Sectoral Decomposition of CO_2 Emissions in China and India for the Period 1980-2010

Ph.D. Candidate Hasan Rüstemoğlu (Eastern Mediterranean University, Cyprus)
Assoc. Prof. Dr. Sevin Uğural (Eastern Mediterranean University, Cyprus)

Abstract

Increasing amount of CO_2 emissions and global warming is one of the hottest topics of world's agenda. At the same time there exists a public awareness about this important chapter. A lot of researcher proved that in order to live in a sustainable world, necessary regulations should be done and CO_2 emissions should be reduced immediately. For this study our aim is to decompose the CO_2 emissions of the world's new super powers, China and India, over 1980-2010. In order to see the accelerating and decelerating factors for CO_2 emissions, the Refined Laspeyres Index used as a method. Consistent data gathered from the official web sites of the World Bank and United Nations. Five main sectors, agriculture, manufacturing, construction, transportation and other services are used. Four different impacts, scale effect, composition effect, energy intensity effect and carbon intensity effect have been discussed to see the increasing or decreasing factors of CO_2 emissions. The results were interesting. The dominant impacts were the scale effect and energy intensity effect. The minor impacts were composition effect and carbon intensity effect. Fuel switching, efficient energy use and increasing usage of renewable resources are efficient tools to reduce the emissions.

1 Introduction

During the last thirty years, increasing amount of CO_2emissions and the threat of global warming is one of the most important topics of World's agenda. The biological and economic impacts of global warming are discussed especially by researchers since the beginning of 1990s. The environmental damage certainly increased due to increasing world population, energy consumption and industrial activities. After the industrial revolution the amount of Greenhouse Gas (GHG) emissions started to increase. Six of the main greenhouse gases are namely, carbon dioxide (CO_2), methane (CH_4), nitrous dioxide (N_2O), Hydrofluorocarbons (HFC),Perfluorocarbons (PFC) and Sulphurhexafluorid (SF_6). CO_2 emissions have the highest share in GHG emissions which also referred to as the 'carbon footprint'. The carbon footprint is a measure of the exclusive total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. The amount of CO_2 concentrations was equivalent to 280 ppm in 1850 and by 2006 this value reached to 384 ppm. CO_2 emissions, is the main cause of global warming, which is estimated to increase up to 5.8 degrees of Celsius until the end of 21st century. According to scientists in order to keep the global temperature increase by 2 degrees of Celsius the overall countries should stabilize their total emissions either 400 ppm or 450 ppm. Accordingly to obtain a sustainable world, countries should reduce their CO_2 emissions by 60% in 2030. Furthermore this limitation should be 80% by 2050. The main element of CO_2 emissions are the fossil fuels that are widely used in all sectors of economics and daily life. Thermal electricity plants, natural gas electricity plants, other fossil fuel electricity plants, transportation (automobiles, buses, trucks, plane), industrial production (cement factories, petrochemical buildings, refineries, iron and steel industry), agriculture and livestock, global trade, tourism, defense industry, domestic electrical devices, deforestation are the main reasons of climate change. According to biological studies the temperature of earth's surface increased by 0.6 degrees of Celsius during the last 20th century (IPCC, 2001a). For Europe this value is equal to 1.2 degrees of Celsius. In the nearest future, because of the global warming and climate change, scientists are expecting extreme droughts and floods for some regions of the world. For example Mediterranean Countries, such as Spain, Greece and Turkey are expected to face a 5 percent average rainfall decline in every next decade. As a result of global warming, especially in summer seasons the ice shelf has been declined by 40 percent and at the same time it has been observed that there exists 10 or 20 cm increase in sea level of the world (IPCC, 2001a). As a result of climate change, hurricanes, floods and extreme droughts reveal a certain danger of extinction of some animal species and biodiversity. Global warming and climate change creates a certain threat on country's economies as well. They will show their negative impacts mainly on agriculture, industry, tourism and insurance sectors if serious preventions and developments on environmental issues are not taken into consideration. Energy policies and environmental issues have an important relationship with the GHG emission and with regard to this understanding and analyzing the decomposition of CO_2emissions are important. In order to reduce the negative impacts of global warming World Wide Organizations (for example United Nations) organized series of meetings. They firstly came together in 1988 and organized the Intergovernmental Panel on Climate Change. The aim of this panel was evaluating technical, scientific and socio-economic information about impacts of climate change. The IPCC published evaluation reports about the CO_2 emissions and global warming regularly. After long discussions, in December 1997 they signed the Kyoto Protocol. The Kyoto Protocol is an agreement under the United Nations Framework Convention on Climate Change (UNFCCC) aims to reduce the amount of

GHG emissions that are the main reason for global warming. It is the only agreement that targets a certain decline on GHG emissions. The protocol puts some restrictions to developed countries such that they would reduce the amount of GHG concentrations 5.2% below 1990 level between the years 2008-2012. It has been started to apply in 2005 after the long ratification process of Russian Federation.

Today the Kyoto Protocol considers more than 160 countries and more than 55% of overall GHG emissions. According to the agreement, there would be a certain decline in GHG emissions between 2008 and 2012 as compared to 1990 levels. The main objectives of Kyoto Protocol are heating with less energy, taking the long way by using less energy, placing less consuming technology systems into the industries, considering the environmentalism as a basic principle for transportation and waste storage, turning to alternative energy sources in order to decrease the amount of CO_2 and CH_4 emissions. Instead of fossil fuels the usage of biodiesel should be increased. High energy consuming enterprises, such as iron and steel, cement and lime factories should be re-organized according to their waste handling. Less carbon technologies in thermal power plants should be used. Strategies should clear the ways of solar energy. Since the nuclear energy is zero carbon energy, it should be placed at forefront in the world. Countries that are consuming high amount of waste and producing too much carbon should pay higher amount of taxes.

