This study is preliminary and is not to be cited

Variations in Energy Productivity in the Industrial Sector of Iran: Input – Output Analysis

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**Abstract**

Because of limitations in resources, one of the ways to achieve high economic growth is increasing energy productivity. In addition, increase in the energy productivity is important for the sake of environment; since it leads to lower consumption of energy for given level of production.

This research aims to calculate variations of energy productivity by use of Input- Output Table of Iran for years 1986 and 2001. Since part of variations energy productivity may originate from the nominal price of production of this sector, comparison of these tables in fixed prices will result in removing these kinds of variations. The researchers expect the results of this on- going study to indicate whether total productivity of energy in the industrial sector of Iran in the studied periods will increase and whether energy productivity in the sub-sectors of industrial sector will have co-movements.

**Keywords:** energy productivity, industrial sector, Input- Output Analysis, and Iran

**1- Introduction**

 Efficient use of energy resources in industrial sector is one of the principal requirements for

sustainable industrial productions; it provides financial savings, fossil resources preservation and air pollution reduction; for enhancing the energy efficiency it must be attempted to increase the production yield or to conserve the energy input without affecting the output.

 Iran is one of the large developing countries in the world. During the last decade, Iran has enjoyed average annual growth rate near 5 percent. To support such economic growth, annual energy consumption in 2011 was 1200 million barrels of crude oil, 23 percent of which was used in the industrial sectors. This paper examines energy productivity in the industrial sectors of Iran during 1986-2001. This research uses Structural Decomposition Method to decompose changes in energy productivity in to five interpretable components. Evidence from government energy programs in Development Plans suggests that there is potential to improve energy use productivity. This research calculates the variations of energy productivity in industrial sub-sectors by use of Input- Output Table of Iran for years 1986 and 2001. Since part of variations energy productivity may originate from the nominal prices of production of these sectors, comparison of these tables in fixed prices will result in removing these kinds of variations.

**2- Method**

The value added of each sector can be calculated from

 $V=\hat{v} \left(I-A\right)^{-1} B F=\hat{v} C B F$ (1)

where,$ V$ is the value added vector of all sectors ($n×1$ vector),$ \hat{v}$ is a diagonal matrix of direct value added coefficient of different sectors,$ C$ is the Leontief inverse matrix, $B$ is a matrix of the all kind of final demands combination ($n×k$ matrix) that shows the share of *n* sectors in *k* kinds of final demands , $F$ is a vector of aggregated value of final demands ($k×1$ vector).

The energy consumption of sectors can be expressed as follows:

 $E=\hat{e} \left(I-A\right)^{-1} B F=\hat{e} C B F$ (2)

 $E$ refers to an ($n×1$) vector of energy consumption of the sectors, $\hat{e}$ represents diagonal matrix of direct energy consumption coefficient in different sectors ($n×n$ matrix).

The energy productivity of sectors is defined through a  vector of *P*:

 $P=\hat{E}^{-1} V$ (3)

here, $\hat{E}^{-1}$ shows the inverse diagonal matrix of the energy consumption of the sectors.

 The variations of energy productivity during a specific ear can be calculated

 $G=\hat{P}^{0}^{-1}P^{1}$ (4)

 In equation (4) upper script $0$ and $1$ are related to base and current periods respectively. Here, $\hat{P}^{0}^{-1}$ is the inverse diagonal matrix of the energy productivity in sectors, in the base time. For each element of the G ($n×1$ vector), we have

 $g\_{i}=\frac{p\_{i}^{1}}{p\_{i}^{0}}=\frac{{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}/{e\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}}{{v\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}/{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}}$ (5)

We use the Structure Decomposition Approach (SDA) to understand behavior of Iran’s energy productivity and energy consumption in industrial sectors from 1986 to 2001. Based on SDA, the changes in energy productivity of sector  can be decomposed attributed to several factors:

