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The Effect of Oil Prices on Industrial Production in Oil-importing Countries: Panel Cointegration Test

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ABSTRACT

The industrialization levels of the countries are an indicator of development. Countries trying to increase their production in the industrial sector prefer to have access to energy in a cheap and easy way. However, economies that do not have sufficient energy reserves may be affected by the changes in energy prices since they will import the necessary energy input. Although there are many studies discussing the effects of energy or oil prices on macroeconomic variables in countries, the research based on industrial production is limited. In this study, the long-term relationship between the changes in oil prices and industrial production in the ten most oil-importing countries (China, Germany, India, Italy, Japan, Netherlands, South Korea, Spain, United Kingdom and United States) was analyzed by Pedroni, Kao and Johansen Fisher cointegration tests. According to the empirical findings of the study, it is concluded that the relationship between the industrial production of oil importing countries and oil prices is positive. This situation can be interpreted as these countries with high levels of industrialization process the crude oil and market the products they produce to foreign countries more profitably.

Keywords: Oil Price, Import, Industrial Production Index, Panel Cointegration, FMOLS, DOLS
JEL Classifications: O10, Q30, Q43

1. INTRODUCTION

In order to ensure development, competing economies in the global world try to provide production and employment structure through industry and service sectors instead of agriculture. The increase in industrial production increases the economic output data of countries and creates positive effects on macroeconomic indicators. On the other hand, energy is the main input of industrial production. Since energy can be an advantage for countries with reserves, it also poses a problem especially for developing countries that lack reserves. Countries that do not have reserves provide energy through imports and thus aim to increase production. However, foreign dependency in energy causes it to be more easily affected by external developments.

Especially the oil shocks that took place in the 1970s, followed by the significant fluctuations in oil prices caused economists and policy makers to focus their attention on the relationship between oil prices and economic activities. The main reason for this is that crude oil is one of the most important energy sources for all economies, regardless of industrialized or developing countries. As it is an important input, the course of crude oil prices is closely monitored. However, many empirical studies are carried out in order to investigate the effects of oil prices on national economies. Many researchers have contributed to the literature on the relationship between oil prices and economic and financial variables, starting with the work of Hamilton (1983). Sadorsky (1999), Basher and Sadorsky (2006), Park and Ratti (2008), Imarhiagbe (2010), Lee and Zeng (2011), Lee et al. (2012), Syzdykova (2018) examining the relationship between oil prices and stock market index; Camarero et al. (2002), Korhonen and Juurikkala (2009), Buetzer et al., (2012), Lin and Su, (2020), Musa et al. (2020), Ding et al. (2020) analyzing the relationship between oil prices and exchange rate, Lardic and Mignon (2008), Lescaroux and Mignon (2008), Mehrara and Mohaghegh (2011), Hamilton (2012), Ashley and Tsang (2013), Maghyereh et al. (2019), Mo et al. (2019), van Eyden et al. (2019), Maheu et al. (2020) examined the relationship between oil prices and growth. In almost all studies investigating the relationship between oil prices and economic growth, the GDP variable has been used as an indicator of economic growth.

In the following part of this study, which aims to examine the relationship between the industrial production index and oil prices in oil-importing countries, the relevant literature is reviewed. Then, the data set and econometric methodology used in the study are explained. In the next section, the empirical finding part is given and the study is completed with the conclusion part.

2. LITERATURE REVIEW

Studies on the macroeconomic effects of oil prices are quite abundant in the economics literature. Similar results have not been obtained in all studies investigating the relationship between oil prices and industrial production index. In this study, the findings of the studies related to oil-importing countries within the scope of the research subject are summarized. Mork et al. (1994), in their study covering the USA, Canada, Japan, Germany, France, United Kingdom and Norway, found that there is a negative and significant relationship between oil price increase and output for countries other than Norway, but no statistically significant contribution of oil price decline. Cuñado and de Gracia (2003) applied a cointegration test that allows structural breakage in a study in which they analyzed the impact of oil price shocks on industrial production and consumer price indices for 14 European countries, and made different transformations to oil price data to take into account the possible nonlinear relationship. They found that oil prices had a permanent effect on inflation and had a short-term but asymmetrical effect on production growth rates, and there was a significant difference in countries' responses to these shocks. Hamilton and Herrara (2004), as a result of the VAR analysis, found that capacity utilization reacted positively to oil price shocks in the 1st and 2nd years, and negatively after the 3rd year. They interpreted that thus reducing the capacity utilization, which would lead to a decrease in total industrial output.

