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# The Relationship between Major Oil Products Consumption and Efficiency of Industry Sector in Selected Oil Exporting and Importing Countries

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***Abstract***

*The aim of this study is to investigate the realization of the law of diminishing returns in usage of major oil products in the industry sector of some oil exporting and importing countries during 2002- 2008. To achieve this aim, in a first stage the efficiency of industry sector of countries has been calculated using DEA window analysis and then in the second stag the existence of an inverted U' shape relationship between major oil product consumption and efficiency has been tested in the context of dynamic panel data (GMM) approach. The results confirm this relationship in each group of countries except that the turning point in the case of oil importing countries is much higher than oil exporting countries. This firstly suggests that oil dependence in oil importing countries is more than oil exporting countries and secondly indicates that the industry sector of oil importing countries have advanced technology and high scale and capacity so that they can take benefits of oil products consumption without decrease in efficiency.*

***Keywords****: Efficiency; Industry Sector; Oil Products Consumption; DEA Window Analysis; Low of Diminishing Returns; Generalized Method of Moments (GMM)*

***JEL Code Classification:*** *C1, D2, E2, L6, Q3, Q4*

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## 1. Introduction

Today the importance and position of energy in the world economy is quite clear to everyone. Energy as the motor of word economy has especial importance in the economic international system so that even the relationship of countries is affected from it. Among the various initial energies including oil, gas, coal, nuclear energy and water-electricity energy, oil and gas have excellent station so that oil represent 34.9 percent of total world energy consumption in 2010. So, oil consumption is still the dominant source of energy.

In recent decades the different views has been raised about the amount and manner of energy's impact on production and economic growth. These views can be presented in two overall frameworks "the view of ecological economists" and "the view of neoclassical economists". In biophysical model of growth, energy is only and most important factor of growth. Because according to the first principle of thermodynamic, energy has a fix amount in the nature, is recoverable and does not disappear. Explicitly, the value that is transforming into the commodity in the economy is due to the energy source employed from nature. So, in the biophysical model expressed by ecological economists such as Aires and Nair energy is the main factor and only factor of production and labor and capital, are intermediate factors that for the deployment requires energy. One of the most important studies of biophysical models is conducted by Cleveland which a close relationship between energy consumption and GDP is derived from this study. The view of neoclassical economists such as Berndt and Denison is opposite of the view of ecological economists. The neoclassical economists believe that energy affects economic growth indirectly through the impact on labor and capital and don't have direct impact on economic growth. Of course some neoclassical economists such as Hamilton, Barbridge and Harrison Considers more essential role for energy which is consistent with the view of ecological economists. However, it has long been argued that energy is vital to the performance of the economy (Cottrell, 1955; Hudson and Jorgenson, 1974; Allen, 1979; Berndt and Wood, 1979). Pokrovski (2003) argue that energy must be considered not only as an ordinary intermediate product that contributes to the value of produced products by adding its cost to the price, but also as a value-creating factor which has to be introduced in the list of production factors in line with production factors of conventional neo-classical economics- capital, K and labor, L. In total, by considering the energy especially major oil products as a factor of production the question arises that whether the law of diminishing returns takes place for it as it is true for other factors of production such as labor and capital?

The law of diminishing returns is an important law in microeconomics states that "if an increasing amount of a variable factor is applied to a fixed amount of other factors per unit of time, the increases in total output will increase initially, but after a point, it begin to decline". The modern economists are of the opinion that the law of diminishing returns is not exclusively confined to agricultural sector, but it has a much wider application. They are of the view that whenever the supply of any essential factor of production cannot be increased or substituted proportionately with the other sectors, the return per unit of variable factor begins to decline. The law of diminishing returns is therefore, also called the Law of Variable Proportions.

So the aim of this study is to test the realization of this law in the case of major oil products[1] consumption in the framework of the hypothesis "there is an inverted 'U'-shape relationship between oil product consumption and efficiency in the industry sector". Considering that oil importing and exporting countries have different attitudes in relation to this essential source and the cost they pay for it is very different, so investigating the realization of the law of diminishing returns in the case of oil products consumption and also comparing the amount of "turning point" in the two groups can illuminate some important points about this two groups of countries.

In the literature of energy consumption- and more especially oil products consumption-there is no study which have investigated its relationship with efficiency in microeconomic level. For example Kraft and Kraft (1978) were among the first who investigated the relationship between energy consumption and economic growth for the USA. They using Sims causality test found a one-way causality from GNP to energy consumption in United States during 1947- 1974. Since then many studies have used Granger causality tests in order to check the relationship between energy and income, and energy and economic growth (Abosedra and Baghestani, 1991; Akarca and Long, 1980; Yu and Choi, 1985; Soytas et al., 2007; Soytas and Sari, 2009; Zhang and Cheng, 2009). However, the reported results vary according to the country and the time period considered.

