

The role of renewable energy consumption and commercial services trade in carbon dioxide reduction: Evidence from 25 developing countries

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HIGHLIGHTS

- We analyze relations between renewable energy, economic growth, services trade, and CO₂ emissions in 25 developing countries.
- We apply the Granger causality test and panel long-run estimates (FMOLS and DOLS).
- Increasing the share of renewable energy consumption has positive effects on CO₂ reduction.
- Increasing the size of renewable energy consumption leads to a rise in CO₂ emissions.
- Commercial services trade could be a contributor to carbon reduction.

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ABSTRACT

Developing countries play a dominant role in global carbon emissions. This study, for the first time, uses a panel of 25 major developing countries during the years 1996–2012 to explore the role of renewable energy consumption and commercial services trade in generating carbon emissions. The share and size of renewables consumption are both analysed for comparison purpose. Granger causality tests show that long-run bidirectional Granger causalities exist between economic growth, renewable energy consumption, international commercial services trade, and carbon emissions. Panel co-integration tests identify that long-run equilibrium exist between analysis variables. We also apply fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) for panel estimates. The Empirical results indicate that economic growth has significant effects on carbon emissions; the Environmental Kuznets Curve hypothesis is verified; increasing the share of renewable energy consumption contributes to carbon reduction; increasing the size of renewable energy consumption contrarily raised emissions; expanding commercial services trade could reduce carbon emissions. Our findings suggest that developing countries should promote commercial services trade and the share of renewable energy consumption for low-carbon economic growth.

1. Introduction

World Meteorological Organization reports from released *Greenhouse Gas Bulletin* (2017) that in 2016, global concentration of carbon dioxide (CO₂) in the atmosphere hit 403.3 ppm (ppm), up from 400.00 ppm in 2015. The CO₂ concentration in 2016 is 145% of pre-industrial levels, and rose rapidly at a staggering rate to its highest level in 800,000 years [1]. Since 350 ppm is supported as one of the planetary boundaries for carbon dioxide in the atmosphere, passing 400 ppm is an important symbolic event. Global temperature is expected to increase by an estimated 2 °C if the concentration level reaches 450 ppm

[2]. Anthropogenic CO₂ emissions mainly result from fossil fuels combustion. From 1990 to 2015, world coal-related CO₂ emissions grew at 2.3% annually, and energy-related CO₂ emissions grew by 1.9%/year. Energy use is at the heart of global warming and the core of solutions [3]. Boosting the share of renewable energy (or reducing the share of fossil fuels) is a key measure to mitigate energy-related CO₂ emissions and promote economic green transformation. Renewable energy sources replenish themselves naturally and, when compared to a limited supply of fossil fuels, are therefore sustainable for the present and future economic, developmental, and social demands [4]. The optimal utilization of renewable energy resources minimizes environmental

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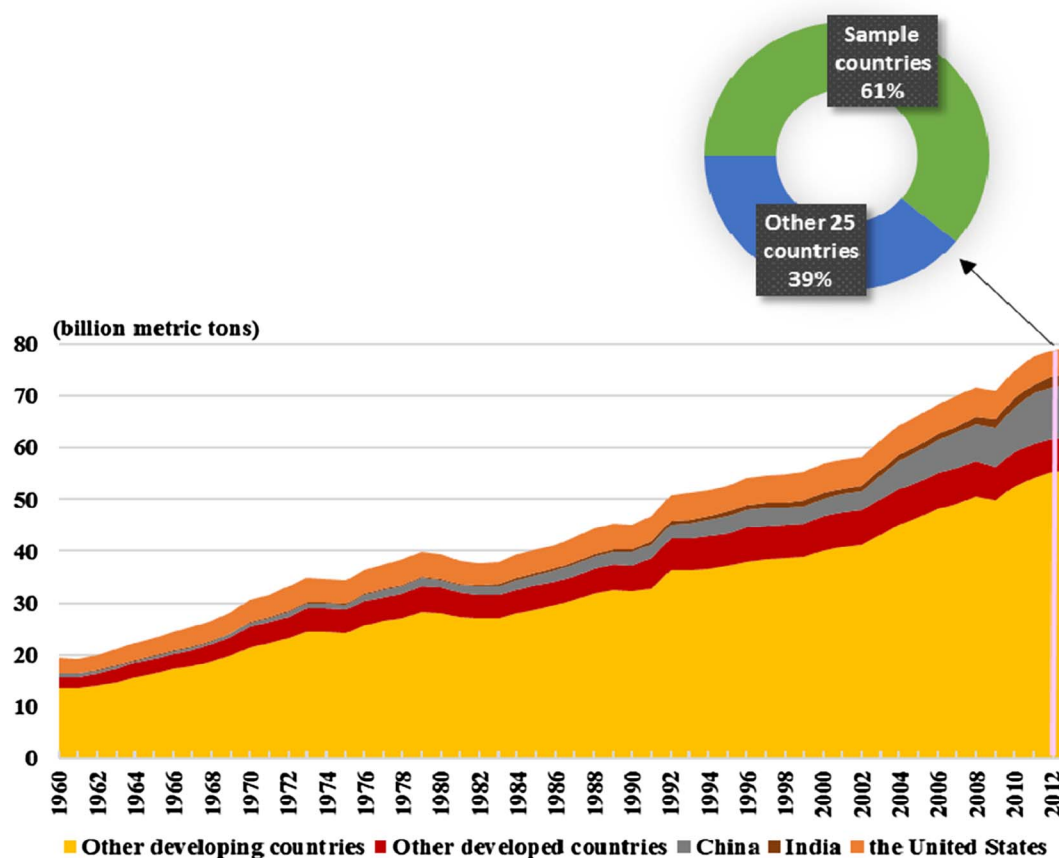


