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Towards a sustainable growth in Latin America: A multiregional spatial decomposition analysis of the driving forces behind CO_2 emissions changes

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A B S T R A C T

This paper aims to understand the driving forces behind the growth of CO_2 emissions in Latin America, as a region, by groups of countries according to their behaviour in terms of growth of income and CO_2 emissions per capita and by countries during 1990–2013. The main drivers for the Latin America region are the activity and the population effects, followed by the fossil fuel and the carbonisation effects, while the intensity effect is revealed as the only inhibitor. The lessons from Latin America's group of countries are the following. First, the necessary decoupling between the growth of CO_2 emissions and the economic activity has not taken place, the population growth also being an important driver effect. Second, the groups of countries with the highest CO_2 emissions growth, show the highest population and fossil fuel effects. This latter confirms the scant efforts made to reduce the weight of fossil fuels in the total primary energy supply. Third, the energy intensity has become the most important inhibitor of CO_2 emissions for those countries that are not able to substitute fossil fuels so easily. Finally, the desirable increase of less pollutant fossil fuels or even the increase of renewable energies has not yet been achieved.

1. Introduction

The security of energy supply and foreign energy dependence are among the issues that Latin America and Caribbean (LAC) countries have faced in the last fifteen years. Additionally, the climate change and their growing energy needs are the most important challenges of the LAC countries for the future. The Paris Climate Agreement that was the result of the COP21 is a new turning point towards a green economy. The objectives set in the Intended Nationally Determined Contributions (INDCs) of the LAC countries show that most of them are convinced of the importance of climate action. In 2014, considering the Non-OECD American countries plus Chile and Mexico, they represent around 8.5% of the world's population, 8.7% of the worldwide Gross Domestic Product in purchase power parity (GDPppp), 7.5% of the global energy production and 5% of the worldwide energy-related CO_2 emissions (IEA, 2016). However, the economic and environmental inequalities among the LAC countries are very significant. On the one hand, the GDPppp can range from the 27 2010 USD of Nicaragua (17 2010 USD of Haiti) up to the 3061 2010 USD of Brazil. On the other hand, the CO_2 emissions per capita are very different among countries, such as the 5 tCO_2/capita of Venezuela or the 0.76 tCO_2/capita of Nicaragua (0.26 tCO_2/capita of Haiti) (IEA, 2016).

The LAC countries are in addition very vulnerable to meteorology and therefore to the effects of climate change. A changing meteorology likewise means unpredictable and more extreme weather events. This situation negatively affects the economy and wellbeing of the LAC countries' populations. Yet there is another issue that should be mentioned. The most important LAC countries in terms of GDP and CO_2 emissions are very dependent on fossil fuels, such as oil. These are the cases of Colombia, Brazil, Ecuador, Mexico, Venezuela, Bolivia and Argentina. As most of the CO_2 emissions are energy related, the transition to a green economy has become a key issue. Some LAC countries have made a great effort in the last years to improve renewable energies, looking for alternative energy sources to fossil fuels and enhancing energy efficiency (Sheinbaum-Pardo and Ruiz, 2012). These efforts will help them to achieve the global goals of the Paris accord of the LAC countries.

The aim of this paper is to analyse the main determinant drivers of CO_2 emission changes in 20 Latin American (LAM) countries between 1990 and 2013. The analysis is carried out for global CO_2 emissions changes in the LAM region, individually for each country and by groups, according to their behaviour in terms of average change of GDPppp per capita ($GDPppp_{pc}$) and CO_2 emissions per capita in the period analysed. This analysis provides a further understanding of the

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interregional differences among LAM countries and the economic and environmental developments that the region has experienced, as well as the progression of these countries in terms of CO_2 emissions growth compared to the average of the group.

From among the different Index Decomposition Analysis methods, the Logarithmic Mean Divisia Index (LMDI) was chosen, based on Ang (1995, 2004, 2005, 2015) and Ang and Liu (2001, 2007). This method was selected taking into account the degree of aggregation of the available data (emissions, economic and energy) and the absence of residues in the results obtained. This methodology has been previously applied to the analysis of groups of countries and regions with a temporal perspective, such as those by Fernández et al. (2013, 2014) for the EU-27 and that by Schymura and Voigt's (2012) for 40 countries of the OECD. Additionally, this methodology is also suitable for a multiregional spatial comparison as is recommended by Ang et al. (2015). In the case of the LAC region and, in particular, of the topic of emissions of greenhouse gases or CO_2 emissions, the analysis by Kuntsi-Reunanen (2007), Malpede (2015), Lan et al. (2016) and van Ruijven et al. (2016) for a set of LAC countries should be highlighted. There are also individual country studies of the LAC region, such as those by Achão and Schaeffer (2009), Wachsmann et al. (2009) and Charlita de Freitas and Kaneko (2011) for Brazil; Mundaca (2013) and Duran et al. (2015) for Chile; Robalino-López et al. (2014a) and Robalino-López et al. (2014a), (2014b) for Ecuador; and González and Martínez (2012) for Mexico. Particularly, in the specific case of the application of the LMDI analysis, the study of the Transportation sector for the LAC region of Timilsina and Shrestha (2009) can be considered, besides global comparisons involving some nations of this region by Pani and Mukhopadhyayb (2010, 2011), Henriques and Kander (2010), Robalino-López et al. (2016) and Ang et al. (2016).

