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Comparisons of decoupling trends of global economic growth and energy consumption between developed and developing countries

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ABSTRACT

The development of economy in developing countries is expected to contribute mostly to the growth of world energy consumption. Using environment Impact-GDP-Technology (IGT) decoupling model, we carry out a comparative study on the decoupling trends of economic growth and energy consumption for both developed and developing countries in past five decades (1965–2015). The results indicate that the decoupling indices of developed countries are superior to that of developing countries. The specific performances are: (1) The decoupling indices of developed countries are shown to be stable and tend to approximate absolute decoupling; (2) The decoupling indices of developing countries fluctuate in the relative decoupling interval. On this basis, this research employs grey relational analysis (GRA) to explore the reasons resulting in the difference of decoupling indices from the perspective of technical progress, industrial structure and economic growth pattern. The findings show that: in developed countries, technical progress factor exerts greatest influence on decoupling indices, followed by industrial structure and economic growth pattern; in developing countries, industrial structure and economic growth pattern have greater impact on decoupling indices than technical progress. Based on research conclusion, this research offers developing countries relevant policy suggestions for energy saving and emission reduction in the future.

1. Introduction

With the rapid development of economy, developing countries[1] are leading the growth of global energy consumption.[2] In 2015, the consumption of primary energy in developing countries was 7.64×10^9 ton oil equivalent (toe), accounting for 58.1% in the world. Compared with 2005, the consumption of primary energy in the world in 2015 increased by toe and that in developing countries rose by 2.38×10^9 toe (BP, 2016). As shown in Fig. 1, in 2012, the energy intensity[3] in Russia (9.49) and China (8.34) is two times that of Germany (3.88) (World Bank, 2013), this indicates that there is a big gap of energy intensity between developed and developing countries. The decrease rate of energy intensity in these countries is similar, it means developing countries decrease energy intensity slowly and meet a bottleneck problem, and unable to further narrow the gap with the developed countries. Furthermore, a large-scale exploitation of primary energy further intensifies the energy supply crisis. At present, the reserve-production ratios[4] of global coal, oil and natural gas are 114, 50.7 and 52.8 years if the recoverable reserves are not increased. The reserve-production ratios of the United States are 292, 11.9 and 13.6 years, while those of China are 31, 11.7 and 27.8 years and are 89, 18 and 50.9 years in India (BP, 2016). It is obvious that the energy supply crisis in developing countries is more serious than developed countries. Therefore, understanding the evolution of energy utilization in developed and

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[1] The definition of "developing countries" was from *World Economic Outlook 2016* (IMF, 2016). IMF provides the country classification of 39 advanced economics and 152 emerging market and developing countries. Here "developing countries" refers to the 152 emerging market and developing countries.

[2] We defined the energy consumption as the use of primary energy before transformation to other end-use fuels.

[3] Energy intensity, as a national energy efficiency index, shows the economic benefits of energy utilization, and the higher the energy intensity, the greater the dependence of a country on energy is.

[4] The data source for the information about the reserve-production ratios of global coal, oil and natural gas are from *Statistical Review of World Energy* (BP, 2016). Available at: http://www.bp.com/statisticalreview.

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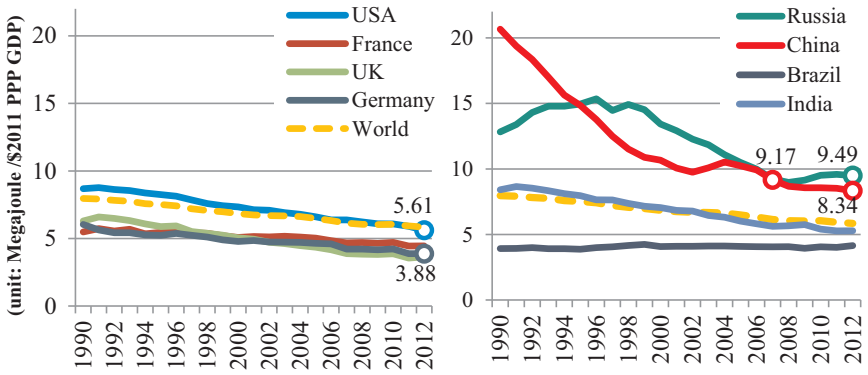

Fig. 1. Energy Intensity (1990–2012).
Sources: World Bank Sustainable Energy for all database.

developing countries becomes more and more important (Van et al., 2008), and how to get rid of the pulling of economic growth on energy consumption and how to decouple economic growth and energy consumption are urgent problems for developing countries to solve.

