JJMIE

Volume 5, Number 2, April 2011
ISSN 1995-6665
Pages 113 - 118

Jordan Journal of Mechanical and Industrial Engineering

Declination of the Aggregate Energy Intensity of the Jordanian Industrial Sector Between Years 1998 and 2005

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Abstract

This paper uses the refined Laspeyers method decomposition technique to explain factors that impact aggregate energy intensity in the Jordanian industrial sector during the period 1998-2005. This kind of study is useful to evaluate the past and predict the future trends for energy-policy evaluation. The Jordanian industrial aggregate energy intensity has decreased from approximately 40.6 to 25.7 MJ/US$ in 1998 and 2005, respectively. The analysis showed that the efficiency and structural effects contribute to decreases of around 33 and 67% respectively of total aggregate energy intensity decline in the industrial sector.

Keywords: Decomposition; Laspeyers index; Jordan, Energy; Efficiency; Structural; Intensity.

1. Introduction

Jordan, which is a relatively small country of about 5.6 million inhabitants, lies in the heart of the Middle East. It is among the low income countries of the region with an average GDP per capita of about US$ 2550 in 2006, compared to US$ 10,000–18,000 for neighboring oil exporting Arab Gulf States [1,2]. The country suffers from an ever-present lack of sufficient supplies of natural resources including water, minerals, crude oil and natural gas. Being a non-oil producing country, there has been an increasing anxiety about energy consumption and its harmful impact on the national economy as well as local environment. At present, Jordan depends profoundly on imported crude oil and natural gas from neighboring Arab countries as main sources of energy which causes a drain of scarce hard currency. The annual energy bill has been hurriedly escalating over the past few years and exceeded US$ 3 billion in year 2006 due to high rates of population and economic growth combined with the successive increase in oil price.

The industrial sector's aggregate energy intensity, defined here as energy consumption divided by the value added output[1] (*MJ/$*), is a key parameter for describing industrial energy efficiency. Decomposition techniques have been conducted extensively to better understand the historical variations in energy use. Extensive research has been conducted to better understand the historical variations in aggregate energy intensity, and two main factors have been identified [3-5]: changes in the structure of production output over time (i.e. structural effect), and changes in energy efficiencies of individual industries (i.e. efficiency effect, also referred to as the intensity effect in some literature)[2]. The impact of the structural effect on aggregate energy intensity and aggregate energy use has been an important subject of research since 1978 [6].

Numerous decomposition studies have been widely used since the early 1980s to decompose the aggregate energy intensity changes into structural, and efficiency effects. Also, the decomposition analysis has been use to decompose the energy consumption changes into production, structural, and efficiency effect. This analysis has been utilized in different countries: Sweden [7]; United Kingdom [8]; Canada [9]; China [10-11]; Spain [12]; Thailand [13]; Turkey [14]; USA [15]. Related literature can be found in [16-19]. This technique is based on economic index numbers; over one hundred of such indexes have been described by Economic index numbers by [20]. Comparisons and linkages between decomposition methods and economic index numbers can be found in literature [21, 4]. Also, decomposition analysis can be used to study the effect of economic growth and vehicle

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[1] Value added has been deflated and expressed in 1999 constant dollars, and so value added output refers to 1999 constant dollar value added

[2] Aggregate energy intensity and energy intensity are different terms. Aggregate energy intensity refers to the total energy consumption divided by the total value added output of all industries within the industrial sector, while energy intensity, on the other hand, is the energy consumption divided by the value added output of each industry within the industrial sector. To avoid confusion, energy efficiency and efficiency effect will refer to energy intensity and intensity effect, respectively. If energy intensity decreases, this means that energy efficiency increases and vice versa.

ownership on transportation carbon dioxide emission and energy consumption [22].