 $g\_{i}=\frac{p\_{i}^{1}}{p\_{i}^{0}}=g\_{i1}g\_{i2}g\_{i3}g\_{i4}g\_{i5}$ (6)

 $g\_{i1}=\frac{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}{e\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}$ (6-1)

 $g\_{i2}=\frac{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}{v\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}$ (6-2)

 $g\_{i3}=\frac{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{0}}{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}×\frac{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{1}}{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}$ (6-3)

 $g\_{i4}=\frac{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{1}}{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{1}b\_{ji}^{0}}×\frac{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{1}}$ (6-4)

 $g\_{i5}=\frac{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{1j}^{1}b\_{ji}^{1}}{v\_{i}^{1}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{1j}^{1}b\_{ji}^{1}}×\frac{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{0}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}{e\_{i}^{0}\sum\_{m=1}^{k}f\_{m}^{1}\sum\_{j=1}^{n}c\_{ij}^{0}b\_{ji}^{0}}$ (6-5)

Equation (6-1) shows the inversed effects of the change in energy input per unit of gross output by sector. Equation (6-2) shows the effects of the change in the value added’s share gross output by sector. Equation (6-3) shows the effects of the changes in sub-sectors. Equation (6-4) shows the effects of the changes in the changes in structure of final demand. Equation (6-5) shows the effects of the changes in the level of final demand.

**3- Data Sources**

The data needed for this study was provided from Input – Output Tables of the Iranian Census Bureau during the years 1986-2001. In order to remove price variations from input – output values of the sectors and to make the comparison of the results possible, fixed price tables were used as the basis for analysis. To achieve this objective, implicit price indexes of the sectors based on the fixed price of year 1997.

 Table (1): Energy Productivity, Iran (1986-2001)