Huang et al. (2005) examined the effects of changes in oil prices and sudden changes in oil prices (oil shock) on industrial production by establishing a multivariate threshold model (MVTAR) in the study where the USA, Canada and Japan were discussed. It has been stated that determining the most appropriate threshold value for countries, the dependence of the country's economies on oil is effective. It has been concluded that if there is a change in oil prices above the threshold value, the effect of oil prices on the economy is more effective than the effect of the volatility in oil prices on the economy, but that both have a limited effect on the output level in case of a change below the threshold value.

Other studies arguing that oil prices have a negative impact on industrial production include Lee and Ni (2002), Jimenez-Rodriguez (2007), Lippi and Nobili (2008), Bredin et al. (2008), Kumar (2009) and Tang et al. (2010). Cobo-Reyes and Quiros (2005) also investigated the relationship between oil price shocks and industrial production, industrial production and stock returns, and concluded that the increase in oil prices negatively and significantly affected industrial production and stock returns. However, this increase had a greater effect on stock returns than industrial production.

Cuñado and de Gracia (2005) revealed that there is no long-term cointegration between oil price and industrial production in Asian countries, its effect is limited in the short term, and that oil price shocks are the Granger cause of output. Jiménez-Rodríguez and Sánchez (2005), as a result of their analysis, revealed that oil price shocks in Japan caused a decrease in industrial production and an increase in inflation, and the relationship between them was not linear.

Blanchard and Gali (2007) analyzed the effects of oil price changes on macroeconomic variables with structural VAR analysis for USA, France, Germany, United Kingdom, Italy and Japan. Findings showed that the complete response to output and employment weakened over time. Zhang (2008) investigated the relationship between oil price shock and Japanese industrial production for the period 1957-2006 and concluded that a non-linear relationship emerged between them. Jimenez-Rodriguez (2008) analyzed the effect of oil price shocks on product output for 6 OECD countries using the VAR model and found that oil price shocks were the same for the USA and the United Kingdom.

Fukunaga et al. (2010) investigated the effects of oil price changes on each composition of industrial production with the VAR model and argues that the effects of oil price changes change according to the characteristics of the industry. Herrera et al. (2011) investigated the effects of oil price shocks on industrial production and sectoral components for the USA and found that the industry's response to real oil price shocks was asymmetrical. Where the sectors were unbundled, they found strong support for asymmetry, especially in energy-intensive industries. Kilian and Vigfusson (2011) reached findings that support the asymmetry effect of oil price shocks in the transition to output for USA.

Ashley and Tsang (2013) decomposed the effect of oil price changes on output growth for 6 countries that are net oil importers by frequency of time series and found that oil price changes have a large and statistically significant effect on future output growth if they are continuous for more than 4 years. However, they found that changes less than 4 years but longer than 1 year had no significant effect on output growth. They conclude that it has a large and statistically significant effect in case of temporary fluctuation less than 1 year. Maghyereh et al. (2019), the period of January 1986 to December 2014 in Jordan and Turkey investigated the effect of oil price uncertainty on real economic activity. The uncertainty in the oil market, studies using bivariate structural VAR and GARCH method shows that Jordan and Turkey's industrial production negatively. Therefore, the authors argue that sound energy policies in these countries, which reduce the impact of oil market uncertainty, will help stabilize production in both countries.

3. ECONOMETRIC METHOD

3.1. Data Set and Model

In the study, the effect of the change in oil prices on industrial production in the top 10 oil-importing countries (Table 1) was analyzed with quarterly data for the period 2000Q1-2019Q4. Industrial production index (*IPI*) data used in the analysis were obtained from IFS (International Financial Statistics) database and crude oil prices (*Olip*) data were obtained from EIA.

The econometric model used in empirical analysis is expressed as follows;

$$IPI_{it}=\alpha_{it}+\beta_{it}\, Oilp_{it}+u_{it} \quad (1)$$

First, unit root analysis was applied to industrial production index (*IPI*) and crude oil price (*Olip*) data. Later, Pedroni (1999), Kao (1999) and Johansen Fisher panel cointegration analysis, which takes into account the constant and time effects, are used to examine the existence of long-term relationships between the industrial production index and crude oil prices. Finally, in order to comment on the long-term relationship between these two variables, *FMOS* (Full Modified Ordinary Least Square) method developed by Pedroni (2000) and (Dynamic Ordinary Least Square) method developed by Pedroni (2001) were applied.

