Journal of Economic Integration
Vol. 40, No. 1, March 2025, 145-155
https://doi.org/10.11130/jei.2024042

pISSN: 1225-651X eISSN: 1976-5525

Effects of Oil Supply News on Korean GDP, Prices and Net Exports: A Proxy FAVAR Approach

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Abstract We consider a proxy FAVAR (Factor-Augmented Vector Autoregression) model to analyze the impact of an oil supply news shock on the Korean economy. To identify an oil supply news shock, we use the variation in oil futures prices around OPEC production announcements as a proxy. Moreover, we include a factor that captures the common movement of many Korean macro variables such as various price indices and investment. The estimation results of the proxy FAVAR model show that an oil supply news shock increases the real oil price and the US CPI, and decreases world oil production and US GDP. As for Korean macro variables, GDP and net exports fall and CPI increases in response to the shock.

Keywords: External Instruments, Factor, High-Frequency Data, OPEC, Oil Supply News Shocks

JEL Classifications: E31, E32, Q43

Received 21 August 2024, Revised 31 August 2024, Accepted 5 September 2024

I. Introduction

Changes in oil prices have been widely regarded by macroeconomists as a key source of economic fluctuations (Blanchard and Galí, 2010; Kim, 2024). Consequently, numerous studies have sought to accurately identify the effects of oil prices on the macroeconomy. In this study, we examine the impact of oil prices on the Korean economy using a proxy FAVAR (Factor-Augmented Vector Autoregression) model.

Most research on the impact of oil prices on the macroeconomy employs VAR models, which typically use recursive ordering or sign restrictions to identify structural shocks. However,

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Funding: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2022S1A3A2A01088457).
Acknowledgement: We would like to thank an anonymous referee. We also clarify that this work is a substantially revised version of the research report for a project commissioned by the Korea Energy Economics Institute. All remaining errors are our own.

the VAR framework is limited by the curse of dimensionality, preventing the inclusion of a large number of variables. As a result, important variables that could contain critical information might be excluded, leading to potential omitted variable bias in empirical models. Furthermore, it is challenging to disentangle the effects of global economic developments on oil prices, which can result in endogeneity issues.

To address these challenges, we propose using a proxy FAVAR model. Specifically, to mitigate omitted variable bias, we estimate a unobserved factor that captures the common movement of various Korean macroeconomic variables. The estimated factor is included as an endogenous variable in the model. Our estimation results suggest that one factor is the most appropriate for this purpose, which we then include in the VAR model.

To deal with potential endogeneity, we employ an external instrument (proxy). Specifically, we use variations in oil futures prices around the Organization of Petroleum Exporting Countries (OPEC) production announcements as a proxy. OPEC holds two ordinary conferences in Vienna each year, with the option to convene extraordinary meetings on short notice if necessary. The issue of reverse causality from the global economic outlook is mitigated because the outlook is already reflected in the futures prices at the time of the announcement. Additionally, since the global economic outlook is unlikely to change within a narrow time window, using this variation as a proxy allows us to isolate the impact of news related to future oil supply.

Our focus is on the responses of Korea's GDP, net exports, and consumer price index (CPI) to an oil supply news shock. Therefore, we include these three variables as endogenous variables in the proxy FAVAR model. Moreover, given that Korea is considered a small open economy and the Korean economy is integrated in the global economy, we include US GDP and CPI in the model, with US GDP serving as a proxy for global economic activity (i.e., global oil demand). We also incorporate the real oil price and world oil production (global oil supply) into the VAR model. The data sample period for this study spans from Q1 1974 through Q4 2022.

The estimation of the proxy FAVAR model reveals that an oil supply news shock increases the real oil price and US CPI while decreasing world oil production and US GDP. In the case of Korean variables, GDP and net exports decrease, while CPI increases in response to the shock.