In Jordan, there are several studies that analyzed current and future energy requirements for different sectors and industries [23-27]; however, few decomposition studies have been reported recently in Jordan. While the previous papers conducted by the authors [28-29] were concerned with the electricity intensity and did not take into consideration the fuel consumption in the Jordanian industrial sector, in this paper, the Laspeyers approach decomposition technique is applied to examine the role of structural, and efficiency effects that impact the Jordanian industrial aggregate energy intensity (both fuel and electricity) during the period from 1998 to 2005. Between these years, there was rapid growth in the demand for energy in the Jordanian industries, led by strong growth in industrial activity and increasing penetrations of new facilities that are occupied with new technologies. This kind of research is useful for analysts and policy makers concerned with energy issues in Jordan, especially those interested in future directions of energy demand in Jordan.

The paper is organized as follows: the next section describes the energy consumption in Jordan; section 3 briefs the various data sources utilized in this study; section 4 presents the descriptive analysis of the industrial energy demand and its relation with the economic growth; section 5 demonstrates the analysis using refined Laspeyers decomposition technique; and sections 6 and 7 display the results and the concluding remarks, respectively.

2. Energy consumption in Jordan

In 2006, the total primary and final energy consumption were about 7.2×10^6 and 4.9×10^6 ton oil equivalent (toe), respectively. The second largest consumer, after transportation, is the industrial sector with a contribution ratio of about one quarter of total energy available for all consumers, as shown in Figure 1 [30]. The rate of energy consumption, especially electricity, is rising rapidly due to the high growth rate of population and urbanization.

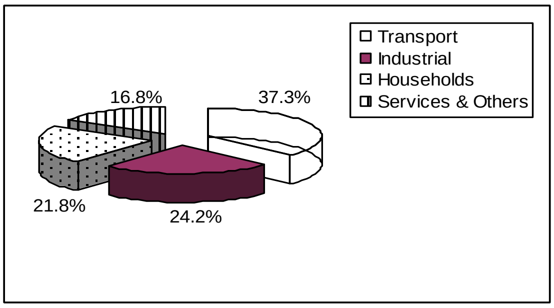

Figure 1.Distribution of final energy consumption in 2006.

3. Data sources and basic assumptions

This study examines and carefully distinguishes between the *site* and *embodied* energy content of electricity. The embodied energy value accounts for the generation and transmission energy losses associated with electricity production, while the site electricity value includes only the site heat value of electricity (3,600 *kJ/kWh*). Electricity used in the manufacturing sector mainly originates from two sources: purchased electricity and electricity produced onsite. In this paper, the heat rate of the electricity is defined as the ratio of the site energy content of electricity produced to the total energy content of fuel input used to produce it. The heat rate of the electricity depends on the generation technology mix used to provide the electricity to the manufacturing sector and has been estimated by as 34%. In this study, the embodied energy has been used for the analyses between years 1998 and 2005. All data were retrieved from various years of Jordan's statistical yearbooks as published by different governmental agencies. The focus on this time frame largely reflects the availability of data as required for the purposes of this study. Due to data availability constraint, the Jordanian industrial sector was disaggregated into seven sub-sectors; namely, mining of chemical and fertilizer minerals, paper, plastics, petroleum, cement, iron and steel, and others industries[3].

It is worthwhile mentioning here that all disaggregated physical energy quantities in a specific period for all Jordanian industries were calculated by converting the monetary values (which are the only available sources of energy data) of each energy source to its corresponding physical value by using the average fuel price in that period. The energy values used in this study are the summation of fuel energy and the embodied energy of electricity. The source of information for the annual energy consumption is the Jordanian National Electric Power Company [31] and the Department of Statistics [32]. Production output is based on the value added as reported by the Jordan Chamber of Industry and Department of Statistics [32]. Value added represents the unique contribution to the production of a finished product/commodity. Use of this value avoids the issue of 'double counting' when a commodity produced by one industry is used as an input for another industry. A change in the value added from one year to another includes an increase (or decrease) in price resulting from inflation or deflation; such changes do not reflect a change in output. Therefore, before using estimates of the values added as an output measure, they were adjusted for the effect of changes in price using the producer price index (as reported in year 1999) obtained from the Department of Statistics [33].

