# $CO_2$ EMISSIONS IN IRAN FOR 1990–2010: A DECOMPOSITION ANALYSIS

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**Abstract.** For over a decade now, decomposition analysis has become popular in energy and environment studies. This paper therefore identifies the factors that have influenced changes in $CO_2$ emissions in Iran for the period 1990–2010. The Refined Laspeyres Index method has been utilized in order to decompose the $CO_2$ emissions while four main factors of the observed changes have been identified: economic activity, energy intensity (energy use per unit of economic output), carbon intensity ($CO_2$ emission per unit of energy use), and population effect. The study period has been divided into two decades, the first one encompassing the period from 1990 to 2000 and the second one from 2000 to 2010. Our empirical findings have revealed that the main factor which is accelerating $CO_2$ emissions in Iran is the economic activity for the entire study period. Also within the first decade of the study, economic activity has been followed by energy intensity while in the second decade; it has been followed by population effect. Furthermore, the carbon intensity has made minor contributions to $CO_2$ emissions in Iran throughout the study period. Given that Iran is an energy intensive and largely oil dependent country; we therefore suggest it would be better off in terms of reduced $CO_2$ emissions by pushing down current energy intensity as its main environmental and economic policy objective. For the future studies, a sectoral $CO_2$ emissions analysis could be conducted for Iran in order to examine the carbon emissions increasing and decreasing factors and provide some sectoral policy implications.
**Keywords:** *environment, energy, sustainability, pollution, intensity, carbon, population*

## Introduction

Environmental problems, especially climate change and global warming, have been on the world's agenda over the past several decades (Halder et al., 2013; Kuo and Perng, 2016; Lin, 2017). These problems have also raised the concern of energy analysts and policymakers about environmental sustainability. Many scientists argue that the increasing amount of $CO_2$ concentration in the atmosphere may create the greenhouse effect and this may cause global warming (IPCC, 2007). As Lotfalipour et al. (2010) states the main source of increasing $CO_2$ emissions in the atmosphere is fossil fuel combustion. The main factors that are raising fossil fuel consumption can be linked to economic development, technological changes, demographic changes, institutional frameworks, lifestyle, and international trade (Hatzigeorgiou et al., 2008).

Most of the Asian countries achieved a spectacular economic growth performance in recent decades (Zhang, 2008). As the Energy Information Administration (EIA) states, amongst these countries Iran is an energy superpower since it accounts for the world's second largest natural gas reserves and fourth largest oil reserves in 2015. Ninety eight % of Iran's overall energy demand is generated from natural gas and oil. On the other hand, Iran has the 7th rank in World Bank's $CO_2$ emissions ranking. Besides its one dimensional structure (depends mostly on oil revenues) Iran's economy expanded by


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139 % in real terms between 1990 and 2010 while the country's $CO_2$ emissions increased by 170.7 % in the same period (World Bank, 2015). Since the acceleration in Iran's $CO_2$ emissions is faster than its GDP increase this could be evidence that Iran's economic development is not environmentally sustainable. For instance, in China (which has experienced the most spectacular economic growth in Asia) the real GDP increased by 630 % while its $CO_2$ emissions increased by 236 % between 1990 and 2010 (World Bank, 2015).

In recent decades, there is an ongoing debate about the environmental impacts of high energy consumption among countries (Kumbaraoglu, 2011). Parallel to this, social and environmental aspects of energy sector projects gained importance in Iran. Accordingly, it is possible to state that there is an increasing awareness about energy production, conversion and utilization in Iranian government, industry and public.

In Iran electricity and heat production are the major activities which create $CO_2$ emissions. They constitute 32 % of overall Iranian emissions in 2010 (World Bank, 2015). In Iran energy prices are low and winter months are cold, therefore electricity consumption is increasing during the winter. Since 95 % of electricity supply is generated using oil and natural gas then this yield to an increase in $CO_2$ emissions (World Bank, 2015). The second major $CO_2$ emitting activities are manufacturing and construction. As the World Bank data indicates 25.8 % of overall $CO_2$ emissions arise from manufacturing and construction. As Moshiri (2012) states, Iran's industrial sector uses old technologies which are inefficient in terms of energy conversion. Transportation is another sector which increases Iran's $CO_2$ emissions. Transportation technologies are old in Iran and there exist high subsidies on gasoline (Moshiri, 2012). Therefore $CO_2$ emissions due to the transportation are increasing. Residential buildings and commercial & public services are also contributing to Iranian $CO_2$ emissions. This is probably due to the insulation deficiencies of the residential and commercial buildings and the use of high energy consuming home appliances. To sum up, it is possible to state that in Iran almost the whole of the economic activities are energy intensive and such high energy intensity increases the $CO_2$ emissions.

Together with the increasing awareness about $CO_2$ emissions reduction among the world countries, analyzing and understanding the factors that cause emissions increase has gained importance. Iran's $CO_2$ emissions exceeded 571 thousand KT in 2010 and this value is higher than those of some other countries that have similar GDP and population. Turkey can be given as an example to these countries. For instance Iran's $CO_2$ emissions are 1.9 times greater than Turkey's overall $CO_2$ emissions, where Turkey has almost the same population and higher GDP as compared with Iran (World Bank, 2015). Accordingly, analyzing the factors that accelerate or decelerate $CO_2$ emissions in Iran has gained great importance over the years. Identifying the components that are changing the $CO_2$ emissions is an important input to the policy makers and energy analysts who are developing some economically and environmentally sustainable projects. In addition, due to the geographic location Iran has the potential to diversify its energy sources. The identification of the sources of $CO_2$ emissions in Iran has not been widely studied. Published studies are mostly for developed countries and some developing countries, such as, China, India, Turkey, and Korea.

