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Mental CO_2 emissions from energy use in Iran and implications for future

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Abstract

This paper aims to identify the factors that have influenced the change of CO2 emissions related to energy use at both aggregated and sectorial levels in the Iranian economy via the Logarithmic Mean Division Index (LMDI) method. The results show that per capita GDP, energy intensity and the fossil fuel intensity of energy are the three dominant contributors to changes in CO2 emissions at the aggregated level. As a conclusion, attention must be paid to the composition of fossil fuels and the share of fossil fuels in energy consumption in order to achieve a decrease in CO2 emission.

Keywords: CO_2, emissions, energy, decomposition, analysis.

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Emisiones de CO_2 del uso de energía en Irán e implicaciones para el futuro

Resumen

Este documento tiene como objetivo identificar los factores que han influido en el cambio de las emisiones de CO2 relacionadas con el uso de la energía en los niveles agregados y sectoriales en la economía iraní a través del método del Índice Logarítmico de Divisía Media (LMDI). Los resultados muestran que el PIB per cápita, la intensidad de la energía, y la intensidad de la energía de los combustibles fósiles son los tres contribuyentes dominantes a los cambios en las emisiones de CO_2 a nivel agregado. Como conclusión, se debe prestar atención a la composición de los combustibles fósiles y la proporción de combustibles fósiles en el consumo de energía para lograr una disminución en la emisión de CO_2.

Palabras clave: CO_2, emisiones, energía, descomposición, análisis.

1. INTRODUCTION

The CO_2 emission related to energy consumption is an important challenge for the world economy. 84 percent of total CO_2 emissions in the world are related to energy consumption and CO2 emissions constitute 64 percent of greenhouse gases emissions in the world. On the basis of the IEA (2009), the growth of CO_2 emissions related to energy consumption will continue as a result of demand growth for fossil fuels by 2030. The CO_2 emissions related to energy consumption increased from 20.9 G.T, in 1990 to 28.8 G.T, in 2007. The forecast of the IEA in (2009) shows that the CO_2 emissions related to energy consumption will increase to 34.5 G.T, and 40.2 G.T, by 2020 and 2030, respectively. Its implications are that CO_2 emissions related to energy consumption will increase on average by 1.5 percent in the period 2000-2030, while the other greenhouse gases will increase on average by 0.3 percent.

The Iranian resource-based structure of the economy and the energy-based production system has caused the consumption of fossil fuels and non-fossil fuels to increase. Although the interrelation between energy consumption and greenhouse gases, especially CO_2, shows the greenhouse gas emissions will be high in the future. The statistics show that CO_2 emissions per capita in Iran have increased from 3.6 T in 1990 to 6.9 T in 2008, while the CO_2 emissions per capita decreased in the US and the European region. Predictions show that the CO_2 related to energy consumption will be an important challenge for the economic future in many countries, such as Iran. Considering the importance of this challenge, several countries have considered decreasing the CO_2 emissions target by the definition of policy tools. To achieve this goal, we need to know the structure of CO_2 emissions related to energy consumption. In this paper, we consider the structure of CO_2 emissions related to energy consumption at the macroeconomic level and as well as different sectors of the economy.

Decomposition Analysis (DA) methodologies, i.e. Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA), have been applied to identify parameters that trigger energy demand and related CO_2 emissions (Ang, 2004). In general, the literature on IDA has reported extensively on the implications of index theory and the specification of the decomposition, whereas the SDA literature has focused attention on distinguishing from a large number of specific determinant effects (Ang, 2004). Furthermore, these methods use historical data, in order to assess how the driving forces of energy demand are connected with the change in particular indicators. An advantage of IDA over SDA methods is that they require less data. On the other hand, IDA studies often use annual time steps. In addition, IDA and SDA methods use different types of indicators; while IDA literature has developed and utilized all three indicator forms (absolute, intensity and elasticity), SDA literature generally restricts itself to the investigation of absolute changes in variables (Ang, 2004). Due to these comparative advantages, IDA methods constitute a widely accepted analytical tool for policymaking in national energy and environmental issues.