4. General picture of Jordanian industrial growth and energy demand

Before applying the decomposition technique, a graphic analysis of energy consumption, industrial

3 This disaggregation level is justified since the mining of chemical and fertilizer minerals, paper, plastics, petroleum, cement, and iron and steel sub-sectors are the main intensive industries in Jordan. In 2005, they contributed to about 70% of total energy demand. The "Other" industries include food, tobacco, textiles, wearing apparel, tanning and dressing of leather, wood, publishing and printing media, chemicals, fabricated metals, machinery, transportation, and furniture industries. These industries were grouped together since no individual data is available for each of them and such industries can be considered as electricity non-intensive industries.

production, and aggregate energy intensity series are discussed briefly. Such analysis could be useful in order to obtain some insight into these time series patterns between 1998 and 2005 years.

4.1. Industrial production output growth

Figure 2 presents the growth in industrial value added for the period 1998-2005. This period represents an approximately constant rapid growth with an annual average growth rate of 13.6%. However, close look at this figure reveals that two regions exist: first one being extends until the year 2002, while the second region is after that year but with higher growth rate than the previous one. This can be attributed to the US invasion and recent crisis in Iraq which caused an increase in industrial production and exports to the Iraqi market. It is worth mentioning that most of small and medium industries, in Jordan, were built during 1980s and 1990s taking into consideration the Iraqi market, i.e. their nominal production capacities are far larger than the demand of the local market. The value added of the industrial sector has increased from 1,467 million dollars in 1998 to 2,865 million dollars in 2005 at constant 1999 prices.

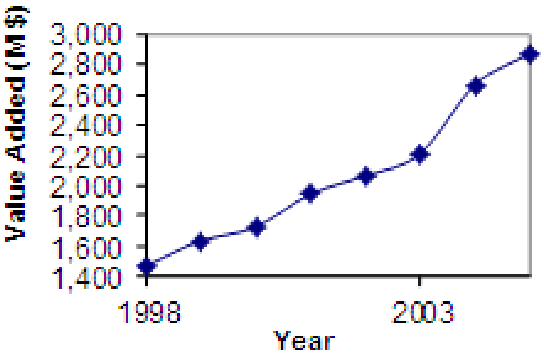

Figure 2.Growth in industrial value added in Jordanian industrial sector.

Table 1 shows the average growth rate and the shares of value added for the seven disaggregated sub-sectors over the period under study. As shown in this table, the overall production outputs of all industries have increased between 1998 and 2005, i.e. have positive annual growth rates. However, the industrial sector has witnessed structural changes during the period of study. Where the "Other industries" sub-sector (non intensive electricity industries) has a dominant share within industrial sector and its importance has increased during this period: from a share of about 63.1% in 1998 to about 69.6% in 2005 with production output average annual growth of 16%; an average growth greater than the total industrial production annual growth. Chemicals manufacture, tobacco products, and food products were among the largest contributors to the non intensive industries. On the other hand, mining of chemicals and fertilizer minerals (e.g. potash and phosphate) is the next important industrial activity (intensive electricity industry) but its share has declined from 17.9% in 1998 to 14.1% in 2005 with average annual production output growth rate of 7.3% which is much lower than the total industrial production output growth rate. A similar situation can be observed for petroleum, cement, and plastics sub-sectors.

These industries can also be considered as intensive electricity industries. although the average annual production output growth for iron and steel, and paper industries (intensive electricity industries) have increased during this period; their shares are small to have significant impacts on annual electricity demand. From the previous analyses, one can conclude that there was a shift in the Jordanian industrial structure towards non intensive electricity industries; and hence, an important contribution due to the structural effect on electricity demand change during the study period is expected.

Table 1. Shares of value added and average annual growth rate of the manufacturing industries (%).

Industry	Year								Average Annual Growth (%)
	1998	1999	2000	2001	2002	2003	2004	2005	
Mining of chemicals and fertilizer minerals	17.9	16.1	15.1	13.6	12.7	12.2	12.5	14.1	7.3
Paper	1.6	2.2	2.1	2.5	2.6	2.4	2.5	2.4	27.1
Plastics	2.1	2.4	2.2	2.5	2.7	2.6	2.2	2.0	12.1
Petroleum	5.9	5.4	5.1	3.9	4.0	3.6	3.2	2.4	4.3
Cement	6.9	6.6	6.3	6.4	5.8	5.6	5.4	5.2	6.4
Iron and Steel	2.5	3.1	3.2	3.3	3.2	3.7	3.8	4.3	32.2
Others	63.1	64.2	66.0	67.8	69.0	69.9	70.4	69.6	16.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	13.6

4.2. Growth in energy demand

Figure 3 shows the annual growth in energy demand in the Jordanian industrial sector, while Table 2 summarizes the average annual growth rates and the shares of energy use for the seven disaggregated sub-sectors. This period represents an approximately constant growth with an average annual growth rate of 3.4% which is much lower than the annual growth for production output.