What are the factors that change the $CO_2$ emissions? This question can be answered by identifying the most important factors contributing to the overall changes in $CO_2$ emissions. One possible way for analyzing the $CO_2$emission changing factors is through econometric regressions. For instance, in his work Halicioglu (2009) proved that there


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exist a long run relationship between $CO_2$ emissions and income, energy consumption and foreign trade. Another possible way for analyzing the factors changing $CO_2$ emissions is the decomposition analysis (Kumbaroğlu, 2011). The method adopted in this paper is the decomposition analysis. The paper contributes to the literature by decomposing the $CO_2$ emissions in Iran, in a detailed way.

The aim of this study is to identify the factors that have been changing Iran's $CO_2$ emissions for the period 1990–2010. The Refined Laspeyres Index (RLI) method which was developed by Sun (1998) has been applied to the data set. The data set is gathered from the World Bank database. The impacts of the four main factors, namely economic activity, energy intensity, carbon intensity, and population, have been considered in the analysis.

The structure of the paper is as follows. In the next section, a brief literature review about the country based decomposition analysis studies is provided. In the third section the decomposition analysis methodology and basically the Refined Laspeyres Index method are discussed. This section is followed by the overview of Iran's economic, demographic, energy, and environmental conditions. The empirical results are presented in section 5. The last section contains the conclusions of the paper.

## Literature Review

Various methodologies have been developed to analyze the variations in energy and environmental factors. Decomposition Analysis (DA) techniques are among these methodologies used to identify the components changing the energy demand and related $CO_2$ emissions. A remarkable literature exists about the country-based decomposition studies. For instance, Paul and Bhattacharya's (2004) country-based study, analyzes the factors that increase and decrease the $CO_2$ emissions from the energy use of India between 1980 and 1996. Their empirical results indicate that economic activity has the greatest increasing effect on $CO_2$ emissions in India. Fankhauser and Cornillie (2004) studied the decomposition of energy data to identify the determining factors for energy intensity improvement in Eastern Europe and former Soviet Union countries. The researchers proved that energy prices and progress in enterprise restructuring are the two major contributors of efficient energy use. Furthermore, Wang et al. (2005) has also studied on decomposition of the energy-related $CO_2$ emissions for China between 1957 and 2000. Their empirical findings have shown that China achieved a remarkable decline in its $CO_2$ emissions due to improvements in its energy intensity. Kawase et al. (2006) have also worked on the decomposition of $CO_2$ emissions in Japan, for the period between 1985 and 1995, and they evaluated the long-term climate stabilization scenarios. On the other hand, Ma and Stern (2008) have also focused on Chinese $CO_2$ emissions between 1980 and 2003, and their results revealed that technological improvements reduced energy intensity, and this led to a reduction in overall $CO_2$ emissions. Moreover, Akbostanci et al. (2009) has studied the decomposition of $CO_2$ emissions for Turkey between 1970 and 2006 and their study showed that economic activity and energy intensity are the two major factors for evaluation of $CO_2$ emissions. Difurio (2010) has also focused the decomposition of $CO_2$ emissions in the US for the period 1990–2004 and their study showed that efficient energy use and reduction of fossil fuels in overall energy consumption offset the accelerating contributions of GDP per capita and population growth in the entire research period. Kumbaroglu's (2011) work has focused on the decomposition of $CO_2$ emissions for Turkey between the years


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1990 and 2007 by main economic activities, including agriculture, manufacturing, electricity, residential buildings, and transportation. His findings reveal that energy intensity and economic activity are the two major determinants of increasing $CO_2$ emissions in Turkey. On the other hand, carbon intensity and composition make only minor contributions to $CO_2$ emissions. Lei and Fan (2015) analyzed the $CO_2$ emissions in Beijing that are emitted from transportation over 1995 – 2012. By using the Generalized Fisher Index (GFI) method, the authors concluded that the economic growth, energy intensity, and population size have raised carbon emissions in the city during the study period. On the other hand they reported that transportation intensity and energy structure are the two factors that reduced the speed of transportation emissions in Beijing. Rüstemoğlu (2016) has provided a comparative decomposition analysis for Turkey's and Iran's carbon dioxide emissions from 1990 to 2011. By utilizing the Logarithmic Mean Divisia Index (LMDI) technique the researcher concluded that economic activity and population are the two major carbon emissions accelerating factors in Turkey and Iran. In addition, the researcher stated that Turkey has better achievements in terms of energy efficiency. *Table 1* summarizes these selected decomposition analysis studies in the literature.

