multivariate GARCH process given F_{t-1} , information set, is assumed to be of the form $E(u_t u_t' | F_{t-1}) = B\Sigma_{\varepsilon,t|t-1}B'$ where $\Sigma_{\varepsilon,t|t-1} = \text{diag}(\sigma_{1,t|t-1}^2, \dots, \sigma_{K,t|t-1}^2)$ is a diagonal matrix. The individual variances of structural shocks are assumed to have a GARCH (1,1) structure to avoid unnecessarily clumsy notation.

$$\sigma_{k,t|t-1}^2 = (1 - \gamma_k - g_k) + \gamma_k \varepsilon_{k,t-j}^2 + g_k \sigma_{k,t-j|t-j-1}^2, \quad k = 1, \dots, K \quad (3)$$

The unconditional covariance matrix of the structural errors is the identity and $E(u_t u_t') = \Sigma_u = BB'$. The conditional variances should have enough heterogeneity to identify the shocks (Lütkepohl and Netsunajev, 2015).

3. The Effects of Oil Price Uncertainty

Crude oil (petroleum) price index, covers simple average of three spot prices (Dated Brent, West Texas Intermediate, and the Dubai Fateh), obtained from International Monetary Fund (IMF) commodity price system, and gross domestic product (GDP), organized according to the base year, obtained from the Central Bank of the Republic of Turkey CBRT electronic data distribution system (EDDS) are used to examine the effect of oil price uncertainty on Turkey's output growth for the monthly period 1986:M01–2019:M06 by the bivariate structural vector autoregression (SVAR) with a multivariate GARCH error structure in which the lagged conditional standard deviation of oil price enters the mean equations of the VAR. Seasonal influences are removed from the series using the Tramo/Seat method. Utilizing the logarithmic first-order differences of the oil price and real GDP variables and multiplying them by 100, growth measures expressed as percentage changes are obtained. For stationary testing of adjusted variables, the Augmented Dickey–Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Phillips–Perron (PP) unit root tests are performed, both with and without a trend, and it is observed that variables are stationary at level. The data are graphed in Figure 1.

Figure 1. (a) Oil price growth rate and (b) output growth rate

While the effect of an oil price uncertainty on output growth can be revealed using a SVAR, the effect of the variance changes in oil price on output growth can be observed by using a GARCH-M model. The impact of uncertainty, as measured by the estimated

conditional standard deviation from a multivariate GARCH specification, on output growth is examined by allowing the conditional volatility of oil price in the mean equations of the SVAR. The GARCH effects can improve the efficiency of the estimates of lag coefficients and change the definition of the shocks. Due to the fact that variance in output growth will not cause a mean shift in oil price growth, the restriction that the only mean effect is on the oil price variance.

The VAR system is set up with four lags on each variable based on an analysis of the Akaike information criterion (AIC) and including a standard deviation of oil price (M-term) which will be generated as part of the likelihood evaluation. The SVAR-GARCH-M equation, the residuals are computed as part of the calculation because M term enters the model equation structure, while the SVAR-GARCH coefficients, the GARCH model applied only to the residuals, are estimated with a two-step process. The parameters are estimated using full information maximum likelihood (FIML). Table 1 displays the estimation results.

Table 1
SVAR-GARCH-M estimation results

BVEC(1)(1)	0.5454***	BVEC(2)(1)	0.0363***	B	-0.1005***
BVEC(1)(2)	-0.3071***	BVEC(2)(2)	0.0203	G(1)(1)	0.0109***
BVEC(1)(3)	0.2692***	BVEC(2)(3)	0.0126	G(1)(2)	0.0731***
BVEC(1)(4)	-0.0446	BVEC(2)(4)	-0.0180***	G(1)(3)	0.8120***
BVEC(1)(5)	-0.3774***	BVEC(2)(5)	-0.3038***	G(2)(1)	0.0709***
BVEC(1)(6)	-0.2696***	BVEC(2)(6)	-0.2278***	G(2)(2)	0.1971***
BVEC(1)(7)	-0.2370**	BVEC(2)(7)	-0.2389***	G(2)(3)	0.7148***
BVEC(1)(8)	-0.1609***	BVEC(2)(8)	0.5817***		
BVEC(1)(9)	0.0291***	BVEC(2)(9)	0.0228***		
BVEC(1)(10)	0.0000***	BVEC(2)(10)	-0.1095***		
SIC for SVAR-GARCH: 450.6710			SIC for SVAR-GARCH-M :447.9382		