A number of studies in energy and environmental economics have examined and used some methods of decomposition for CO_2 emissions related to energy consumption. Diakoulaki (2005) applied a decomposition analysis of CO_2 emissions in Greece for the period of 1990-2002 split into two equal time intervals. The results of the analysis explained the observed increase in CO_2 emissions and point on policy priorities in order for Greece to comply with the Kyoto target. Lee and Oh (2006) decomposed the changes in CO_2 emissions in APEC countries over time as well as the difference of CO_2 emissions among three income groups of APEC countries at a given period of time. The results showed that the growth in GDP per capita and population are the two dominant contributions to the increase in CO_2 in most cases. Paul et al. (2004) analyzed the CO_2 emissions related to energy consumption in India for the period 1980-1996. The results showed that the economic growth has the largest positive effect in CO_2 emissions changes in all the major economic sectors. Malla (2009) by using the decomposition method, examined the role of three factors (electricity production, electricity generation structure and energy intensity of electricity generation) affecting the evolution of CO_2 emissions from electricity generation in seven Asia-Pacific and North American countries. The analysis shows production effect as the major factor responsible for rise in CO_2 emissions during the period 1990-2005. Hatzigeorgiou (2008) applied the decomposition analysis for CO_2 emissions related to energy consumption in Greece for period 1990-2002. The results show the income effect is the most important factor contributing to the increase of CO_2 emissions while the energy intensity effect has an inverse contribution as the most significant factor reducing CO_2 emissions. In Iran, Lotfalipour and Ashena (2010) analyzed the changes in CO_2 related to energy consumption for 1994-2007. The results show that the economic growth is a determinant factor in CO_2 emissions. This paper is organized as follows; section 2, we describe the methodology and data that used for decomposition of CO_2 emissions. Section 3, we present the empirical results of decomposition analysis in macroeconomic and sectoral levels. Finally, we conclude this study.

2. Methodology

On the basis of Kaya (1990) identity, the CO_2 emissions in a country i can be expressed as the products of the five factors as follows:

$$E_i = \left(\frac{E_i}{FEC_i}\right)\left(\frac{FEC_i}{TEC_i}\right)\left(\frac{TEC_i}{GDP_i}\right)\left(\frac{GDP_i}{POP_i}\right)POP_i = C_i S_i I_i G_i P_i \qquad (1)$$

Where,

E= the amount of CO_2 emissions

FEC= the fossil fuel energy consumption

TEC= the total primary energy consumption

GDP= the Gross Domestic Product

POP= the population

In the EQ. (1), C is the CO_2 emissions coefficient, S is the share of fossil fuel consumption in total energy consumption, I is the energy intensity, G is the per capita GDP, and P is the population. The change of the country's CO_2 emissions between a base year 0 and a target year T, ΔE_i can be decomposed to the effects of: (i) the change in the C (the coefficient effect, C_{eff}); (ii) the change in the S (the substitution effect, S_{eff}); (iii) the changes in the I (the intensity effect, I_{eff}); (iv) growth in the G (the per capita GDP effect, G_{eff}); and (v) the expansion of the P (the population effect, P_{eff}) in additive form as follows;

$$\Delta E_i = E_i^T - E_i^O = C_{eff} + S_{eff} + I_{eff} + G_{eff} + P_{eff} \quad (2)$$

Superscripts 0 and T denote a base year and a target year, respectively. There are different techniques such as the Logarithmic Mean Divisia Index (LIMDI), Arithmetic Mean Divisia Index (AMDI), and Laspear's Index (LI) for index decomposition analysis. Among these methods, the Logarithmic Mean Divisia Index has important characteristics such as time independence, computation flexibilities, consistency in aggregation, and the possibility of negative and zero computation (Ang, 2007). In this paper, we used the LMDI technique. When LMDI is applied, each effect in the right hand side of Eq. (2) is given by:

$$C_{eff} = L\left(E_i^0, E_i^T\right)\ln\left(C_i^T / C_i^0\right),$$

$$S_{eff} = L\left(E_i^0, E_i^T\right)\ln\left(S_i^T / S_i^0\right),$$

$$I_{eff} = L\left(E_i^0, E_i^T\right)\ln\left(I_i^T / I_i^0\right),$$

$$G_{eff} = L\left(E_i^0, E_i^T\right)\ln\left(G_i^T/G_i^0\right),$$

$$P_{eff} = L\left(E_i^0, E_i^T\right)\ln\left(P_i^T/P_i^0\right).$$

Where $L\left(E_i^o, E_i^T\right) = \dfrac{E_i^T - E_i^o}{\ln\left(\frac{E_i^o}{\square} E_i^T\right)}$ is a log mean of CO_2 emission in year 0 and year T.