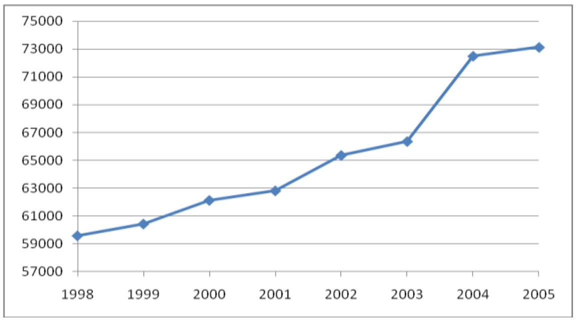

Figure 3: Growth in energy demand (TJ) in the Jordanian industrial sector.

Table 2: Shares of energy use and annual growth rate of the manufacturing industries (%).

Industry	Year								Average Annual Growth (%)
	1998	1999	2000	2001	2002	2003	2004	2005	
Mining of chemicals and fertilizer minerals	25.1	21.9	20.5	18.7	18.0	18.2	18.4	19.4	-0.6
Paper	2.0	2.1	2.8	3.1	3.0	2.9	2.8	2.8	9.9
Plastics	1.8	2.1	2.3	2.2	2	2	2	2	4.9
Petroleum	16.2	17.8	18.3	15.8	15.5	15.8	15.1	14.9	1.9
Cement	25.9	24.0	22.9	26.8	26.9	26.0	26.6	26.2	3.6
Iron and Steel	3.1	4.2	3.3	3.6	3.7	4.6	5.1	5.3	16.1
Others	25.9	27.9	30.0	29.7	30.8	30.5	30.0	29.5	5.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	3.4

As can be seen from Table 2, all types of industries have annual growth of energy use smaller than the annual growth of production output shown in Table 1. This simply means that all industries gained improvement in energy efficiency over the study period and therefore, a general conclusion that can be drawn here is that there was a significant energy efficiency improvement during the 1998-2005 period. Again, this table demonstrates that the role of energy intensive industries has decreased as can be seen from the decrease in energy demand shares for mining of chemicals and fertilizer minerals, and petroleum industries.

But it should be noted that increased prices of energy and increased rates of production the country witnessed during this period would lead to lower ratios of specific energy consumption per final unit produced, i.e. less losses, due to increased awareness and capacity utilization factors. As a result a general conclusion that can be drawn here is that there was a significant improvement in energy utilization efficiency during the period 1998-2005.

4.3. Aggregate energy intensity variation

From the previous data and analysis, one can foresee that aggregate energy intensity should decline during the study period 1998-2005, since the annual growth of energy is less than the annual growth of the Jordanian industrial production output. Figure 4 shows the aggregate energy intensity of the Jordanian industrial sector during the study period. As can be seen from this figure, aggregate energy intensity has decreased from 40.6 *MJ/$* in 1998 to 25.7 *MJ/$* in 2005 at an average decline of 5.24%yr^{-1}. Although the previous analysis and data give some indications of the factors that result in aggregate energy intensity reduction, however, a method to quantify these factors is still needed; the purpose of this study is to quantify and explain the factors affecting this variation. This will be explained in the following section.