Fig. 1. Total carbon emissions in developing and developed countries. Source: World Bank, World Development Indicators (2016).

impact and the amount of CO₂ produced - further mitigating global warming [5].

The *Paris Climate Agreement* and United Nations *Sustainable Development Goals* pledge to prevent the intensification of global warming, and promote sustainable development, particularly in the renewable energy field [6]. Since 2015, investments in developing countries for all renewable sources other than hydro-electricity had started to surpass those in developed countries. Concretely, developing countries invested 156 billion USD in 2015, whereas developed countries invested 130 billion USD. For developing countries, this amount was 19% more than the investment made in 2014, and 17 times as much as in 2004 (9 billion USD). China has played a predominant role, raising investments by 17% to 102.9 billion USD, approximately 36% of the global total. In addition to China, Brazil and India, other developing countries have increased their investment in new energy fields by 30%, reaching 36 billion USD, nearly 12 times as much as in 2004. In contrast, investments in developed countries decreased by 8% to 130 billion USD. Europe experienced the most remarkable decline in investment, down 21% to 48.8 billion USD, although it also financed offshore wind farm projects worth 17 billion, up 11% from 2014 [7].

Despite increasing renewables investments, developing countries still cannot sustain themselves without heavily depending on fossil fuels. Since fossil fuels are currently the cheapest and most reliable energy resources, developing countries need fossil fuels for economic growth and poverty elimination. Over past decades, non-OECD Asia caused over 80% of aggregate increase in petroleum and other liquid fuels consumption. China remains the world's largest coal user [3]. Renewable energy sources are generally distributed across the globe [8]. Their production usually depends on seasonal variations. Present technologies have difficulties handling intermittent production and can cause discontinuities in power supplies [9]. For example, if electricity

producers are incapable of providing adequate technologies to resolve the intermittent supply of renewable energy in developing countries carbon generating energy resources need to be consumed when a power shortage occurs. In these cases, it needs researches on whether the development of renewable energy in developing countries contributes to carbon reduction.

Energy applications, for instance, the deployment of renewable energy technologies, rely on commercial services. Commercial services can provide energy solutions, including energy risk management, energy saving financing plan, energy infrastructure outsourcing, energy saving retrofitting, energy audit, energy conservation improvement, etc. Commercial services are also likely to generate important economic impacts given that they are dynamically interacted with other sectors of the economy. Since the *General Agreement on Trade and Service* was ratified in 1995, international commercial services trade has since been developing rapidly. The growth rate of commercial services trade significantly exceeds that of the goods trade, and the volume of commercial services trade has made up nearly 25% of the global trade [10]. Commercial services trade may affect CO₂ emission and energy use [11,12]. They are intangible, non-storable, simultaneously produced and consumed and include accounting, banking, cleaning, consultancy, education, insurance, and expertise. Relatively they cause much less waste and emissions to the environment than goods [13]. We argue that trade in commercial services may not only directly affect CO₂ emission, but also indirectly affect the environment through its influences on the economy and renewable energy. To our knowledge, little attention has been paid on the relations of commercial services trade with CO₂ emissions [14,15]. Relevant studies are inconclusive as yet.

The present study aims to study the role renewable energy consumption and commercial services trade play in CO₂ emissions for developing countries. We, for the first time in literature, identify

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