The Kyoto Protocol has three mechanisms, namely, Joint Implementation Mechanism, Clean Development Mechanism and Emission Trading Mechanism. According to the Joint Implementation Mechanism, if one country (that determined an emission target) makes an investment in another country (that also determined an emission target) in order to reduce GHG emissions then it will gain Emission Reduction Units. ERUs will be subtracted from the country's total emission targets. In the case of Clean Development Mechanism, if one country (that determined an emission target) makes an investment to reduce GHG emissions on another country (that did not determine an emission target) then it will gain Certified Emission Reduction Units. CERUs will also be subtracted from the total emission target. According to the third mechanism, Emission Trading, the countries that determined the emission targets can make emission trade between themselves. If a country obtains a higher reduction performance than its determined emission target then it will be able to sell the extra reduced emission units to other country.

The aim of this study is to decompose the CO_2 emissions for the most crowded countries China and India between the years 1980 and 2010 according to sectors agriculture, manufacturing, construction, transportation and service sectors. For each sector four effects (scale effect, composition effect, energy intensity effect and carbon intensity effect) are considered. The aim is to determine the accelerating and decelerating effects for CO_2 emissions. By using this analysis, it will be possible to apply true policies to reduce the amount of emissions.

2 Literature Review

For the concern of decomposition analysis, researchers followed different ways to do their research. Some researchers either did some comparison for decomposition analysis or they evaluated some extensions for available methods in order to reduce the value of residual terms and obtain a better approach. However, in the second category some researchers used the available methods to decompose the CO_2 emissions of countries according to sectors.

Ang et al. (2003) analyzed the perfect decomposition techniques for energy and environmental issues. They stated, "as there has been a great deal of interest in decomposition analysis in energy policy studies, we extend the work by Albrecht et al. (Energy Policy 30 (2002) 727) by giving a more complete and up to date overview of perfect decomposition techniques and their role in energy demand and related analysis."

Ang et al. (2004) developed a general Fisher index approach to energy decomposition analysis. By extending the conventional two-factor Fisher index decomposition approach to n factors, the authors evaluated a complementary approach for the existing methodology. The new approach possesses some desirable properties and may be used for some situations in energy studies. The authors also notice that the new formula is more complex than the other commonly adopted IDA approaches.

Liu (2006) did a comparison analysis for methodologies related with the decomposition approach based on energy consumption. The author considered the size of residual term as a comparison tool and he concluded the adaptive weighting Divisia index method and simple average Divisia index method represent most robust and smallest residual term.

Paul & Bhattacharya (2003) focused the factors that are increasing or decreasing CO_2 emissions emitted from the energy use of India. They did their research for time period 1980-1996. For their study, they used decomposition method and considered four main factors such as, pollution coefficient, energy intensity, structural changes and economic activity to explain the changes in CO_2 emissions. The authors applied the decomposition method and hence they proved that economic growth has the largest positive impact on CO_2 emissions changes, for all major economic sectors. As a result of the improved energy efficiency and fuel switching, they mentioned for all industrial sectors and transportation there is a decline for CO_2 emissions. The authors also underlined the reduction of pollution coefficient and energy intensity for CO_2 emissions emitted

from agriculture can be ignored. They finally concluded that the energy intensity has had a greater impact on energy induced CO_2 emissions than the production coefficient.

Comillie&Fankhauser (2004) decomposed energy data to identify the main factors behind the improvements in energy intensity. For more efficient energy use they concluded energy prices and progress in enterprise restructuring are two important factors. The authors also underlined the economies of Central and Eastern Europe and the former Soviet Union countries have been highly energy intensive. They also stated there is a decrease for energy intensity during the transition but still the transition countries are very energy intensive.

Kawase et al. (2005) discussed the long-term scenarios in other countries and the medium-term scenarios for Japan in order to develop Japan's long term climate stabilization scenario. For their study, the authors decomposed the CO_2 emissions by using extended Kaya identity according to following indexes: CO_2 capture and storage, carbon intensity, energy efficiency, energy intensity and economic activity. They also constructed a Reduction Balance Table. The authors also calculated the necessary energy intensity improvement and carbon intensity decline to achieve a 60-80% reduction for CO_2 emissions. ,

Ma & Stern (2007) examined the factors related with changing energy intensity schedule of China for time period 1980-2003. The authors used logarithmic mean Divisia index (LMDI) techniques to decompose the changes that are accelerating or decelerating energy intensity. They concluded technological change is the dominant factor for decreasing energy intensity. Structural change for industry sector increased the energy intensity during that period. Structural change considers shifts of production between sub-sectors, represent a declining trend for energy intensity. They also reported that increasing energy intensity after 2000 is because of the negative technological progress. Finally, inter-fuel substitution is a small contributor for changes in energy intensity.

