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Driving forces and mitigation potential of global CO_2 emissions from 1980 through 2030: Evidence from countries with different income levels

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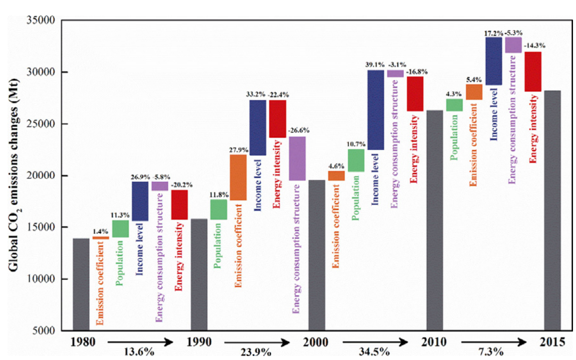
HIGHLIGHTS

- We decompose changes in global CO_2 emissions with consideration of different income levels for 1980–2015.
- We conduct scenario analysis of the global emissions reduction potential up to the year 2030.
- Income is the dominant driving force behind increases in global emissions.
- Energy intensity is the most significant factor in inhibiting global emissions.
- Upper-middle-income countries will offer much more emissions mitigation potential in the future.

GRAPHICAL ABSTRACT



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ABSTRACT

To mitigate global carbon dioxide (CO_2) emissions in an effective manner, it is essential to identify the driving forces and estimate the reduction potential of changes to CO_2 emissions. Using an extended logarithmic mean Divisia index (LMDI) method, this study decomposes the changes in global emissions between 1980 and 2015 with consideration of different income levels; it also reports on scenario analysis of the global emissions reduction potential up to the year 2030 to explore feasible mitigation pathways. The results suggest that the key driving force responsible for promoting global emissions from 1980 through 2015 is income, while energy intensity is the most significant factor in inhibiting global emissions. Furthermore, the countries with the largest reductions in global emissions are mainly upper-middle-income (UMI) countries. The key driving forces of emissions changes in countries with different income levels offer mixed results. In addition, the forecast results indicate that the future emissions reduction potential across the globe is significant and that UMI countries offer the

Abbreviations: AIM, Asian-Pacific integrated model; BAU, Business-as-usual; BP, British Petroleum; CE_{BAU}, CO_2 emissions from the BAU scenario; $CE_{SCENARIO}$, CO_2 emissions from the specified scenario; CEMP, CO_2 emissions mitigation potential; CO_2, Carbon dioxide; DEA, Data envelopment analysis; EC, Emission coefficient; ECS, Energy consumption structure; EI, Energy intensity; GDP, Gross domestic product; GM, Grey prediction model; GNI, Gross national income; HI, High-income; IDA, Index decomposition analysis; IEA, International Energy Agency; LI, Low-income; LMDI, Logarithmic mean Divisia index; LMI, Lower-middle-income; P, Population; PCG, Per capita GDP; TIMES, Integrated MARKAL-EFOM system; UMI, Upper-middle-income; WDI, World Development Indicators.

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Scenario analysis
Country income level

greatest emissions mitigation potential. Finally, this study provides several targeted policy suggestions for reducing emissions across the globe.

1. Introduction

Over the last several decades, the world has witnessed unparalleled economic development and population growth thanks to rapid industrialization and urbanization (Fig. 1). One consequence of such economic and population growth is rapidly increasing energy consumption. According to statistics from BP (formerly British Petroleum) (BP, 2017), global energy consumption has almost doubled, from 6642.3 million tonnes oil equivalent (Mtoe) in 1980 to 13,105.0 Mtoe in 2015 (Fig. 1). Simultaneously, the rapidly increasing energy needs across the globe have triggered tremendous challenges related to environmental pressure, in particular, carbon dioxide (CO_2) emissions (Dong et al., 2018a, 2018b; Shuai et al., 2017a, 2017b). Based on statistics from BP, fossil fuel use in relation to human activities associated with economic development led to the creation of 33.3 billion tons of CO_2 emissions worldwide in 2015 (Fig. 1). Increasing CO_2 emissions and the associated environmental pressures have ignited worldwide concerns. Therefore, a better understanding of the driving forces of global emissions changes is particularly useful for policymakers and government officials not only in devising long- and short-run policies for tackling CO_2 emissions, but also in exploring feasible mitigation pathways.

