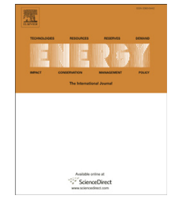
Energy 103 (2016) 27–37

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy



Drivers in CO_2 emissions variation: A decomposition analysis for 33 world countries

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ARTICLE INFO

Article history:
Received 10 April 2015
Received in revised form
14 December 2015
Accepted 16 February 2016

Keywords:
Energy intensity
Carbon dioxide emission intensity
Economic growth
Index decomposition analysis
WIOD

ABSTRACT

A decomposition analysis of energy related CO_2 emissions is carried out for 33 world countries. The data pertain to the period 1995–2007. The methodology used is the Index Decomposition Analysis that allows to investigate the contribution of the following factors: *(i)* changes in abatement technologies, fuel quality and fuel switching; *(ii)* changes in the structure and efficiency of the energy system; *(iii)* relative ranking of a country in terms of the total GDP (Gross Domestic Product) generation and *(iv)* changes of the country specific total economic activity. The WIOD (World Input Output Database) has been used together with Organization for the Economic Co-operation and Development (OECD) data on GDP. Results show that economic growth has been the main driving factor of energy related CO_2 emissions increase. However, in fast developing countries like India and China, an important contribution has also been the increasing role that these economies are playing in the global economic panorama. Improvements on energy efficiency have been the main element contributing to reduce the overall CO_2 emission increase in all the countries considered in this study.

1. Introduction

CO_2 emissions has risen by more than 30 ppm in the last seventeen years and the carbon dioxide concentration, now standing at around 400 ppm, is expected to reach 450 ppm by 2030 [1,2]. The IPCC (Intergovernmental Panel on Climate Change) estimates a concentration between 540 ppm and 970 ppm over the next century, should the emission remain at business-as-usual levels [3,4]. Since the Kyoto agreement in 1997, international measures and policies have been implemented to reduce the human effects on climate change and decouple economic growth from emission levels. Based on the idea of obtaining an economic growth that does not imply necessarily an increase in emissions, decoupling is an ambitious objective both at national and international level [5].

The emissions of CO_2 of anthropogenic origin depend by a large portion on energy production and use. The ever increasing demands of energy by developed and developing economies can be contained by shifting towards renewables or by adopting technological improvements in the energy production cycles that would reduce the CO_2 emission per unit of energy produced. The improvements in energy use and production can already account for a large reduction of CO_2 emissions (31% according to [6]). Trends appear in energy intensity reduction at both country level and sectorial level, with different nuances from sector to sector [7,8].

There are ways to investigate how efficient the economic growth process has been CO_2-wise and how much the technological improvements have contributed to reduce the energy requirements and the emission generation. The OECD (Organization for the Economic Co-operation and Development), European Commission, United Nations and other organizations have collected data than can be used to perform a decomposition analysis with the scope to investigate the contribution of different socio-economic and technological factors.

In this paper, a decomposition analysis is performed to investigate the main elements that generated CO_2 emissions variations in 33 world countries. The group of countries includes developed economies and developing ones so that different possible ranges of economy-dependent CO_2-emissions are considered. The period of the analysis is particularly interesting as it starts in 1995, slightly before the signature of the Kyoto protocol (1997), and ends in 2007, two years from its implementation and right before of the global economic crises.

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http://dx.doi.org/10.1016/j.energy.2016.02.096
0360-5442/

Nomenclature

CI	the CO_2 intensity effect that describes changes in abatement technologies, fuel quality and fuel switching;
EI	the energy intensity effect that reflects changes in the structure and efficiency of the energy system;
ES	the structural change effect that identify the relative position of a country in the total Gross Domestic Product (GDP) generation
G	economic activity growth effect that summarize the changes of the total economic activity.
IDA	The Index Decomposition Analysis
IPCC	Intergovernmental Panel on Climate Change
OECD	Organization for the economic co-operation and development
ppm	parts per million
SDA	Structural Decomposition Analysis
WIOD	The World Input Output Database

The main factors responsible for changes in the energy-related CO_2 emission considered here are: *(i)* changes in abatement technologies, fuel quality and fuel switching; *(ii)* changes in the structure and efficiency of the energy systems; *(iii)* the relative position of a country in the global GDP (Gross Domestic Product) generation and *(iv)* changes of the total economic activity. The decomposition among these parameters allows us to estimate how much CO_2 variation can be attributed to technologies improvements, to a more efficient use of energy, and how those two relate to the relative improvement, stagnation or reduction of the individual country economic situation. The focus of this paper is a comparative analysis of the decomposed factors across different world areas in an attempt to assess the status of the actions taken by world countries toward a reduction of CO_2 emissions.

