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Does intensive land use promote a reduction in carbon emissions? Evidence from the Chinese industrial sector

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ABSTRACT

Human land use activity is an important contributor to the growth of CO_2 emissions. Thus, reasonable land use is an effective method of reducing CO_2 emissions. Based on an extended STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model, the impacts of population size, wealth level, technology level, and four representative indicators of intensive industrial land use (IILU) on CO_2 emissions in China from 2006 to 2015 were estimated. The results showed that research and development (R&D) investment intensity is negatively related to CO_2 emissions in all three regions (east, central and west) of China; labor intensity is negatively related to CO_2 emissions in the eastern region; and capital intensity is negatively related to CO_2 emissions in the western region. We further calculated the contribution of changes in each driving factor to the growth of CO_2 emissions in the study period, and the results showed that changes in R&D investment intensity contributed the most to CO_2 emissions reductions, whereas the decrease in the labor intensity in the central region and the increase in the capital intensity in the western region show weaker but similar effects. Targeted policy implications are proposed to adjust the mode of IILU from the perspectives of labor, energy, capital and R&D investments in the three regions across China.

1. Introduction

China has achieved notable economic progress over the past four decades since the reform and opening up policies were promulgated in the late 1970 s. In 2015, the gross domestic product (GDP) reached 68.55 trillion yuan RMB (11.01 trillion US dollars[1]), and industrial sectors contributed a considerable proportion. Accounting for approximately 32% of the country's total GDP, the industrial GDP was 21.52 trillion yuan RMB (3.455 trillion US dollars) in 2015. However, this gratifying achievement is accompanied by enormous land waste and a sharp increase in industrial pollutant emissions (e.g., CO_2 emissions). In 2010, the total carbon emissions of industrial sectors were 6.201 billion tons, which accounted for 85.66% of China's total carbon emissions of 7.238 billion tons (Wu et al., 2014). Specifically, in 2015, the total industrial land area reached 10.3 thousand km^2, which accounted for approximately 19% of the total urban area in China. This proportion is much greater than that in many developed countries and regions, e.g., Japan and Hong Kong (Bertaud and Renaud, 1997). However, industrial land waste is common, and massive amounts of unused or idle industrial land are observed in many regions of China. Reportedly, over 4% of the land in urban areas is completely idle and approximately 40% is inefficiently used (Wang et al., 2012; Wu and Qu, 2007). Therefore, developing methods of avoiding wasting industrial land has become an urgent issue. The industrial sector is the key sector for energy conservation and emissions reductions (Dong et al., 2018). In the context of limited urban land reserve and impeded outward expansion of urban space, studies on the influence of industrial intensive land use on CO_2 emissions reductions are conductive to improving the overall industrial land use efficiency and promoting urban sustainable development; moreover, building low-carbon economies and transforming economic development modes are of great strategic and practical significance for integrating economic, social and environmental benefits.

China has been the largest CO_2 emitter since 2010 in the world and thus has received pressure from many developed countries in recent international environment conferences (Wang et al., 2016). To address such problems, a series of policies aimed at reducing CO_2 emissions were launched by the central and local governments in China. In 2007, to enhance people's understanding on the importance and urgency of tackling climate change, the China State Council issued *China's National*

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[1] The average exchange rate in 2015 was 1 US dollar = 6.2284 yuan RMB. See http://news.eastday.com/eastday/13news/auto/news/china/20160229/u7ai5342233.html (in Chinese).

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Climate Change Program.[2] At the 2009 United Nations Climate Change conference, China's Premier Wen Jiabao made a commitment to reducing carbon emissions, especially in industrial production (Xie et al., 2017). To encourage low-carbon living and consumption, the National Development and Reform Commission of China has introduced the *Interim measures for certification of low-carbon products*[3] and *Management method of energy savings and low carbon product certification*.[4] However, the effect of these policies has not been determined.

Land use has been regarded as one of the major contributors to the sharp increase in global CO_2 emissions since the 19th century (Chuai et al., 2015). According to Houghton (2002), the CO_2 emissions caused by land use activity from 1950 to 2005 was as high as 10.6 billion tons, which accounted for approximately 30% of the CO_2 emissions caused by human activities. Certain related studies have confirmed the close link between land use and CO_2 emissions (Ali and Nitivattananon, 2012; Sun et al., 2015; Xu et al., 2009). The sale of land has long been a major source of fiscal revenue for the Chinese government, and the CO_2 emissions generated from China's industrial sectors are expected to increase in the near future. According to China's Ministry of Finance, the fiscal revenue from selling land reached 3.37 trillion yuan RMB (0.54 trillion US dollars) in 2015, accounting for over 40% of China's local governments' total fiscal revenue. To address the fiscal revenue and expenditure gap, local governments have long been keen to attract industrial investment (Xie et al., 2018), which has led to dramatic industrial expansion, staggering land waste and rapid carbon emission growth. In China, the annual growth rate of carbon emissions has exceeded 10% in certain regions due to rapid industrial development (Zhang and Xu, 2017).