***Table 1.*** *Selected studies that provide an overview of country based decomposition analysis*

| Study | Methodology | Empirical Findings |
|---|---|---|
| Paul and Bhattacharya, 2004. $CO_2$ emissions from energy use in India: A decomposition analysis | • Refined Laspeyres Index Method | • Economic Activity is the major factor which is increasing the $CO_2$ emissions. |
| Fankhauser and Cornillie, 2004. The energy intensity of transition countries | • Laspeyres Index Method<br>• Paasche Index<br>• Average Divisia Index Method<br>• Adaptive Divisia Weighting Method | • For efficient energy use, they concluded that energy prices and progress in enterprise restructuring are the two main factors. |
| Wang et al, 2005. Decomposition of energy – related $CO_2$ emissions in China: 1957 – 2000. | • Logarithmic Mean Divisia Index Method | • China achieved a success to reduce the speed of $CO_2$ emissions by energy efficiency. |
| Kawase et al, 2006. Decomposition analysis of $CO_2$ emissions in long – term climate stabilization scenarios. | • Extended Kaya Identity<br>• Scenario Analysis | • They evaluated the long term climate stabilization scenarios for Japan. |
| Ma and Stern, 2008. China's changing energy intensity trend: A decomposition analysis. | • Logarithmic Mean Divisia Index Method | • A decrease is observed in energy intensity due to the technological improvements. |
| Akbostanci et al, 2009. A decomposition analysis of $CO_2$ emissions from energy use: Turkish case. | • Logarithmic Mean Divisia Index Method | • Economic activity and energy intensity are the two major contributing factors to Turkish $CO_2$ emissions. |


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| | | |
|---|---|---|
| Difurio, 2010.<br>A decomposition nalysis of $CO_2$ emissions in the United States. | • Logarithmic Mean Divisia Index Method | • Efficient energy use and decreasing use of fossil fuels helped to reduce the increasing impact of economic activity and population growth in $CO_2$ emissions in US. |
| Kumbaroglu, 2011.<br>A sectoral decomposition analysis of Turkish $CO_2$ emissions over 1990 – 2007. | • Refined Laspeyres Index Method. | • Major contributing factors: Scale effect and energy intensity.<br>• Minor contributing factors: Carbon intensity and domposition effect. |
| Lei and Fan, 2015.<br>Decomposition analysis of energy – related carbon emissions from the transportation sector in Beijing. | • Generalized Fisher Index (GFI) method. | • Economic growth, energy intensity and population have raised carbon emissions in the sector.<br>• Energy structure and transportation intensity have followed a decreasing trend in $CO_2$ emissions in transportation sector. |
| Rüstemoğlu, 2016.<br>Environmental cost of economic growth: Determinants of $CO_2$ emissions in Turkey and Iran. | • Logarithmic Mean Divisia Index Method. | • Major determining factors: Economic activity, population.<br>• Better energy efficiency achievements in Turkey as compared to Iran. |

## Decomposition Analysis Methods

### *Introduction to Decomposition Analysis*

Decomposition analysis techniques can be considered mainly in two groups, Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA). SDA uses the input–output model in quantitative economics; however, IDA uses the index number concept under various methods linked to different index computations (Kumbaroğlu, 2011).

Both SDA and IDA methodologies are utilized in energy and $CO_2$ decomposition analysis, however, the use of IDA studies regarding $CO_2$ emissions is much larger. Ang and Zhang (2000) produced a survey of IDA related to the energy and environmental studies. In addition, Hokestra and Van Den Bergh (2003) made a comparison between SDA and IDA techniques and they stated that SDA is more efficient for the decomposition of economic and technological effects and IDA is more efficient for more detailed time and country studies. According to Ma and Stern (2008), the main advantage of IDA is it can be applied to any available data at any level of application. Like any other methods decomposition analysis also have some shortcomings. For instance, the analysis does not include the biomass use, since the comparable international data is not available. Therefore non - $CO_2$ greenhouse gas emissions are not included. In addition, $CO_2$ emissions only from fossil fuel combustion are


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considered. The other activities (forestry, land use changes) which also emit $CO_2$ emissions are not analyzed, again since the comprehensive data for them is not available. However, since it identifies the major contributing factors of $CO_2$ emissions generally a decomposition analysis is employed in the paper.

### *Refined Laspeyres Index Method*

Different methods have been developed and utilized under the IDA methodology. As Kumbaroglu (2011) states, the Laspeyres Index isolates the impact of a variable by letting that specific variable change between two years while holding other variables as a constant at the base year values. The Laspeyres Index method contains a residual term; therefore, a refinement process is suggested by Sun (1998) to eliminate it. Sun's refinement process distributes the residual term to each variable. This approach is referred to as the Refined Laspeyres Index method and according to Ang and Zhang (2000) it passes all tests, namely time reversal, factor reversal, and zero value robustness. We chose to use the Refined Laspeyres Index method because it is easy for both calculation and understanding and does not leave any residual terms.