Al-mulali (2011) investigated the impact of oil consumption on economic growth of MENA countries during 1980-2009. He using panel data model and based on cointegration test results concluded that CO2 emission and oil consumption have a long-term relationship with economic growth.

Apergis and Payne (2010) examined the relationship between coal consumption and economic growth for 15 emerging economies in the framework of multivariate panel data model over the period 1980– 2006. Their results suggest that there is a Long-run equilibrium relationship between real GDP, coal consumption, real gross fixed capital formation and labor force. Whereas in long-run both variables of real gross fixed capital formation and labor force have positive significant effect on real GDP, coal consumption has negative effect. Panel causality test revealed two-way causality between coal consumption and economic growth, both in the long-run and short-run.

Bartleet and Gounder (2010) examined the relationship between energy consumption and growth in New Zealand. They checked the long-term and short-term causal relationship between energy and macroeconomic variables using demand-side tri-variable model and production multivariate model in the period

[1] The major oil products which have most use in the industry sector and have been considered in this study include kerosene, gas oil, fuel oil and engine gasoline.

1960-2004. The results of demand model revealed a long-run relationship between energy consumption, real GDP and energy prices. The short-run results indicated that real GDP is Granger cause of energy consumption and the relationship is one-way which consistent with the theorem that energy demand is a derived demand. Production model results indicate a long-run relationship between real GDP, energy consumption and the employment. Granger causality founded from real GDP to energy consumption provided more evidences in supporting the neoclassical theorem that energy consumption in New Zealand is mainly resulted by economic activities.

Halkos and Tzeremes (2011) investigated the economic efficiency–oil consumption relationship in 42 countries during the period 1986–2006. In order to capture heterogeneities among countries' development stages they separated the analysis into two groups (advanced economies and developing/emerging economies). They finally argued that oil consumption is the main driver behind the progress of industrialization and urbanization regardless of the country's development stage.

In contrast to the majority of studies investigating the energy consumption–GDP relationship, our paper following Halkos and Tzeremes (2011) investigates the efficiency-oil products consumption relationship to check the realization of the law of diminishing returns. However, as it is obvious, the law of diminishing returns is a phenomenon that takes place in producing sectors and since the industry sector is one of the most important infrastructural parts of any economy, we investigate this relationship in the industry sector.

This paper has been organized as follows. Section 2 presents the data used in the analysis, Section 3discusses the proposed methodology and the adopted econometric method. Section 4 presents the empirical results while the last section presents the conclusions.

## 2. Data

The data set contains information on industry sector of 24 countries over the years 2002 to 2008. From these 24 countries, 11 countries are placed in the oil exporting countries group and 13 countries are placed in the oil importing countries group. Countries selection has been based on the rank of countries in oil export and import which Organization of Petroleum Exporting Countries (OPEC) publishes and also has been based on the data availability for the countries. It is notable that because of the absence of data for some major oil exporting countries such as Saudi Arabia, United Arab Emirates and Russia, these countries does not included in our sample inevitably.

The variables used includes number of employee, gross fixed capital formation (at current US$), value added (at current US$) and major oil product consumption (in thousand tones). The data correspond to the first three variables which will use in the first stage in order to calculate the efficiency has been obtained from UNIDO Database for the period 2002- 2008. Also data for major oil product consumption has been obtained from International Energy Agency (IEA), World Energy Balances (2011 Edition).

## 3. Methodology

### 3.1 DEA Window Analysis

DEA window analysis calculates the average efficiency of models with constant returns and variable returns to scale and is applicable to determine the efficiency trend over time. So it can be used to determine the trend of decision maker unit's (DMU) performance over time (Al–Eraqi et al., 2010). Charnes and Cooper (1985) introduced this type of DEA method with the ability to measure the efficiency and handle cross-sectional and time-varying data. Tulkens and Vanden Eeckaut (1995) suggest that the number of time periods (years in our case) included in the analysis form a "window". In our study we use 24 countries (n=24) for the period 2002–2008 (T=7). Asmild et al. (2004) highlight the fact that there are no technical changes within each of the windows because all DMUs in each window are measured (compared) against each other and suggest that in order for the results to be credible a narrow window width must be chosen. So in our analysis a 3-year window has been chosen (w=3). Then each DMU which is placed in the window treated as different DMU for each of the three years (the width of the window). Thus in our case the first window contains the years 2002, 2003, and 2004 increasing DMUs from 24 to 72 (n×w=24×3) and performing the analysis to these DMUs. The window then moves on one year and the analysis is performed on the next three year set (2003, 2004, and 2005), dropping the original year and adding a new year. The process continues until the last window (5 windows and 360 in total 'different' DMUs) containing the years 2006, 2007 and 2008 has been analyzed.

