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The Impact of Sector Expansion on Energy Intensity in OPEC Countries vs. the Rest of the World

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ABSTRACT

The relationship between energy intensity and economic expansion is important because countries need to grow within the current high-price energy environment. This study estimates the impact that production structure on energy use across countries and how changes in production over time have influenced energy intensity. The impact of expanding different economic sectors on energy intensity in OPEC countries is compared with the rest of the world during 1980-2005 using panel data with fixed and random effects regression models. Expansion of the agriculture, transportation and communication sectors, plus an increase in total economic production, is the main reasons behind a fall in energy intensity internationally. The results show that OPEC countries have higher energy intensity due to their smaller service sectors and unused economic growth capacity.
JEL Classification: C_{23}, C_{51}, O_{13}
KEYWORDS: Energy Intensity, Energy Efficiency, Gross Domestic Product, Production Structure, Panel Data, Sector Analysis.

INTRODUCTION

In recent years high energy prices have encouraged investigations of energy demand and its impacts on economic growth (Shamizadeh et al., 2012, and Mohammadi and Nejad, 2012). Other studies have investigated the efficiency of energy use in order to conserve it. The energy intensity index measures how much energy is used for each unit value added in a given production process for a given country or region. This index has risen sharply in the Middle East, especially Iran, over time. Energy intensity in Iran is currently twice the average energy intensity in the rest of the world (Iranian Energy Report, 2009). This increase in energy intensity is happening at a time when the index has been fairly constant or even falling in many countries around the world (Figure 1). One of the reasons behind high energy intensity in a country is the use of outdated technology.

Outdated technology is not the only cause of high energy intensity. Production conditions, such as production scale, input mix, and social and environmental conditions (such as weather and factor endowments), can also have an impact on energy intensity (Stern, 2010; and Cornillie and Fankhauser, 2004). Therefore, energy intensity alone is not a sufficient criterion for evaluating energy efficiency in the long run. Structural changes in the production process in the long run will have an impact on energy intensity through changes in the share of different economic sectors that consume energy and contribute to total production at a macro-level.

The goal of this study is to determine the impact that production structure on energy use across countries and how changes in production over time have influenced energy intensity. This will allow us to gauge the efficiency of energy use among countries. We divide countries between OPEC and non-OPEC countries because it is believed that OPEC countries are particularly inefficient in their energy use. In contrast to previous studies, the analysis incorporates trade-offs among production factors (specifically tradeoffs between energy and capital, and energy and labor) in explaining energy intensity.

This paper uses panel data from seventy-five countries over a twenty-six year period to estimate the impacts of production structure on energy intensity. Specifically, the paper 1) estimates the overall effects of GDP increases on energy intensity, 2) estimates the trade-off between energy and other input factors (capital and labor); 3) estimates the effects of output changes in each sector on energy intensity; and 4) suggests ways that OPEC countries can lower their energy intensity.

The remainder of the paper is organized as follows: section 2 is the literature review, section 3 summarizes the model specification and outlines data used, section 4 provides details on the model estimation and results of various specification tests, section 5 discusses the estimation results, and section 6 has concluding remarks.

1. LITERATURE REVIEW

Most of the energy related studies performed in the Middle East have used decomposition techniques to analyze use by sector (Sadeghi and Heydari, 2004, Sharifi et al., 2008). The results of these studies show that structural changes have had little impact on energy intensity variations in the region. Sharifi et al. (2003) studied the energy intensity of the OECD countries during 1965-1996. Using GDP, energy consumption and the exchange rate in a linear logarithmic model they showed that higher energy efficiency has lowered the energy intensity in OECD countries. They also studied the causal relationship among energy intensity, GDP, and prices. Their results showed that energy intensity has been falling steadily.

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Bentzen, (2001) used an autoregressive model to study energy intensity trends in thirteen East Asian and Pacific countries during 1971-1999. His results show that even though the energy intensity among these countries has been converging over time, energy intensity and consumption depends mainly on internal factors within these countries. Filippini and Hunt (2009) used stochastic frontier analysis to study the relationship between energy efficiency and energy intensity in twenty-nine OECD countries during 1978-2006. Their results show that the energy intensity index is not necessarily a good measure of energy efficiency. They also showed that by studying economic and social factors one can show the difference in energy efficiency among different countries. Stern (2010) also used stochastic frontier analysis to compare energy efficiency trends for eighty-five countries during 1971-2007. His results indicate that during that period energy efficiency among the countries has been converging. The findings of other studies, such as Farrel et al. (2008) show that developing countries can reduce their energy consumption by 50% if they employ efficient energy techniques.

