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# Reasons behind Energy Changes of the Jordanian Industrial Sector

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**Abstract**

In order to identify main drivers behind changes in electricity and fuel consumptions in the industrial sector in Jordan; a Laspeyers decomposition technique was used to identify the factors affecting this demand during 1998-2005 years Changes have been disaggregated into production, structural, and efficiency effects. Results of the decomposition analysis prove that rapid increases in industrial production output had the most important implications on increasing energy demand in this sector which causes an annual energy increase of 10.9% $yr^{-1}$. However, these increases were countered mainly by efficiency gains and to a lesser extent by structural changes in the industrial sector. The analysis showed that the structural effect contributes to an annual energy decrease of around 2.28% $yr^{-1}$ while the efficiency effect contributes to an annual energy decrease of 5.65% $yr^{-1}$.



*Keywords:* Decomposition; Laspeyers index; Jordan; Energy; Efficiency; Structural

## 1. Introduction

Jordan is considered among low-middle income countries, within the Middle East Region, with an average income per capita of about US$ 2,770, in 2007, and its population reached 5.723 million inhabitants [1, 2]. It suffers from a chronic lack of adequate supplies of natural resources including fresh water, crude oil and other commercial minerals. Thus, Jordan depends heavily on imports of crude oil, refined products and natural gas from neighboring Arab countries as main sources of energy. Its current imports of around 100,000 barrels of crude oil per day are placing the country under extreme economic pressures, especially with increasing unit price of oil in the international market. The annual energy bill has been rapidly increasing over the past few years due to high rates of population and economic growth combined with the consecutive increase in oil price. Consequently, there has been a growing concern about energy consumption and its adverse impact on the economy and environment, with special focus on the industrial sector, because its contribution accounted for about one third of final energy and electricity consumption.

In recent years, concerns about energy consumption in Jordan have been growing, especially in the industrial sector, which was probably affected the most by the economic and technological changes that the country has witnessed during the past two decades. Therefore, the provision of reliable information on industrial energy use is essential.

Decomposition techniques have been conducted extensively to better understand the historical variations in energy use, and three main factors have been identified in [3]: changes in the industrial activity (production effect), changes in the structure of production output over time (the structural effect), and changes in energy efficiencies of individual industries (the efficiency effect). This technique has been used to analyze energy changes in different countries [4-13]. Related literature can be found in [14-16]. This technique is based on economic index numbers; over one hundred of such indexes have been described by [17]. Comparisons and linkages between decomposition methods and economic index numbers can be found in literature [18-19]. An overview of several decomposition methods was outlined by [20-21].

In Jordan, there are several studies that analyzed current and future energy requirements for different sectors and industries [22-26]; however, few decomposition studies have been reported recently in Jordan. While the previous papers conducted by the authors [27-28] were concerned with the electricity consumption 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 production, structural, and efficiency effects that impact the Jordanian industrial energy demand (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.

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The paper is organized as follows: the next section presents the energy use in Jordan; section 3 describes the different data sources utilized in this study; section 4 presents a descriptive analysis of the industrial energy demand and production output growth; section 5 presents the decomposition analysis using Laspeyers decomposition technique; section 6 presents the results and discussions; and section 7 presents some concluding remarks.

## 2. Energy Use in Jordan

In 2005, Jordan's consumption of primary energy (crude oil and petroleum products, natural gas, renewable energy, imported electricity) amounted to $7.028\times10^6$ Ton Oil Equivalent (TOE) while the final energy consumption was $4.802\times10^6$ TOE. Final energy consumption in Jordan is mainly distributed between three major sectors: transportation, industrial, and residential. The distribution of final energy consumption among different sectors over the past five years is presented in Table 1[29]. It can be seen that the industrial sector is the second largest consuming sector of final energy The share of this sector has been nearly constant over the past few years at nearly 24% of final energy consumption.

Table 1: Sectoral distribution of the final energy consumption in Jordan during the period 2001-2005 (Thousand TOE)

| Year | Sector | | | | Total |
|---|---|---|---|---|---|
| | Transport | Industrial | Household | Other | |
| 2001 | 1411 (38.2%) | 826 (22.4%) | 849 (23.0%) | 606 (16.4%) | 3692 (100%) |
| 2002 | 1435 (37.7%) | 846 (22.2%) | 868 (22.8%) | 662 (17.4%) | 3811 (100%) |
| 2003 | 1495 (37.0%) | 878 (21.7%) | 945 (23.4%) | 722 (17.9%) | 4040 (100%) |
| 2004 | 1693 (37.4%) | 1034 (22.8%) | 1007 (22.2%) | 792 (17.5%) | 4526 (100%) |
| 2005 | 1779 (37.0%) | 1159 (24.1%) | 1060 (22.1%) | 804 (16.7%) | 4802 (100%) |

## 3. Description of Data Sources

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% [30]. 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.

