Journal of Cleaner Production 184 (2018) 1060–1071

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Does industrial green transformation successfully facilitate a decrease in carbon intensity in China? An environmental regulation perspective

Jian Hou [a, *], Thompson S.H. Teo [b, c], Fuli Zhou [d], Ming K. Lim [e, f], Heng Chen [a]

[a] School of Economics and Management, Harbin Engineering University, Harbin, China
[b] School of Business, National University of Singapore, Singapore
[c] School of Computing, National University of Singapore, Singapore
[d] School of Management, Chongqing University of Technology, Chongqing, China
[e] School of Mechanical Engineering, Chongqing University, China
[f] Centre of Supply Chain Improvement, The University of Coventry, United Kingdom

ARTICLE INFO

Article history:
Received 6 November 2017
Received in revised form
26 February 2018
Accepted 28 February 2018
Available online 3 March 2018

Keywords:
Industrial green transformation
Carbon intensity
Environmental regulation
Dynamic threshold model
China

ABSTRACT

Global climate change caused by carbon emissions poses a severe challenge to human economic and social development. The Chinese government has committed to a series of emission reduction initiatives to achieve carbon intensity targets by actively promoting the green transformation of the industrial sector—the main source of energy consumption and environmental pollution. This transformation has been ongoing for more than five years, and the effects, problems and experiences are worth discussing. Therefore, using province-level panel data for China's industry from 2010 to 2015, we systematically analyze the regional structure and developmental trend of industrial green transformation and empirically investigate its dynamic threshold effects on carbon intensity under different degrees of environmental regulation. The results show that China's industry has gradually undergone a green transformation, which has significantly reduced pollution emissions. However, the process has a large developmental scope due to regional heterogeneity and fluctuation characteristics. Interestingly, the impact of the industrial green transformation on carbon intensity is limited by the "critical mass" of environmental regulations. Paradoxically, weak environmental regulation significantly facilitates a decrease in carbon intensity through industrial green transformation. Once environmental regulation surpasses a critical level, the role of this transformation in CO_2 reduction is weakened, resulting in a failure to decrease carbon intensity. We provide insights into the driving factors that reduce carbon intensity and improve our understanding of the driving forces, paths and policy designs needed to successfully reach carbon intensity targets.

1. Introduction

Carbon dioxide (CO_2) emissions, as one of the main contributors to environmental pollution, pose a severe challenge to the global ecosystem and socio-economic development. Reducing CO_2 emissions and realizing a low-carbon economy have become key measures used by all countries to address environmental challenges (Wang et al., 2012; Xu and Lin, 2016). As one of the world's most fossil fuel-dependent and carbon-intensive economies, China has surpassed the United States to become the world's largest emitter of CO_2 (International Energy Agency, 2009). The problem of haze pollution, which shrouded “the Gray Great Wall” and stretched for thousands of kilometers, is particularly severe in China (Hou et al., 2017). Total CO_2 emissions in China are affected by long-term sustained economic growth and industrialization and are likely to continue increasing. Because of the global push to reduce carbon emissions and considerable pressure from domestic support resources and environmental carrying capacity, the reduction of China's CO_2 emissions has become a focus of the international community. In December 2009, the Chinese government pledged that by 2020, carbon intensity would be reduced by 40%–45% compared to 2005 levels and would be incorporated as a binding indicator into the long-term planning of China's national economic

* Corresponding author.
E-mail addresses: houjian1128@163.com (J. Hou), bizteosh@nus.edu.sg (T.S.H. Teo), deepbreath329@outlook.com (F. Zhou), ac2912@coventry.ac.uk (M.K. Lim), chenh@hrbeu.edu.cn (H. Chen).

https://doi.org/10.1016/j.jclepro.2018.02.311
0959-6526/

and social development. In 2014, China and the USA issued the U.S.–China Joint Announcement on Climate Change in which China promised to reach peak CO_2 emissions near 2030. On 30 June 2015, China promulgated the Enhanced Actions on Climate Change, which indicates that by 2030, carbon intensity will be reduced by 60–65% compared to 2005 levels.

While the realization of these targets depends on the substantive transformation of the structure of regional economic growth, it depends even more on specific actions related to energy conservation and emission reduction in the industrial sector (Lü et al., 2015). China's economy is still in an industry-led developmental stage, with China's industrial GDP growing at an average annual rate of 11.5%. However, the basis of this extensive industrial growth is high energy consumption and high industrial emissions; it consumes 67.9% of the country's energy and emits 83.1% of the country's CO_2. Industry has become the main source of energy consumption and environmental pollution in China (Suh, 2016). In view of the significant role of industry in China's economic growth, energy consumption and carbon emissions, China's industrial sector must take the lead in realizing green transformation in the context of addressing emission targets. This leadership would have a positive demonstration effect on promoting the development of China's green economy and would also profoundly affect the push to decrease carbon emissions around the world.