Vinuya et al. (2010) decomposed the CO_2 emissions growth in US according to states between the years 1990 and 2004. They used the Logarithmic Mean Divisia Index (LMDI) method to decompose the emissions into five effects, namely, emissions per unit of fossil fuel, share of fossil fuel in total energy consumption, energy intensity, gross state product per capita and population. Their analysis showed that, during the 15 years period there is an increase in efficiency for energy use. At the same time, lowering the share of fossil fuels in total energy consumption and lowering the emissions intensity balances the effect of Gross Domestic Product (GDP) per capita and population growth in carbon emissions for US.

Kumbaroğlu (2011) examined CO_2 emissions for Turkey for time period 1990-2007 according to sectors agriculture, manufacturing, electricity, residential buildings and transportation. The author considered four main effects (composition effect, scale effect, energy intensity effect and carbon intensity effect) and he used Refined Laspeyres Index Method to decompose the CO_2 emissions. He also noted that various interesting results on the underlying effects of sectors emission data are found. He also underlined the valuable insights that are gained into CO_2 impacts of sector policies including energy and emission intensities, fuel switching and activity changes.

The aim of this study is analyzing the most dominant effects of CO_2 emissions for China and India between 1980 and 2010 according to sectors. 5 different sectors (agriculture, manufacturing industries, construction, transportation and other service sectors) and 4 different effects (scale effect, composition effect, energy intensity effect and carbon intensity effect) will be considered. For decomposition analysis, Refined Laspeyres Index Method and a consistent data that is gathered from World Bank and United Nations will be used.

3 Overview of China and India

After the market reforms in 1978, Chinese economy moved from a centrally planned to a market based economy. As a result of this, China obtained a rapid economic and social development. In 1980, the total population of China was 981.235.000. By showing an annual average population growth of 1.02%, in 2011 its population reached 1.344.130.000. The total GDP of China was $189.399.992.473 in 1980 and by showing a great and impressive average economic growth performance (equal to 10%) it reached $7.318.499.269.769 in 2011. Today China is the second biggest economy of the world, as a result of rapid growth 600 million people have lifted out of poverty. China is an upper middle income country, its GDP per capita was equal to $193 in 1980, but after the thirty years significant growth performance, it reached $5444.79 in 2011. However, according to the World Bank records still more than 170 million people are below the $1.25 a day international poverty line.

CO_2 emissions of China showed annual 5.99% growth during the last thirty years. Today, China has the first position in world's CO_2 emissions classification. In 1980, CO_2 emissions per capita were equal to 1.5 metric tons and after thirty years it reached to 5.77 metric tons. During that period the CO_2 emissions share schedule from the fuel consumption didn't change significantly. Still more than 73% of the CO_2 emissions are due to solid fuel consumption. Liquid fuel consumption is responsible from 14% of CO_2 emissions. Gaseous fuel consumption is responsible only 2% of CO_2 emissions from whole fuel consumption. These values definitely prove that, China should focus to pollution reduction and it also should set new energy efficiency targets. If one considers

according to the sectors of Chinese economy, it can be easily seen that the schedule for CO_2 emissions completely changed during the three decades. In 1980, the biggest carbon dioxide share was related with the manufacturing industries and construction sectors. Numerically they considered 46.48% of all CO_2 emissions that are obtained from fuel combustion. In that year, second biggest CO_2 emissions were obtained from electricity and heat production, equivalently 25.02% of total fuel combustion. Third biggest share for CO_2 emissions was related with residential buildings and commercial and public services. They considered 17.26% of total fuel combustion in 1980. Transport sector and other service sectors considered small amount of total CO_2 emissions. Only 5.71% and 5.53% of total fuel combustion, respectively. In 2010, biggest share for CO_2 emissions was obtained from electricity and heat production. Compared to 1980 share, the percentage of emissions doubled. Numerically they considered 53% of all CO_2 emissions. The share of manufacturing industries and construction gradually decreased. By 2010, the numerical value for this sector was equal to 32.25%. Compared by 1980 level the CO2 emissions share of transport sector increased with little amount. Numerically it was equal to 7.04% in 2010. CO_2 emissions share of residential buildings and commercial and public services decreased to 6.08%. Finally the other service sector was responsible only 1.63% of all CO_2 emissions in 2010.

As the population increased and technology developed, the energy use of Chinese economy also increased rapidly. During the thirty years period annual energy use of China increased by 4.82%. In 2010, the total energy consumption of China reached 2417125.926 kt. For electricity production, the situation of China is quite interesting. In 1980, the share of electricity production from coal sources was equivalent to 54.6%. During the thirty years the dependence of electricity production to coal sources increased gradually. By 2010, China was getting 77.7% of its electricity production from coal sources. In 1980, oil was the second biggest source for electricity production of China equivalent to 25.80% of overall production. Until 2010, the production from oil resources showed a huge decreasing performance. On average, it decreased by 12.53% annually. In 2010, only 0.31% of electricity production of China depends to oil. There are no big fluctuations in Chinese electricity production from hydroelectric sources. It was equivalent to 19.36% and 17.16% in the years 1980 and 2010, respectively. Electricity production from nuclear sources, natural gas sources and renewable sources has really small shares, respectively 1.75%, 1.64% and 1.14% according to 2010 records. Those values are proving the idea that rapidly growing Chinese economy didn't show enough responsibility in case of environmental sustainability. Significant policy adjustments are necessary for China to obtain a sustainable growth. Past experiences are proving that it's more difficult to move from middle income to high income than to move from low income to middle.