|  |  |  |  |
| --- | --- | --- | --- |
| Industry | Year 1986 | Year 2001 | Growth Rate% |
| Mining | 0.000101 | 0.001251 | 1140 |
| Crude petro. | 0.000124 | 0.002348 | 1791 |
| Food | 0.000295 | 0.026086 | 8746 |
| Tobacco | 3.65E-05 | 0.000386 | 956 |
| Textiles | 0.017485 | 0.015407 | -12 |
| Leather products | 0.000204 | 0.000698 | 241 |
| wood products | 0.000274 | 0.002187 | 698 |
| Paper products | 0.0001 | 0.001384 | 1280 |
| Printing | 0.000253 | 0.000109 | -57 |
| Petro. refinery | 0.000256 | 0.00068 | 166 |
| Chemical products | 1.2E-05 | 2.88E-05 | 140 |
| Rubber products | 6.05E-06 | 0.000224 | 3598 |
| glass products | 0.000293 | 0.000512 | 75 |
| Non metallic mineral products | 9.45E-05 | 6.85E-05 | -27 |
| Iron & Steel products | 1.97E-05 | 7.01E-05 | 255 |
| Nonferrous metal products  | 4.08E-05 | 3.8E-05 | -61 |
| General tools and machinery nec | 6.09E-05 | 0.000529 | 770 |
| Machinery | 8.39E-05 | 0.000943 | 1024 |
| Household electric appliances  | 0.00016 | 0.00135 | 746 |
| Other electric appliances  | 0.000933 | 0.000988 | 6 |
| TV & communication equipment | 0.000311 | 0.001923 | 518 |
| Tools | 0.001498 | 0.00241 | 61 |
| Motor vehicles | 0.000295 | 0.001185 | 301 |
| Other industrial products | 0.00031 | 0.002404 | 676 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Industry | $$g$$ | $$g\_{1}$$ | $$g\_{2}$$ | $$g\_{3}$$ | $$g\_{4}$$ | $$g\_{5}$$ |
| Mining | 12.4043 | 0.837476 | 14.81154 | 0.996878 | 0.000193 | 5185.964 |
| Crude petro. | 18.97984 | 1.023309 | 18.54751 | 0.717598 | 0.002424 | 574.784 |
| Food | 88.46092 | 1.005246 | 87.99925 | 1.203479 | 0.000347 | 2394.284 |
| Tobacco | 10.55631 | 0.922301 | 11.44562 | 1.11812 | 0.000364 | 2453.711 |
| Textiles | 0.88113 | 0.540752 | 1.629454 | 0.994632 | 0.570259 | 1.763053 |
| Leather products | 3.412533 | 0.703089 | 4.853626 | 1.125511 | 0.001972 | 450.6267 |
| wood products | 7.977683 | 0.851704 | 9.366728 | 1.131202 | 0.002768 | 319.3567 |
| Paper products | 13.79624 | 0.922388 | 14.95709 | 1.503043 | 0.000338 | 1966.206 |
| Printing | 0.430977 | 0.781612 | 0.551395 | 2.087203 | 0.007846 | 61.06326 |
| Petro. refinery | 2.657572 | 0.80428 | 3.304288 | 1.161137 | 0.002864 | 300.7212 |
| Chemical products | 2.399422 | 0.626215 | 3.831625 | 1.166456 | 3.81E-05 | 22519.91 |
| Rubber products | 36.97858 | 1.165886 | 31.71716 | 2.041039 | 0.00014 | 3511.011 |
| glass products | 1.746919 | 0.694904 | 2.513901 | 1.181747 | 0.004137 | 204.5331 |
| Non metallic mineral products | 0.725251 | 0.594573 | 1.219784 | 1.303044 | 0.000537 | 1429.323 |
| Iron & Steel products | 3.55421 | 0.758672 | 4.68478 | 1.001733 | 8.66E-05 | 11529.46 |
| Nonferrous metal products  | 0.931901 | 0.489741 | 1.902843 | 0.920439 | 0.00175 | 620.7435 |
| General tools and machinery nec | 8.697685 | 0.852342 | 10.20446 | 0.572727 | 0.003009 | 580.2118 |
| Machinery | 11.24222 | 1.017686 | 11.04685 | 0.877211 | 0.00114 | 999.5771 |
| Household electric appliances  | 8.456961 | 1.003637 | 8.426317 | 0.725855 | 0.013965 | 98.65097 |
| Other electric appliances  | 1.058454 | 0.819668 | 1.29132 | 0.981213 | 0.003797 | 268.4305 |
| TV & communication equipment | 6.177629 | 0.77024 | 8.020397 | -0.19638 | -0.05153 | 98.81991 |
| Tools | 1.608573 | 0.394449 | 4.078026 | 0.931449 | 0.090417 | 11.87387 |
| Motor vehicles | 4.011534 | 0.9696 | 4.137307 | 0.606581 | 0.022202 | 74.25551 |
| Other industrial products | 7.757653 | 0.697043 | 11.12938 | 0.382249 | 0.026302 | 99.46547 |

Table (2): The Structure of Energy Productivity Changing, Iran (1986-2001)

**4-Results**

Table (1) shows energy productivity of Iranian industries during 1986-2001. Based on the table, for the exception of Printing, non metallic mineral products, textiles and nonferrous metal products industries, other industries experienced an increase in energy productivity in the period under study. Food, rubber products, paper products and machinery industries enjoyed most increase in energy productivity respectively.

The structure of changes in energy productivity during the 1986-2001 is shown in Table (2). This table, shows that food industry energy productivity increased 88times as much in 2001 compared to 1986, which indicates the most energy productivity increase. The next highest increase occurred in the following industries respectively: rubber products, paper products and machinery industries.

**5- Conclusions**

Efficient use of energy resources in industrial sector is one of the principal requirements for

sustainable industrial productions; it provides financial savings, fossil resources preservation and air pollution reduction; for enhancing the energy efficiency it must be attempted to increase the production yield or to conserve the energy input without affecting the output. The results indicate that energy productivity in different industries has increased differently: while food, rubber products, paper products and machinery industries experienced the most increase, printing, non metallic mineral products, textiles and nonferrous metal products industries experienced a negative increase.

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