To further explain assume that there are N DMU's (n=1, ..., N) for T periods (t=1,...,T) and they uses r inputs to produce s outputs. Therefor the sample will include N×T observations where an observation n in period t, ($DMU_t^n$) has an r dimensional input vector $x_t^n = (x_{1t}^n, x_{2t}^n, ..., x_{rt}^n)'$ and an s dimensional output vector $y_t^n = (y_{1t}^n, y_{2t}^n, ..., y_{st}^n)'$. Then a window kw with k×w observations is denoted starting at time k, 1≤ k ≤T with width w, 1≤ w ≤ T−k. So the matrix of inputs and outputs is given as:

$$X_{KW} = (X_K^1, X_K^2, ..., X_K^N, X_K^1 + 1, ..., X_K^N + 1, X_K^1 + W, ..., X_K^N + W) \quad (1)$$

$$Y_{KW} = (Y_K^1, Y_K^2, ..., Y_K^N, Y_K^1 + 1, ..., Y_K^N + 1, Y_K^1 + W, ..., Y_K^N + W) \quad (2)$$

The input oriented DEA window problem (constant returns to scales, CRS) for $DMU_t^n$ is given by solving the following linear program:

$$\theta'_{k_w t} = \min_{\theta, \lambda} (\theta) \quad (3)$$

s.t.

$- X_{kw} \lambda + \theta X_t' \geq 0$ , t = 1,…,T

$Y_{kw} \lambda - y_t' \geq 0$ , t = 1,…,T

$\lambda_n \geq 0$ , n= 1 ,…, Nxw

In this study we add the restriction $\sum_{1}^{N} \lambda_n = 1$ (Banker et al., 1984; Halkos and Tzeremes, 2011) in order to allow for variable returns to scale (VRS), since the countries used in our analysis have different economic scales and major heterogeneities (Halkos and Tzeremes, 2009a, 2009b, 2011) and also have different industry scale. Since the size of the countries' industry sector influences their ability to affect outputs efficiently, the assumption of CRS is inappropriate. The less restrictive VRS frontier allows the best practice level of outputs to inputs to vary with the size of the sampled countries (Halkos and Tzeremes, 2011).

### 3.2 Panel Data Model

In this step, we establish a general autoregressive-distributed lag model (ARDL (p, q)) with the dependent variable lagged p times and the independent variables lagged q times. By omitting the insignificant lags the general ARDL (1,1) is reduced to an ARDL (1,0) model and having only the dependent variable lagged by one period and oil consumption and quadratic term of oil consumption as regressors. Also we use a partial adjustment model to specify how the efficiencies adjust to the long-run equilibrium level, that is:

$$eff_t = eff_{t-1} + \lambda(eff_t^* - eff_{t-1}) \quad (4)$$

Where $eff_t^*$, $eff_t$ and $eff_{t-1}$ are the desired, the actual and the lagged actual levels of efficiencies respectively and γ is the adjustment coefficient (0<γ<1). In order to test the existence of an inverted U-shape relationship between efficiency and oil products consumption the following quadratic model (Halkos and Tzeremes, 2011) is estimated in levels:

$$eff_t = \beta_0 + \beta_1 oil_{it} + \beta_2 oil_{it}^2 + \beta_3 eff_{i,t-1} + \varepsilon_{it}$$

$$\varepsilon_{it} = v_i + e_{it} \quad (5)$$

Where i denote the countries and t denote the years; oil stands for major oil products consumption and $oil_{it}^2$ is its squared term; eff stands for efficiency and effi,t-1 is efficiency lagged by one period; $\varepsilon_{it}$ is the disturbance term which itself includes country specific fixed effects, $v_i$ and error component, $e_{it}$ .

It is notable that the turning point (TP) level of efficiency is calculated as:

$$TP = -\frac{\beta_1}{2\beta_2} \quad (6)$$

### 3.2.1 Generalized Method of Moments (GMM)

In the equations which in their estimation the nonvisible effects of country-specific and the existence of lagged dependent variable in explanatory variables is an essential problem, the GMM estimator- that is based on dynamic panel data model- is used (Barro and Lee, 1996). Also according to Baltagi (2008) the GMM method is used when the number of cross-sections (N) is greater than the number of time intervals (T), (N>T), which is the case in this study, that is the number of countries in each group is greater than the number of years.