India is a very crowded country like China and also in the last decade it showed a significant economic growth. According to WB 2011 records India is the 4th largest economy in the world. India is also an active player of global economy now. Recently there exists a slowdown in GDP growth of India. It seems that this will consider because of the tight macroeconomic policies, slow growth in the core OECD countries, weakness of investment and also because of an expectation for a global recession. Between 2004 and 2010 poverty showed a certain decline in India. It was 37.2% in 2004 and after six years it reduced to 29.8%. The Indian government does some necessary investment in order to bring fundamental services to the poor people. Elementary education, basic health care, health insurance, rural roads and rural connectivity are the examples for the investments that Indian government is doing.

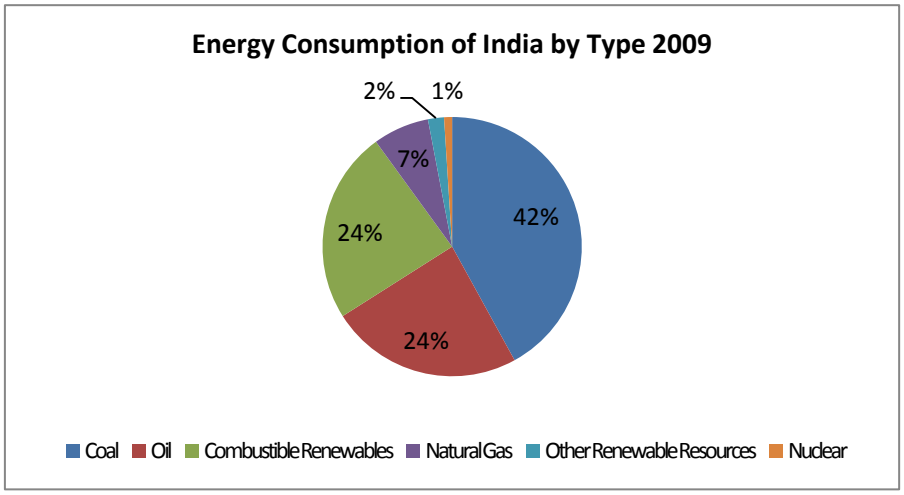
The need for universalizing secondary education has obtained because of the necessary number of children entered to elementary school. A large number of Indian people are not able to access to good quality health care, and progress in improving health indicators is slow. India also has a certain malnutrition problem.

In 1980, the population of India was equal to 700.058.589. However, by showing annual average growth rate of 1.86% it reached 1.241.491.960 in 2011. During the thirty years, annual GDP growth rate of India was equivalent to 6.24%, as a result of this remarkable success Indian GDP reached to $1.847.976.748.641. In 1980, GDP per capita for India was equal to $270.83, by showing 4.28% annual average GDP per capita growth rate performance, in 2011, it reached to $1488.51. In case of environmental sustainability, like China, India also must show enough responsibility. According to World Bank records, during the thirty years period, CO_2 emissions of India, increased annually by 6.19% on average. The total amount of CO_2 emissions was equal to 1979424.60 kt. In 1980, CO_2 emissions per capita, was equal to 0.5 metric tons and after three decades this value reached to 1.64 metric tons. The CO_2 emissions of India are due to solid fuel consumption at most. In 1980, solid fuel consumption accounts 72.54% of overall CO_2 emissions where liquid fuel consumption accounts 23.88% and gaseous fuel consumption accounts 0.71%. During the three decades, the schedule didn't change too much. In 2009, solid fuel consumption is responsible from 67% of overall CO_2 emissions, 23.74% is the share of liquid fuel consumption and 3.99% is the share of gaseous fuel consumption. If we check the responsibility of CO_2 emissions of the main economic sectors it can be see that situation of India, like China is quite interesting. In 1980, electricity and heat production considers 31.39% of total emissions where manufacturing industries and construction were responsible from 32.16% of emissions from fuel combustion. In 1980, for CO_2 emissions, transport sector consists 19.97%, residential buildings and commercial and public services consist 12.33% and

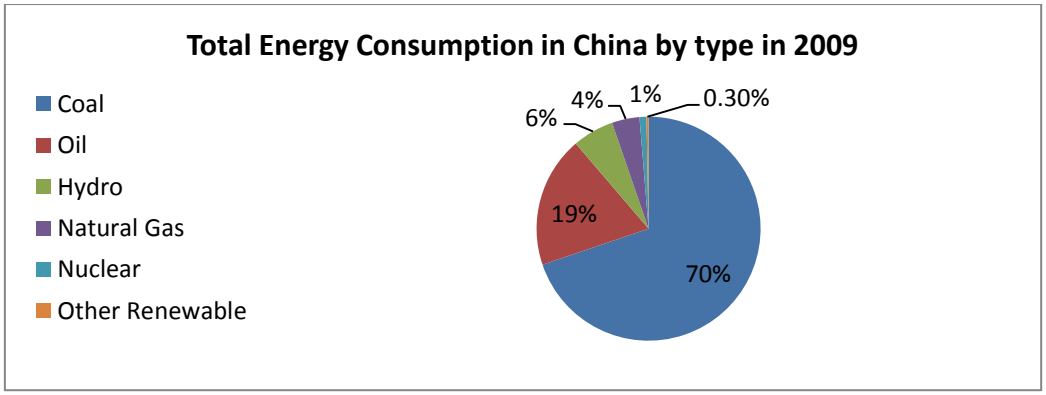
finally other service sectors considers 4.14% of overall CO_2 emissions from total fuel combustion. During the three decades the schedule completely changed. Responsibility of the electricity and heat production increased to 57.63%. During that period CO_2 emissions share of manufacturing industries and construction sectors declined to 24.66%. CO_2 emissions from transport, residential buildings and commercial and public services, other service sectors declined to 9.93%, 5.49% and 2.29% respectively.