This paper contributes to the literature on oil prices and the macroeconomy. Most studies conclude that oil prices significantly impact the macroeconomy (Hamilton, 1983; Burbidge and Harrison, 1984; Rotemberg and Woodford, 1996; Cuñado and Gracia, 2003; Leduc and Sill, 2004, among others). However, some research indicates that oil prices have minimal effects on the macroeconomy (Kim and Loungani, 1992; Dhawan and Jeske, 2008, etc.). Other studies argue that the relationship between oil prices and macroeconomic variables weakens or becomes insignificant when using more recent data (Darrat et al., 1996; Hooker, 1996; Blanchard and Galí, 2007; Kim, 2020, etc.).

Additionally, this paper is related to the body of work on proxy VAR models (e.g., Mertens and Ravn, 2013; Gertler and Karadi, 2015). Among these, Känzig (2021) is most closely related to this study. Känzig (2021) analyzes the macroeconomic effects of oil supply news by leveraging OPEC's institutional characteristics and high-frequency data to identify an oil supply news shock, demonstrating that the shock has statistically and economically significant effects. Känzig (2021) also shows that high-frequency oil supply surprises are strong instruments for oil prices. Our paper builds on Känzig (2021) by using these high-frequency oil supply surprises as an external instrument (proxy) and extends the literature by incorporating a factor into the proxy VAR model.

Finally, this study has an important policy implication. Specifically, in an economically integrated environment, to accurately analyze the impact of a certain shock on the economy (especially in small open economies) empirical and theoretical models should consider other countries, such as the US.

The remainder of the paper is organized as follows: Section II explains the econometric approach, Section III presents the estimation results of the proxy FAVAR model, and Section IV concludes the paper.

II. Econometric Approach

Our approach consists of two steps. First, we estimate factors that capture the common movements of various Korean macro variables that are not included as endogenous variables in the model. Then, we estimate the proxy FAVAR model in which the estimated factor is included.

A. Estimating Factors

To estimate the factors, we use the following equation:

$$X_t = \Lambda^F F_t + \Lambda^z z_t + u_t, \tag{1}$$

where X_t is the $N \times 1$ observed data in time t; F_t is the $k \times 1$ vector of the unobservable factors that represent the common movement in the left-hand side variables; Λ^F is the $N \times k$ factor loading matrix; z_t is $r \times 1$ observed variables included in the proxy FAVAR, and Λ^z is a $N \times r$ matrix. Specifically, X_t contains 24 logarithmic variables.[1] Note that some variables

1) The 24 variables are private final consumption expenditure, government final consumption expenditure, construction

such as interest rates are not included in X_t because they are not available for the sample period (Q1 1974-Q4 2022). z_t includes the real oil price, US CPI, world oil production, US GDP, Korean GDP, Korean net exports, and Korean CPI in logarithmic form.[2] By including z_t in the right hand side, one can estimate F_t that drives the variables in X_t but cannot be explained by z_t.

To estimate the unobserved factor(s), the number of factors must be determined. For a given number of factors (say k), we can estimate F_t^k and $\Lambda^{F,k}$ that minimize $V(k)$ given in Equation (2) in the following manner. In the initial step, the z_t variables are ignored and the initial estimates for F_t^k (and $\Lambda^{F,k}$) are obtained via the principal component analysis (PCA). Next, this initial estimate for F_t^k is plugged in Equation (1), and the loading matrices (Λ^F and Λ^z) are estimated by OLS. Then replace Λ^z by its estimate (denoted by $\widetilde{\Lambda}^z$) in Equation (1) and consider the following factor equation to estimate the factor again via the PCA: $X_t - \widetilde{\Lambda}^z z_t = \Lambda^F F_t + u_t$.

$$V(k) = \min_{\Lambda^k, F^k} (NT)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(X_{i,t} - \lambda_i^{F,k\prime} F_t^k - \lambda_i^{z,k\prime} z_t\right)^2. \tag{2}$$