The Refined Laspeyres Index method is an extension of the Kaya Identity. The Kaya Identity is used to investigate the role of different factors that change $CO_2$ emissions (Kumbaroğlu, 2011). It describes the $CO_2$ emissions as a multiplication of four factors: population (POP), carbon intensity of energy use ($CO_2$/ENG), energy intensity of production (ENG/GDP), and production per capita (GDP/P). That is:

$$CO_2 = POP * \frac{CO_2}{ENG} * \frac{ENG}{GDP} * \frac{GDP}{POP} \quad \text{(Eq. 1)}$$

For this study, our aim is to show the overall impacts of the main components on $CO_2$ emissions. Therefore, we calculate the cumulative contributions of the four main components, as follows:

$$CO2(i) = \sum_j CO2(j),$$
$$POP(i) = \sum_j POP(j),$$
$$ENG(i) = \sum_j ENG(j),$$
$$GDP(i) = \sum_j GDP(j).$$

Then the first equation can be written as,

$$CO_2(i) = \sum_j POP(j) * \frac{CO2(j)}{ENG(j)} * \frac{ENG(j)}{GDP(j)} * \frac{GDP(j)}{POP(j)} \quad \text{(Eq. 2)}$$

It is possible to denote the carbon intensity by CI, the energy intensity by EI, and economic activity by EA. Then the previous equation can be written as:

$$CO_2(i) = \sum_j POP(j) * CI(j) * EI(j) * EA(j) \quad \text{(Eq. 3)}$$

The effect of changes in production activity is referred to as the economic activity effect $(EA_i^t)$, and it can be calculated as:


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*Economic Activity Effect*

$$(EA_i^t) = \sum_j \Delta EA(j) * \left\{POP(j) * EI(j) * CI(j) + \frac{1}{2} * (\Delta POP(j) * EI(j) * CI(j) + POP(j) * \Delta EI(j) * CI(j) + POP(j) * EI(j) * \Delta CI(j))\right\} + \sum_j \Delta EA(j) * \{\frac{1}{3} * \left(\Delta POP(j) * \Delta EI(j) * CI(j) + \Delta POP(j) * EI(j) * \Delta CI(j) + POP(j) * \Delta EI(j) * \Delta CI(j)\right) + \frac{1}{4} * (\Delta POP(j) * \Delta EI(j) * \Delta CI(j))\} \quad \text{(Eq. 4)}$$

The economic activity effect ($EA_i^t$) shows the change in $CO_2$ emissions results from changing activity levels. According to the economic activity effect, an increase in activity levels increases the amount of $CO_2$ emissions, and a decrease in activity levels decreases the amount of $CO_2$ emissions.

*Population Effect*

$$(POP_i^t) = \sum_j \Delta POP(j) * \{EA(j) * EI(j) * CI(j) + \frac{1}{2} * (\Delta EA(j) * EI(j) * CI(j) + EA(j) * \Delta EI(j) * CI(j) + EA(j) * EI(j) * \Delta CI(j))\} + \sum_j \Delta POP(j) * \{\frac{1}{3} * \left(\Delta EA(j) * \Delta EI(j) * CI(j) + \Delta EA(j) * EI(j) * \Delta CI(j) + EA(j) * \Delta EI(j) * \Delta CI(j)\right) + \frac{1}{4} * (\Delta EA(j) * \Delta EI(j) * \Delta CI(j))\} \quad \text{(Eq. 5)}$$

The population effect ($POP_i^t$) shows the change in $CO_2$ emissions results from changes in the population. An increase in population increases $CO_2$ emissions and a decrease in population decreases $CO_2$ emissions.

*Energy Intensity Effect*

$$(EI_i^t) = \sum_j \Delta EI(j) * \left\{EA(j) * POP(j) * CI(j) + \frac{1}{2} * \left(\Delta EA(j) * POP(j) * CI(j) + EA(j) * \Delta POP(j) * CI(j) + EA(j) * POP(j) * \Delta CI(j)\right)\right\} + \sum_j \Delta EI(j) * \{\frac{1}{3} * (\Delta EA(j) * \Delta POP(j) * CI(j) + \Delta EA(j) * POP(j) * \Delta CI(j) + EA(j) * \Delta POP(j) * \Delta CI(j)) + 1/4 * (\Delta EA(j) * \Delta POP(j) * \Delta CI(j))\} \quad \text{(Eq. 6)}$$

The energy intensity effect ($EI_i^t$)suggests an indication of efficiency in the energy process, conversion technologies, and energy conservation. Energy-saving activities, reducing the use of fossil fuels and the use of renewable technologies increase energy efficiency. As a result, energy efficiency reduces the amount of $CO_2$ emissions.

*Carbon Intensity Effect*

$$(CI_i^t) = \sum_j \Delta CI(j) * \left\{EA(j) * POP(j) * EI(j) + \frac{1}{2} * \left(\Delta EA(j) * POP(j) * EI(j) + EA(j) * \Delta POP(j) * EI(j) + EA(j) * POP(j) * \Delta EI(j)\right)\right\} + \sum_j \Delta CI(j) * \{\frac{1}{3} * (\Delta EA(j) * \Delta POP(j) * EI(j) + \Delta EA(j) * POP(j) * \Delta EI(j) + EA(j) * \Delta POP(j) * \Delta EI(j)) + 1/4 * (\Delta EA(j) * \Delta POP(j) * \Delta EI(j))\} \quad \text{(Eq. 7)}$$

The carbon intensity effect ($CI_i^t$) is used to show the impact of fuel substitution on $CO_2$ emissions. For instance, if the share of renewable sources increases or if people use natural gas instead of coal, there will be a decline in overall $CO_2$ emissions.