Total energy use of India increased gradually during the last three decades. By showing, on average, 4.14% increase it reached to 692689.009 kt of oil equivalent. In 1980, coal was the main source for electricity production. Numerically 51.53% of overall electricity production was obtained from coal. In that time, for India, water was also an important source for electricity generation. It considers 39.03% of overall electricity production. In 1980, electricity production from oil sources consists of 6.38% of overall electricity generation. Nuclear energy and natural gas sources consist only 2.51% and 0.52% of overall electricity production, respectively. When we check 2010 shares, it can be easily seen that electricity production scheme has completely changed during the last three decades. Share of coal sources increased to 68.02% and of course huge amount of coal dependence is challenging the environmental sustainability. During that period share of natural gas sources for electricity production showed an increasing performance and 2010 WB records show that they consist 12.27% of overall production. At the same time, hydro sources showed a sharp decline and today they account 11.92% of total production. Electricity production from oil sources and nuclear sources consider 2.75% and 2.73% respectively. India started use renewable sources for electricity generation in 1986. According to 2010 records 2.29% of electricity needs are obtained from renewable resources.

Because of its growing economy India is a significant consumer of oil and natural gas. According to 2009 energy results, India located at the 4th position in the energy consumption list of world just after US, China and Russia. Even a lot of countries suffered from global recessions the energy need of India will consider to increase. Petroleum demand of transport sector will continue to rise due to the expansion of car ownership.



Source: The International Energy Agency



Source: US Energy Information Administration International Statistics.

In 2010, Indian oil production was equivalent to 950 thousand barrels per day (bbl/d) and oil consumption was equivalent to 3.2 million barrels per day (bbl/d). India was the fifth largest oil importer of the world by 2010. In 2011 China obtained an annual growth performance equivalent to 9.2% where in the first half of 2012 this value was 7.8%. During the second half of 2012, growth of Chinese economy considers to slow because of global

financial crisis, decrease in industrial production and exports. According to 2011 energy statistics, China is the second largest oil consumer just behind the US. More interestingly China was a net oil exporter country at the beginning of 1990s and just after two decades it is the second largest oil importer of world. China produced an estimated 4.3 million barrels per day (bbl/d) of total liquids in 2011, of which 95% was crude oil (EIA). However, at the same year, the total consumption of country was 9.8 million bbl/d. Net oil import of China was equivalent to 5.5 million bbl/d.

4 Methodology

There exist, mainly two methods for decomposing the indicator changes according to sectors: namely the Structural Decomposition Analysis (SDA) and the Index Decomposition Analysis (IDA). As Kumbaroglu stated, SDA is related with the input output model of quantitative economics and its theoretical foundations and major properties are discussed by Rose and Casler. In literature mostly the IDA methods are used. The main advantage of IDA is it can be easily applied to any data at any level of aggregation. The well-known Laspeyres index method isolates the impact of a variable by letting that specific variable to change between two years while holding other variables constant at their base year values (Kumbaroğlu, 2011). Various methods have been developed and employed under IDA methodology (Kumbaroglu, 2011). In 2000, Ang and Zhang provided a survey of index decomposition analysis in energy and environmental issues. Refined Laspeyres Index (RLI) method is developed from Laspeyres Index Method by Ang and Zhang and it distributes the residual term evenly to each variable. RLI method widely used because, it is easy for calculation and understanding. According to Ang and Zhang, who include a comparison of several IDA methods, the refined Laspeyres Index Method passes all tests (time reversal, factor reversal and zero value robustness) and possesses several desirable properties (Kumbaroğlu, 2011). In this study to decompose Chinese and Indian CO_2 emissions, the Refined Laspeyres Index method is used.

The RLI method is based on the extension of Kaya Identity, which it is widely used to analyze the role of different factors, which influence the CO_2 emissions. The Kaya Identity explains carbon emissions (C) as a multiplication of four effects: population (POP), carbon intensity of energy use (C/E), energy intensity of production (E/P) and per capita production (P/POP). Mathematically, it can be shown as,

$$C = POP * \frac{C}{E} * \frac{E}{P} * \frac{P}{POP}$$

For this study the above given Kaya Identity is expanded to account for impacts at subsectors level. Therefore CO_2 emissions are calculated as a multiplication of the subsectoral total of four effects given as

$$CO_{2i}^t = P_i^t * \sum_j \frac{CO_{2j}^t}{E_j^t} * \frac{E_j^t}{P_j^t} * \frac{P_j^t}{P_i^t}$$

where $\frac{CO_{2j}^t}{E_j^t}$ represents the carbon intensity of energy use in subsector j at time t, $\frac{E_j^t}{P_j^t}$ represents the energy intensity of production in subsector j at time t, and $\frac{P_j^t}{P_i^t}$ is equivalent to share of subsector j within sector i, at time t and can denote the carbon intensity by CI, the energy intensity by EI and the sectors share by SS then the previous equation can be written as;

$$CO_{2i}^t = P_i^t * \sum_j CI_j^t * EI_j^t * SS_j^t$$

The effect of changes in production activity which is referred to as scale effect, composition effect, energy intensity and carbon intensity can be calculated as:

