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Decomposition of Natural Gas Intensity in Energy-Intensive Industries in Iran

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Abstract. Natural gas is main energy carrier used across industrial sector in Iran. The macro-level policy is to substitute natural gas for other oil products due to environmental and economic impacts. In this article, the natural gas intensity in energy-intensive industries is decomposed into output, structural and pure intensity effects in Iran during the period 1971 to 2011. The increasing share of value added as a proxy for structural changes represents a significant impact on reducing natural gas intensity. The output effect is of the high estmagnitude in changing natural gas consumption, and the pure intensity and structural effects rank the second and third in terms of the overall change in natural gas use, respectively.
Keywords. Decomposition, Output effect, Structural effect, Energy-intensive manufacturing sector.
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1. Introduction

There is a close relationship between energy consumption and industrial development (Adom *et al*, 2012; Camioto *et al*, 2014; Al-Mulali & Ozturk, 2015). In manufacturing sector, the increase in output needs to use energy in high volume. Each industrial unit may exploit particular fuel in accordance to technology design and physical characteristics (Reddy & Ray, 2010; Mi *et al*, 2015).

Manufacturing sector records a substantial growth rate in Iran, which results in increasing consumption of energy carriers and energy intensity. According to the Central Bank of Iran (CBI), manufacturing and mining sector, excluding oil and gas, accounts for 17.8% and 19.8% of total GDP and non-oil GDP in the country, respectively. In 2014, the growth rate of this sector in terms of change in value-added was reported at 6.9% in constant prices of 2004 (CBI, 2015).

In the industrial sector of Iran, natural gas as a clean and abundant source of energy is usually used to fuel furnaces, and to generate heat and steam. Sincethe national energy policy emphasizes on increasing use of natural gas in domestic energy bundle and exporting processed petroleum products (NIGC, 2010), an analysis of natural gas [use] intensity is necessary for management and planning goals.

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According to the latest official data of Iran, the energy end-use in industrial sector with 301.9 million barrel of oil equivalent (MBOE) accounted for 24.6 percent of total energy end-use (Iran Energy Balance Sheet, 2013). In this regard, natural gas provided more than 73 percent of energy requirements of the manufacturing sector in 2013.

In this article, natural gas intensity is defined as the natural gas used per one unit of output. In manufacturing sector, the natural gas intensity is influenced by overall economic growth, which increases demand for manufactured goods, price level, the industrial value-added, technology, returns to scale, and so forth. Thus, the structural and technological developments influence the quantity of natural gas used in these industries (Huntington, 2007; Chi *et al*, 2009; Palomino & Nebra, 2012; Chengza *et al*, 2014).

This paper aims to decompose the natural gas intensity in Iran and focuses on energy –intensive industries, including food, chemicals, textiles, nonmetallic ores, basic metals, wood and paper, which differ in size and use different technologies.

The next sections of this study are organized as follows: Section 2 devotes literature review, and section 3 explains the method to decompose natural gas intensity. Section 4 represents data, and section 5 denotes to results in detail. Section 6 concludes and gives some suggestions.

2. Literature Review

The studies on the analysis of natural gas consumption in manufacturing sector are relatively limited in the academic sphere. The most of researchers have focused on demand for energy in aggregate or by sectors. For example, Huang (1993) decomposed the effects of structural change and improvements in energy intensities of individual industries in China using the Division index during 1980-88. He concluded that the main factor in changing aggregate energy intensity was the change in energy intensities of individual industries.

In projecting demand for petroleum products and natural gas in India, Parikh *et al* (2007) believe that the energy consumption within energy-intensive industries has experienced dramatic changes; in such a way, that share of oil products in the energy end-use has been decreased, while the share of natural gas is growing. The similar trend is observable for Iran. The common feature of energy consumption within Iranian industries is the substitution of natural gas for petroleum products.