To the best of our knowledge, a simultaneous multiregional temporal and spatial LMDI analysis of CO_2 emissions changes has not been carried out before for the LAM countries. In this paper we aim at filling this gap in the research literature based on the following questions: Which are the main drivers of aggregate CO_2 emissions changes in LAM countries? Are the drivers of CO_2 emissions similar when LAM countries are grouped by the decoupling capacity, that is, in terms of their economic activity and emissions growth? Do the differences in LAM countries increase due to carbonisation and intensity effects in relation to the reference country between 1990 and 2013? The novelty of this research article is based on the combination of temporal and spatial decompositions of aggregate CO_2 emissions changes. Additionally, the decomposition analysis of LAM countries grouped by their decoupling efforts is also a novelty that provides information about the effectiveness of the measures implemented in the area of mitigating CO_2 emissions and some energy policy conclusions and recommendations.

This research is structured as follows. After this introduction, Section 2 refers to the methodology applied, both LMDI analysis and the grouping methodology. Section 3 describes the database and the variables that the study takes into account. Section 4 shows the results obtained at the general and the group level and discusses the efforts achieved by the Latin American countries. The study's main conclusions and some policy recommendations are in Section 5.

2. Methodology

Though various decomposition methods are known, the LMDI has gained strength in recent years due to its properties of facilitating the interpretation and handling of the changes in logarithmic terms which, as expressed by Ang (2004) and Ang and Liu (2007), make them more objective. In the literature there is a useful guide of the implementation of the methods of decomposition via indexes in Ang (2015). This offers general information about the methods of decomposition and their possible applicability. It is however of vital importance to take into account the advances that Ang himself has been providing during the last years (Ang and Lee, 1994; Ang, 1995, 1999, 2005; Ang and Choi, 1997; Ang et al., 1998, 2003, 2009; Ang and Zhang, 2000; Ang and Liu, 2001; Choi and Ang, 2003).

Given that our analysis is focused on the study of CO_2 emissions changes for 20 Latin America countries, the multiplicative LMDI method has been considered in order to display the results in relative terms, instead of the additive one, in order to establish comparisons among countries in the period analysed. Likewise, the LMDI-I method will be implemented based on the properties analysed by Ang (2004, 2015).

2.1. Multiplicative temporal LMDI I analysis

The total CO_2 emissions of n countries considered in the disaggregation level are decomposed as follows:

$$C = \sum_{j=1}^{n} C_j = \sum_{j=1}^{n} \frac{C_j}{FF_j} \cdot \frac{FF_j}{TPE_j} \cdot \frac{TPE_j}{Y_j} \cdot \frac{Y_j}{P_j} \cdot P_j = \sum_{j=1}^{n} U_j \cdot F_j \cdot I_j \cdot G_j \cdot P_j \tag{1}$$

Where $C = \sum_{j=1}^{n} C_j$ are the total aggregate CO_2 emissions of n countries (j = 1…n), C_j is the CO_2 emissions of country j, FF_j is the fossil fuels energy consumption of country j, TPE_j is the total primary energy supply of country j, Y_j is the GDP in purchase power parity of country j, and P_j is the population of country j.

Consequently, the total emissions by country j can be disaggregated into five factors: the carbon intensity (U_j), the fossil fuels weight on TPE (F_j), the energy intensity (I_j), the income per capita (G_j) and the population (P_j).

From Eq. (1), according to Ang and Liu (2001), the overall ratio of change in CO_2 emissions of n countries (D_{tot}) following a period-wise multiplicative LMDI-I method between period T and 0, is decomposed into Eq. (2):

$$D_{tot} = \frac{C_T}{C_0} = D_{car} \cdot D_{ff} \cdot D_{\text{int}} \cdot D_{act} \cdot D_{pop} \tag{2}$$

Where D_{car}, D_{ff}, D_{int}, D_{act}, D_{pop} represent the carbonisation, fossil fuels, intensity, activity and population effects respectively and are defined as follows:

$$D_{car} = \exp\left(\sum_{j=1}^{n} w_j \ln\left(\frac{U_j^T}{U_j^0}\right)\right) \tag{3}$$

$$D_{ff} = \exp\left(\sum_{j=1}^{n} w_j \ln\left(\frac{F_j^T}{F_j^0}\right)\right) \tag{4}$$

$$D_{\text{int}} = \exp\left(\sum_{j=1}^{n} w_j \ln\left(\frac{I_j^T}{I_j^0}\right)\right) \tag{5}$$

$$D_{act} = \exp\left(\sum_{j=1}^{n} w_j \ln\left(\frac{G_j^T}{G_j^0}\right)\right) \tag{6}$$

$$D_{pop} = \exp\left(\sum_{j=1}^{n} w_j \ln\left(\frac{P_j^T}{P_j^0}\right)\right) \tag{7}$$

The weighting factor w_j is the logarithmic average of emissions of country j between period 0 and T ($C_{j,T}$ and $C_{j,0}$, respectively) with respect to the logarithmic average of the total emissions of the n countries between the period T and 0 (C_T and C_0, respectively).

$$w_j = \frac{L(C_{j,0}, C_{j,T})}{L(C_0, C_T)} = \frac{\frac{C_{j,T} - C_{j,0}}{\ln C_{j,T} - \ln C_{j,0}}}{\frac{C_T - C_0}{\ln C_T - \ln C_0}} \tag{8}$$

It must be taken into account that the results of applying the previous method will always show positive values. Any effect which displays values lower than the unit indicates that this effect is contributing to the reduction of the emissions during the study period, while those