The GMM estimators are of the moments of the form

$$h(\beta) = \sum_{i=1}^{N} h_i(\beta) = \sum_{i=1}^{N} \Psi_i' u_i'(\beta) \tag{7}$$

Where $\Psi_i$ is a $T_i \times p$ matrix of instruments for cross section i and $u_i(\beta) = (Y_i - f(X_{it}, \beta))$. Specially, GMM minimizes the following quadratic model with respect to β

$$M(\beta) = \sum_{i=1}^{N} \Psi_i' u_i(\beta) W \sum_{i=1}^{N} \Psi_i' u_i(\beta) = \zeta(\beta)' W \zeta(\beta) \tag{8}$$

Where W is a $p \times p$ weighting matrix. The coefficient covariance matrix may be estimated as

$$V(\hat{\beta}) = \sum_{i=1}^{N} (G'WG)^{-1} (G'W \Xi WG)(G'WG)^{-1} \tag{9}$$

Where Ξ is estimated as follow:

$$E(\zeta_i(\beta)\zeta_i(\beta)') = E(\Psi_i' u_i(\beta) u_i(\beta)' \Psi_i) \tag{10}$$

And G is a $T_i \times k$ matrix given as

$$G(\beta) = \left( - \sum_{i=1}^{N} \psi \nabla f_i(\beta) \right) \tag{11}$$

The weighting of matrix W can be calculated using the White robust covariance. The coefficient covariance estimates are obtained as

$$\left( \frac{M^*}{M^* - k^*} \right) \left( \sum_t X_t' X_t \right)^{-1} \left( \sum_t X_t' \hat{u}_t \hat{u}_t' X_t \right) \left( \sum_t X_t' X_t \right)^{-1} \tag{12}$$

Where, $\left( \frac{M^*}{M^* - k^*} \right)$ is an adjustment to the degrees of freedom relying on the total number of observations; M* is the number of stacked observations and K* is the number of estimated parameters.

According to Arellano (1988) orthogonal deviations express each observation as the deviation from the mean of future observations in the sample and in order to standardize the variance weight each deviation:

$$x_{it}^{*} = \frac{[x_{it} - \frac{x_{i(t+1)} + ... + x_{iT}}{T-t}]\sqrt{(T-t)}}{\sqrt{T-t+1}} \qquad (13)$$

t = 1, ..., T-1

We can write the (Ti - q) equations for individual unit i as

$$Y_i = \delta w_i + d_i \eta_i + v_i \qquad (14)$$

Where δ is a vector of parameters including $\alpha_k$'s, β's and $\lambda$'s; and wi is a matrix containing the time series of the lagged endogenous variables, the time dummies, and the x' s. di is a (Ti - q) $\times 1$ vector of ones.

Linear GMM estimators of δ may be computed by (Arellano and Bond, 1998)

$$\hat{\delta} = \left[\left(\sum_i w_i^{*\prime} z_i\right) . \frac{1}{\frac{1}{N}\sum_i Z_i' H_i Z_i}\left(\sum z_i' w_i^{*}\right)\right] - 1 \times \left(\sum_i w_i^{*\prime} z_i\right) . \frac{1}{\frac{1}{N}\sum_i Z_i' H_i Z_i}\left(\sum_i Z_i' Y_t^{*}\right) \qquad (15)$$

Where $w_i^{*}$ and $Y_t^{*}$ is some transformation of wi and Yi such as orthogonal deviations, first differences or levels. Zi is a matrix including the instrumental variables and Hi is an individual specific weighting matrix.

## 4. Empirical Results

In this paper, a DEA window analysis with a 3-year window has been used to calculate the efficiency. As mentioned before, since the size of the countries' industry sector influences their ability to affect outputs efficiently, the assumption of CRS is inappropriate. The less restrictive VRS frontier allows the best practice level of outputs to inputs to vary with the size of the sampled countries (Halkos and Tzeremes, 2011); hence the results of VRS model are more relevant and more reliable. In addition, DEA models can be distinguished according to whether they are input-oriented or output-oriented. The former is closely related to operational and managerial issues, whilst the latter is more related to planning and strategies (Cullinane et al., 2004). Since our issue is more operational and managerial, rather than planning and strategies, we apply an input-oriented DEA. The efficiency scores have been calculated using DEAP 2.1 software.