A similar analysis has been recently presented by Ref. [7] that used the same database [9] used in the present paper. The decomposition approach and the factor included in this paper are however different from Ref. [7]. Other works that used decomposition analysis to investigate CO_2 emission variations. Among others [10–16], with a particular focus on USA, China and India. The present work falls into the category of the multiple country analysis and, differently from other works [17–19], it includes both OECD and non-OECD areas.

The paper is structured as follow: in Section 2 the data are presented and analysed. Section 3 introduces the decomposition technique adopted in this study. The results of the analysis are represented in Section 4 while limitations of this work and the conclusions are presented in Sections 5 and 6 respectively.

2. Data and data analysis

The decomposition analysis performed in this paper aims at investigating the main factors responsible for the changes in the energy-related CO_2 emission of 33 countries around the world. The study refers to the period 1995–2007 and considers both developed and developing countries. The data used have been taken from OECD and from the World Input-Output Database (WIOD). In particular, the data on emission-relevant energy use and the quantity of energy-related carbon dioxide emissions have been collected from the World Input-Output Database that includes a set of socio-economic and environmental information for 40 world countries plus the Rest of the World for the time period 1995–2009 (for a description of the database see Ref. [20]). Gross Domestic Product (GDP) data were taken from Ref. [21] that provides data at constant prices for 31 of the 33 countries considered in this paper for the period 1995–2007. GDP data for Brazil and India are only available for the time period 2000–2008 for Brazil and 2004–2008 for India. For this reason the decomposition analysis performed for these two countries have been keep separate from the decomposition analysis performed for the other 31 countries. These data are analysed hereafter. The key objective is to provide an overview of the main trends and relationships existing between energy use, CO_2 emissions and GDP. In the following section the energy related CO_2 emissions will be decomposed in the factors presented in Section 3.

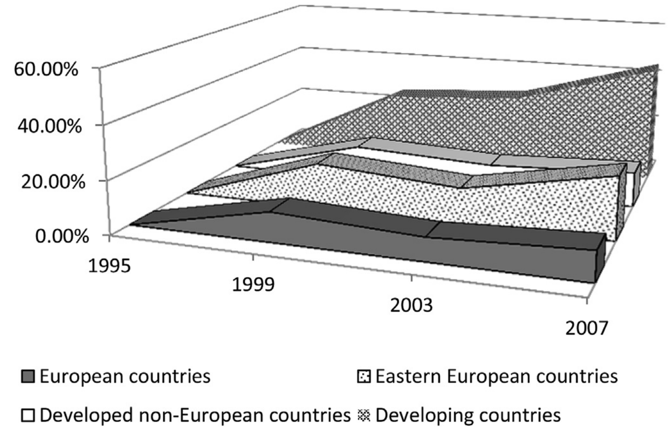

Fig. 1. % variation on GDP. Note: European Countries include: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherland, Portugal, Spain, Sweden, and UK. Eastern European countries include: Czech Republic, Estonia, Hungary, Poland, Slovak Republic, and Slovenia. Developed non-European countries include: Australia, Canada, Japan, South Korea, Russia, and USA. Developing countries include, Developing countries include: China, Indonesia, Mexico, and Turkey. Source: [9, 21]

2.1. Overview of the data used

Figs. 1–3 summarize in percentage the variations of GDP, CO_2 emissions and energy consumption for the countries considered in this paper[1] grouped in European, Eastern European, Developed non-European and Developed countries. The objective is to provide an overview of the main trends existing between 1995 and 2007 and to identify patterns that can be useful to explain the results obtained in the decomposition exercise. According to data reported in the following Figures, developing countries show the largest percentage variations in GDP, CO_2 emissions and energy use (+136.3%, +87.8%, +83.9% respectively between 1995 and 2007). Easter European countries also had a large variation in terms of GDP (64.7% between 1995 and 2007) and in particular after the accession to European Union in 2004 (+117% between 2004 and 2007). The energy consumption increase (+3.2%), however, have been largely smaller than in the case of developing areas and the quantity of CO_2 emissions decreased (−5.3%) across the period even if a slightly increase (+2.1%) took place between 2004 and 2007 as a consequence of the economic boom [22]. In a similar way, European countries and developed non-European areas had a positive variation of GDP (+34% and 42.8%), relatively small energy consumption increase (11.9% and 12.7%) and low variations in CO_2 emissions (+5.4% and 13.4% respectively).

[1] Since data for India and Brazil are not available for the entire time period considered in the paper, these two countries are not included in the analysis performed in this section.