This study also applies the decomposition analysis to sectorial data in Iran. For this purpose, GDP is disaggregated into three sectors including; agricultural sector comprising agriculture, forestry, and fisheries; industry sector comprising energy production and manufacturing industry; and services sector comprising the rest of the economy, mostly transport, residential, and commercial.

Decomposition is carried out similarly Eq. (1), but C_{eff}, S_{eff}, and I_{eff} are defined differently, and there is an extra term H_{eff}. So:

$$\Delta E_j = C_{eff,j} + S_{eff,j} + I_{eff,j} + H_{eff,j} + G_{eff} + P_{eff} \qquad (3)$$

In Eq. (3), j is one of the three sectors, E_j is the CO_2 emissions of sector j, C_{eff} takes fossil fuel consumption in sector j (and similarly for S_{eff} and I_{eff}), and H_{eff} is sector j's share of GDP; G_{eff} and P_{eff} are identical to those in Eq. (2). The calculation of the sector-specific terms is given by:

$$H_{eff,j} = L\left(E_j^0, E_j^T\right)\ln\left(H_j^T / H_j^0\right),$$

We used macroeconomic and sectorial energy consumption, energy and primary energy consumption data from Energy Data Yearbook published by Iranian Ministry of Power. Carbon dioxide (CO_2) emissions are calculated from the Iranian energy balance reports. The GDP and population data are collected from the National Accounts Statistics of Iran.

3. EMPIRICAL RESULTS

3.1. Decomposition of CO_2 in Macroeconomic level

The results of applying decomposition analysis for Iranian economy show that the CO_2 emissions related to energy consumption at macroeconomic and sectorial levels have increased for the period of 1967-2008 except for the period of 1976-1981. The changes in GDP per capita have had a determinant effect on the CO_2 emissions related to energy consumption. As a result, the achievement of economic growth goals will be accompanied by increasing CO_2 emissions related to energy consumption in Iran. The results of this study as shown in table 1 show that the changes in population (P_{eff}) have had a positive effect and have led to an increase in CO_2 emissions for all the periods under study. As a result, the changes in CO_2 emissions are in line with the population changes in Iran. Therefore, policies for controlling population will have a positive on decreasing in CO_2 emissions related to energy consumption.

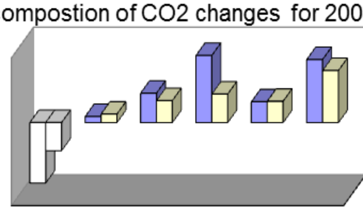
The share of fossil fuels in energy consumption (S_{eff}) has increased over the period 1967-1986. These changes have led to an increase in CO_2 emissions related to energy consumption. The share of fossil fuels had a negative effect on the CO_2 emissions for 1987-2001, but at the beginning of the 2000s, this share has increased and has caused an increase in CO_2 emissions. These results show that, unlike world experiences and the global shift to use of non-fossil fuels, the share of fossil fuels in Iranian energy consumption has increased. Therefore, attention to alternative energy sources is necessary for decreasing in CO_2 emissions in Iran. The energy intensity of the Iranian economy has increased over a long period and this has resulted in an increase in CO_2 emissions related to energy consumption. This result shows that unlike world experiences, the energy consumption in the Iranian economy is very high. Therefore, economic policies for reducing in energy consumption are necessary in order to achieve the goal of lowering in CO_2 emissions.