Using an econometric approach, Gardner & El-khafif (1998), examined the changes in industry structure and energy intensity that occurred in Ontario between 1962 and 1992. They identified and measured cyclical and trend components for both the structural and intensity indices and found that the cyclical component was due to changes in industrial output and the trend component was due to changes in technology and consumer preferences. Using decomposition analysis, Reddy & Ray (2010), found that most of the intensity reductions in manufacturing sector of India over the period 1992-2005 are driven by structural effect rather than actual improvement in energy efficiency. Behboudi *et al* (2010) identified key factors affecting energy intensity in Iran over the period of 1968-2006. Applying decomposition methodology, they found that energy productivity and the structure of economic activity affect energy intensity.

3. Method

Higher energy intensity does not always indicate low energy efficiency. Some advanced economies may experience higher energy intensity due to using large-scale energy-intensive machinery and equipment. In this group and in the developing countries, the evaluation of energy efficiency based on energy intensity indexes may be controversial and misleading. Therefore, the analysis of energy consumption requires decomposition techniques. These techniques determine the components of changes in energy consumption (energy intensity) for a given period. Generally, changes in the energy intensity are divided into three effects as follows (Ang & Lee, 1994):

Output effect (OE): change in total energy consumption due to increase in output;

Structural effect (SE): change in energy consumption as a result of change in the composition of economic activities; and

Intensity effect (IE): change in energy use due to change in energy efficiency.

The basic model for decomposing output, structural and net effects follows a mathematical expansion. This model accounts for instability factors in energy consumption around time trends, and enables the researcher to forecast future consumption with regard to growth rate of energy consumption.

If G denotes total natural gas consumption in energy-intensive industries, and ifG_i is energy consumption in sector$i$, then we can write:

$$G = \sum_{i=1}^{n} G_i \tag{1}$$

In sector levels, the value added is a proxy for economic activity, therefore we rewrite equation (1) as follows:

$$G = \Sigma_{\mathrm{i}} \frac{\mathrm{G_i}}{\mathrm{Q_i}} \cdot \frac{\mathrm{Q_i}}{\mathrm{Q}} \mathrm{Q} \tag{2}$$

Where Q_i and Q represent value added in sector i, and aggregate value added, respectively.

If we define $I_i = \frac{G_i}{Q_i}$ as energy intensity in sector *i* and $S_i = \frac{Q_i}{Q}$ as share of value added of sector *i*, we obtain the following equation:

$$G = \sum_i I_i . S_i . Q \ \ (3) \tag{3}$$

Accordingly, the consumption of natural gas is decomposed to three effects included in I_i, S_i and Q. In time series analysis, we areinterested in studying the changes in consumption over time, so we denote natural gas use in periods 0 (basic year) and T (end year) with $G^0$and G^T, respectively, then we get the following identity:

$$G^T \equiv G^0 + OE + \mathrm{SE} + \mathrm{IE} \tag{4}$$

Where:

$$OE = \sum_{n}^{i} (\Delta Q)\, S_i^0 I_i^0 + \frac{1}{2} \sum_{n}^{i} \Delta Q \left[(\Delta S_i) I_i^0 + S_i^0 (\Delta I_i) \right] + 1/3 \sum_{i}^{n} \Delta I_i \Delta S_i Q \tag{5}$$

$$SE = \sum_{n}^{i} (\Delta S_i)\, I_i^0 Q^0 + \frac{1}{2} \sum_{n}^{i} \Delta S_i \left[(\Delta I_i) Q^0 + I_i^0 (\Delta Q) \right] + 1/3 \sum_{i}^{n} \Delta I_i \Delta S_i Q \tag{6}$$