Obviously, developing countries that lead the world energy consumption should study how to get rid of the pulling of economic growth on energy consumption to decouple them. The realization of strong decoupling to economic development and energy consumption has been taken as the policy goals by many countries, regions and international organizations such as *Organization for Economic Co-operation and Development* (OECD), the *European Union* (EU) and *United Nation Environment Programme* (UNEP) (EU, 2005; OECD, 2002; UNEP, 2011). Hence, it is of significance to offering policymakers of developing countries by referring decoupling experiences of developed countries, which is also conducive to decreasing the difference of energy efficiency between developed and developing countries and promoting sustainable development of global energy economy. Existing literatures on the relationship between economic growth and energy consumption can be classified into two categories : studies of measuring decoupling degrees of economic development (Freitas and Kaneko, 2011; Martin and Abby, 2006; Peng et al., 2011; Soytas et al., 2007) and energy consumption using different indices and research into the influencing factors of decoupling trends using multiple approaches (Loganathan and Subramaniam, 2010; Van Caneghem et al., 2010; Yu et al., 2017; Zhang et al., 2015). However, the former usually focuses on individual cities and rarely perform the comparative study of different regions; while, the latter also seldom concentrates on the comparative analysis of multiple regions. Based on literature review, we comparatively analyze six approaches of calculating current decoupling related indices. The research findings show that as IGT decoupling model presents distinct classification performance and is easy to be calculated as well as better understanding, and therefore, it is more appropriate to be applied in the comparison of decoupling indices among multiple countries. Thus, we use IGT decoupling model to evaluate decoupling indices. Learning the decoupling experience from developed countries is of great significance to promote energy development in developing countries. This study establishes a decoupling model concerning economic growth and energy consumption according to the decoupling process in developed (USA, France, UK, Germany) and developing countries (Russia, China, Brazil, India) from 1965 to 2015. On this basis, this research employs GRA model to explore the reasons resulting in the difference of decoupling indices from the perspective of technical progress, industrial structure and economic growth pattern. This is conducive to narrowing the gap of energy intensity between developed and developing countries and sustainably developing global energy economy.

The contributions of this study include that: (1) We research the relationship between the economic growth and energy efficiency of developed and developing countries, and compare the decoupling trends of it; (2) GRA model is used to assess the significance of different influencing factors of decoupling degree based on the research of Lu et al. (2011).

The paper is organized as follows: Section 2 reviews the research on the theory of decoupling between economic growth and environmental pressure, and classifies them. Section 3 Introduces the IGT decoupling model and GRA model and data sources, while Section 4 presents the comparison of decoupling index. In Section 5, Analysis and comparison of influencing factors of decoupling. Section 6, the conclusions and policy suggestions are presented.

2. Literature review

The decoupling theory is an appropriate tool to study the relationship between economic growth and energy consumption (Zhang et al., 2015), and the earliest study of decoupling should be adapted to environment studies at the beginning of the 2000s by Zhang (2000). And in 2002, OECD firstly utilized the decoupling index method to measure whether the damages of environmental quality has a synchronous change relationship with economic growth. Since then, the academic research on decouple has been developed, not only to establish a reasonable decoupling theory system, but also developed a variety of measures to measure the decoupling index. As shown in Table A1 and the references summarize is provided in Appendix A.

2.1. Decoupling index method

The first decoupling method was provided by OECD (2002). The environmental pressures and economic driving forces are used in the OECD decoupling method, and it provides a reasonable indicator of measuring the effectiveness of related policies. By using OECD decoupling method, Freitas and Kaneko (2011) calculated the decoupling indexes of economy development and CO_2 emissions in Brazil and verified the importance of energy structures. Similarly, Yu et al. (2013) obtained that energy consumption shows a relative decoupling state with emissions of SO_2, CO_2 and wastewater in 1981–2010. This kind of decoupling type is divided into decoupling and non-decoupling, the data required are few and the calculation is simple. However, it cannot distinguish absolute decoupling and relative decoupling and further divide non-decoupling.

2.2. Variation analysis method

Vehmas et al. (2003) put forward the variation analysis method in the study of global environment pressures and economic growth trends. This is the first time that de-linking and re-linking of influences of economic growth on environment and environmental Kuznets curve are applied to study the problems of industrialized countries. Guo and Ma (2012) used this method to analyze the decoupling relationship between economy growth and energy consumption in China. Zhu et al. (2013) utilized this method to investigate the relationship between the