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# Main drivers of changes in $CO_2$ emissions in the Spanish economy: A structural decomposition analysis

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## HIGHLIGHTS

- Kyoto's Protocol and European Directives acted against $CO_2$ emissions in Spain.
- Changes in primary energy mix acted against increasing $CO_2$ emissions.
- Energy efficiency seems to have improved.
- Historical analysis gives support for most mitigation measures currently in force.

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## ABSTRACT

The aim of this paper is the analysis of structural decomposition of changes in $CO_2$ emissions in Spain by using an enhanced Structural Decomposition Analysis (SDA) supported by detailed Input–Output tables from the World Input–Output Database (2013) (WIOD) for the period 1995–2009. The decomposition of changes in $CO_2$ emissions at sectoral level are broken down into six effects: carbonization, energy intensity, technology, structural demand, consumption pattern and scale. The results are interesting, not only for researchers but also for utility companies and policy-makers as soon as past and current political mitigation measures are analyzed in line with such results. The results allow us to conclude that the implementation of the Kyoto Protocol together with European Directives related to the promotion of RES seem to have a positive impact on $CO_2$ emissions trends in Spain. After reviewing the current mitigation measures in Spain, one policy recommendation is suggested to avoid the rebound effect and to enhance the fight against Climate Change that is tax benefits for those companies that prove reductions in their energy intensity ratios.


## 1. Introduction

Not only the amount of carbon dioxide ($CO_2$) but also other greenhouse gases (GHG) in the atmosphere are increasing, which is leading to global climate change (IPCC, 2013a). The main anthropogenic driver of GHG emissions is fossil fuel combustion. Anthropogenic activities under business-as-usual scenario would lead to a 5 °C increase in global temperature but proper and timely interventions could restrict it within 2 °C (The World Bank, 2010; Das and Kumar, 2014). In 1997, the Kyoto Protocol Agreement achieved the consensus among countries about its mitigation and showed that only with global measures it would be achieved. For European Union (EU) members states, such measures continued with Directive 2003/87/CE (European Commission, 2003) and the so-called 2020 Horizon approved in 2009 (European Parliament, 2009). This latest European agreement established three important targets to reach by 2020; a 20% reduction in GHG emissions, a 20% reduction in energy consumption and a share of 20% of Renewable Energy Sources (RES) in the energy matrix. This document also established national targets. For the case of Spain, the fixed target was to reduce its GHG emissions for 2020 up to 10% in relation to 2005. In Spain, the main contributor to total GHG emissions is $CO_2$ which shares around 80% (Spanish National Inventory GHG emissions, 2013).

If we focus on $CO_2$ emissions, although a set of mitigation measures are in force, their effectiveness could be enhanced thanks to the results coming from the main drivers of changes in $CO_2$ emissions. In other words, the previous knowledge of key drivers will provide further information in order to achieve the decoupling between economic growth and $CO_2$ emissions. That will allow countries to meet economic growth with lower $CO_2$ emissions. Indeed, it would be possible to meet the economic growth and even decrease the $CO_2$ emissions, without ignoring the link between

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energy consumption and growth (Pablo-Romero and Sánchez-Braza, 2015).

This paper analyzes the structural decomposition of changes in $CO_2$ emissions in Spain by using an enhanced structural decomposition analysis (SDA) supported by detailed Input–Output tables from WIOD database.

In the environmental area, the decomposition analysis allows us to show the effects that are more crucial to reduce $CO_2$ emissions. Grossman and Krueger (1991) were the first to use a decomposition analysis for environmental studies in member countries of the North American Free Trade Agreement and concluded that economic growth tended to decrease pollution problems. Freitas and Kaneko (2011) offered an overview of decomposition studies from the seminal paper by Grossman and Krueger (1991). Similarly, Torvanger (1991) analyzed the change in emissions in the industrial sectors of nine OECD countries. Their results indicated that the main factor contributing to the decline of emissions was the diminishing of the energy intensity from production. This method was also applied to studies by the International Energy Agency (IEA/OECD, 2004).

The decomposition analysis involves mainly two methods: the Index Decomposition Analysis (IDA) and the structural decomposition analysis (SDA). Ang and Zhang (2000), Ang (2005), Hoekstra and van der Bergh (2002, 2003) and later, Su and Ang (2012) compared both of them. Policy makers use widely these techniques as an analytical tool. It must be recognized that most studies applied the IDA model to decompose the changes in $CO_2$ emissions (Ang, 2015). Although it is flexible in formulation and has a relatively lower data requirement, the IDA method covers only the direct effects, ignoring the effects of the indirect and final demands (also named consumption perspective) (Zeng et al., 2014). Recently, IDA has also been applied to analyze the decomposition of changes in energy consumption (Tunç et al., 2009; Oh et al., 2010; Lin and Du, 2014; Xu and Ang, 2014b; Colinet and Román, 2015) and in $CO_2$ emissions (such as Lee and Oh, 2006; Lu et al., 2007; Dong et al., 2010; Duarte et al., 2013); among other topics.