3.2. Econometric Methodology

3.2.1. Panel unit root tests

One of the points to be considered in panel data analysis is that the series are stationary. Because, when analysis is made between non-stationary series, spurious regression is encountered and may give biased results. Therefore, stability should be tested first (Syzdykova et al.,2020). Im et al. (2003) and Maddala and Wu (1999) tests were used in the study. Im et al. (2003) consider a regression equation as follows:

$$\Delta Y_{it} = \mu_i + \beta_i Y_{i,t-1} + \sum_{k=1}^{\rho_i}\theta_{i,k}\Delta Y_{i,t-k} + \gamma_i t + \varepsilon_{it} \quad (2)$$

Table 1: Top 10 oil importing countries as of 2019

Rank	Importer	Billion USD	Share in total (%)
1	China	238.7	22.6
2	United States	132.4	12.5
3	India	102.3	9.7
4	Japan	73.1	6.9
5	South Korea	70.2	6.6
6	Netherlands	46.4	4.4
7	Germany	40.7	3.9
8	Spain	30.5	2.9
9	Italy	29.6	2.8
10	United Kingdom	24.5	2.3

Source: EIA, 2020. These countries meet 74.6% of the total crude oil imports in the world.

Where i=1,2,…N and t=1,2,…T will be. In this test, the zero hypothesis is established as "β_i=0 for all i (i.e. horizontal cross-sectional units)," while the alternative hypothesis is formed as "β_i<0 for at least one i." The critical values required dynamics test are taken from table values in Im et al. (2003). Here, the T statistic for each horizontal cross-section unit is calculated as $t_i=\beta_i/sh(\beta_i)$. Then, the $\bar{Z}$ statistic is obtained as follows:

$$\bar{Z}=\left(\frac{\sqrt{N}(\bar{t}-E(\bar{t}))}{Var(\bar{t})}\right)\sim N(0,1) \quad (3)$$

$$\bar{t}=\frac{1}{N}\left(\sum_{i=1}^{N}t_1\right) \quad (4)$$

The panel unit root test developed by Maddala and Wu (1999), also known as the Fisher ADF test, proposed a Fisher type test based on the combination of p values obtained from unit root test statistics for each horizontal section:

$$P=-2\sum_{i=1}^{N}\ln p_i \quad (5)$$

P exhibits a χ^2 distribution with a 2N degree of freedom. The Fisher ADF test does not require a balanced panel data, but can use different lengths of lag in individual ADF regressions.

3.2.2. Panel cointegration tests

Whether there is a long-term relationship was examined by Pedroni, Kao and Johansen Fisher cointegration test. Pedroni put forward several test proposals that allow heterogeneity in cointegration analysis in 1997, 1999, 2000 and 2004 (Asteriou and Hall, 2007. p. 373). This test developed by Pedroni allows heterogeneity between cointegrated vectors both in the short term and in the long term. Kao (1999) cointegration test also accepts the heterogeneity between cointegration vectors, but the rule of endogeneity of independent variables is violated due to asymptotic equivalence. Pedroni (1999) cointegration regression equation represented by the regression equation as follows;

$$y_{it}=\alpha_i+\delta_{it}+\beta_{1i}\,x_{1it}+\beta_{2i}\,x_{2it}+\cdots+\beta_{Mi}\,x_{Mit}+e_{it} \quad (6)$$

t=2000Q1,…,2019Q4; i=1,…,10;m=1,…,M

In equation 6, T represents the number of observations, N represents the number of individuals on the panel, M represents the number of regression variables. Since there are N individuals on the panel, there will be N different equations for each M regressor. $\beta_{1i}+\beta_{2i}+\cdots+\beta_{Mi}$ are the coefficients representing the differences between the individuals in the panel. The α_i parameter is the constant effects parameter that allows the difference between parameter individuals. In addition to this parameter, if there is a deterministic trend among individuals in the panel, the parameter δ_{it} is added to the equation.

3.2.3. FMOLS and DOLS estimations

After applying the cointegration tests, two different methods, the *DOLS* (dynamic ordinary least square) method and the *FMOLS* (Full Modified Ordinary Least Square) method, were used to calculate the final non-deviating coefficient, which was developed by Pedroni (2000) in order to make inferences about the long-term relationship between variables.