Ideally, the fine level of disaggregation level is desirable in order to accurately disentangle the structural effect from efficiency effect [8]. However, the choice for a level of sector disaggregation is mainly dictated by the data availability. 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 other industries[1].

The source of information for the annual energy consumption is the Jordanian National Electric Power Company [31] and the Jordanian department of statistics [32]. 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. Production output is based on the value added as reported by the Jordanian department of statistics [32]. Use of this value avoids the issue of 'double counting' when a product produced by one industry is 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 (deflation); such changes do not reflect a change in output. Therefore, before using estimates of the added values as an output measure, they were adjusted for the effect of changes in price using the producer price index (1999 constant) obtained from the Department of Statistics [33].[2]

## 4. Historical Jordanian Industrial Production and Energy Demand

As shown in Figure 1, a constant rapid growth of the Jordanian industrial production with an annual average growth rate of 13.2% has been witnessed between years 1998 and 2005. The value added of the industrial sector has increased from 1,468 million dollars in 1998 to 2,822 million dollars in 2005 at constant 1999 prices.

As shown from this table, the overall production outputs of all industries have increased between 1998 and 2005 years (as indicated by positive annual growths); however, these increases are at different rates. As an example, the "Other industries" sub-sector (non intensive energy 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

1 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.

2 The data set can be obtained from the corresponding author upon request.

other hand, mining of chemicals and fertilizer minerals (ex., potash and phosphate) is the next important industrial activity (intensive energy 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 energy 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 energy demand. From the above analyses, one can conclude that there was a shift in Jordanian industrial structure toward non intensive energy industries; and hence, a contribution due to the structural effect on energy demand change during the study period is expected

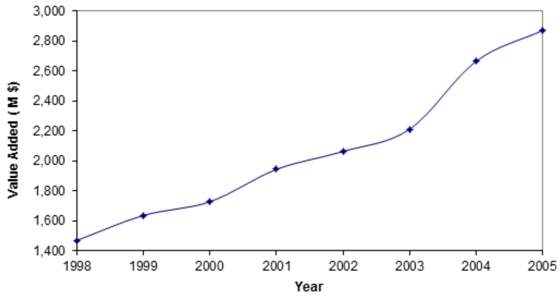


Figure 1: Growth in industrial value added in Jordanian industrial sector.

Table 2: 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 | 13.2 |

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

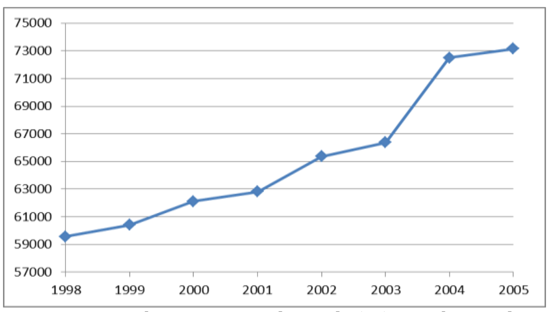

Figure 2: Growth in energy demand (TJ) in the Jordanian industrial sector.

Table 3: 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 |

It is clearly shown from this table that all types of industries have annual growth of energy use smaller than the annual growth of production output shown in Table 2 which means that all industries gained improvement in energy efficiency over the study. A general conclusion that can be drawn here is that there was a significant energy efficiency improvement during the 1998-2005 period.

## 5. Methodology

The methodology adopted in this study has been used before in [27]. Three factors will be studied in this paper; namely, the production, structural, and efficiency factors. The production factor is a measure of changes in total industrial production output as measured by constant value added from one year to another. 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, boilers, ect.

The total change in industrial energy demand between t and 0 years can be expressed as follows:

$$(\Delta E_{TOT})_{0,t} = (\Delta E_{OUT})_{0,t} + (\Delta E_{STR})_{0,t} + (\Delta E_{EFF})_{0,t} \qquad (1)$$

Where,

$(\Delta E_{TOT})_{0,t}$: Total change in industrial energy demand between $t$ and 0 years (TJ).

$(\Delta E_{OUT})_{0,t}$: Change in industrial energy demand due to changes in activity between t and 0 years (TJ).

$(\Delta E_{STR})_{0,t}$: Change in industrial energy demand due to structural effect between t and 0 years (TJ).

$(\Delta E_{EFF})_{0,t}$: Change in industrial energy demand due to efficiency effect between $t$ and 0 years (TJ).