However, SDA uses data from Input–Output (IO) Tables and offers a broader range of information concerning technical aspects and the effects of final demand than IDA does. The typical SDA studies are able to provide a more detailed structural factors, such as the Leontief effect (or technical effect) (Xie, 2014) and can shape socio-economic drivers from both production and final demand perspectives. In other words, decomposition approaches different from SDA do not allow researchers to analyze so deeply into the internal production linkages within an economy and their implications on the changes of $CO_2$ emissions (Brizga et al., 2014).

One of the seminal papers (Rose and Chen, 1991) uses SDA to analyze changes in sectoral energy consumption in the U.S. and later, Rose and Casler (1996) showed the main principles to obtain equations of structural changes. SDA can be carried out with two types of decomposition: additive and multiplicative (Dietzenbacher et al., 2000). The main difference between these two types of decomposition analysis is the discussion about results. Any case, certain limits also affect SDA (Dietzenbacher and Loss, 2000).[1]

SDA has been applied to analyze the structural decomposition of changes in $CO_2$ emissions. These are the cases of Chang et al. (2008), Guan et al. (2008), Zhang (2009), Achão and Schaeffer (2009), Baiocchi and Minx (2010) who use a multi-regional IO model, as do Cellura et al. (2012) and Zhu et al. (2012). It should be also mentioned Raupach et al. (2007) and IPCC (2013b). Most papers use a reduced number of decomposition factors from a range of four or five. However, literature offers a number of studies with a higher number of factors, such as the case of Lim et al. (2009) with eight factors; Chang et al. (2008) with nine factors or Wood (2009) with ten factors. Although in SDA studies it is commonplace to consider demand side factors, papers with a supply side factors are available. These papers use the Goshian instead of the Leontief matrix (Zhang, 2010).

In the case of Spain, papers focusing on GHG include the following works by Llop (2007), Roca and Serrano (2007), Tarancón and del Rio (2007a, 2007b), Bartoletto and Rubio (2008), Alcántara and Padilla (2009), Butnar and Llop (2011), Alcántara et al. (2010), Bhattacharyya and Matsumura (2010), Cansino et al. (2011, 2015), Zafrilla et al. (2012), and Demisse et al. (2014) among others. However, neither of them conducted a multisectoral SDA approach similar to our proposal in this paper.

This paper aims to contribute to the growing body of knowledge about structural decomposition of changes in Spanish $CO_2$ emissions by carrying out a structural decomposition analysis (SDA) based on Input–Output Tables from WIOD database. The results are interesting, not only for researchers but also for utility companies and policy-makers. Past and current political mitigation measures are also analyzed in line with such results. This paper focuses on the main drivers that explain the annual change in $CO_2$ emissions from 1995 to 2009 in Spain. This period of analysis, 1995–2009 is determined by the available dataset as it is described below. Emissions from biomass and marine and aviation bunkers are excluded from the analysis.

To do this, an enhanced SDA is carried out with a multi-sectoral approach. To the best knowledge of the authors, drivers of changes in GHG (in particular $CO_2$) emissions in Spain have not been previously investigated from such an approach. The solution implemented in order to find out the right choice among the huge number of theoretical solutions of the SDA analysis enhance the paper that has been developed with the following main objectives:

1. The decomposition of changes in $CO_2$ emissions between 1995 and 2009 into carbonization effect, energy intensity effect, technology effect, the structural demand effect, the consumption pattern effect and scale effect.
2. The decomposition of changes in $CO_2$ emissions between 1995 and 2009 at the sectoral level and tracing the changes in emissions derived from each consumption category by sectors.
3. The analysis of the impact of past relevant policy measures. For that, the entire period was divided into four sub-periods: 1995–2000 (before European Directive 2001/77/EC of Renewable Energy Sources – European Commission 2001–), 2001–2004 (after European Directive 2001/77/EC and before Kyoto – United Nations, 1998–), 2005–2007 (after Directive 2003/87/EC – European Commission, 2003 – and after Kyoto implementation), and 2008–2009 (after Kyoto first stage).
4. The analysis of the impact of current policy measures oriented towards $CO_2$ emissions' mitigation and the provision of energy policy recommendations at the sectoral level.

This paper has been structured as follows. After the introduction, Section 2 provides the methodology. Section 3 shows the dataset used. The results are presented and discussed in Section 4. Current political measures are examined in Section 5. In the light of our results, we draw a number of conclusions, which are presented in Section 6.

[1] SDA approach is not free of limits. Dietzenbacher and Loss (2000) found dependency problems between the individual factors in the value added decomposition for The Netherlands (1972–1986). They suspect that such a problem could also emerge, for example, in decomposition of changes in labor requirements and in energy use. They suggest the need of further theoretical work on this issue that measures the size of the error caused by dependency problems. More recently, Rørmose (2010) carried out an investigation of the sensibility of the structural decomposition analysis to a number of the most important challenges faced by the method (aggregation level, adding or removing variables, etc.). The author concludes that SDA is still a very sensible way to draw information from a mixture of physical and economic variables like e.g. emission of $CO_2$.