FMOLS and *DOLS* methods show success in producing reliable results in small samples. FMOLS tries to overcome this problem by using the kernel estimators of the parameter that causes the problem of endogeneity. In addition, FMOLS uses the covariance matrix of error terms to eliminate problems arising from long-term correlations between cointegration equations and stochastic processes. The theoretical foundations of the FMOLS method can be given by the following equation:

$$y_t^* = y_{t-1}\bar{w}_{12}©_{22}^{-1}u_{2t} \quad (7)$$

It can be expressed as a bias correlation term:

$$y_{12} = y_{12} - \bar{w}_{12}©_{22}^{-1}\xi_{22} \quad (8)$$

Where, Ω and ξ terms are long-term co-variance coefficients calculated using residues u_t=(u_{1t} u_{2t}')'. In this case, FMOLS estimation can be performed with the following equation (9):

$$\theta = \begin{bmatrix}\alpha\\ \beta\end{bmatrix} = \left(\sum_{i=1}^{T} S_t S_t^{'}\right)\left(\sum_{i=1}^{T} S_t y_t^* - T\begin{bmatrix}y_{12}\\ 0\end{bmatrix}\right)^{-1} =$$

$$\left(\left(\sum_{i=1}^{T} x_t^{'} d_t^{'}\right)^{'}\left(\sum_{i=1}^{T} x_t^{'} d_t^{'}\right)^{-1} y_t^* - T\begin{bmatrix}y_{12}\\ 0\end{bmatrix}\right) \quad (9)$$

It is given here as S_t=(x_t' d_t'). However, the DOLS method presents an asymptotically effective estimator that eliminates feedback effects in the cointegration equation. The DOLS method can be expressed by the following equation (10):

$$y_t = x_t^{'}\beta + d_{1t}\psi_1 \sum_{j=q}^{r} \Delta x_{t+j}^{'}\delta + u_{1t} \quad (10)$$

In this equation, *q* and *r* allow to differentiate explanatory variables that eliminate long-term correlation between error terms. The estimation process reveals parameter estimates with asymptotic distribution as in the *FMOLS* method. The *DOLS* method takes into account the first difference of explanatory variables, allowing delays to be included in the estimate.

4. RESULTS

Table 2 includes panel unit root rest statistics and probability values results applied to oil prices and industrial production index (*IPI*) data for the period 2000Q1-2019Q4 for the 10 most oil importing countries in the world included in the analysis.

In the second stage, according to the Pedroni cointegration test, where we investigated the long-term relationship between the industrial production index and crude oil barrel price, the H_0: "No cointegration between series" hypothesis was rejected (Table 3). In all tests except group rho and group PP statistics, the null hypothesis "no cointegration" was rejected. Pedroni (1999) stated that panel-ADF and group-ADF tests will give more meaningful results, especially for small samples. The significance of these tests is an indicator of the cointegration in the panel data.

Kao (1999) cointegration test (based on Engle-Granger) is another cointegration test applied in the study. Kao test is estimated using Schwarz criterion and Newey-West estimators to find long-term variance when there is an individual constant. The result of the application of the test to the panel data set is arranged in Table 4. According to the results of the Kao cointegration test, as a result of the probability value being significant, the null hypothesis that there is no cointegration was rejected and the alternative hypothesis, there is cointegration, was accepted.

The following results are obtained when the Johansen-Fisher panel cointegration test is applied with the 3 lags found as a result of the Kao cointegration test in the constant and trend model (Table 5).

As a result of the Johansen-Fisher panel cointegration test, the null hypothesis was rejected according to the probability values of both trace and max-eigen statistics. Thus, the result that the industrial production index and crude oil barrel price variables are co-integrated in the 10 most oil-importing countries is accepted consistently, effectively and strongly. After assuming

Table 2: Panel unit root test results

Variables	Level		1st difference	
	IPS	Fisher ADF	IPS	Fisher ADF
IPI	1.608 (0.709)	20.459 (0.234)	–2.122 (0.001)*	72.618 (0.000)*
Olip	6.579 (0.614)	46.087 (0.399)	–2.831 (0.002)*	33.008 (0.009)*

The numbers in parentheses for the IPS test are the P-values for the average t statistics. The numbers in parentheses for the Fisher ADF test are the p values for the Fisher ADF χ^2 statistics. *It shows that the statistic is significant at the level of 1% significance

Table 3: Pedroni panel cointegration test results

$IPI_{it}=\alpha_{it}+\beta_{it}\ Oilp_{it}+u_{it}$				
	t-statistic	Prob.	Weighted	t-statistic
Panel v	6.4340	0.0000	3.0967	0.0000
Panel rho	–3.2298	0.0006	–4.2086	0.0008
Panel PP	–4.5294	0.0000	–4.1047	0.0000
Panel ADF	–5.1516	0.0000	–2.5028	0.0000
Group rho	0.9639	0.8325		
Group PP	–0.2361	0.4067		
Group ADF	–2.8018	0.0025		

Table 4: Kao cointegration test results

Tests	t-statistic	Prob.
Augmented Dickey-Fuller	–3.186470	0.0007
Residualvariance	0.0022	
HAC variance	0.0023	

Table 5: Johansen-Fisher panel cointegration test results

Hypothesized No. of CE(s)	Fisher stat. (fromtrace test)	Prob.	Fisher stat. (frommax-eigen test)	Prob.
None	204.3	0.0000	190.5	0.0000
At most 1	98.73	0.0012	98.73	0.0012

the cointegration entity in the model, the long term cointegration equation can be estimated.