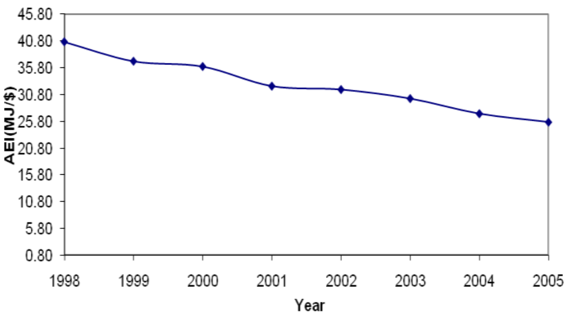

Figure 4. Aggregate energy intensity (AEI) of the Jordanian industrial sector

5. Methodology

The methodology adopted in this study has been used before in [34]. This method of decomposition results in no residual, meaning that it is able to explain all of the changes in the aggregate energy intensity decomposed. Before introducing this method, it is necessary to define the two factors that will be investigated in this study; namely, the structural and efficiency factors. Structural factor is a measure of production shift from/to energy intensive to/from energy non intensive industries while the efficiency factor is an indication of the amount of energy used per unit of constant value added of individual industries. Decreases in energy intensities mean improvement in energy efficiency and vice versa. Improvement in energy efficiency is associated with the technical characteristics of the equipment being run, including fans, compressors, electric furnaces, etc.

The total change in industrial aggregate energy intensity between *T* and *0* years can be expressed as follows:

$$(\Delta I_{TOT})_{0,T} = (\Delta I_{STR})_{0,T} + (\Delta I_{EFF})_{0,T} \qquad (1)$$

$$(\Delta I_{TOT})_{0,T} = (I_{TOT})_T - (I_{TOT})_0 \qquad (2)$$

$$(I_{TOT})_t = \frac{(E_{TOT})_t}{(Y_{TOT})_t} \qquad (3)$$

Where,

$(\Delta I_{TOT})_{0,T}$: Total change in aggregate industrial energy intensity between *T* and *0* years (*MJ/$*).

$(\Delta I_{STR})_{0,T}$:Structural effect between *T* and *0* years (*MJ/$*).

$(\Delta I_{EFF})_{0,T}$:Efficiency effect between *T* and 0 years (*MJ/$*).

$(I_{TOT})_t$: Industrial aggregate energy intensity at year *t*.

$(E_{TOT})_t$:Total industrial energy consumption (TJ).

$(Y_{TOT})_t$:Total industrial production value added (Million $ in 1999 constant prices) at year *t*.

The aggregate energy intensity can be expressed as follows:

$$(I_{TOT})_t = \sum_i (E_i)_t / (Y_{TOT})_t \qquad (4)$$

Where,

$(E_i)_t$: Energy consumption in industry *i* at year *t* (*GWh*).

equation (4) can be rewritten as:

$$(I_{TOT})_t = \sum_i ((Y_i)_t / (Y_{TOT})_t)((E_i)_t / (Y_i)_t) = \sum_i (y_i)_t (I_i)_t \qquad (5)$$

Where,

$(Y_i)_t$: Production value added of industry *i* (Million $ in 1999 constant prices) at year *t*.

$(y_i)_t$: Production share of industry *i* (= $(Y_i)_t/(Y_{TOT})_t$) at year *t*.

$(I_i)_t$: Energy efficiency of industry *i* (= $(E_i)_t/(Y_i)_t$) at year *t*.

where the summation is taken over all sub-sectors (industries). The aggregate energy intensity can be expressed in terms of production structure and industry energy efficiency as follows:

Equation 2 can be re-written as:

$$(\Delta I_{TOT})_{0,T} = (I_{TOT})_T - (I_{TOT})_0 = \sum_i (y_i)_T (I_i)_T - \sum_i (y_i)_0 (I_i)_0 \qquad (6)$$

equation (6) can be rewritten as:

$$(\Delta I_{TOT})_{0,T} = \sum_i ((y_i)_T - (y_i)_0)(I_i)_0 + \sum_i ((I_i)_T - (I_i)_0)(y_i)_0 + \sum_i ((y_i)_T - (y_i)_0)((I_i)_T - (I_i)_0) \qquad (7)$$

where the first two terms on the right-hand side of Equation (7) are the structural effect ($(\Delta I_{STR})_{0,T}$) and the efficiency effect ($(\Delta I_{EFF})_{0,T}$) respectively. The third term, which is the interaction, is the residual; this residual is split equally between the structural and efficiency effects:

$$(\Delta I_{STR})_{0,T} = \sum_i ((y_i)_T - (y_i)_0)(I_i)_0 + \frac{1}{2}\sum_i ((y_i)_T - (y_i)_0)((I_i)_T - (I_i)_0) \quad (8)$$

$$(\Delta I_{EFF})_{0,T} = \sum_i ((I_i)_T - (I_i)_0)(y_i)_0 + \frac{1}{2}\sum_i ((y_i)_T - (y_i)_0)((I_i)_T - (I_i)_0) \quad (9)$$