DEA window analysis results can be interpreted in two different ways (see Table 1). Firstly, the ‘column views’ enable us to examine the stability of the environmental efficiencies of the DMUs across the different datasets which occur through the different replacement procedures. Secondly, the ‘row views’ determine trends and observed behavior across the same dataset (Cooper et al., 2007). This has been clearly shown in Table 1. For instance and in the case of Iran's industry the efficiency with the variable returns to scale assumption in the first window is 1.000, 0.975 and 1.000 in comparison to raw average of 0.991 and total average of 0.998; these figures correspond to the estimated relative efficiency for 2002, 2003 and 2004 and clear that trend behavior in the first row is firstly negative and then in positive, but its amount in the years 2002 and 2004 is higher than total average and in 2003 is lower than it. Still taking the France, as an example, its efficiency varies from 0.956 to 1.00 during 2002-2008 (adopting a row view perspective). At the same time, the efficiency of a DMU within the different windows can also vary substantially (adopting a column view perspective). This variation reflects simultaneously both the absolute performance of a DMU over time and its relative performance in comparison to the others in the sample (Hemmasi et al., 2011).

**Table 1: A Three Year Window Analysis of Economic Efficiency for the Case of Iran and France**

| | | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Averages |
|---|---|---|---|---|---|---|---|---|---|---|
| Iran | Window 1 | VRS | 1.000 | 0.975 | 1.000 | | | | | 0.991 |
| | | CRS | 1.000 | 0.917 | 1.000 | | | | | 0.972 |
| | Window 2 | VRS | | 1.000 | 0.994 | 1.000 | | | | 0.998 |
| | | CRS | | 0.943 | 0.976 | 1.000 | | | | 0.973 |
| | Window 3 | VRS | | | 1.000 | 1.000 | 1.000 | | | 1.000 |
| | | CRS | | | 0.976 | 1.000 | 1.000 | | | 0.992 |
| | Window 4 | VRS | | | | 1.000 | 1.000 | 1.000 | | 1.000 |
| | | CRS | | | | 1.000 | 1.000 | 1.000 | | 1.000 |
| | Window 5 | VRS | | | | | 1.000 | 1.000 | 1.000 | 1.000 |
| | | CRS | | | | | 1.000 | 1.000 | 1.000 | 1.000 |
| | Averages | VRS | 1.000 | 0.988 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 0.998 |
| | | CRS | 1.000 | 1.000 | 0.984 | 1.000 | 1.000 | 1.000 | 1.000 | 0.987 |
| France | Window 1 | VRS | 0.972 | 1.000 | 1.000 | | | | | 0.990 |
| | | CRS | 0.780 | 0/989 | 1.000 | | | | | 0.923 |
| | Window 2 | VRS | | 1.000 | 1.000 | 1.000 | | | | 1.000 |
| | | CRS | | 0.989 | 1.000 | 1.000 | | | | 0.996 |
| | Window 3 | VRS | | | 1.000 | 0.997 | 1.000 | | | 0.999 |
| | | CRS | | | 1.000 | 0.994 | 1.000 | | | 0.998 |
| | Window 4 | VRS | | | | 1.000 | 1.000 | 1.000 | | 1.000 |
| | | CRS | | | | 0.997 | 1.000 | 1.000 | | 0.999 |
| | Window 5 | VRS | | | | | 1.000 | 0.956 | 1.000 | 0.985 |
| | | CRS | | | | | 0.955 | 0.955 | 1.000 | 0.983 |
| | Averages | VRS | 0.972 | 1.000 | 1.000 | 0.999 | 1.000 | 0.978 | 1.000 | 0.993 |
| | | CRS | 0.780 | 0.989 | 1.000 | 0.997 | 0.998 | 0.978 | 1.000 | 0.963 |

**Source:** Authors' Calculations Using DEAP 2.1

It is notable that the technical efficiency scores in addition to affected by operational and managerial factors, are also affected by environmental factors such as countries' development stage, energy policies and financial policies. In the case of development stage, for example, as a country move up from a lower level of development into an higher level, the quality of technology and raw materials used in various sectors will be upgraded and consequently their efficiency will also be increased.

Tables 2 and 3 provides the average values as have been obtained from DEA window analysis under the assumption of variable returns to scale for every country in two groups for the period 2002–2008.