Scale Effect (P_i^t)

$$= \Delta P(i) \sum_j \left\{ SS(j)EI(j)CI(j) + \frac{1}{2} * \left(\Delta SS(j)EI(j)CI(j) + SS(j)\Delta EI(j)CI(j) + SS(j)EI(j)\Delta CI(j) \right) \right\}$$
$$+ \Delta P(i) \sum_j \{ \frac{1}{3} * (\Delta SS(j)\Delta EI(j)CI(j) + \Delta SS(j)EI(j)\Delta CI(j) + SS(j)\Delta EI(j)\Delta CI(j)) + 1/4$$
$$* (\Delta SS(j)\Delta EI(j)\Delta CI(j)) \}$$

First effect is the scale effect and it shows the change in CO_2 emissions due to the changing activity levels. According to the scale effect, the increase of activity levels increases the amount of CO_2 emissions and the decrease of activity levels reduces the amount of CO_2 emissions.

Composition Effect (SS_j^t)

$$= \sum_j \Delta SS(j)\{P(i)EI(j)CI(j) + \frac{1}{2} * (\Delta P(i)EI(j)CI(j) + P(i)\Delta EI(j)CI(j) + P(i)EI(j)\Delta CI(j))\}$$
$$+ \sum_j \Delta SS(j)\{\frac{1}{3} * (\Delta P(i)\Delta EI(j)CI(j) + \Delta P(i)EI(j)\Delta C(i) + P(i)\Delta EI(j)\Delta CI(j)) + 1/4$$
$$* (\Delta P(i)\Delta EI(j)\Delta CI(j))\}$$

Composition effect represents the change of emissions due to the changes in the composition of sector. A structural change toward less carbon intensive subsectors decreases CO_2 emissions and a structural change toward more carbon intensive subsectors increases CO_2 emissions.

Energy Intensity Effect (EI_j^t)

$$= \sum_j \Delta EI(j)\{P(i)SS(j)CI(j) + \frac{1}{2} * (\Delta P(i)SS(j)CI(j) + P(i)\,\Delta SS(j)CI(j) + P(i)SS(j)\Delta CI(j))\}$$
$$+ \sum_j \Delta EI(j)\{\frac{1}{3} * (\Delta P(i)\Delta SS(j)CI(j) + \Delta P(i)SS(j)\Delta CI(j) + P(i)\Delta SS(j)\Delta CI(j)) + 1/4$$
$$* (\Delta P(i)\Delta SS(j)\Delta CI(j))\}$$

Energy intensity effect suggests an indication for efficiency of energy process, conversion technologies and energy conservation. Energy saving activities reducing the use of fossil fuels and use of renewable technologies increases the energy efficiency. As a result of this there will be a decline in CO_2 emissions.

Carbon Intensity Effect (CI_j^t)

$$= \sum_j \Delta CI(j)\left\{P(j)SS(j)EI(j) + \frac{1}{2} * \left(\Delta P(i)SS(j)EI(j) + P(i)\Delta SS(j)E(j) + P(i)SS(j)\Delta EI(j)\right)\right\} +$$

$$\sum_j \Delta CI(j)\{\frac{1}{3} * (\Delta P(i)\Delta SS(j)E(j) + \Delta P(i)SS(j)\Delta EI(j) + P(i)\Delta SS(j)\Delta EI(j)) + \frac{1}{4} * (\Delta P(i)\Delta SS(j)\Delta EI(j))\}$$

Carbon intensity effect is used to analyze the effect of fuel substitution on CO_2 emissions. For example, if the share of renewable resources increases or if people use natural gas instead of coal, there will be a certain decline in CO_2emissions. The change of CO_2 emissions between two time periods is the sum of these four effects.

$$\Delta CO_2(i) = Scale\ Effect\ (i) + Composition\ Effect\ (i) + Energy\ Intensity\ Effect\ (i) + Carbon\ Intensity\ Effect\ (i)$$

For the detailed analysis about the RLI method one can follow the work of Ang and Zhang, called Methodological Issues in Cross-Country/Region Decomposition of Energy and Environment Indicators.

5 Empirical Results for China & India

5.1 Agriculture

For agriculture sector of China, scale effect is one of the most dominant effects for identification of CO_2 emissions. Generally scale effect for agriculture shows an increasing trend because the output for agriculture increased during the last three decades despite the decreasing share of agricultural output in GDP. Energy intensity effect for agriculture sector of China shows a negative trend generally. For some years it has an increasing effect on emissions due to modern agricultural production techniques (i.e. for one unit of agricultural output more agricultural machinery has been used) but at the same time agricultural production is decreasing for some years therefore the energy use for this sector is also decreasing. Another reason is that, by time, the agricultural machinery equipment is getting more fuel efficient. Carbon intensity effect is negligibly small for Chinese agricultural production. For GDP decomposition analysis, agriculture is accepted as the primary industry. As it considered as a whole, there is no composition effect for agriculture.

For India, as the agricultural production of India continuously increased during the last three decades, scale effect is one of the most important contributors of CO_2 emissions and generally it showed an increasing trend. Despite the share of agriculture gradually decreased, still an important part of the population obtain their income from agriculture, therefore scale effect importance is not a surprising result for Indian carbon emissions. In this study, agriculture considered as the whole of primary industry there is no composition effect for Indian agriculture sector. For energy intensity, during the first half of time period, energy intensity effect showed an increasing performance for agriculture. After that, in the second half, energy intensity generally represents a decreasing trend because of the increasing energy efficiency. Carbon intensity effect is also an important contributor of CO_2 emissions. Generally it shows a decreasing trend.