6. Results and Discussion

Figure 5 presents how the aggregate energy intensity varies with time, and how these changes are decomposed by the Refined Laspeyers Method. It is obvious that the aggregate energy intensity has declined over the studied period, at an annual rate of approximately 5.24%. During this period, improvements in energy efficiency contributed largely to this decline, and caused, on average, approximately 3.51% yr^{-1} decline in aggregate energy intensity. This could be attributed to some improvements in energy utilization efficiency, especially in newly established industries which usually tend to employ latest machinery and technologies. Another factor that may contribute to the reported decline in aggregate energy the consecutive increase in energy unit price, which has been adjusted three times during 1998-2005, forced all sectors of the economy, including industries of all categories and sizes, to think carefully about enhancing efficiency in all activities and operations [35]. On the other hand, moving towards non-intensive energy industries, i.e. structural effect, such as electronics, tobacco and clothes, accounts for about 1.73% yr^{-1} decline in aggregate energy intensity. In 1998 there were 9,039 industrial establishments registered in Jordan. However, this figure rose to reach approximately 13,791 in 2005 [32]; the net increase occurred in small industrial firms that usually considered as non-intensive energy consuming industries.

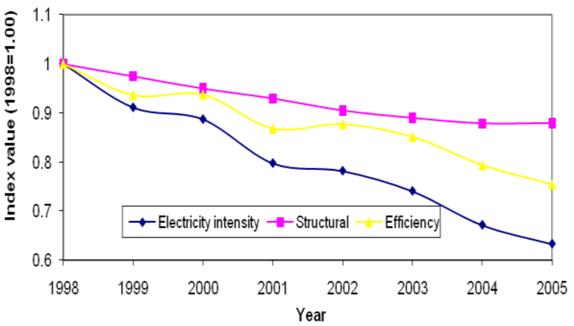

Figure 5.Time series decomposition for the Jordanian industrial energy intensity.

However, during the last decade, it can be said that energy conservation and management measures were taken more seriously by the top management of large industries in Jordan. For example, the new strategic partner, LFARGE, with Jordan Cement Factories Company worked hard in the last few years to reduce operating costs, including fuel and electricity consumption [36]. Recently, in 2005, MEMR in close cooperation with qualified consultants in the filed of energy management conducted a field study and detailed energy audits for about 15 medium-size industries representing most industrial sub-sectors. The final report concluded that it is possible to save about 15-25% of energy and electricity consumption in these industries with relatively low investments: short pay back periods of less than 14 months [37].

7. Conclusions

In this paper, factors that have influenced changes in aggregate energy intensity of the Jordanian industrial sector were determined. Between 1998 and 2005, aggregate energy intensity of the Jordanian industrial sector decreased from 40.6 *MJ/$* in 1998 to 25.7 *MJ/$* in 2005 (constant 1999 prices). Results of the decomposition analysis prove that efficiency effect to be greater, implying innovation, technical change, diffusion and adaptability to more efficient technologies as main sources of aggregate energy intensity reduction. Contributions to aggregate energy intensity decrease are 33 and 67% for structural and efficiency effects respectively.

To ascertain the relative importance of structural change and intensity change is important not only because it provides policy makers with the energy impact of the policies that have been implemented, but also because a good understanding of this issues helps to improve the credibility of future projections for energy demand and energy-related emissions.

Forecasting of energy use in the future has to be based on information and understanding of the developments in the past; therefore, this kind of analysis may give policy makers and analysts indication of how energy demand, and required capacity, may change into future. This paper can be considered as a milestone for improving and restructuring the Jordanian industrial sector in the near future for purposes of improving its energy utilization efficiency.

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