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Drivers of fuel based carbon dioxide emissions: The case of Turkey☆

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ABSTRACT

In this study, CO_2 emissions of Turkish economy are decomposed for 1990–2013 period for five sectors; agriculture, forestry and fishery, manufacturing industries and construction, public electricity and heat production, transport and residential. Additionally, manufacturing and construction sector's CO_2 emissions are decomposed for iron and steel, non-ferrous metals, chemicals, pulp, paper and print, food processing, beverages and tobacco, non-metallic minerals, petroleum refining and other industry for the 2003–2012 period. Both analyses are conducted for five fuel types; liquid, solid, gaseous fuels, biomass and other fuels. In decomposition analysis Log Mean Divisia Index (LMDI) method is used. The results of the analysis point out that energy intensity is one of the determining factors behind the change in CO_2 emissions, aside from economic activity. The fuel mix component especially for the manufacturing industries and construction sector lowers CO_2 emissions during the crisis periods when the economic activity declines. Among GDP sectors, manufacturing industries and construction and public electricity and heat production are the two sectors that dominate the change in CO_2 emissions. Additionally, residential and transport sectors' contributions have gained importance during recent years. Among the manufacturing industries and construction, the non-metallic minerals sector has the highest contribution to CO_2 emissions followed by the chemicals sector.

1. Introduction

Excessive use of fossil fuels is the major reason that led to climate change, which is considered as the most important environmental problem of our time. In the Fifth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) [1], it is indicated that global carbon dioxide (CO_2) concentration needs to be stabilized below 450 particles per million (ppm) in order not to reach tipping point. The global CO_2 concentration was 280 ppm in mid 1800s, exceeded 350 ppm in 1980s and nowadays it is around 400 ppm.

Turkey joined United Nations Framework Convention on Climate Change (UNFCCC) in 2004 and ratified Kyoto Protocol in 2009. As an Annex I party to the Convention, Turkey is required to develop annual inventory reports on emissions and removals of greenhouse gases not controlled by the Montreal Protocol using *Revised 2006 IPCC Guidelines, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* [2]. Though the required contents and timetable for their submissions for Annex I and non-Annex I parties differ, all parties must submit national reports on the implementation of the Convention. Turkey submitted her First National Communication on 20/02/2007 and the Fifth National Communication on 17/12/2013. These reports provide a data base of emissions and fuel use that are consistent with international standards.

As a result of carbon intensive growth policies Turkey has increased her greenhouse gas emissions rapidly. Specifically, overall greenhouse gas emissions expressed in CO_2 equivalent have increased from 218.2 million tons in 1990 to 459.1 million tons in 2013. This corresponds to 110.4% increase throughout this time period and these figures do not include Land Use Land-Use Change and Forestry (LULUCF) [2]. In terms of 2013 carbon dioxide equivalent emissions excluding LULUCF, the energy sector has the largest share with 67.8%, followed by the industrial processes and product use with 15.7%, the agriculture with 10.8% and the waste with 5.7% [2]. CO_2 emissions per capita were 6.04 t in 2013, while it was 3.96 t for the year 1990 [3]. Per capita electricity consumption and per capita greenhouse gas emission levels in Turkey are about one third of those in other OECD countries. On the other hand, the energy intensity of the Turkish economy is higher than that of other OECD countries nearly by one third [4]. The major source of greenhouse gases is fossil fuel combustion; and energy sector is the main responsible sector in terms of emission of greenhouse gases in Turkey. Considering greenhouse gas emissions (excluding LULUCF) the energy sector's share is 67.8% in 2013. This number increases to 82.2% in terms of CO_2 emissions [2]. The highest proportion of CO_2 emissions from fuel combustion is from energy industries (public

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electricity and heat production, petroleum refining and manufacture of solid fuels) both in 1990 (27%) and 2013 (37%) [2]. Considering Turkey's ambitious growth perspective that does not take environmental impact of emissions into account, analyzing the sources of emissions is an important issue for developing alternative policy proposals.

In this study Index Decomposition Analysis (IDA) which utilizes index number computations is used to analyze the effects of CO_2 emissions on the economy both at the aggregate level and at the sectoral level, specifically on the manufacturing and construction sector. Log Mean Divisia Index (LMDI) method developed by Ang [5] is employed to investigate the leading factors that cause the change in Turkish economy's CO_2 emissions.

In addition to this study Karakaya and Özçağ [6], Lise [7], Tunç et al. [8], Akbostancı et al. [9] and Kumbaroğlu [10] are studies that decompose the sources of CO_2 emissions in the Turkish economy using IDA method. Apart from these Yao et al. [11] decomposes CO_2 emissions for G20 countries in which Turkey is also included, using IPAT relationship. Even though methods of analysis, levels of aggregation and periods of investigation differ, the common finding of these studies is that growth of the economy is the main responsible factor in terms of changes in CO_2 emissions.[1]

Decomposition analysis is used to identify the relative effects of different factors on the changes in CO_2 emissions resulting from fuel combustion for the Turkish economy over the period 1990–2013, and for manufacturing and construction sector for the period 2003–2012. One of the novelties of this study comes from the use of emissions data made available through National Greenhouse Gas Inventory Report 1990–2013[2] [2]. Therefore, the data set of the study is consistent with international standards.