In the next step, the estimates for F_t^k obtained in the preceding step is plugged in Equation (1) and estimate the loading matrices (in particular, $\widetilde{\Lambda}^z$) by OLS. Then go back to the equation $X_t - \widetilde{\Lambda}^z z_t = \Lambda^F F_t + u_t$ and obtain an estimate Λ^F and F_t^k by the PCA. Repeat these procedures until a criteria for convergence is satisfied. Finally, the estimates for Λ^F, F_t^k, and Λ^z can be obtained for each given value of k. For detailed estimation methods, see Bai (2004), Boivin and Giannoni (2009), and Kilian and Lütkepohl (2017).

To determine the number of factors, we calculate $V(k)$, $k = 1, 2, \ldots, k_{\max}$. We find k that minimizes the following equation (See Bai, 2004):

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investment, facilities investment, intellectual property products, inventory changes, goods and services exports and imports, the sectoral GDP (agriculture, forestry and fisheries, manufacturing, construction, utilities, services, finance and insurance, mining), Korean won to U.S. dollar exchange rate, producer price index (PPI), energy PPI, food PPI, overall export and import price indices, and M1. All are obtained from the Bank of Korea.

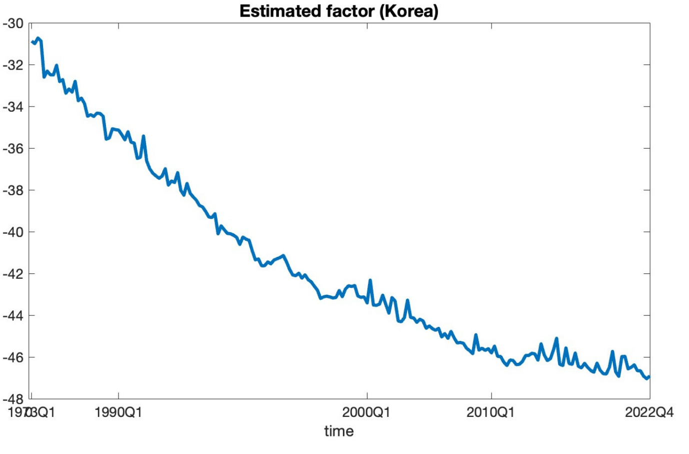
2) We use the WTI spot price deflated by the US CPI as the real oil price. The source of the WTI spot price and the US CPI is the Federal Reserve Economic Data (FRED). The source of world oil production is from the US Energy Information Administration, the source of US GDP, Korean GDP, and Korean net exports (exports/imports) is from the OECD, and the Korean CPI is from the FRED.

$$IPC(k) = V(k) + k\hat{\sigma}^2 \alpha_T \left(\frac{N+T}{NT}\right) \log\left(\frac{NT}{N+T}\right). \tag{3}$$

where $\hat{\sigma}^2 = V(k_{\max})$ and $\alpha_T = \frac{T}{4\log log(T)}$.

When we set $k_{\max} \leq 5$, the number of factors is estimated to be 1. Figure 1 shows the estimated factor. The estimated factor represents an unobserved factor that drives the variables in X_t but cannot be explained by z_t (the global oil market variables and the U.S. macro variables)

Figure 1. Estimated factor



B. Estimating the Proxy FAVAR Model

We consider the following VAR model:

$$Ay_t = \sum_{j=1}^{p} C_j y_{t-j} + \epsilon_t, \tag{4}$$

where y_t is a vector containing 8 variables: log real oil price, log US CPI, log world oil production, log US GDP, log Korean GDP, log Korean net exports, log Korean CPI, and the factor estimated above. A and C_j, $j = 1, 2, ..., 8$, are 8×8 matrices of coefficients, and ϵ_t denotes an 8×1 vector of structural shocks.