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The change of $CO_2$ emissions between two years is the sum of these four effects:

$$\Delta CO_2(i) = Economic\ Activity(i) + Population(i) + Energy\ Intensity\ (i) + Carbon\ Intensity(i) \quad \text{(Eq. 8)}$$

For a detailed analysis regarding the RLI method, Ang and Zhang's (2001) work could be followed.

## Analysis of Data

The decomposition analysis covers the period 1990–2010, and the energy, $CO_2$, economic activity, and population data sets employed in this study are taken from the World Bank database. An overview of the economic and demographic developments, energy market, and emission growth trajectories is presented below. [1]

### *Economic and Demographic Developments in Iran*

During 1990–2010, real GDP grew at an annual average rate of 4.5 %. However, Iran's economy was faced by recession in the years 1993 and 1994 and the real GDP declined by 1.6 % and 0.4 % (World Bank, 2015). Recently, economic sanctions, which are targeting the oil and natural gas sectors, hampered Iran's economy profoundly (EIA, 2015). Starting from 2008 the economic growth of Iran slowed down and in 2012, real GDP declined by 1.9 %. Real GDP per capita also increased from \$1801 to \$3259 during the research period (World Bank, 2015).

Iran's population has increased from 56.3 million (in 1990) to 74.4 million (in 2010). The average population growth rate of Iran is 1.4 % and this value is very similar to the world's population growth rate (World Bank, 2015). The share of the urban population also increased from 56.3 % (in 1990) to 68.9 % (in 2010) (World Bank, 2015).

### *Energy Market in Iran*

Iran is the 12$^{th}$ largest energy consumer in the world and during the study period its energy consumption has increased from 69.3 thousand kt to 210.6 thousand kt (World Bank, 2015). Similarly, the energy production of Iran has increased rapidly from 187.8 thousand kt to 350.1 thousand kt between 1990 and 2010. According to EIA (2015), Iran is the fourth largest oil producer and second largest natural gas producer in the world and 98 % of overall energy demand is generated from these sources. The electricity production and electricity consumption of the country is 3.9 times and 3.7 times greater in 2010 if we compare with the 1990 level. As the World Bank data indicates, 95.8 % of overall electricity demand was generated by nonrenewable energy sources in 2010 (World Bank, 2015). In 2011, Iran's first nuclear energy power plant became operational.

### *$CO_2$ Emissions in Iran*

Iran's overall $CO_2$ emissions increased from 211 thousand kt (in 1990) to 571 thousand kt (in 2010) and the country follows the most developed countries such as the US, Germany, Japan, and the UK and the rapidly developing populous countries such as

[1] The data set is available for the interested researchers through the authors' e-mail.


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China and India in the emission rankings (World Bank, 2015). Similarly, per capita emissions of the country have increased from 3.7 tons (in 1990) to 7.7 tons (in 2010). In 2010, shares of the liquid and gaseous fuels in $CO_2$ emissions are equivalent to 43.2 % and 51.4 % respectively (World Bank, 2015).

## Results and Discussion

Before proceeding to the results of the RLI method, we discussed the general structure of Iran's economy, energy market, and $CO_2$ emissions between 1990 and 2010. The impacts of all identified factors on $CO_2$ emissions during 1990–2010 can be followed in *Figure 1*.

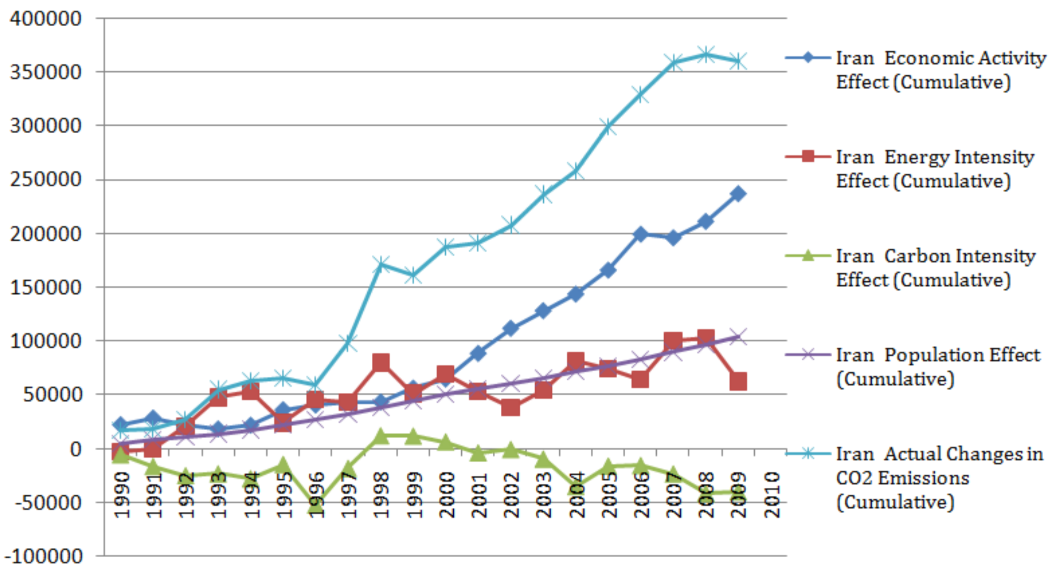


***Figure 1.** Decomposition of $CO_2$ emissions in Iran between 1990 and 2010*

*Figure 1* indicates that the major determinant of Iran's $CO_2$ emissions is the economic activity. The economic activity is followed by the energy intensity and population. Finally, the carbon intensity has some minor reducing effects on $CO_2$ emissions in Iran. The detailed analysis about the impacts of the identified factors on $CO_2$ emissions is presented below.