According to the modified Laspeyers decomposition method proposed by [8], production, structural, and efficiency factors can be estimated as follows:

 

$$\Delta E_{OUT} = (Y_t - Y_0)\sum_i (y_{i,0} I_{i,0}) \quad (2)$$

$$\Delta E_{STR} = \sum_i (Y_t y_{i,t} I_{i,t} - Y_t y_{i,0} I_{i,t}) = Y_t \sum_i (y_{i,t} - y_{i,0}) I_{i,t} \quad (3)$$

$$\Delta E_{EFF} = \sum_i (Y_t y_{i,t} I_{i,t} - Y_t y_{i,t} I_{i,0}) = Y_t \sum_i (I_{i,t} - I_{i,0}) y_{i,t} \quad (4)$$

Where,

$Y$ = total industrial production value added (Million \$ in 1999 constant prices).
$Y_i$ = production value added of industry $i$ (Million \$ in 1999 constant prices).
$y_i$ = production share of industry $i$ (= $Y_i/Y$).
$I_i$ = energy intensity of industry $i$ (= $E_i/Y_i$).
$Y$ = total industrial production value added (Million \$ in 1999 constant prices).
$Y_i$ = production value added of industry $i$ (Million \$ in 1999 constant prices).
$y_i$ = production share of industry $i$ (= $Y_i/Y$).
$I_i$ = energy intensity of industry $i$ (= $E_i/Y_i$).

The summation is taken over all sub-sectors. A change in production factor is obtained by allowing production to change with time, while holding all others constant. Changes in structure are accounted for by differences between the amount of energy use that would be used if each sub-sectoral activity at year $t$ was produced at the energy intensity of year 0 and if the aggregate production at year $t$ was composed in the same way as at year 0. Changes in efficiency represent the difference between the observed energy use and what the energy use would be if each sub-sectoral activity at year $t$ was produced at the energy intensity of year 0.

## 6. Results and Discussion

By implementing the methodology described earlier, the growth in energy demand between years 1998 and 2005 can be decomposed into production, structural, and efficiency factors. These factors as vary with time are shown in Figure 3. During this period, the production effect contributes largely to this increase, and cause 10.9% $yr^{-1}$ increase in energy use during this period. On the other hand, improvements in energy efficiency accounts for 5.65% $yr^{-1}$ decline in energy use. The structural effect had the least effect during this period and results in 2.28% $yr^{-1}$ decline in energy use. The three affects together make the energy use to increase at annual rate of 3.4% $yr^{-1}$.

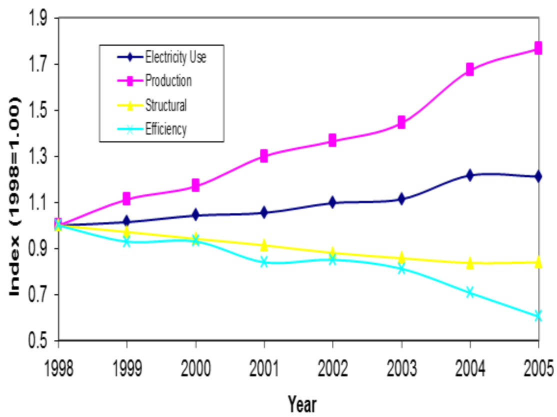


Figure 3: Time series decomposition for the Jordanian industrial energy demand.

In order to gain more insights for the energy demand changes between years 1998 and 2005; results of the analysis are compared between 1998 and 2005 and shown in Table 4. Again, it is obvious that the most important factor that has shaped industrial energy demand in Jordan was the production effect. However, decreases in the energy intensity countered this increase in demand. By 2005, industrial energy intensity was only 67% of 1998 value. As discussed before, there was a shift from energy-intensive industries in Jordan during the study period; however, this structural shift was not the most important factor. In comparison with an approximate 14,627 TJ decrease in demand between 1998 and 2005 attributed to structural effect, a decrease of 28,086 was attributed to the efficiency effect.

Table 4: Jordanian industrial sector energy demand decomposition results between 1998 and 2005 years.

| | 2005 compared to 1998 |
|---|---|
| | Contribution (TJ) |
| Production effect | 56,748 |
| Structural effect | -14,627 |
| Efficiency effect | -28,086 |
| Total | 14,035 |

## 7. Conclusion

This paper showed that the main driver behind the energy demand increase between years 1998 and 2005 was the rapid increase in industrial production output. However, significant improvements on efficiency effect, due to implying innovation, technical change, diffusion and adaptability to more efficient technologies and the structural changes in the industrial sector has countered this rapid increase.

These kind of studies give a depth understanding of the energy development in the past in order to 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 reducing its energy use.

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