5.2 Manufacturing Industries

Secondary industry for China is considered as the total of manufacturing industries and construction. The major impact for CO_2 emissions through manufacturing sector directly comes from the scale effect. As the Chinese economy showed a significant growth performance during the last three decades the results are not surprising. China has a huge manufacturing capacity today (40% of its GDP can be explained by manufacturing industries) and the scale effect for Chinese emissions showed a positive trend. Another major impact for manufacturing industries was the energy intensity effect. After 1990's the energy intensity effect shows a decreasing trend because of the raising energy efficiency. Energy use of the country increased but per unit of industrial output is produced by less energy. Carbon intensity effect for manufacturing industries is negligibly small during the last thirty years. Composition effect is even smaller than carbon intensity effect, because the share of manufacturing industries did not change too much in the same time interval.

The scale effect shows an increasing trend generally due to the raising capacity of manufacturing industries for India. Composition effect is smaller than the other effects for Indian manufacturing industries but it is a positive contributor for carbon emissions since its share in secondary industry increased faster than the share of construction. Energy intensity generally showed a decreasing trend during that period. Most probably it is due to increasing energy efficiency but in some years it represents a sharp increasing performance. This shows that India should do necessary regulations for energy efficiency. Carbon intensity shows a negative trend on average, that means some environmental regulations started to show their positive impacts however more regulations are needed for Indian manufacturing industries.

5.3 Construction

The dominant factor for Chinese construction sector for CO_2 emissions is the scale effect. As the population growth and country developed, the need for construction sector increased. Therefore scale effect for construction also showed an increasing trend. Composition effect also represents a raising trend especially in the last decade, because the share of construction sector of China is gradually increasing. Consequently the share of construction sector also grows in the overall share of secondary industry. Energy intensity effect for construction sector is also one of the major effects. It shows a negative trend as a result of increasing energy efficiency. Carbon intensity effect is also important for construction sector. For some years it shows a decreasing performance and for some years it represents an increasing performance. On average the impact of carbon intensity is negative on emissions.

As the population of the country increased the scale effect has a positive impact on carbon emissions in India, which is an expected result. Composition effect is negligibly small but generally has a negative trend for emissions. This was also an expected result because the increase of the share of construction sector is slower than the increase of manufacturing industries' share. For reducing the costs of construction, construction companies started to use their energy more efficiently. As a result of this, in the second half of research period, there is a certain decline for energy intensity effect. On average carbon intensity effect is also declining during the 30 years period, implies that construction sector started to be more environmentally efficient.

5.4 Transportation

The major determinant for Chinese transportation sector is the scale effect. As the production and use of cars, buses, trucks and other vehicles increased and as the population of China rapidly increased, the scale effect represents a significant impact on CO_2 emissions. The composition effect is also important for transport sector and it generally shows a negative trend during the last thirty years. Especially for recent years, composition effect becomes larger on the negative way. The main reason is share of transportation sector becomes smaller in tertiary industry. Energy intensity effect shows generally a decreasing trend for transportation sector because new technological vehicles are consuming less energy, i.e. there is an increase on fuel efficiency. Carbon intensity effect is negligibly small for Chinese transportation. Generally shows a decreasing trend due to alternative energy sources for transportation.

Compared to other sectors scale effect plays a smaller role for Indian transportation sector. There is an unexpected decrease in transportation GDP in 2010 and this decline also reduces the overall impact of scale effect. The composition effect plays also small negative role on the emissions for transportation sector. As the share of transportation grows with a smaller performance than the other service sectors, a negative impact is not surprising. However, this impact can be neglected. For India energy intensity effect represents a negative impact on CO_2 emissions. However in the last years of analysis there is a certain increase on this concept. This proves the idea that India needs certain regulations on fuel efficiency. The carbon intensity effect nearly has zero impact on emissions from transportation.

5.5 Other Service Sectors

As the output of service sector increased the main determinant factor is the scale effect for other service sectors and it represents an increasing trend during the last three decades. The second determinant factor is the energy intensity effect and generally it shows a decreasing performance. This is, probably, because of the increasing usage of nuclear sources, natural gas sources and renewable sources for electricity and heat

production for households and other main service sectors. Carbon intensity effect also represents a negative trend during the period. This is again, probably, due to the changing energy schedule for the country. Clean energy share is increasing for China but still country needs many reforms to prevent the air pollution. Finally the smallest impact for other service sectors is due to composition effect. It shows generally an increasing trend because of the increasing share of other service sectors concerning the tertiary industry.

As the population of the India increased very rapidly, a dominant scale effect is not a surprising result for other service sectors. The enormous growth of energy use at 2001 brings a big positive impact on energy intensity effect. The average energy intensity effect is also positive for other service sectors of India. Increasing usage of renewable sources and natural gas resources for residential and commercial buildings may be a true solution for energy intensity damage in the future. Carbon intensity effect is also left some dominant impacts on CO_2 emissions on the declining way. By doing necessary modifications this impact can be even smaller.

6 Conclusion

For this study, CO_2 emissions of the most populous countries, China and India decomposed according to data obtained for time period 1980-2010. Refined Laspeyres Index method has been used and some interesting results and valuable insights obtained. The countries' economies are subdivided into countries namely, agriculture, manufacturing industries, construction, transport and other service sectors. Four important effects considered, scale effect, composition effect, energy intensity effect and carbon intensity effect.