### *Economic Activity Effect*

As Kumbaroglu (2011) states, the economic activity effect represents the changes in $CO_2$ emissions resulting from changing economic activities. Except for the years 1993 and 1994, real GDP in Iran has increased. During the period 1990–2010, Iran's GDP and GDP per capita have experienced 139.1 % and 80.9 % increases respectively (World Bank, 2015). As a result of the spectacular economic growth, the economic activity played a dominant role in the decomposition of $CO_2$ emissions. In the first decade, we observed that the share of economic activity is 34.5 % in overall $CO_2$ emissions. Moreover, in the second decade, the contribution of economic activity in $CO_2$ emissions became more visible. The share of the economic activity in $CO_2$


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emissions has increased to 65.6 % between the years 2000 and 2010. *Figure 2* represents the contribution of economic activity regarding $CO_2$ emissions.

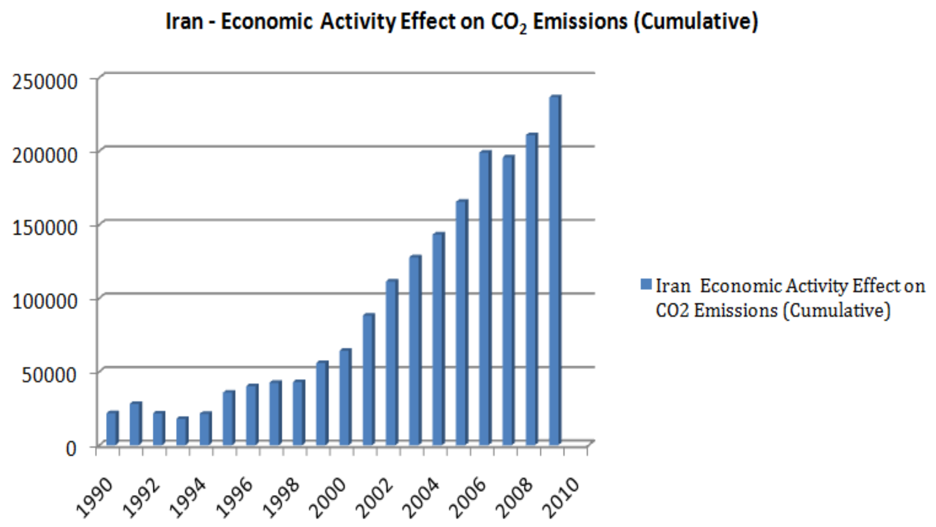


***Figure 2.*** *Contribution of the economic activity to $CO_2$ emissions in Iran over 199–2010*

### *Energy Intensity Effect*

According to Kumbaroglu (2011), the energy intensity effect provides an indication of the efficiency in energy processes, conversion technologies, and energy conservation. Increasing energy efficiency decreases the $CO_2$ emissions and vice versa. An energy efficiency goal can be obtained either by using renewable energy sources or reducing the use of fossil fuels by implementing the appropriate energy-saving policies. The energy intensity is the second determining factor on $CO_2$ emissions in the first decade. The share of the energy intensity is calculated as 31.3 % in overall $CO_2$ emissions. However, the energy intensity followed a negative trend in the years 1991, 1996, 1998, and 2000. In the second decade the contribution of the energy intensity in $CO_2$ emissions started to decrease. The share of energy intensity is calculated as 17.1 % in $CO_2$ emissions between 2000 and 2010. In addition, the energy intensity followed a negative trend in the years 2002, 2003, 2006, 2007, and 2010. The decomposition analysis results indicate that Iran achieved a success in reducing the energy intensity especially in the second decade, however, this success cannot be considered as remarkable since the cumulative contribution of the effect is still positive on $CO_2$ emissions. The energy intensity effect offsets the accelerating impact of other components when its cumulative impact on $CO_2$emissions turns to negative. *Figure 3* shows the contribution of the energy intensity effect in $CO_2$ emissions.

### *Population Effect*

The population effect describes the changes in $CO_2$ emissions due to the increases or decreases that are observed in the population. Iran's population accelerated to 74.4 million from 56.3 million in 20 years, which corresponds to a 32.1 % increase (World Bank, 2015). As a result of its remarkable growth, population increased $CO_2$ emissions constantly in the entire research period. Between 1990 and 2000, population


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is the third major determining factor of $CO_2$ emissions and its share is calculated as 26.9 %. However, during the second decade, the population effect became the second major determining factor on $CO_2$ emissions and its share has increased to 28.3 %. Since the population of Iran is increasing, then accelerating $CO_2$ emissions due to the population effect is an expected and a consistent result. *Figure 4* indicates the impact of population effect in Iran's carbon emissions from 1990 to 2010.