The objective for most of the above studies is to compare energy efficiency among countries and to identify ways to use energy efficiently. However, these studies do not offer any policies for expanding different economic sectors aimed at improving energy intensities. In fact, most of these studies show that with the passage of time, structural changes have impacted energy intensities. For this reason, assuming identical technologies for all countries in the long run, the current study attempts to look into the differences in the energy intensity indices that result from structural differences in various production sectors for seventy-five countries.

2. Model Specification and Data

Structural changes in the producing sectors and changing consumer habits cause energy consumption to vary by country. The utility function is important for consumers, but differing production techniques are important for production. The stochastic frontier analysis employed by Fillipini and Hunt (2010) and Stern (2010) imposes specific assumptions on the distribution of the error terms, which is an obvious limitation. For this reason we begin with a basic energy demand function that is derived from the output of the various sectors:

$$E = AY^{a_Y} K^{a_K} L^{a_L} \exp(\sum_{j=1}^{7} \gamma_j \eta_j) \quad (1)$$

Where E is energy use, Y is GDP, K is capital stock, and L is labor force. A is the technology level. There are seven sectors in the economy (agriculture, animal husbandry and fishing; mining, water and electricity; manufacturing; construction; transportation and communications; services; and others sectors). In equation (1) η stands for the value added of each sector.

Taking the log of both sides and simplifying the result gives us equation (2):

$$Ln\left(\frac{E}{Y}\right) = Ln(A) + \alpha_K Ln\left(\frac{K}{Y}\right) + \alpha_L Ln\left(\frac{L}{Y}\right) + (\alpha_Y + \alpha_K + \alpha_L - 1) Ln(Y) + \sum_{j=1}^{7} \gamma_j \eta_j \quad (2)$$

Equation (2) shows that the elasticity of energy intensity with respect to output level not only depends on the output energy elasticity but also on the substitution elasticity between capital stock and energy and the substitution elasticity between labor supply and energy. Since the purpose of this paper is to compare the effect of various factors on energy intensity in different countries we use panel data. Models using panel data provide more reliable estimates than models using time series data; especially for long run analyses.

The data used are for seventy-five countries which had data on all variables over the 1980-2005 observation period. The data were obtained from the World Bank and Penn World Trade with the exception of capital. Data for capital stock were obtained by the Permanent Inventory Method (PMI) approach. The following equation is used to estimate the capital stock for various years:

$$K_t = K_{t-1}(1-\delta) + I_t = K_0(1-\delta)^t + I_t \quad (3)$$

K_t is the capital stock in year t, K_0 is the capital stock in the first year, I_t is the gross initial capital stock in year t and δ is the capital depreciation rate. We used Caselli's (2005) equation to estimate the capital stock in the first year:

$$K_0 = \frac{I_0}{(g+n+\delta)} \quad (4)$$

In the above equation I_0 is gross capital formation in the first year, g is the average economic growth rate and n is the population growth rate in the first two years. Assuming that:

$$\beta = (\alpha_Y + \alpha_K + \alpha_L - 1) \quad (5)$$

Using equation (5) we can rewrite equation (2) in the following form:

$$Ln(\frac{E_{it}}{Y_{it}}) = \alpha_0 + \alpha_K Ln(\frac{K_{it}}{Y_{it}}) + \alpha_L Ln(\frac{L_{it}}{Y_{it}}) + \beta Ln(Y_{it}) + \sum_{j=1}^{7} \gamma_j \eta_j + u_{it} \quad (6)$$

Where α_0 is Ln(A)

3. Model Estimation:

Before final estimation the data are tested for the existence of unit roots in the variables. The existence of such unit roots can result in misleading values for the t and F statistics, and increasing the chance that estimation results are spurious. There are different types of unit-root tests in the literature (Baltagi, 2005). In Table 1 we show the results of some the more common unit-root tests on the variables of the model. All the variables used in the model are stationary and so the presence of a unit-root in these variables is ruled out. This is not surprising since most of the variables have been divided by GDP.

Thus, equation (5) is estimated with regression analysis from the panel data and coefficient estimates are obtained using fixed or random effects models. A fixed effects model is used when the whole population is under study. But if samples of population are selected randomly a Random Effect Model is more efficient (Egger, 2000). The Hausman test had a value of essentially zero and the Limmer F test (Baltagi, 2005) had a value of 1.27 (critical value of 1.30) for all countries, but it was 19.91 (critical value of 2.92) for OPEC countries. Thus we decided to use the fixed effects model for OPEC countries and the random effects model for other countries.