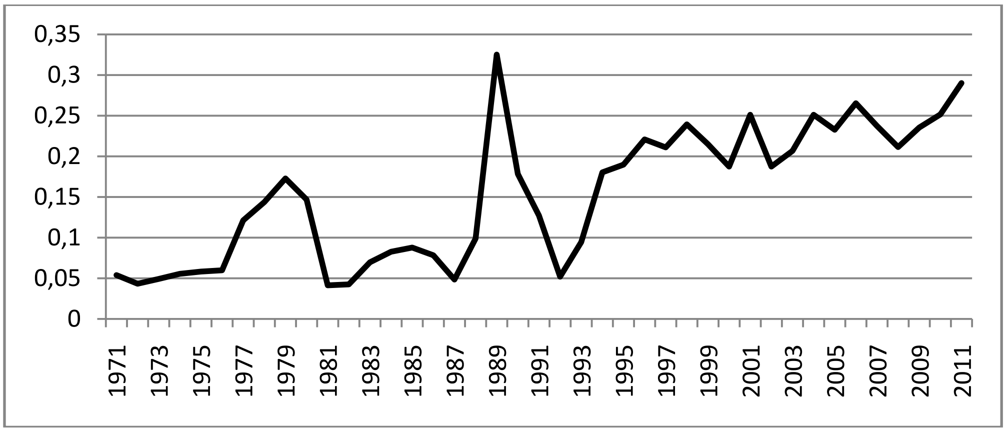
$$IE = \sum_{n}^{i} (\Delta I_i)\, S_i^0 Q^0 + \frac{1}{2} \sum_{n}^{i} \Delta I_i \left[(\Delta S_i) Q^0 + S_i^0 (\Delta Q) \right] + 1/3 \sum_{i}^{n} \Delta I_i \Delta S_i Q \tag{7}$$

4. Data

This research includes time series on natural gas consumption in energy-intensive industries over the 1971-2011**.** Data on value added and natural gas consumption are collected from Survey on Manufacturing Establishments with 10 and More Workers" (Statistical Centre of Iran). The energy-intensive industries in terms of 2-digit ISIC codes consist of chemicals, basic metals (including iron and steel, lead and zinc, copper and aluminum, and metallurgy subsectors), food industry, nonmetallic ores, wood, paper and textiles (Iran Energy Efficiency Organization, 2013).

Graph 1 depicts the trend of natural gas consumption in Iran. After the victory of the Islamic Revolution in Iran in 1979, and the nationwide political developments, the natural gas consumption fell sharply. In this period, manufacturing sector was in trouble in meeting its energy requirements despite of low prices of natural gas. Due to continuous air attacks to the refineries and oil and gas fields by Iraqis, various fuels including natural gas was supplied through a national rationing system. In 1987, natural gas intensity increased for all energy intensive industries and reached to its peak at 0.32 cubic meters per Iranian Rials in 1989 because of abolition of the rationing system.

After 1987 (the start of the first national development plan), natural gas intensity decreased again, so that it recorded 0.05 cubic meters per Iranian Rials in 1992. The relatively increasing trend is observed after 1992. This is in line with inter-fuel substitution in the manufacturing sector and gasification of large industries recommended by policies of the Second Five-Year National Socio-Economic Development Plan (Plan and Budget Organization, 1996), which continued in the subsequent national plans.



Graph 1. *Natural gas intensity(cubic meter per Iranian Rials)*

5. Results

The decomposition method presented in section 2 is applied to analyze the factors affecting natural gas use in energy-intensive industries. The 40- year period of this study is divided into five time intervals and decomposition of the natural gas intensity is reported separately for each period.

5.1. Pre-revolution Era: 1972-1978

The first period includes 1972 to 1978 years with 1972 as a base year for the calculation of natural gas intensity. Our calculations show that, in the pre-revolution period in Iran, output effect having a share of 48.4 percent plays the most important role in changing natural gas consumption. The intensity and structural effects place in the second and third ranks with 46.5 percent and 5.1 percent, respectively. The increasing trend in the natural gas consumption illustrated in Figure 1is consistent with the output and pure intensity effects. In general, it can be said that factors affecting output effect, such as increasing oil revenues and expanding industries, and pure intensity effect due to low natural gas priceshave moved in the same direction and have increased the use of natural gas in energy-intensive industries.

Table 1. *Pre-revolution Era (1972-1978)*

Period	TE	OE	SE	IE	Residual
1973-1974	64.09	37.02	2.37	24.7	0
1974-1975	247.51	136.98	43.18	67.36	0
1975-1976	259.85	145.57	32.15	82.13	0
1976-1977	275.27	172.40	9.13	93.74	0
1977-1978	567.37	192.6	-14.74	389.51	0
1972-1978	1414.1	684.6	72.1	657.43	0
Share in total effect (%)		48.4	46.5	5.1	0

Note. TE= Total change in natural gas consumption, OE= output effect, SE=structural Effect, IE=[pure] intensity effect. All figures are in billion cubic meter. This note holds for the next Tables, too.

