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Factors affecting CO_2 emissions in top countries on renewable energies: A LMDI decomposition application

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ABSTRACT

This study breaks down carbon emissions into six effects considering the current Top 23 countries group on renewable energies, afterwards divided into two different groups (the TOP countries in Europe and the remaining group entering into the Top 23 countries included in the category Rest of the World). It analyses the effects evolution using a larger available data span that runs from 1985 until 2011, to determine which of the effects had more impact over changes of CO_2 emissions. The complete additive decomposition technique was used to examine carbon dioxide (CO_2) emissions and its components. Moreover, it is performed a comparative analysis to contrast their performance, and a decoupling analysis is presented. For the 1985–2011 period results point for different positive and negative impacts in the behavioral change of CO_2 emissions throughout Europe as compared to the Rest of the World. Moreover, the productivity of renewable sources and the financial development effect in renewable electricity generation per GDP are the main responsible for the total and negative changes of CO_2 emissions in the last decade; whereas an increase in total changes of emissions are observed due to the fossil fuel energy consumption effect. The multiplicative cross effect, into these two important effects in CO_2 emissions decomposed, indicate an aggregate proxy effect of the energy technology level of a country's economy.

1. Introduction

Climate change and global warming are among the main concerns for all nations globally. The environmental consequences of increasing greenhouse gas emissions, and particularly carbon dioxide (CO_2), have started becoming visible not only in the temperature levels of the planet but also, due to changing weather conditions that consequently affect the nation's economy. Stakeholders, policy makers, researchers and organizations search for technologies, programs and policies to assist them with the goal of emissions reduction and mitigation. On the demand-side, energy efficiency improvements are proposed way forward. This is to ensure reducing energy requirements of countries or to ensure they consume energy less intensively. From a supply side point of view, the most effective solution is to combine environmental concerns with worries on the scarcity of natural resources. For that it should be considered the substitution of fossil fuel-based energy generation with renewable and cleaner energy sources alternatives.

The European 2020 strategy has settled three goals (the "20-20-20" targets) for climate and energy policy to be reached (reducing at least 20% of GHG emissions as compared to 1990 levels, increase to 20% the renewable energy share in final energy consumption and increase energy efficiency by 20%). According to the European Commission (2014), the strategy points out that the EU is committed to take a decision to move to a 30% reduction by 2020 as compared to 1990 levels. Climate and energy policies despite considering a transition towards a low carbon economy preventing the inevitable catastrophic climate change also contribute to the European 2020 strategies core goals of enabling sustainable growth. The key pedals for emissions reduction, renewable energies and energy efficiency, can promote innovation and create jobs [1].

With a low carbon economy we could generate wider socioeconomic benefits given that energy dependence is reduced. Moreover, there is the replacement of parts of fossil fuel imports with domestic resources, helping to reduce air pollution and associated health risks. Furthermore, it lowers health costs while increasing socioeconomic well-being. In current reality, the use of energy is by far the largest source of emissions and its CO_2 emissions dominate total GHG emissions in about three quarters. Summing up, increasing demand comes

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from economic growth and development worldwide, where energy demand from fossil fuels plays a key role in the upward trend in CO_2 emissions. In this "game" there are countries which are placed at the forefront and others that remain very distant from their goal targets in the world replacement of a nonpolluting environment.

Provided the relevance and applicability of renewables in energy production in a way to mitigate carbon emissions, from a selected sample of countries ranked in accordance to the Renewable Energy Country Attractiveness Index (RECAI),[1] this article major contribution is to consider in the Log-Mean Divisia Index (LDMI) model decomposition including the following factors: carbon intensity, the use of renewable resources resulting from trade openness, non-renewable resources intensity, renewable resources productivity and the effect of financial credit capacity to promote renewables usage in energy production. In this article we try to stretch answers to the following relevant and unexplored questions: i) from the numbered factors in carbon emissions mitigations which are the most relevant?; ii) given the selected sample, are there different impacts of explanatory effects among European countries and countries outside Europe?; iii) from the most important factors, in which country inside each group existed higher explanatory power to mitigate changes in emissions? It is considered that the answers to these questions here provided will be a useful instrument for energy policy decision makers and to other players/decision makers that act in energy markets.

The RECAI index ranks countries internationally based on their renewable energy adoption using various factors such as the political support for renewables, affordability of renewables in their region, infrastructure, technology potentials and others. The top 23 of these countries (at least those that have been ranked high in their renewable energy attractiveness) have embraced the renewable energy potentials and hence, it would be expected their emissions to show a decreasing trend.[2] With these countries selection, this work allows us to unfold the driving forces of emissions changes in two distinct groups of countries. These results will be important not only for policy makers in countries with high contributions of renewable energies in their supply mix, but also to the rest of the countries, which could learn what their future path might be with the adoption of renewable energies. By identifying and understanding the importance of the factors and their contribution's magnitude, policy makers can select the most appropriate policies to reduce CO_2 emissions [2].