**Table 2: Oil Exporting Countries' Economic Efficiency Scores (Average Values Obtained by DEA Window Analysis)**

| Countries | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Averages |
|---|---|---|---|---|---|---|---|---|
| Oman | 1.000 | 0.999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| New Zealand | 1.000 | 1.000 | 1.000 | 0.993 | 1.000 | 1.000 | 1.000 | 0.999 |
| Iran | 1.000 | 0.988 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 | 0.998 |
| Indonesia | 1.000 | 0.995 | 1.000 | 1.000 | 0.981 | 1.000 | 1.000 | 0.997 |
| Netherland | 1.000 | 0.983 | 1.000 | 1.000 | 0.996 | 1.000 | 1.000 | 0.997 |
| Singapore | 0.983 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.974 | 0.994 |
| Romania | 1.000 | 0.966 | 0.985 | 1.000 | 1.000 | 1.000 | 1.000 | 0.993 |
| Norway | 0.944 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.992 |
| Mexico | 1.000 | 1.000 | 0.949 | 1.000 | 0.997 | 1.000 | 1.000 | 0.992 |
| Azerbaijan | 0.944 | 1.000 | 1.000 | 0.998 | 1.000 | 0.979 | 1.000 | 0.989 |
| Ecuador | 0.985 | 1.000 | 1.000 | 0.959 | 0.941 | 1.000 | 1.000 | 0.983 |
| mean | 0.987 | 0.994 | 0.994 | 0.995 | 0.992 | 0.998 | 0.997 | 0.994 |
| Std | 0.022 | 0.011 | 0.015 | 0.012 | 0.018 | 0.006 | 0.008 | 0.005 |
| min | 0.944 | 0.966 | 0.949 | 0.959 | 0.941 | 0.979 | 0.974 | 0.983 |
| max | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Source: Authors' calculations

**Table 3: Oil Importing Countries' Economic Efficiency Scores (Average Values Obtained by DEA Window Analysis)**

| Countries | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Averages |
|---|---|---|---|---|---|---|---|---|
| South Korea | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| India | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Sweden | 1.000 | 0.997 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Spain | 1.000 | 1.000 | 1.000 | 1.000 | 0.997 | 1.000 | 1.000 | 1.000 |
| Poland | 1.000 | 1.000 | 1.000 | 1.000 | 0.996 | 1.000 | 1.000 | 0.999 |
| Germany | 1.000 | 0.999 | 0.993 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 |
| Italy | 1.000 | 0.991 | 0.988 | 1.000 | 1.000 | 1.000 | 1.000 | 0.997 |
| Japan | 0.982 | 1.000 | 1.000 | 1.000 | 0.999 | 0.976 | 1.000 | 0.994 |
| France | 0.972 | 1.000 | 1.000 | 0.999 | 1.000 | 0.978 | 1.000 | 0.993 |
| UK | 0.968 | 1.000 | 0.998 | 0.981 | 1.000 | 1.000 | 1.000 | 0.992 |
| Turkey | 1.000 | 1.000 | 1.000 | 1.000 | 0.940 | 0.999 | 1.000 | 0.991 |
| Belgium | 0.940 | 1.000 | 1.000 | 1.000 | 0.992 | 1.000 | 1.000 | 0.990 |
| USA | 0.893 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.985 |
| mean | 0.981 | 0.999 | 0.998 | 0.998 | 0.994 | 0.996 | 1.000 | 0.995 |
| Std | 0.032 | 0.003 | 0.004 | 0.005 | 0.016 | 0.009 | 0.000 | 0.005 |
| min | 0.893 | 0.991 | 0.988 | 0.981 | 0.940 | 0.976 | 1.000 | 0.985 |
| max | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Source: Authors' calculations

According to Table 2 the rank of efficiency of oil exporting countries' industry sector is as follow: Oman, New Zealand, Iran, Indonesia, Netherland, Singapore, Romania, Norway, Mexico, Azerbaijan and Ecuador. Also according to Table 3, the rank of oil exporting countries is as follow: South Korea, India, Sweden, Spain, Poland, Germany, Italy, Japan, France, UK, Turkey, Belgium and USA.

After calculating the efficiency scores, we move on to estimate the model presented in relation 5. This equation is estimated using GMM approach and STATA 11.

There are two methods to estimate the model in GMM approach. The initial base of GMM models was introduced by Arrelano- Bond (1991) which is called as first-difference GMM. Arrelano- Bover (1995) and Blandel- Bond (1998) were proposed orthogonal deviations GMM method with some changes in first difference GMM (henceforth the first difference GMM is shown by DGMM and orthogonal GMM is shown by OGMM). The difference between these two methods is the way in which individual effects are included in the model; In DGMM the differencing is used while in OGMM the orthogonal deviations are used. In Arrelano- Bond method (DGMM) whole lags are used as instrumental variables while in OGMM the Lagged levels are used as instrumental variables.