5.2. Post-revolution Transitional and War Period: 1979-1988

The second period covers 1979 to 1988 years with 1979 as base year. For this period, structural effect is negative because of post-revolution transitional problems and war imposed against Iran. This considerable negative effect means a reduction in total natural gas consumption. In this period, there are residual effects consistent with reductions in natural gas intensity. After revolution and war period in Iran, the pure intensity effect and output effects have been recorded the same changes. Consequently, the intensity of natural gas consumption decreased in the industries under study.

Table 2. *Post-revolution Transitional and War Period (1979-1988)*

Period	TE	OE	SE	IE	Residual
1978-1979	334.86	-20.23	219.85	135.03	0.21
1979-1980	882.51	417.17	31.45	435.27	-1.4
1980-1981	-409.31	360.38	-1104.95	262.72	72.53
1981-1982	-459.29	320.17	-1017.89	191.25	47.2
1982-1983	-337.84	186.16	-628.70	97.04	7.7
1983-1984	-488.3	9.46	-417.42	-80.08	-0.3
1984-1985	-617.39	-130.48	-327.28	-166.97	7.34
1985-1986	-555.58	-107.88	-428.57	-19.96	0.83
1986-1987	-28.81	582.59	-1265.13	488.58	165.15
1987-1988	744.78	577.3	-542.25	655.95	53.8
1978-1988	-934.4	2194.64	-5480.9	1998.83	353.02
Share in total effect (%)		-234.8	586.6	-213.9	-37.9

5.3. Post-war Reconstruction Era: 1989-1996

The third period covers the years 1989-1996 with 1989 as the base year. Change in the total consumption of natural gas is positive for all years but 1989. Output and structural effects are positive totally during this period. The output effect plays the most determinant role in change the total consumption of natural gas in reconstruction era after war. However, the negative pure intensity effect resulted in reducing natural gas consumption. This period coincided with implementation of the first and second national five-year development plans. The decreasing natural gas intensity is attributable to the following policies:

1. Reduction in the consumption of oil products and replacement them with natural gas;
2. Codification of technical standards related to energy consumption in energy-consuming equipment and system;

3. Set seasonal work hours in factories in order to decrease power and energy consumption and energy consumption in peak loads; and

4. Provide incentives for using energy in off-peak times.

As a result, the output effect led to increase in the consumption of natural gas.

Table 3. *Post-war Reconstruction Era (1989-1996)*

Period	TE	OE	SE	IE	Residual
1989-1990	-365.152	449.95	-152.34	-662.76	0
1990-1991	1860.922	3112.29	1325.12	-2576.49	0
1991-1992	159.6751	2894.25	1153.62	-3888.19	0
1992-1993	1401.176	3383.78	1379.07	-3361.67	0
1993-1994	4151.049	4595.53	1781.74	-2226.22	0
1994-1995	4598.243	4705.95	2008.23	-2115.94	0
1995-1996	5729.097	5460.82	1952.46	-1684.17	0
1989-1996	17535.01	24602.6	9447.9	-16515.43	0
Share in total effect (%)		140.3	53.9	-94.2	0

5.4. Reformist Cabinet: 1997-2004

The fourth period covers the years 1997 to 2004 with 1997 as the base year. The period led by President Khatami, introducer of the idea of dialogue among civilizations, is specified with better and more democratic processes such as relatively freer mass media, establishment of non-governmental organizations and steady- state economic growth. The calculations show that output effect with a share of 73.5 percent has the highest share in changing the total consumption of natural gas. The pure intensity effect and structural effect place the next orders with 14.7 percent and 11.8 percent, respectively. The volatile and increasing trend of natural gas intensity has been influenced strongly by changes in the production of industries. In fact, the adoption of macroeconomic policies, industrial development policies, and shifts in consumer demand as structural factors, have limited the output effect. As a result, output effect has the least impact on the natural gas intensity in this period.