For China, scale effect plays an important role for the agricultural production. It shows an increasing trend during the research period. Energy intensity effect is also important for agricultural production. However it represents a decreasing trend during the research period. This is the result of increasing fuel efficiency. For India, scale effect is also remarkable for agricultural production. This is not a surprising result, because, despite the decreasing share of agriculture in Indian GDP, still agriculture is an important tool of GDP. Energy intensity effect started to show a decreasing trend but our study showed that for India, still energy regulations are necessary in order to reduce the energy intensity. Carbon intensity effect is more important for India in agriculture if we compare with China. In manufacturing sectors for both countries scale effect is dominating the CO_2 emissions. For both countries, energy intensity effect is an important tool to explain the emissions due to manufacturing industries and because of the efficient energy use it represents a declining performance. Because of the rapid technological growth the carbon intensity effect shows an increasing trend for manufacturing industries in China. This is not a surprising result, as the economy of the country boomed then the environmental damage is unavoidable. For construction sector of countries, the major effects are scale effect and energy intensity effect. They represent their dominant impacts on positive and negative directions respectively for both countries. As the population of both countries increased, the positive scale effect for construction sector is expected. During the thirty years there are some developments on construction sector for each of the countries. Construction companies are well organized and more efficient for energy use and other materials use, therefore there exists a decreasing trend on energy intensity effect. For composition effect there exist interesting results for both countries. For China there is a positive trend for construction according to composition effect and the opposite is observed for India. This is because of the changing share of construction sectors of countries, in the secondary industry. As mentioned before, secondary industry is classified as manufacturing industries and construction. For this case, carbon intensity effect can be ignored.

For transportation sector some interesting insights observed. For both of the countries, as their population increased, the transportation need also increased. Therefore a positive scale effect occurred during the research period. As the share of transportation in tertiary industry getting smaller then negative composition effect expected and observed. Because of the technological developments, new vehicles are consuming less fuel if one compare with the past. Today, cars, buses, trucks, ships etc… are more energy and economically efficient. As a result of this, energy intensity effect, on average, represents a decreasing trend for both China and India. However, if one compare these two countries, China is much better than India in energy intensity for transport sector. Since the alternative fuels have started to use, there exists a decline for carbon intensity for both countries. But, also for carbon intensity both countries need certain regulations.

Both of the countries were getting more and more crowded during the last three decades. At the same time the number of residential buildings, commercial buildings, hotels, restaurants and other service buildings increased. Therefore scale effect showed its positive dominant impact for both countries for service sectors. Composition effect for service sectors is also positive in India and in China because, the share of service sectors was increasing in tertiary industry. For energy intensity Chinese service sector shows a certain decline as the share of natural gas sources and renewable sources increased for residential and commercial electricity production. For India, energy intensity is generally increasing for service sectors. Probably, it will consider increasing in the near future, because 40% of the houses still do not have electricity generation according to World Bank.

Our work was interesting, because we also tried to show the similarities and differences of one upper middle income and one lower middle income countries. At the beginning of the research period, China and India had almost the same amount of GDP even in the concept of per capita income India was better than China. Today, of

course, China is in better conditions compared to India. However both of the countries still need certain regulations for environmental issues. They considered more than 40 percent of total world population. That means well organized economic and energy policies will bring a great success. The dominant scale effect also proves the idea that these two countries need modifications. The modest energy intensity effect is increasing the motivation that environmental success is not away from world. These countries may avoid to apply the policies related with environmental issues, because, they do not want to interrupt their economic growth.

References

- Ang, B. W., Liu, F., & Chew, E. (2003). Perfect decomposition techniques in energy and environmental analysis. Energy Policy 31 , 1561-1566.
- Ang, B., & Zhang, F. (2000). A survey of index decomposition analysis in energy and environmental studies. Energy 25 , 1149-1176.
- B. W. Ang, F. L.-S. (2004). A generalized Fisher index approach to energy decomposition analysis. Energy Economics 26 , 757-763.
- Cornillie, J., & Fankhauser, S. (2004). The energy intensity of transition countries. Energy Economics , 283-295.
- DiFurio, S. V. (2010). A decomposition analysis of CO2 emissions in the United States. Applied Economics Letters , 925-931.
- Dislers, K. L. (2011, June). CO2 Emission Reduction Practices of Road Freight Transportation: which could be implemented by Small and Medium Sized Enterprises in Latvia. Jönköping, Sweden.
- Kawase, R., Matsuoka, Y., & Fujino, J. (2006). Decomposition Analysis of CO2 emissions in long-term Climate stabilization scenarios. Energy Policy 34 , 2113-2122.
- Liu, C.-C. (2006). A Study on Decomposition of Industry Energy Consumption. International Research Journal of Finance and Economics .
- Ma, C., & Stern, D. I. (2008). China's changing energy intensity trend: A decomposition analysis. Energy Economics 30 , 1037-1053.
- Mishina, Y., & Muromachi, Y. (2011). Revisiting Decomposition Analysis For Carbon Dioxide Emissions From Car Travel: Introduction of Modified Laspeyres Index. Yokohama: TRB 2012 Annual Meeting.
- Paul, S., & Bhattacharys, R. N. (2004). CO2 emission from energy use in India: a decomposition analysis. Energy Policy 32 , 585-593.