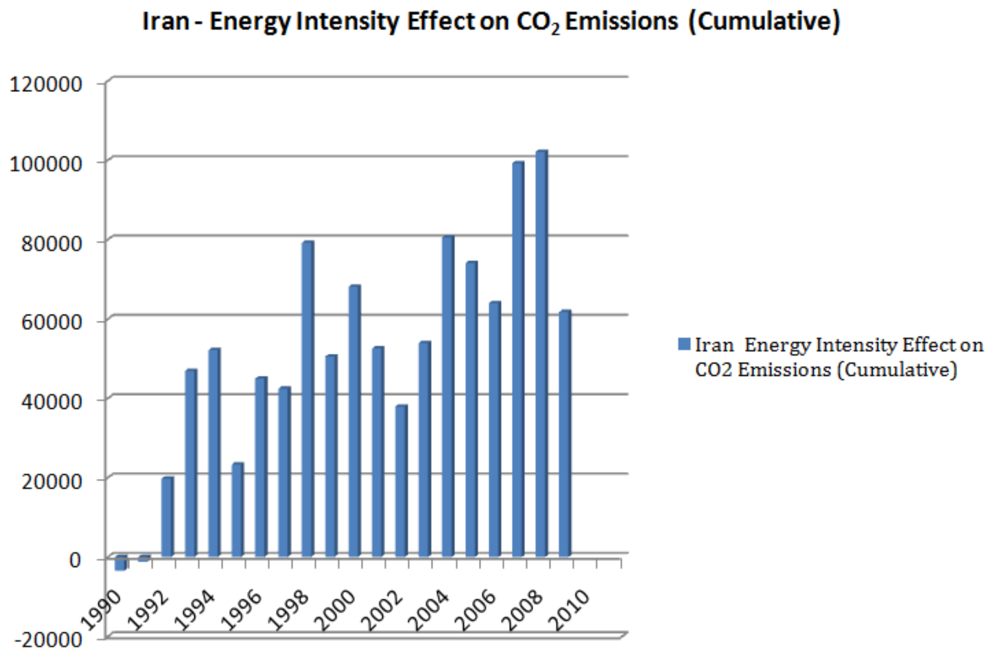


***Figure 3.*** *Contribution of the energy intensity on $CO_2$ emissions in Iran over 1990–2010*

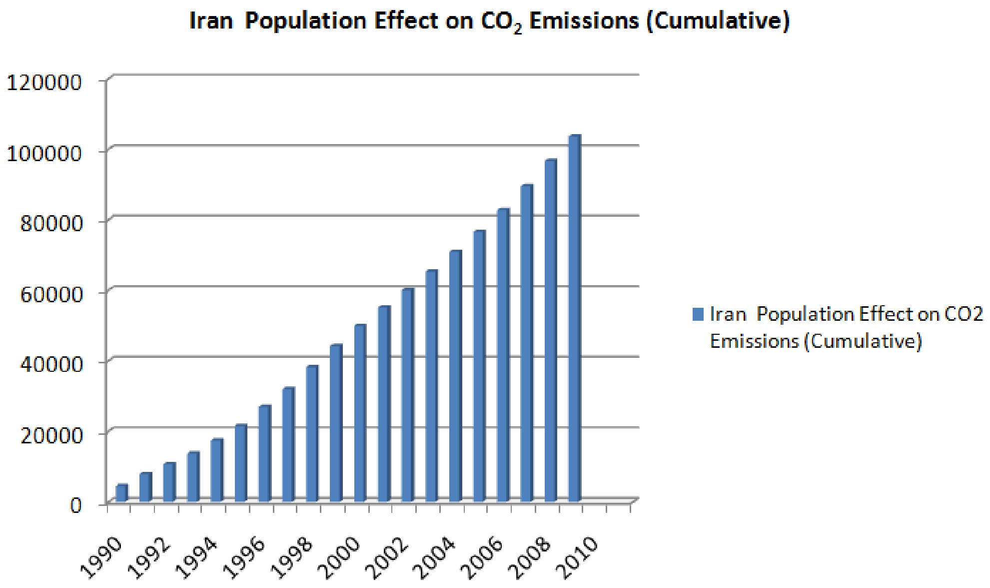


***Figure 4.*** *Contribution of population on $CO_2$ emissions in Iran over 1990–2010*


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### *Carbon Intensity Effect*

The carbon intensity effect has been used to estimate the impact of fuel substitution in $CO_2$ emissions. If the energy mix becomes less carbon intensive or renewable sources are implemented instead of nonrenewable sources, then emission reduction can be obtained (Kumbaroğlu, 2011). The share of the carbon intensity in overall $CO_2$ emissions was 7.2 % during the first decade. Additionally, in the years 1991, 1992, 1993, 1995, 1997, and 2000 the carbon intensity followed a decreasing trend. Furthermore, between 2000 and 2010, the overall contribution of the carbon intensity on $CO_2$ emissions turned to negative. The share of the carbon intensity is estimated at -11 %, which is a desirable result for a reduction of the emissions. In the second decade, the carbon intensity decreased during the years 2001, 2002, 2004, 2005, 2008, and 2009. This remarkable decline is probably the result of a decreasing share of oil and increasing share of natural gas in overall energy consumption. For instance, in electricity production, the share of oil declined from 37.1 % to 19.8 % and the share of natural gas increased from 52.5 % to 75.9 % for the entire period (World Bank, 2015). The pollution coefficient of natural gas is relatively smaller than the pollution coefficient of oil. The carbon intensity is the only factor that offsets a small amount of the negative contributions of the income effect, the energy intensity effect, and the population effect for Iran's $CO_2$ emissions. *Figure 5* indicates the declining trend of carbon intensity in $CO_2$ emissions.

