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A three-step strategy for decoupling economic growth from carbon emission: Empirical evidences from 133 countries

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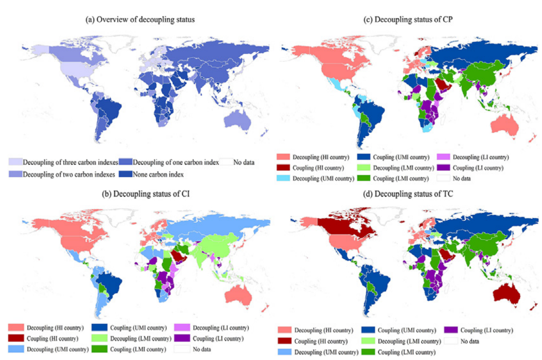
HIGHLIGHTS

- Three carbon indexes for decoupling analysis is proposed.
- The decoupling analyses of 133 countries are identified.
- Absolute decoupling of the carbon indexes occurs constantly in three steps.
- The income level of countries spurs the absolute decoupling.

GRAPHICAL ABSTRACT



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ABSTRACT

To decouple the economic growth and carbon emission has been considered imperative to promote low-carbon economy. Nevertheless, previous studies on decoupling analysis between economic growth and carbon emission were contextualized merely in individual countries rather than the globe, which are insufficient for developing the low-carbon economy as a global target. Carbon intensity (CI), carbon emission per capita (CP), and total carbon emission (TC) serve as three important indicators of the status of regional carbon emission, but only decoupling economic growth from TC was analyzed in previous studies. To close the two gaps, this study aims to investigate the global decoupling statuses of economic growth from not only TC but also CI and CP by using Tapio decoupling index. The decoupling statuses of 133 countries and income-level groups to which they are classified are identified using the data from 2000 to 2014. According to the results, it is observed that economic growth decouples from CI, CP, and TC in sequential order, which is called three-step decoupling. In the period, countries whose economic growth having decoupled from CI, CP, and TC, account for 74%, 35% and 21% respectively. Higher income-level group has the larger proportion of countries having reached their decoupling statuses. These findings may serve as valuable references for policy-makers to understand the current decoupling statuses and make three-step strategies if necessary towards the global low-carbon economy.

1. Introduction

Over the past six decades, the world economy has shot up with the deepening of globalization. According to the World Bank (2016), the

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Nomenclature list

Abbreviation

CI	carbon intensity
CP	carbon emission per capita
TC	total carbon emission
DR	decoupling relationship
ADR	absolute decoupling relationship
OECD	Organization for Economic Cooperation and Development
GDP	gross domestic product
HI	high-income
UMI	upper-middle-income
LMI	lower-middle-income
LI	low-income
ST	short-term
MT	middle-term
LT	long-term
SD	strong decoupling
WD	weak decoupling
EC	expansive coupling
END	expansive negative decoupling
SND	strong negative decoupling
WND	weak negative decoupling
RC	recessive coupling
RD	recessive decoupling
IEA	International Energy Agency

global GDP has surged from 1.367 trillion dollars in 1960 to 75.845 trillion dollars in 2016, accounting for approximately 55 times with an annual increase rate of 7.6%. The massive use of energy, which is demanded by economic activities, results in large amount of carbon emission (Deutch, 2017). The total amount of carbon emission at the global level has approximately tripled from 9385.8 million tons in 1960 to 36,138.3 million tons in 2014, showing an annual increasing rate of 2.6%. Carbon emission has been widely recognized as the main cause of climate change, which has led to over 600,000 people died and 4.1 billion people wounded, as well as the loss of over 1.9 trillion dollars in the past two decades (World Bank, 2016). Carbon emission reduction has therefore become an urgent task requiring the great efforts of global countries (Chen et al., 2017; Liu et al., 2018; Ma and Cai, 2018; Ma et al., 2017c; Shuai et al., 2018). Bearing this task, global countries should transform the current highly carbon emission related economic development pattern into a low-carbon economy (Chen et al., 2018; Li et al., 2017; Ma et al., 2017a; Ma et al., 2017b; Pan et al., 2018; Shi et al., 2017; Yan et al., 2017). To do that efficiently, decoupling, which can break the linkage between economic growth and carbon emission, has been well appreciated for promoting global low-carbon economy (Dong et al., 2018a; Dong et al., 2018b; Wu et al., 2018; Shen et al., 2018b).