By multiplying both sides of equation (4) by A^{-1}, the reduced form can be obtained.

$$y_t = \sum_{j=1}^{p} B_j y_{t-j} + u_t, \tag{5}$$

where u_t is an 8×1 vector of reduced form shocks. From equations (4) and (5), the relationship between u_t and ϵ_t can be written as

$$Au_t = \epsilon_t,\ u_t = S\epsilon_t,\ S = A^{-1}, \tag{6}$$

Since $E\left[\epsilon_t \epsilon_t^T\right] = I$, where E is the expectation, I is an 8×8 identity matrix, and the superscript T denotes transpose, the 8×8 variance-covariance matrix of the reduced form is

$$\Sigma = E\left[u_t u_t^T\right] = E\left[S\epsilon_t \epsilon_t^T S^T\right] = E\left[SS^T\right]. \tag{7}$$

Let the first element of y_t (say y_t^1) be the real oil price. Then, the first element of ϵ_t (say ϵ_t^1) is the associated real oil price shock. To obtain impulse responses of variables to the shock, we need to identify only the first columns of $S=\left[s^1, s^2, \cdots, s^8\right]^T$, since we can obtain estimates of B_j by using least squares estimation of equation (5).

Let p_t be the instrumental variable for the real oil price shock (i.e., the oil supply surprise series).[3] In order for p_t to be a valid instrument, following conditions (relevance and exogeneity conditions) should be satisfied.

$$E\left[p_t \epsilon_t^1\right] \neq 0, \quad E\left[p_t \epsilon_t^2\right] = E\left[p_t \epsilon_t^3\right] = \cdots = E\left[p_t \epsilon_t^n\right] = 0 \tag{8}$$

Let $\hat{u}_t$ be the estimate of u_t by OLS of equation (5), and let $\hat{u}_t^h$ $(h = 1, 2, \cdots, 8)$ be the hth element of $\hat{u}_t$. To obtain estimates of $\left[s^1, s^2, \cdots, s^8\right]^T$, first, regress $\hat{u}_t^1$ on p_t and obtain the fitted value of $\hat{\hat{u}}_t^1$. By doing this, we can isolate the variations in $\hat{u}_t^1$ owing to the structural real oil price shock (ϵ_t^1). Then, regress $\hat{u}_t^k$ $(k = 2, 3, \cdots, 8)$ on $\hat{\hat{u}}_t^1$. Since the coefficient of this regression means the variation of $\hat{u}_t^k$ caused by the variations in $\hat{u}_t^1$ owing to ϵ_t^1, it is s^k / s^1.

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3) We use the updated oil supply surprise series of Känzig (2021), which can be found at https://www.diegokaenzig.com/data. We present the detailed method for constructing a time series of oil supply surprises in the online Appendix.

$$\hat{u}_t^k = \frac{s^k}{s^1}\hat{u}_t^1 + \zeta_t. \tag{9}$$

If we can find s^1, other elements of the first column of S are easily found from the estimates of equation (9). s^1 can be obtained from equations (7) and (9). First, partition S and Σ. Then, from equation (7),

$$S = \begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s_{2,2} \end{pmatrix}, \ \Sigma = \begin{pmatrix} \Sigma_{1,1} & \Sigma_{1,2} \\ \Sigma_{2,1} & \Sigma_{2,2} \end{pmatrix} = \begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s_{2,2} \end{pmatrix}\begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s_{2,2} \end{pmatrix}^T. \tag{10}$$

Then,

$$\begin{aligned} (s^1)^2 &= \Sigma_{1,1} - s_{1,2}s_{1,2}^T, \\ s_{1,2}s_{1,2}^T &= \left(\Sigma_{2,1} - \frac{s_{2,1}}{s^1}\Sigma_{1,1}\right)^T Q^{-1}\left(\Sigma_{2,1} - \frac{s_{2,1}}{s^1}\Sigma_{1,1}\right), \\ Q &= \frac{s_{2,1}}{s^1}\Sigma_{1,1}\frac{s_{2,1}^T}{s^1} - \left(\Sigma_{2,1}\frac{s_{2,1}^T}{s^1} + \frac{s_{2,1}}{s^1}\Sigma_{2,1}^T\right) + \Sigma_{2,2}. \end{aligned} \tag{11}$$

Therefore, the ordering of variables is arbitrary in this framework.