To achieve this goal, this work makes use of the LMDI method to disaggregate changes in CO_2 emissions of the top 23 countries listed in RECAI for the period 1985–2011 into six factors: carbon trade intensity, fossil fuels trade effect, fossil fuel intensity, renewable source productivity, the financial power of electricity effect and financial development effect.

We contribute to previous research in several different ways. First, following a LMDI approach, the CO_2 mitigation is analyzed into two distinct groups and considering a larger data span from 1985 until 2011, allowing us to evaluate the impact of the entry into force of energy emission policies. Second, the LMDI is used to identify the different driving factors of emissions related to energy. This allows explaining the differences into the levels of efficiency among the two distinct groups of countries. Third, it is performed a comparative analysis to contrast their performance, and a decoupling analysis is presented. Finally, we use the entire sample of 23 countries ranked in the top RECAI as a group, and also analyzing them in an individual way within each group to check out for still persistent differences.

The LDMI method allows to decompose changes in CO_2 emissions (and intensities) into separate indexes for emissions intensity and other indexes that represent various types of structural factors. It is used to decompose emissions at any level of aggregation into major components, all expressed as indexes relative to a selected base year when combining the intensity indexes. The shares of emissions serve as weights in calculating a weighted average of year-to-year changes in the intensities for the various elements considered to influence emissions. LDMI is an easy formulation which gives perfect decomposition where results do not contain an unexplained residual term, simplifying results interpretation. It is also consistent in aggregation since effects estimates at the sub-group level can be aggregated to provide the corresponding effect at the group level [3].[3]

The rest of the article develops as follows. Section 2 discusses the literature developments and applications of the LMDI method in the energy literature, with particular focus on other studies dealing with the decomposition of emissions. Section 3 explains the methodology adopted in this paper and Section 4 presents the empirical results. Finally, Section 5 summarizes the study and provides some policy implications and a general discussion of the attained results.

2. Literature review

As [4] explain, in the past, primarily econometric and multivariate techniques were used to examine the factors behind the trends of economic, environmental, and social indicators. "However, their main objective is to reduce the attribute space of a large number of variables to a smaller one for indicating the most influential factors" ([4]: p. 4160). The decomposition techniques provide a different approach to study the complexity of the reality. The purpose of this type of analysis is to disaggregate an indicator in quantifiable factors, *ceteris paribus.* Interactions between factors are not detected but their relative change contributions over time can be revealed, in an effort to inform about policies to be pursued and measures to be adopted.

In the energy literature, the decomposition techniques have been a particularly suitable and convenient tool over the last two decades in order to decouple the determinants of various indicators such as energy consumption and efficiency ([5–13,2,14,15]) and carbon emissions ([16–20,1,22–26]).

Studying and applying LMDI decompositions in Europe, [27] conclude that changes in the economy structure are predominant drivers of energy intensity in the economy, using a sample of EU 15 countries between 1991 and 2005. They even suggest that an economy restructuring towards services would not be likely to lead to an improvement in the energy efficiency component due to heterogeneity and lack of international competition. For the sample of EU 27, [28] reported that the structural effect together with the activity effect were able to offset the positive intensity effect. Together they lead to energy consumption growth of 2.25% in the 2001–2008 period. Afterwards, [29] used detailed data of activity sectors for 20 selected EU countries reinforcing their previous conclusion and marking the industry sector as the prime energy efficiency improvement mover. They provide special credit to energy efficiency improvement in post-communist countries [30].

In 2015, [30] used the LMDI decomposition technique to analyze energy consumption using three different levels of data aggregation for the complete sample of EU28 countries in the pre-crisis period of (2004–2008) and the crisis period (2008–2012). The authors conclude that the recent decline in energy consumption is mainly caused by economic slowdown provided that improvements in energy intensity in the EU 28 seem to be slowing. They observe that the intensity effect was

[1] http://www.ey.com/GL/en/Industries/Power—Utilities/EY-renewable-energy-country-attractiveness-index-our-index.

[2] We have considered the top 23: Australia, Austria, Belgium, Brazil, Canada, Chile, Denmark, France, Indonesia, Italy, Japan, Kenya, Mexico, Netherlands, Norway, Peru, Philippines, Portugal, Spain, Sweden, Turkey, United Kingdom and United States. Note that, in 2014, the top 23 from the Top 40 countries were: US, China, Germany, Japan, UK, Canada, India, Australia, France, South Korea, Italy, Brazil, Belgium, Chile, Denmark, Netherlands, Portugal, Spain, South Africa, Sweden, Taiwan, Thailand and Turkey, in this order, but we were not able to work with all due to data availability issues.

[3] [3] provides a practical guide useful to all that wish to implement the method.