Table 4. *Reformist Cabinet (1997-2004)*

Period	TE	OE	SE	IE	Residual
1997-1998	1628.95	-61.55	710.50	980.00	0
1998-1999	2150.20	915.01	1085.15	150.04	0
1999-2000	-276.00	805.92	-256.29	-825.63	0
2000-2001	1690.26	961.16	-640.94	1370.05	0
2001-2002	1429.68	1984.54	377.04	-931.90	0
2002-2003	3040.02	2741.45	482.18	-183.60	0
2003-2004	5414.02	3730.14	15.54	1668.34	0
1997-2004	15077.15	11076.7	1773.18	2227.30	0
Share in total effect (%)		73.5	11.8	14.7	0

5.5. Hardliner cabinet: 2005-2011

The fifth period includes the years 2005 to 2011 with 2005 as the base year.In this period, which hardliners were in power, output effect with a share of 57.6 percent in total effect is of the most influential impact on change in the total consumption of natural gas. The structural effect and pure intensity effect place in the second and third rows with 25.6 percent and 15.7 percent, respectively. In addition, the residual effect has the least share with 1.2 percent. In this period, the increasing trend in natural gas consumption shown in Figure 1 corresponds to the output and pure intensity effects. The ruling cabinet implemented “cutting energy subsidies policy”, which resulted in higher energy carriers prices including natural gas (IMF, 2014). As a result, the output and structural effects played key roles in changing consumption of natural gas.

Table 5. *Hardliner Cabinet (2005-2011)*

Period	TE	OE	SE	IE	Residual
2005-2006	2915.86	1123.74	-5.79	1797.18	0.73
2006-2007	4789.25	2551.87	1934.03	340.23	-36.88
2007-2008	4059.36	2717.69	2708.88	-1602.42	235.22
2008-2009	7627.47	3556.29	3876.31	237.18	-42.32
2009-2010	7059.45	4210.27	1625.18	1334.52	-110.51
2010-2011	6179.04	4636.14	-1796.27	3006.72	332.45
2005-2011	32630.44	18796	8342.34	5113.41	378.69
Share in total effect (%)		57.6	25.6	15.7	1.1

Finally, the change in the total natural gas consumption for the entire period (1972-2011) is decomposed into different effects taking into account 1972 as base year. According to the results, the output effect with a share of 46.3percentplaysthe most important role in changing the total consumption of natural gas. The pure intensity effect and structural effect place in the next ranks with 40.5 percent and 13.2 percent shares, respectively. In general, output effect has the highest share in change in the consumption of natural gas. Moreover, pure intensity effect and structural effect rank the next places.

Table 6. *Decomposition of Natural Gas Intensity (1972-2011)*

Period	TE	OE	SE	IE	Residual
1972-2011	223139.9	103332.9	29383.5	90423.5	0
Share in total effect (%)		46.3	13.2	40.5	0

6. Conclusions

According to the decomposition results, change in the total natural gas consumption is positive for all periods except for the second period (due to problems caused by the war). It can be said that the output effect is the dominant one during the period under study. Therefore, natural gas consumption has been developed according to increase in the production level of energy-intensive industries.

Our findings indicate that increases in value added share of energy-intensive industries can be regarded a proxy for structural changes that have shown significant effects on decreasing natural gas intensity. If the composition of economic activities varies in favor of energy-intensive industries, then natural gas savings will take place due to structural developments. Of course, these changes are influenced by macro-economic industrial development policies, which are long term in nature and do not directly pursue the aim of saving in natural gas.

Various policies can be made in order to decrease the natural gas intensity. For instance, cutting natural gas subsidies, switching between fuels, managing energy demand in manufacturing sector and using energy-saving production technologies may help tosave natural gas. More specifically, if energy-intensive manufacturing sector turns to equip with advanced and energy-saving technologies, then a substantial reduction in natural gas intensity will occur. Therefore, fuel productivity will be increased.

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