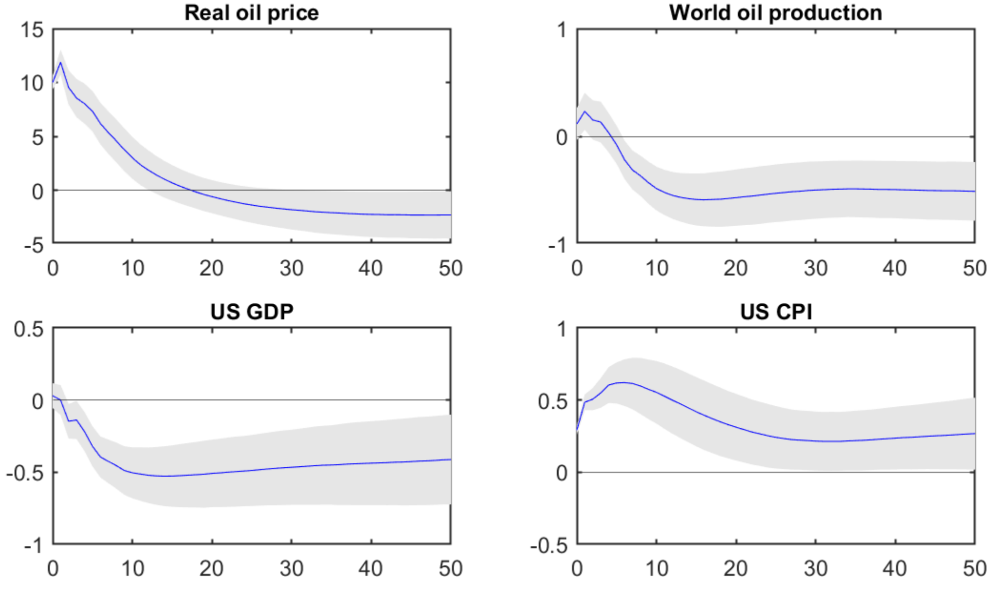
III. Estimation Results

In this section, we provide the estimated impulse response functions of the proxy FAVAR model to an OPEC oil supply news shock. The sample period is Q1 1974-Q4 2022, and the lag length is set to be four, as is usual for quarterly data analysis.

Figure 2 shows the impulse responses of US and oil market variables to a positive oil supply news shock. Note that the oil supply surprise increases when oil futures prices rise after the OPEC announcement. Therefore, a positive oil supply news shock increases the real oil price. Moreover, an increase in oil futures prices after the OPEC announcement implies that the conference decided to reduce OPEC production. Hence, a positive oil supply news shock decreases world oil production. Note, however, that there is an increase in world oil production in the first quarter after the shock. This is because even if the conference decides to reduce OPEC production, the decision takes effect 30 days later. In addition, an increase in the real oil price due to the shock can lead to an increase in oil production in non-OPEC countries. In response to a positive oil supply news shock, US GDP decreases, and its CPI increases.

These responses of US variables are natural because the U.S. is a major oil-importing country. Thus, an increase in the real price of oil triggered by the shock has adverse effects on the US economy.