G(.) (1) is the variance intercept, G(.) (2) is the coefficient on the lagged squared residual and G(.) (3) is the coefficient on the lagged variance of the GARCH models on the structural residuals. Due to the fact that the GARCH parameter estimates are positive and statistically significant, it can be said that there is evidence of heteroscedastic effects and shocks are linked to increases in uncertainty. Moreover, the M effect is the BVEC(2)(10) coefficient, the contemporaneous response of growth output to oil price uncertainty, is negative and statistically significant, which has the expected sign. Schwarz criterion is computed and the SVAR-GARCH-M model is found more preferable. The impulse-response functions for the

SVAR-GARCH and SVAR-GARCH-M specification are displayed in Figure 2.

Figure 2. (a) Response of output growth to positive oil price shock with M-term, (b) response of output growth to negative oil price shock with M-term, (c) response of output growth to positive oil price shock without M-term and (d) response of output growth to negative oil price shock without M-term

The volatility response is dependent upon the context in which the shock is made because of non-linearity. There is a difference between computing impulse responses (for the mean) in this model and standard model, since the volatility response feeds into the mean effect (M-term) and both the size of the shock (for the volatility effects) and the sign (for the mean effects) is important. Due to the fact that there's no fixed covariance matrix, to provide a natural size and shape, the size of the shock is chosen as the square root of the estimated GARCH variance. The response to a positive (negative) oil price shock is to decrease (increase) output growth. The model is estimated both with and without the M terms to show how the variance terms enter the responses. However, a much smaller decline(increase) in output growth is observed if the impact of uncertainty is removed. The effect of the variance dominates both the positive and negative IRF's, almostly, after two years. IRFs with simulated confidence bands are displayed in Figure 3. Due to the nonlinear nature, Random Walk Metropolis is used to compute the error bands.

Figure 3. The IRFs confidence interval:(a) responses of output growth to positive oil price shock and (b) responses of output growth to negative oil price shock

4. Results and Findings

Since the expectations and uncertainties regarding the commodity market can affect macroeconomic variables directly or indirectly, fluctuations in prices are crucial for policy makers and market practitioners. In this study, the crude oil price index is chosen to represent commodity prices, considering its high trading volume and its macroeconomic effects on economies as well as financial markets. In this study, the structural relation between oil price uncertainty and output growth is represented as a structural vector autoregression with a generalized autoregressive conditional heteroscedasticity error structure. Uncertainty in oil prices may affect economic activity through conversion mechanisms or different channels. Changes in oil prices have structural effects on the economy because of the dependence on oil. In developing countries, which are characterized by structural problems, tend to close the budget deficits through borrowing, and import oil, the increase in oil prices may lead to increases in the prices of goods and services and inflation by pushing up the direct input costs. In oil-exporting countries, conversely, oil helps to increase the export item, and therefore, increases in oil prices have positive effects on the economy. Since shocks in oil prices complicate decision-making process, determine the distribution of the resources that may be used for investment, make long-term policy decisions subject to revisions, influence macroeconomic variables, and result in the emergence of inflation uncertainty, these shocks impact the financial sector, real sector and also regulatory authorities through interaction with macroeconomic variables.

Owing to the dependence of production and industry on oil, fluctuations in oil markets have significant effects on economic growth. Increases in the prices of imported commodities and decreases in the value of exported goods create inflationist effects and affect the balance

of payments. Efficiency declines as the amount of the imported energy decreases. National income decreases and economic growth is adversely affected because of the hindrance of production as one of the basic elements of economic growth. Since it uses imported inputs for the production activities geared toward exports or domestic demand, Turkey is adversely affected by oil price uncertainty and if inflow of sufficient foreign currency cannot be ensured, current deficit increases. Due to the fact that oil is not only a final product but also a compulsory production input in the industry sector, and it is crucial for the continuity of production, Turkey, as a developing and oil-importing country, should turn to alternative energy sources to avert oil price uncertainties and ensure sustainable growth through clean energy.

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