Table1. Decomposition of CO_2 changes in macroeconomic level- tons

	P_{eff}	G_{eff}	I_{eff}	S_{eff}	C_{eff}	ΔE
1967-1971	8826.56	28760.96	-12869.9	17174.64	-12899.6	30992.64
1972-1976	13492.24	36793.36	17768.2	3989.3	-23227.7	48816.8
1977-1981	20351.07	-64058.3	46111.11	3886.36	-56915	-50684.7
1982-1986	21135.35	-20022.01	-20022.01	38580.3	14870.8	8128.6
1987-1991	18148	27921.12	14980.3	-161.2	10060.2	70948.6
1992-1996	14115	14464.96	43674.2	-10708.36	-1014.6	60714.2
1997-2001	22649.06	19562.25	-16577.5	-13130.2	39932.5	52435.9
2002-2006	26047.17	88024.33	14742.39	3918.6	-138819.8	98913.8

The decomposition of changes in CO_2 emissions to effecting factors for the sub period of 2004-2006 and 2006-2008 show that the changes in GDP per capita, population and energy intensity had a determinant effect on the changes in CO_2 emissions. The results show that the changes in substitution effect have been in line with the changes in CO_2 emissions, but the share of this factor is less than other factors. It is noteworthy that the changes in carbon of fossil fuels (carbon intensity) in both periods have negative effect on the CO_2 emissions. This means that a part of changes in CO_2 emissions has substituted by the changes in carbon of fossil fuels (see Fig. 1).

Fig.1
Decompostion of CO2 changes for 2004-2008



3.2. Decomposition of CO_2 emissions in sectorial levels

In this section we analyze the decomposition of CO_2 emissions in Iranian economic sectors include agriculture, industry and services for the sub periods of 2004-2006 and 2006-2208. Look at the sectors of the Iranian economy, the changes in CO_2 emissions related to energy consumption in services have been more changes than other sectors for

2004-2006. The changes in CO_2 emissions related to energy consumption in industry have increased more than twice for a period of 2006-2008. During this period, the changes in CO_2 emissions related to energy consumption in services have decreased. The changes in GDP per capita, the share of industry in GDP, and energy intensity have had a determinant effect on the changes of CO_2 emissions related to energy consumption in industry for the period of 2004-2006. However, the changes of carbon intensity and the share of fossil fuels in industry have increased, but the changes of each factor are low.

The changes in CO_2 emissions in the industry have increased for 2006-2008. In this period, unlike the past period, the changes in share of fossil fuels in energy consumption and carbon intensity have had a determinant role in changes in CO_2 emissions related to energy consumption in industry (see Fig. 2). The changes in GDP per capita and energy intensity have had a determinant role in changes in CO_2 emissions related to energy consumption in agriculture for period of 2004-2006. During this period, however, the changes in the share of agriculture of GDP have had a positive effect; this effect is less than the changes of GDP per capita. The share of fossil fuels in agriculture, unlike the industry has changed in reverse line the changes in CO_2 emissions related energy consumption.

The changes in share of fossil fuels, unlike past period have changed in line the changes in CO_2 emissions in agriculture for period of 2006-2008. During this period, the changes in carbon intensity similar the changes in GDP per capita and population have had a determinant effect on the changes in CO_2 emissions related to energy consumption in agriculture. Also, unlike the past period, the changes in the share of agriculture in GDP have changed in reverse the changes in CO_2 emissions related to energy consumption in agriculture (see Fig. 3). The changes in GDP per capita and energy intensity have had a determinant effect on the CO_2 emissions related to energy consumption in services for period of 2004-2006. During this period, the share of services in GDP has had little effect on the CO_2 emissions related to energy consumption (see Fig. 4).

The share of the agricultural sector in GDP has played a decreasing role in generating CO_2 emission. This result is in conflict with experience of industry and service experiences. The share of carbon in fossil fuels used in the agricultural sector, unlike that in the industry sector, has increased. These results show that on the one hand, agricultural growth has changed in line with CO_2 emissions while, on the other hand, the share of carbon in fossil fuels used in the agricultural sector, caused an increase in CO_2 emissions. Hence, attention must be paid to the composition of fossil fuels and the share of fossil fuels in energy consumption in order to achieve a decrease in CO_2 emission.