Although the Arrelano- Bond method is more famous than OGMM method but the OGMM method has some advantage compared to DGMM so that the researchers prefer to use it. Among the notable advantage is that the OGMM method by improving accuracy and reducing bias of sample size limitations provide a more efficient and accurate estimations compared to DGMM.

In this paper the system GMM method is used. According to Baltagi (2008) the system GMM usually provides a more efficient and more accurate estimates compared to DGMM by improving the accuracy and reducing the bias of sample size.

The validity of the SGMM results is related to the statistical diagnostics; so, we first interpret the model diagnostics which are reported in Table 4. In this study two-step estimates are applied that yield theoretically robust results. In addition, the two-step estimator gives the robust Hansen J-test (with the null hypothesis of “the instruments as a group are exogenous”) instead of Sargan test, which are not available in one-step estimation. The first test for System-GMM estimation is Arrelano-Bond test with null hypothesis that there is no serial correlation. The p-values of this test that are reported in Table 4 indicate that the model specification is valid in each group– we have no second order autocorrelation in two groups.

The second test – a test that checks joint validity of GMM and IV instruments- is Hansen test of over identified restrictions. The value of this test is 0.621 and 0.622 for group 1 and group 2, respectively in the case of orthogonal deviation method which indicates that we cannot reject the null hypothesis of joint validity of selected instruments.

**Table 4: Model Diagnostics**

| Groups / Test | Group 1 | | Group 2 | |
|---|---|---|---|---|
| | DGMM | OGMM | DGMM | OGMM |
| Number of groups (panels) | 11 | 11 | 13 | 13 |
| Number of instruments | 8 | 10 | 8 | 8 |
| Number of observations | 66 | 55 | 78 | 78 |
| Wald- test of joint significance Ho: Independent variables are jointly equal to zero, prob > chi2 | 60337.75 (0.000) | 43451.67 (0.000) | 18090.07 (0.000) | 33989.45 (0.000) |
| Arellano-Bond test for AR(1) in first differences Pr > z (null – no autocorrelation) | 0.131 | 0.130 | 0.207 | 0.205 |
| Arellano-Bond test for AR(2) in first differences Pr > z (null – no autocorrelation) | 0.683 | 0.679 | 0.476 | 0.452 |
| Hansen test of over id. Restrictions Prob > chi2 (null –the instruments as a group are exogeneous) | 0.611 | 0.621 | 0.570 | 0.622 |
| GMM instruments Hansen test excluding group Prob > chi2 | 0.804 | 0.758 | 0.500 | 0.673 |
| Difference-in-Hansen tests of exogeneity of GMM instruments Prob > chi2 (null – instruments are exogeneous) | 0.370 | 0.329 | 0.480 | 0.437 |
| IV instruments Hansen test excluding group Prob > chi2 | 0.917 | 0.819 | 0.295 | 0.386 |
| Difference-in-Hansen tests of exogeneity of IV instruments Prob > chi2 (null – instruments are exogeneous) | 0.215 | 0.356 | 0.927 | 0.789 |

**Source:** Authors' Calculations Using STATA 11

The p-values of Hansen test excluding group and difference-in-Hansen test show validity of IV and GMM instrument subsets apart. The null hypothesis of first test is that excluded instruments as a group, are not correlated with independent variables; the last test check whether instruments are exogenous. These tests are also satisfied in our each two groups.

Roodman (2007) suggests that the number of instruments which has been used in the GMM should be reported; since those models may generate some potentially "weak" instruments which can cause biased estimates. There are some rules of thumb and telltale signs to specify how many instruments are reliable. First, the number of instruments should not exceed the number of observations, which is the case in our each two groups. Second, a telltale sign is a perfect Hansen J-statistic with the p-value equal to 1.00. At the same time, the p-value should have a higher value than the conventional 0.05 or 0.10 levels, at least 0.25 is suggested by Roodman (2007, p. 10). In our two groups, the Hansen J-test reports a p-value of 0.611, 0.57, in the case of first difference and 0.621, 0.622 in the case of orthogonal deviations equation which satisfies both rules.

In total, the conducted statistical tests show that this model is an appropriate econometric model.

Now, after ensuring of suitability of model we move on to interpret the results reported in Table 5. According to the table, the lagged dependent variable, (EFFt-1) has a positive and significant effect on efficiency in each two groups. In other words, the efficiency of prior period has positive impact on current efficiency.