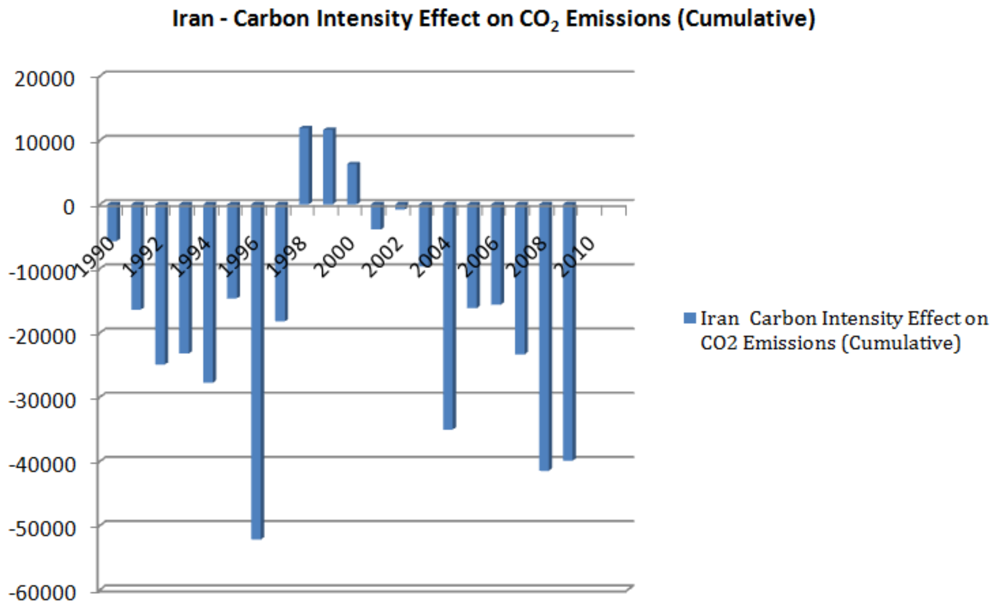


***Figure 5.*** *Contribution of carbon intensity on $CO_2$ emissions in Iran over 1990–2010*

## Conclusion

In this paper, a decomposition analysis is used to identify the factors that influence the changes in Iran's $CO_2$ emissions for the period 1990 – 2010. The factors that lead to changes in $CO_2$ emissions are economic activity, energy intensity, population, and carbon intensity. A particular decomposition technique – the Refined Laspeyres Index method – is used to evaluate the relative contribution of these components that account for changes in $CO_2$ emissions.


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Our empirical results have shown that in Iran economic activity was the most important component of $CO_2$ emissions change during 1990–2010. Energy intensity also increases $CO_2$ emissions; however, its contribution in the second decade was relatively smaller than in the first decade. Population is also a dominant factor on Iran's $CO_2$ emissions changes; it constantly increased the amount of $CO_2$ emissions during the study period. Especially in the second decade the contribution of population on $CO_2$ emissions became more visible. The carbon intensity made minor increasing contributions to $CO_2$ emissions between 1990 and 2000. However, in the second decade its impact on $CO_2$ emissions turned to negative, which is a desirable result for emissions reduction. The decrease in the carbon intensity is probably an outcome of the fuel switching. In Iran, during the period 1990–2010 the share of natural gas consumption gradually increased while the share of oil gradually decreased. Since the pollution coefficient of natural gas is relatively smaller than the coefficient of oil, then this led to a reduction in emissions due to the carbon intensity.

Regarding decomposition analysis, Iran is not a widely studied country. Therefore, in this respect, our study contributes to the literature by analyzing Iran. In the future, GDP and population of the country are expected to increase and, therefore, economic activity and population will raise the $CO_2$ emissions. However, the emission reduction goal can be accomplished by reducing the contributions of energy intensity and carbon intensity. This study creates an opportunity for policy makers to develop economically and environmentally sustainable projects.

Given that Iran is indeed an upper-middle income country which is dependent on oil revenues, volatility in oil prices would create a distortionary and direct impact on the economy. Our policy suggestions include a massive diversifications of the economy to other equally productive sectors; particularly agriculture and industry. Also a very robust and consistent policy framework should be directed towards energy conservation principles in every economic sector. This can be achieved through a high-tech mechanization including the use of fuel efficient equipments in the agricultural sector, use of heat insulators and double layer glasses, and sealing doors and windows in homes and the provision of small loans to households will encourage them to purchase a more energy efficient appliances. In the transportation sector policies should equally be directed not only towards a reduction in gasoline subsidies to bring down $CO_2$ emissions; but also setting appropriate policies that adheres to energy efficient manufacturing standard vehicles.

Finally since Iran has a remarkable high solar, wind and hydro energy potential due to its geographic location, a policy that is directed towards energy principles will lead to a richer Iran in the near future.

This study made a decomposition analysis to identify the factors that contributed the most to $CO_2$ emissions in Iran. A further research would be to employ an econometric analysis as of Halicioglu (2009) to include the effect of foreign trade in the determining factors.

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