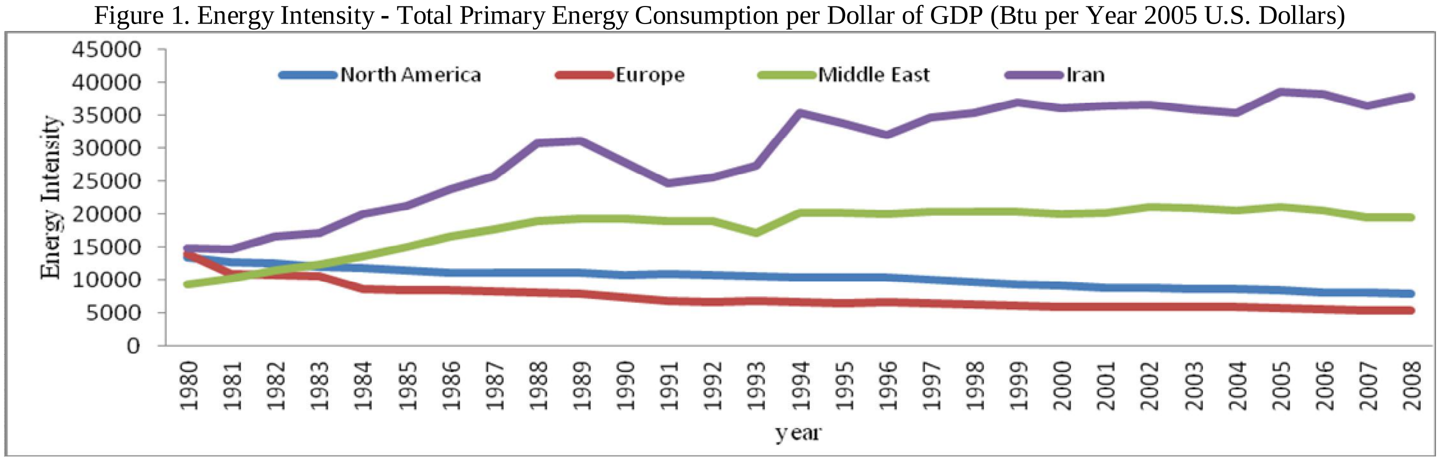
4. Estimation Results:

Table (2) shows the estimation results for equation (7) for the OPEC countries and all the other countries. Coefficients for the logarithm of capital intensity as well as the labor supply have a positive sign and are significantly different from zero for both country groups (Table 2). The magnitudes are slightly higher for oil exporting countries. This indicates that the possibility of substituting capital and labor with energy in the oil exporting countries is weaker. This could be due to energy's abundance in these countries relative to capital and labor. The output elasticity of energy is a much higher negative value (-6.90) in the OPEC countries than for other countries (-0.13). This shows how far OPEC countries have come in making their economies more energy efficient. A one percent increase in the growth rate of the oil producing countries lowers the energy intensity in these countries by 6.90 percent, a tremendous accomplishment. The coefficient might also indicate how inefficient these economies were in their energy use during early parts of the observation period.

The effect of the expansion in different sectors on energy intensity shows that the growth rate in the agriculture, animal husbandry, and fisheries share for both sets of countries is very close and negative. This sector is a less intensive user of energy than other sectors. The results indicate that the manufacturing and construction sectors in the oil producing countries do not have a significant impact on energy intensity whereas these sectors increase energy intensity 2.48% and 9.58%, respectively, in all other countries. Construction has the largest effect on energy intensity for both sets of countries. The elasticity of energy intensity with respect to transportation and communication is similar for both country sets: -3.96 in the OPEC countries and -4.42 in other countries. The OPEC countries, which are mainly among the developing countries, lower energy consumption and improve their energy use as they transform their outdated and primitive transportation system. A 1% increase in the share of the mining, water, and power sector has a positive and significant impact on the energy intensity in both groups of the countries.

The service sector has a minimal impact on energy intensity for other countries (-0.00013). At the same time the elasticity of energy intensity for the service sector's share in OPEC countries is -8.09, the largest negative coefficient for those countries. The service sector in the OPEC countries is a small fraction of the GDP compared to other countries in the world and it appears that it has improved its energy efficiency immensely with its growth over time. The other valued added parts of the economy (the seventh sector analyzed) have a positive and significant impact on energy intensity for both country groups (as seen in the last row of Table 2).