**Table 5: GMM Estimation Results**

| Variables | Group1 | | Group2 | |
|---|---|---|---|---|
| | DGMM | OGMM | DGMM | OGMM |
| $EFF_{t-1}$ | 0.987 [0.000] | 0.988 [0.000] | 0.966 [0.000] | 0.971 [0.000] |
| Oil | 0.000008 [0.082] | 0.000007 [0.052] | 0.000007 [0.033] | 0.000007 [0.038] |
| $Oil^{2*}$ | -8.67 e –10 [0.058] | -7.14 e –10 [0.051] | -1.89 e – 10[0.013] | -1.60 e –10 [0.020] |
| Wald statistic ($\chi^2(3)$) Prob > chi2 | 60337.75 [0.000] | 43451.67 [0.000] | 18090.07 [0.000] | 33989.45 [0.000] |
| Turning point (TP) | 4614 (1000 tons) | 4902 (1000 tons) | 18518 (1000 tons) | 18750 (1000 tons) |

**Source:** Authors' calculations using STATA 11
p- values in brackets
* Quadratic term of oil products consumption

The coefficient of variable oil products consumption (oil) is positive and statistically significant and indicates that the oil products consumption increases the efficiency of industry. But, since the coefficient of quadratic term of oil product consumption variable is negative and statistically significant, we can conclude that the oil products consumption does not increases the efficiency constantly. In other words, the coefficient of last two variables show that there is an inverted U' shape relationship between efficiency and oil products consumption due to the fact that the marginal rate of efficiency first increases, and then decreases as more of the oil products are used, following the law of diminishing returns. This result confirms the studies by Berndt and Wood (1975, 1979) arguing that energy and labor are substitutes. In addition, Griffin and Gregory (1976) and Jorgensen and Wilcoxen (1990) have obtained results proving that energy and capital are substitutes. Similarly, Smulders and de Nooij (2003) claim that labor and energy inputs are gross complements and are being combined with specific complementary intermediate inputs which in turn are interpreted as capital in the production function. Also, more recently, Warr and Ayres (2006) suggest that energy is a substitute for labor and capital.

Also, the coefficient of lagged dependent variable in the estimated equation shows that the rate of adjustment of efficiency is around 2% per year (1–0.98) for group1 (oil exporting countries) and 4% per year for group2 (oil importing countries). This implies that 2% of the difference between the desired and the actual levels of efficiencies are adjusted in a year in the case of oil exporting countries. In other words, the adjustment of efficiency is effected within almost fifty periods. While the adjustment of efficiency for group 2 is affected within almost 25 periods. This difference can be caused by differences in management and different industrial and economical structure of these two groups.

The considerable result of this research is that the turning point of efficiency for first group has been calculated equal to 4614 and 4902 thousand tones in DGMM and OGMM, respectively. While for the second group, the amount of this point is equal to 18518 and 18750 thousand tones in DGMM and OGMM, respectively. As it can be seen the amount of turning point in second group (oil importing countries) is almost four times higher than its amount in first group (oil exporting countries). Hence we can conclude that the oil importing countries need to consume a greater amount of oil products in order to reach to the efficiency point and this implies on oil dependency in industry sector of oil importing countries. Also we can conclude that since the oil importing countries (group 2) are mainly developed countries and their industry sector have a high capacity for the use of production factors, their marginal rate of efficiency reach to zero in a higher amount of oil product consumption. In other words, the law of diminishing returns in oil importing countries takes place in higher amount of oil products consumption compared to oil exporting countries.

## 5. Conclusion

In this paper the relationship between oil products consumption and efficiency in industry sector of a sample of 24 countries, including 11 oil exporting countries and 13 oil importing countries during 2000-2008 was investigated. To achieve this aim, in the first step, the DEA window analysis was applied to calculate the efficiency of countries' industry sector. Then, in the second step, the generalized method of moments (GMM) was used and its results revealed an inverted U-shape relationship between oil products consumption and efficiency in each two groups; except that the amount of turning point for the industry sector of oil importing countries is much higher than its amount in another group. Therefore, it is concluded that the industry sector of oil importing countries in order to achieve the maximum point of efficiency needs to consume a more amount of oil products compared to oil exporting countries group and this implies the fact that the industry sector of importing countries is more energy-intensive compared to those for the oil exporting countries group.

Also the results indicate that the adjustment rate of efficiency for group1 is 2% (in both DGMM and OGMM) and for group 2 is equal to 3% and 4% in OGMM and DGMM, respectively. As it is seen, the adjustment rate for group 2 (oil importing countries) is almost 2 times more than its value in the case of group 1.

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