There are two mainstream decoupling methods, OECD and Tapio (Chen et al., 2018). It is commonly appreciated that "decoupling" originated from physics, and was firstly defined as breaking the link between economic growth and environmental degradation by the OECD (Wu et al., 2018). Due to its less calculation, the OECD method is widely used since then (De Freitas and Kaneko, 2011; Mulder and de Groot, 2004; Yu et al., 2013). However, the drawback of OECD decoupling index is also obvious, it is too sensitive for the choice of base time period, leading to the poor stability of the calculated results (Zhou et al., 2017). Besides, the OECD decoupling index is only associated to a reduction in emissions' intensity, but that can coexist with emissions that are not decreasing when the economy is in expansion and with emissions decreasing but with economic activity falling (Grand, 2016). In order to solve these shortages, the research by Tapio (2005) defined another decoupling method when studying the decoupling status in the European transport industry. Since Tapio method can provide rational decoupling positions with eight possible combinations of environmental pollution variables and economic variables, the Taipo decoupling method has being widely used by many researchers (Wang et al., 2017; Wu et al., 2018). Therefore, the Tapio decoupling method is used in this study.

The topic of studying decoupling relationship (DR) of carbon emission and economic growth has attracted much attention from researchers. Previous research often focused on the decoupling status at sectoral and national level. For example, Wang and Yang (2015) studied the DR of industry sector in Beijing–Tianjin–Hebei district, and found decoupling status was yet to come. Xiong et al. (2016) examined the DR using the evidence of agriculture sector in Xinjiang, China, and also found the coupling status between the economic growth and carbon emission. Zhao et al. (2017) investigated the DRs in China in terms of five major sectors, namely industry, agriculture, construction, transport, service and residential sectors, and pointed out the economic growth and carbon emission of the five sectors were still coupled. Chen and Chen (2017) used the Tapio decoupling index to analyze the absolute decoupling relationship (ADR) of economic growth and total carbon emission (TC) in Macao, and opined that the decoupling status varied over time. Loo and Banister (2016) studied the DRs of economic growth and TC in transport sector of 15 individual countries, and found that decoupling had taken place in most of countries.

Roinioti and Koroneos (2017) examined the DR in Greece and confirmed the existence of its ADR of economic growth and TC. Jiang et al. (2016) studied the DR in United States, found that its economic growth was still coupled with carbon emission. De Freitas and Kaneko (2011) tested the DR in Brazil from 2004 to 2009 employing the OECD decoupling method, and concluded that the decoupling status did not occur. The research by Zhang and Da (2015) investigated the DR in China, and stated that there was no decoupling effect during 2003–2004. Similarly, Wang et al. (2017) examined the DR in China during 1996–2013 and did not found the decoupling status.

To date, a few studies focused on analyzing the decoupling status of a certain group of countries. For instance, Dai et al. (2016) explored the DRs in BRICS countries and denied the existence of ADR; and Schandl et al. (2016) examined the DRs of 13 large carbon emitters in world regions including China and India, and found none of them has decoupled the economic growth from TC.

The findings of existing studies are multifarious and lack of guiding significance for global low-carbon economy since they are either bounded by the limited research region scale (i.e. single or several sectors or countries) or the single measure of carbon emission (i.e. only TC) (Loo and Banister, 2016; Schandl et al., 2016). Firstly, climate change is a global challenge, which requires every country in the world to contribute its endeavors to mitigate carbon emission. It is thus imperative to provide the decoupling statuses of global countries for better balancing the relationship between economic growth and carbon emission. Secondly, all of previous studies analyzed the DR merely focusing on TC, which drew a similar conclusion, i.e. most of the studied countries had not reached the decoupling statuses (Xiong et al., 2016; Zhao et al., 2017). Bai et al. (2016) argued that single carbon emission index may fail to comprehensively reflect regional carbon emission scenario. In fact, the research by Shen et al. (2018a) provided that there are three representative indexes of carbon emission including not only TC but also carbon intensity (CI) and carbon emission per capita (CP), and further verified the turning years of the three indexes over economic growth are sequential in Beijing, China. If this sequential order is