In a previous study by Akbostancı et al. [9], the authors use fuel combustion data for 57 manufacturing industry sectors for the period 1995–2001 at 4 digit ISIC revision detail. In that study emissions of each sector were calculated by the authors using emission factors provided by IPCC [13]. However, this data source is not updated after 2001. In the current study by using the National Greenhouse Gas Inventory reports it is possible to look into the recent developments in the manufacturing industry at the sectoral level.

Decomposition analysis is performed in two parts. The first part utilizes five GDP sectors: “agriculture, forestry and fisheries”, “manufacturing industries and construction”, “public electricity and heat production”, “transport” and “residential”. Using these sectors' fuel combustion data for five fuel types, namely, liquid, solid, gaseous fuels, biomass and other fuels, effects of the five components on the change in CO_2 emissions are calculated for 1990–2013 period. The components of the CO_2 emission changes that are calculated in decomposition analysis are: changes in activity, activity structure, sectoral energy intensity, sectoral energy mix and emission factors.

In the second part, decomposition analysis is carried for manufacturing industry sectors, namely, “iron and steel”, “non-ferrous metals”, “chemicals”, “pulp, paper and print”, “food processing”, “beverages and tobacco”, “non-metallic minerals”, “petroleum refining” and “other industry” for 2003–2012 period. These sectors in general correspond to dirty industries that are energy intensive and have high levels of emissions. The National Greenhouse Gas Inventory Report provides detailed data for these sectors. Therefore, one of the advantages of this study is that the sources of CO_2 emissions in these dirty industries are decomposed for five different fuel types in addition to the aggregate level.

2. Methodology and data

In the literature, one of the frequently employed methods to analyze the effects of CO_2 emissions on the economy is “decomposition analysis”. Overall, decomposition analysis could be defined as separating an identity into its components. As mentioned in the introduction part LMDI method developed by Ang [5] is used to investigate the leading factors that cause the change in Turkish economy's CO_2 emissions. LMDI method does not bear a residual term and all zeros in the data set may be replaced by a small positive constant [14]. Mainly because of these two properties, many applications could be found in the literature utilizing this method.

Changes in CO_2 emissions are decomposed into five effects using the additive decomposition method which is presented in the following equation [5; 870]:

$$\Delta C_{tot} = C^t - C^{t-1} = \Delta C_{act} + \Delta C_{str} + \Delta C_{\text{int}} + \Delta C_{mix} + \Delta C_{emf} \quad (1)$$

In Eq. (1) ΔC_{tot} which is the change in total CO_2 emissions is decomposed into: ΔC_{act}, the activity component that captures the change in the emissions due to the change in economic activity, ΔC_{str}, the structure component that captures the change in the emissions due to the change in the activity structure, ΔC_{int}, the intensity component that denotes the change in emissions associated with the change in sectoral energy intensity, ΔC_{mix}, the energy mix component that shows the impact of the use of different fuels on the emissions, and finally ΔC_{emf}, the emission factor component that shows the impact of efficiency of fuels on the emissions.[3]

Turkey, as a party to UNFCCC, reports annually on greenhouse gas inventories. The Fifth National Communication contains national greenhouse gas emission data for the period 1990–2013 and the report utilizes *IPCC 2006 Guidelines*. This study uses CO_2 emissions as well as energy consumption and fuel combustion values for the relevant sectors supplied by this report.

The first part of the study concentrates on the Turkish economy as a whole and matches emissions data with GDP sectors. At the aggregate level emissions data set is available for 5 sectors; “agriculture, forestry and fisheries”, “manufacturing industries and construction”, “public electricity and heat production”, “transport” and “residential”. Therefore, the study is confined to these sectors. Using these sectors' fuel combustion data for five fuel types (liquid, solid and gaseous fuels, biomass and other fuels), effects of the above five components on the change in CO_2 emissions are calculated. In the decomposition analysis for the output of these sectors the real GDP data provided by TURKSTAT is used. However, the real GDP values are available for different base years. Therefore, for the period 1990–1997 real GDP values at 1987 prices are used, while for the period 1998–2013 real GDP values at 1998 prices are used. Since there are no overlapping values provided by TURKSTAT, this analysis has a gap at 1997–1998 period. Except this gap, the change in the base year does not constitute a problem since the decomposition analysis is based on the annual changes in the CO_2 emissions.

Second part of the study focuses on the manufacturing industries and construction sector's emissions. At this level eight subsectors are examined, for which emissions data is available. These subsectors are: “iron and steel”, “non-ferrous metals”, “chemicals”, “pulp, paper and print”, “food processing, beverages and tobacco”, “non-metallic minerals”, “petroleum refining” and “other industry”. Again decomposition analysis is performed for five different fuel types. Output values for manufacturing industry are extracted from TURKSTAT (Some Basic Indicators by Economic Activity According to NACE Revision 2). Output values for sectors at this detail are available only for 2003–2012 period. Moreover, for pulp, paper and print sector CO_2 emissions

[1] Xu and Ang [12] provide a thorough literature survey on the studies that utilize IDA in terms of energy-related CO_2 emissions covering the period 1991–2012. For a detailed review of literature on CO_2 and energy decomposition studies for Turkey see Tunç et al. [8] and Akbostancı et al. [9].

[2] This is one of the first studies that endeavors the official database, for the other see Kumbaroğlu [10].

[3] For a detailed discussion of methodology on additive decomposition see Akbostancı et al. [9].