In essence, industrial green transformation is a win-win situation for realizing intensive industrial growth and carbon emission reduction and for improving the contribution of green total-factor-productivity (TFP) to industrial economic growth under certain restrictions regarding energy and the environment. Reasonable environmental regulations that promote the continuous improvement of industrial green TFP will inevitably lead to the path of industrial transformation (Lü et al., 2015). Furthermore, behavior that affects carbon emissions is an externality in the process of production and consumption and requires supplementary restrictions in the form of environmental regulation. Therefore, industrial green development depends heavily on a series of environmental regulations. However, Schou (2002) argues that environmental regulations are unnecessary and that pollution will automatically decrease as natural resources continue to be consumed. Particularly since Sinn (2008) initiated the “Green Paradox” theory, scholars have increasingly raised doubts about the necessity and effectiveness of environmental regulation. Meanwhile, due to the regional heterogeneity of environmental regulation in China, the influence of driving factors on CO_2 emissions is uncertain. Thus, considering the different degrees of environmental regulations in China, what are the driving mechanisms of and differences in industrial green transformation as they relate to carbon intensity? Does industrial green transformation successfully facilitate a decrease in carbon intensity? How do we achieve CO_2 emissions-reduction targets for a green economy in the region? Due to the global low-carbon push, it is of theoretical value and practical significance to investigate the process of industrial green transformation and explore the driving forces, realized paths and policy designs for decreasing carbon intensity.

In this paper, we endeavor to provide a better understanding of the linkages between industrial green transformation, environmental regulation and carbon intensity by taking into account the perspective of “threshold effect”. First, we construct an index that can be used to evaluate the industrial green transformation in 30 provinces in China. This index captures the contribution of green TFP, including certain energy and environmental restrictions on industrial growth, by combining the slack-based measure and the Malmquist-Luenberger productivity index (SBM-ML). Second, we examine industrial green transformation and carbon intensity in various regions in China. We assume that a nonlinear relationship exists between industrial green transformation and carbon intensity. In doing so, we shed light on how different levels of regulation affect the relationship between industrial green transformation and carbon intensity, and whether thresholds or turning points exist in the relationship. The results provide a reference for regional policy-making with respect to the establishment of optimal industrial environmental regulation.

2. Literature review

Several studies have examined the characteristics and determinants of CO_2 emissions at industrial and regional levels through quantitative analysis, such as index decomposition analysis (Wang et al., 2016), structural decomposition analysis (SDA) (Lin and Xie, 2016), multi-objective optimization (Xu et al., 2015), and nonparametric additive regression models (Xu and Lin, 2017). The factors considered in these analyses are usually limited to energy intensity, technological change, industrial structure, etc. (Zhao et al., 2016). Furthermore, countermeasures and suggestions for promoting low-carbon production processes in industrial enterprises are often discussed. However, the existing literature has not conducted a direct study on the impact of industrial green transformation on carbon intensity, particularly in China. By considering green activities and CO_2 emissions as the main components of the industrial green transformation, we can still draw important references from relevant studies on the effect of industrial green transformation on carbon intensity.

According to scientific reports, CO_2 emissions are predominantly caused by industrial production and the combustion of fossil fuels (Intergovernmental Panel on Climate Change (IPCC), 2007). Industry is one of the most important energy-consuming sectors, resulting in a carbon intensity approximately 2.5–5 times that of tertiary industry. Therefore, the industrial green efforts in a specific region have a profound impact on carbon emissions (Suh, 2016). Diakoulaki and Mandaraka (2007) studied changes in CO_2 emissions in EU countries and found that most countries have made great efforts to reduce emissions, but the contribution to overall emission reduction is relatively small. Studying energy consumption and the efficiency of Japan's manufacturing industry, Sueyoshi and Goto (2014) also found that improving energy efficiency contributes to mitigating the energy intensity and CO_2 emissions of the manufacturing industry.

More researchers have begun to concentrate on China, and particularly its industries, since it has become the largest CO_2 emitter in the world. Regarding output, Zhao et al. (2010) analyzed the main factors responsible for industrial CO_2 emissions in Shanghai from 1996 to 2007 and found that reducing industrial output could decrease carbon emissions. Lin and Tan (2017) believe that the industrial scale is the main factor increasing CO_2 emissions. However, Chen et al. (2010) and Zhao et al. (2016) suggest that investment is the dominant factor increasing China's CO_2 emissions and that enhancing capital productivity and green investment would effectively mitigate CO_2 emissions. In addition, Zhang et al. (2017) indicated that investment intensity is the primary driver for the increase in China's industrial CO_2 emission intensity, while some uncertainty exists regarding the realization of the 2030 emission-peak target, and extra effort is needed to improve efficiency and structural adjustments. For energy-related activities, Lin and Liu (2016) investigated the transfer of CO_2 emissions between different industrial sectors. The regression estimation results indicate that energy consumption is the main factor in CO_2 emissions and that energy-saving technologies could significantly reduce energy intensity and CO_2 emissions. With the same method, Lin and Xie (2016) indicate that expanding the production scale led to increased CO_2 emissions, while a reduction in energy intensity