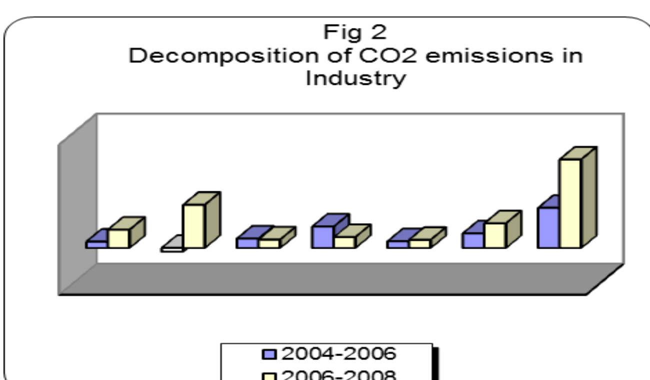


Fig 3.
Decomposition of CO2 emissions in agriculture

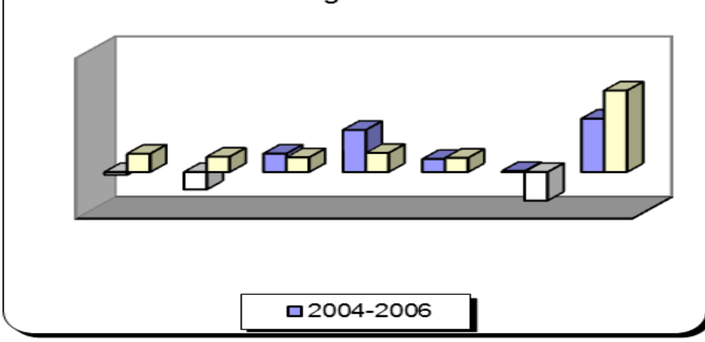
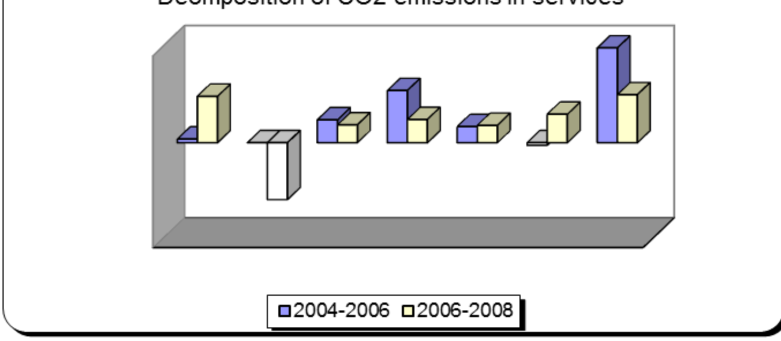


Fig 4.
Deomposition of CO2 emissions in services



4. SUMMARY AND CONCLUSIONS

In this paper, a decomposition analysis is presented to find the nature of factors that influence the changes in CO_2 emissions related to energy consumption in macroeconomic and sectorial levels for Iran. The factors that lead to changes in CO_2 emissions are energy intensity, carbon intensity, GDP, the share of fossil fuel and population. A particular decomposition technique (LMDI) is used to analysis the CO_2 emissions related to energy consumption. Our results show that in Iran the economic growth is the most important component of CO_2 emissions in the macroeconomic lever and in the industry and services sectors. The share of fossil fuels in energy consumption has increased over the 1967-1986. These changes have led to an increase in CO_2 emissions related to energy consumption. These results show the lower price of fossil fuels in Iran led to increase in fossil fuels consumption. Therefore, increasing in price of fossil fuels led to decrease in fossil fuels consumption. Also, attention to alternative energy sources is necessary for decreasing in CO_2 emission related to energy consumption in Iran.

The share of the agricultural sector in GDP has played a decreasing role in generating CO_2 emission. This result is in conflict with experience of industry and services experiences. The share of carbon in fossil fuels used in the agricultural sector, unlike that in the industry sector, has increased. These results show that on the one hand, agricultural growth has changed in line with CO_2 emissions while, on the other hand, the share of carbon in fossil fuels used in the agricultural sector, caused an increase in CO_2 emissions. Hence, attention must be paid to the composition of fossil fuels and the share of fossil fuels in energy consumption in order to achieve a decrease in CO_2 emission.

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