To analyze the driving forces of CO_2 emissions changes, the logarithmic mean Divisia index (LMDI) method introduced by Ang and Zhang in 2000 has been widely used to decompose emissions changes due to its ability to handle cases with zero values without leaving residuals, its consistency in aggregation, and its path independence (Ang, 2004, 2005, 2015; Ang et al., 2003; Ang and Liu, 2001). Since the 2000s, a growing body of studies has employed the LMDI approach to identify the driving forces of CO_2 emissions changes at country-specific and regional levels (e.g., de Freitas and Kaneko, 2011; Feng et al., 2013; González et al., 2014; Hatzigeorgiou et al., 2008; Jiang et al., 2017; Ma, 2014; Moutinho et al., 2015; Mousavi et al., 2017; Oh et al., 2010; O'Mahony et al., 2012; Tunç et al., 2009; Xu et al., 2016; and Zhang et al., 2013; also see Table A1 in Appendix A). Despite the driving forces of CO_2 emissions changes being extensively studied at a single-country or regional level, based on the literature surveyed and to the best of our knowledge, very few studies have been conducted to investigate the driving forces6 of global CO_2 emissions changes, such as the works of Pani and Mukhopadhyay (2010) and Peters et al. (2017). Also, most studies on the global CO_2 emissions changes have overlooked the differences in patterns and changes in countries with different income levels.

On the other hand, in the existing literature (e.g., Bian et al., 2013; Köne and Büke, 2010; Pao et al., 2012; Pao and Tsai, 2011; Wen et al., 2014; and Rout et al., 2011), several forecasting techniques are used to estimate CO_2 emissions reduction in the future, including data envelopment analysis (DEA), Asian-Pacific integrated model (AIM), the integrated MARKAL-EFOM system (TIMES) model, grey prediction model (GM), and trend analysis. As Lin and Ouyang (2014) and Lin and Tan (2017) indicate, scenario analysis is superior to other forecasting approaches in analyzing the uncertainty of future developments for climate change, energy consumption, and energy intensity. Also, scenario analysis is particularly useful for policymakers and government officials in designing feasible mitigation pathways (also see Section 3.3). However, based on a review of the literature to date, very few scholars have conducted scenario analysis on the global emissions reduction potential based on the LMDI decomposition results.

Given the above motivation, this study employs the LMDI decomposition technique to measure accurately the contributions of various driving forces of global emissions changes between 1980 and 2015 with consideration of different income levels. After decomposing the global emissions changes, this study also carries out scenario analysis of the global emissions reduction potential up to the year 2030 to uncover feasible mitigation pathways.

Three main features distinguish this paper from previous studies on the research topic and contribute to filling the gap in the literature. First, different from prior studies, this study uses the most recent data; this contributes to provide new insights into recent trends, thereby giving policymakers a better understanding of global emissions changes. Second, given the significant differences in the income levels of country studies, in addition to the global decomposition, decomposition of emissions changes in countries with different income levels is also carried out; this is particularly useful for the countries with different income levels in devising effective and targeted policies to tackle CO_2 emissions. Third, scenario analysis of the global emissions reduction potential up to the year 2030 can play a vital role in designing feasible mitigation pathways for policymakers and government officials.

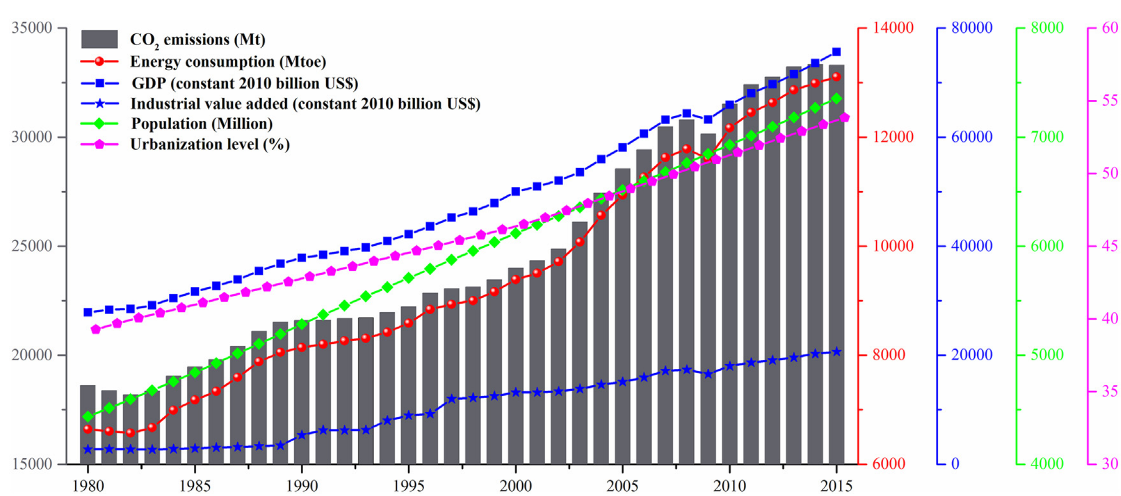

Fig. 1. History of global CO_2 emissions, energy consumption, gross domestic product (GDP), population, industrial value added, and urbanization level from 1980 through 2015. Data source: BP, 2017; World Bank, 2017b.