4.1. FMOLS and DOLS Results

When the FMOLS method developed by Pedroni (2000) was applied (Table 6) the elasticity of oil prices across the panel was estimated at 0.38%. The coefficient is positive and statistically significant at the level of 1% significance. This means that the 1% change in the price of a barrel of crude oil across oil-dependent countries will result in a change of about 0.38% over the long term on the industrial production index. When the panel FMOLS test results are evaluated on a country basis, the coefficient estimated in all other countries except Germany and Japan is positive and statistically significant at the level of 1%. The country with the highest coefficient of elasticity among these countries is the United States with a coefficient of 1.09%, while the country with the lowest coefficient of elasticity is South Korea with a coefficient of 0.04%.

Table 7 shows the Panel DOLS test results. When the DOLS method developed by Pedroni (2001) was applied, this coefficient was estimated as 0.36. The estimated result is positive and statistically significant at 1% significance level. Panel DOLS results are in line with FMOLS test results. The 1% change in the barrel price of crude oil across 10 oil-dependent countries will cause a 0.36% change in the industrial production index in the long run. When the Panel DOLS test results regarding the effect of oil prices on the industrial production index are evaluated on a country basis, the coefficient is positive in all countries except Japan and statistically significant at the level of 1%. Among these countries, the country with the highest elasticity coefficient is USA with 0.9497%, while the country with the lowest elasticity coefficient is South Korea with a coefficient value of 0.0517%.

Table 6: Panel FMOLS results

$IPI_{it}=\alpha_{it}+\beta_{it}\ Oilp_{it}+u_{it}$		
Panel/Countries	**Coefficient**	**t-statistic**
Panel	0.3813***	78.80
China	0.76***	–17.9
United States	1.09***	–4.27
India	0.52***	–27.78
Japan	5.58	15.03
South Korea	0.04***	–12.04
Netherlands	0.08***	–17.6
Germany	1.11	10.06
Spain	0.08***	–10.35
Italy	0.63***	–9.86
United Kingdom	0.36***	–30.51

*, ** and *** represent significance levels of 10%, 5%, and 1 % respectively

Table 7: Panel DOLS results

$IPI_{it}=\alpha_{it}+\beta_{it}\ Oilp_{it}+u_{it}$		
Panel/Countries	**Coefficient**	**t-statistic**
Panel	0.3686***	113.0789
China	0.7241**	15.9941
United States	0.9497***	4.2251
India	0.7521***	38.6669
Japan	0.5005	96.8253
South Korea	0.0517***	8.0201
Netherlands	0.5596**	4.3727
Germany	0.0616*	35.2798
Spain	0.3502***	25.9776
Italy	0.8098***	12.1440
United Kingdom	0.4623**	27.1393

*, ** and *** represent significance levels of 10%, 5%, and 1 % respectively

The positive results of both *FMOS* and *DOLS* coefficients show that there is a positive relationship between oil prices and industrial production in the long run. It can be interpreted that oil importing countries sell the products they produce using crude oil to the foreign market at a higher price. The other point of note is that these relations are not statistically significant for Japan and Germany. In South Korea, which is an exporter of high technology products, the coefficient of the relationship between variables is very low.

5. CONCLUSION

Although there are many studies discussing the effects of energy or oil prices on macroeconomic variables in countries, the research based on industrial production is limited. In this study, the existence of long-term relationship between oil price changes and industrial production in the ten most oil-importing countries (China, Germany, India, Italy, Japan, Netherlands, South Korea, Spain, United Kingdom and United States) has been revealed. Theoretically, a negative relationship is expected between the increase in oil prices and industrial production in oil importing countries. As a matter of fact, the increase in crude oil price, which is an important production input in industrial production, puts a significant cost on companies; This situation decreases the production output level with the decrease of production efficiency.

According to the empirical findings of the study, it is concluded that the relationship between the industrial production of oil importing countries and oil prices is positive. This situation can be interpreted as these countries with high levels of industrialization process the crude oil and market the products they produce to foreign countries more profitably. On the other hand, a significant effect of the change in oil prices on Japan's industrial production index has not been determined. However, this effect was found to be very low for South Korea. It is thought that conducting sectoral analysis for future studies, especially for Japan and South Korea, may yield more detailed results.

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