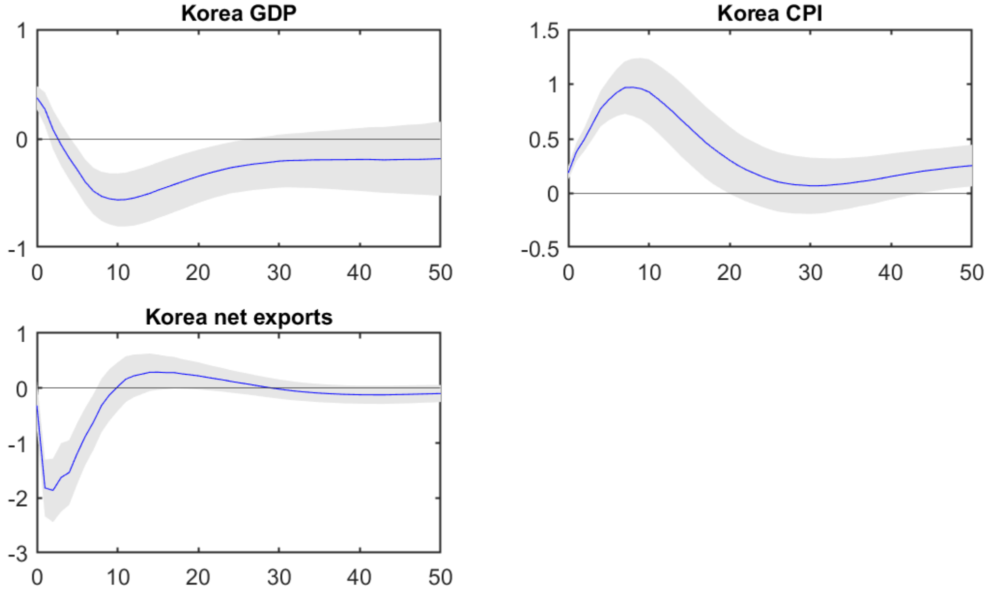
Figure 2. Impulse responses of US and oil market variables to a positive oil supply news shock



Notes. The solid lines are the median impulse response, and the dashed lines are 68% confidence intervals obtained by bootstrapping with 5,000 draws. The units of the X and Y axes are quarters and percent, respectively.

Figure 3 shows the impulse responses of Korean macro variables to a positive oil supply news shock. Specifically, the shock, which increases the real price of oil, decreases GDP and net exports and increases the CPI. These responses to the shock are also natural given that Korea is an oil importer. Hence, the shock that increases the real oil price has a negative impact on the Korean economy. Note, however, that Korean GDP increases in the first two quarters after the shock. This is mainly because US GDP does not fall in the first two quarters after the shock and because world oil production increases in the first quarter after the shock.

Figure 3. Impulse responses of Korean variables to a positive oil supply news shock



Notes. The solid lines are the median impulse response, and the dashed lines are 68% confidence intervals obtained by bootstrapping with 5,000 draws. The units of the X and Y axes are quarters and percent, respectively, except for net exports. The unit of the Y-axis for net exports is percentage points.

IV. Conclusions

This paper considers a proxy FAVAR model to analyze the effects of oil supply news shocks on the Korean economy. We include the global oil market variables and some important U.S. macro variables in the VAR system in order to reflect the key feature of the Korean economy which is basically fully integrated in the global economic system. We use the variation in oil futures prices around OPEC production announcements, obtained from Känzig (2021), as an external instrument to accurately identify an oil supply news shock. Moreover, to mitigate the curse of dimensionality we estimate a factor that captures the common movements of various Korean macro variables and include the factor in the proxy FAVAR model.

According to the estimation results of the proxy FAVAR model, a positive oil supply news shock increases the real oil price and the US CPI, and decreases world oil production and US GDP. Regarding Korean macro variables, GDP and net exports fall and CPI increases in response to the shock.

It should finally be noted that we use only institutional features of OPEC and high-frequency data to analyze the impact of the oil price on the Korean economy. However, according to Antolín-Díaz and Rubio-Ramírez (2018), narrative sign restrictions, that constrain the structural shocks and/or the historical decomposition around key historical events, are very helpful to accurately identify structural vector autoregressions for the oil market. Therefore, it would be interesting to add narrative sign restrictions to the proxy FAVAR model in this paper. However, it is beyond the scope of this paper, so we leave it for future research.

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