Figure 1. Energy Intensity - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars)



Source: www.eia.dov.org

Table 1. Panel Unit Root Test for All Variables

Variable	Levin-Lin & Chu		Breitung		Im, Pesaran & Shin		A-F - Fisher Chi-square		PP - Fisher Chi-square	
	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob
Energy Intensity	- 8.42	0.00	-12.61	0.00	-18.28	0.00	619.55	0.00	1477.73	0.00
(K/GDP)	-15.91	0.00	-14.62	0.00	-21.35	0.00	726.28	0.00	1258.91	0.00
(L/GDP)	-7.59	0.00	-13.61	0.00	-18.85	0.00	635.83	0.00	1524.35	0.00
GDP	-8	0.00	-13.93	0.00	-19.94	0.00	-659.10	0.00	1557.50	0.00
Manufacturing value added (% of GDP)	7.05	0.00	-14.23	0.00	-15.30	0.00	520.17	0.00	1306.88	0.00
Mining, water and power value added (% of GDP)	-6.57	0.00	-13.80	0.00	-15.39	0.00	563.37	0.00	1304.97	0.00
Agriculture, animal husbandry, and fisheries value added (% of GDP)	-7.28	0.00	-6.58	0.00	-16.43	0.00	552.71	0.00	1356.55	0.00
Transportation and communication value added (% of GDP)	-5.69	0.00	-13.36	0.00	-13.98	0.00	488.10	0.00	1256.81	0.00
Construction value added (% of GDP)	-6.54	0.00	-13.78	0.00	-15.82	0.00	539.12	0.00	1286.76	0.00
Service value added (% of GDP)	-6.28	0.00	-14.80	0.00	-15.51	0.00	528.29	0.00	1296.81	0.00
Other value added (% of GDP)	-6.45	0.00	-13.94	0.00	-15.43	0.00	524.27	0.00	1304.83	0.00

* : Rounded to two decimal points

Table 2. The Estimation Results* of Model

OPEC countries			.all other Countries			Variable
Prob	t-Statistic	Coefficient	Prob	t-Statistic	Coefficient	
0.02	2.28	0.02	0.09	1.72	0.005	(K/GDP)
0.00	250.09	0.93	0.00	558.14	0.86	(L/GDP)
0.00	-7.61	-6.90	0.00	-64	-0.13	GDP
0.10	1.65	1.79	0.00	7.6	2.48	Manufacturing value added (% of GDP)
0.005	2.79	1.98	0.00	9.88	2.10	Mining value added (% of GDP)
0.00	-3.06	-4.46	0.00	-6.98	-3/07	Agriculture value added (% of GDP)
0.28	-1.09	-3.96	0.00	-4.02	-4.42	Transport value added (% of GDP)
0.16	1.41	6.13	0.00	7.29	9.85	Construction value added (% of GDP)
0.04	-2.05	-8.09	0.00	-10.55	-0.00013	Service value added (% of GDP)
0.01	2.57	1.87	0.00	9.47	2.07	Other value added (% of GDP)

* :Rounded to two decimal points

5. Concluding Comments:

One of the main comparison tools in energy consumption is the Energy Intensity. Since there are noneconomic factors affecting energy intensity, such as social and environmental factors, we need to look at proper strategies that can lower energy intensity. In this article we have studied the impact of the expansion of different economic sectors on energy intensity in OPEC countries versus the rest of the world during 1980-2005. This analysis can help improve allocation of resources through identifying a country's competitive advantages which would help policy makers in such countries to implement more efficient development programs, especially in energy-rich countries, and environmental burdens. The results indicate that with an increase in the share of construction; mining, water, and power; and manufacturing in the economy, energy intensity goes up. Expansion in the agriculture, animal husbandry, and fisheries; transportation and communications; and services sectors contribute more to value added from a one unit increase in energy consumption. The results also indicate that the proper strategy for the oil producing countries to lower their energy intensity is to improve their economic growth and expand the service sector. Increased economic growth provides money for investing in increased energy efficiency.

The fact that energy intensity trends show that the marginal return of energy use in the OPEC countries are lower than the other countries in this study shows that the possibility of factor substitution between the energy carriers and other inputs is low in these countries. In other words compared to other countries OPEC countries do not have a balanced use of productive factors. Therefore, it is necessary for these countries to initiate policies to enhance the substitution between energy and other factors of production.

The impact of an increase in GDP on energy intensity in the OPEC countries is -6.9 which is much higher than that for the rest of the world (-0.13). This result confirms the inverse relation between economic growth and energy intensity as demonstrated by Dinda (2004). In other words the marginal return of energy consumption in the OPEC countries compared to other countries is much lower. This could be attributed to the lack of a balanced use of productive factors in the oil producing countries. Therefore, concomitant with efforts to enhance growth, OPEC countries should implement policies to improve their energy use.

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