Goh et al. (2018) suggested that low-carbon land use was an effective method of reducing CO_2 emissions. Intensive industrial land use not only improves the use efficiency of industrial inputs but also facilitates the treatment of industrial pollutants (e.g., industrial waste water, industrial waste solid and industrial CO_2 emissions) (Chen and Lu, 2017). Fortunately, intensive industrial land use (IILU) has attracted the attention of the Chinese land management department. A series of policies aimed at increasing industrial resource inputs (e.g., investments in industrial fixed assets and scientific research funding) per unit of industrial land and conserving precious industrial land have been launched in recent years, e.g., the *Decisions to deepen the reform of strict land management* issued by the China State Council in 2004, the *Guidance on promoting the intensive use of land*[5] and *Guidelines for the implementation of industrial land policy*[6] issued by the Ministry of Land and Resources of China in 2014 and 2016, respectively. These policies are conductive to avoiding large-scale industrial pollution incidents and conserving valuable industrial land. However, studies estimating the impact of IILU on CO_2 emissions are rare, and few guidelines are available for adjusting the mode of IILU in China to reduce CO_2 emissions. To address this issue, this study incorporates representative IILU indicators into the basic STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model to explore the relationship between IILU and CO_2 emissions and the contributions of changes in each driving factor to the growth of CO_2 emissions in China from 2006 to 2015. The following questions are addressed in this study.

(1) What are the trends of CO_2 emissions in China? What are the IILU indicators? Are there significant regional differences?
(2) What are the impacts of IILU indicators on carbon emissions?
(3) What is the contribution of changes in each IILU indicator to the growth of CO_2 emissions?
(4) What adjustments to IILU indicators can be made to promote CO_2 emissions reductions?

The remainder of this paper is organized as follows. Section 2 presents the literature review and contributions of this paper. Section 3 describes the methodology and materials. Section 4 presents the empirical results, and section 5 provides the conclusions and proposes policy implications.

2. Literature review

Although studies on the relationship between intensive land use and carbon emissions are rare outside of China, many domestic studies have shown that the dynamic change in the pattern and mode of land use is responsible for the rapid growth of CO_2 emissions. The extensive expansion of urban built-up land and rapid industrial development are the main causes underlying the rapid increase in CO_2 (Arvin et al., 2015; Li et al., 2008; Huang et al., 2016; Feng et al., 2018). Xu (2013) found that a 1% increase in land use intensity would lead to a 1.906% reduction in CO_2 emissions, and other reports have indicated that intensive land use is positively related to CO_2 emissions, with more intensive land use corresponding to greater emissions of CO_2 (Zhang et al., 2013). Moreover, the positive link between intensive land use (a comprehensive indicator containing a variety of intensive land use indicators) and CO_2 emissions weakens with the success of industrial upgrades (Zhang, 2015). In summary, the conflicting conclusions of these studies are mainly attributable to the definition of land use intensity. To better study the relationship between intensive land use and carbon emissions, industrial intensive land use, which is a comprehensive indicator containing a variety of intensive land use indicators, refers to the relative amount of production factors, such as capital or labor, which are inputted to the per unit land in the industrial production process in this paper.

Industrial land is an important component that consists of urban built-up land. Therefore, in recent years, many researchers have investigated the drivers of CO_2 emissions from industrial sectors and attempted to find effective methods of mitigating the rapid growth of CO_2 emissions (Ji and Chen, 2015). The comprehensive evaluation index system is a commonly used approach to estimating intensive land use. However, this approach is subjective and may lead to confusing conclusions. To avoid with these problems, the evaluation index system should cover areas that include labor, energy, capital and R&D investments.

The STIRPAT model, which aims to estimate the impacts of population size, wealth level and technology level on the environment in a given region, has become a popular method for investigating the social and economic drivers of pollutant emissions. A major advantage of the STIRPAT model over other methods (e.g., IPAT model and IMPACT model) is that representative drivers from other perspectives (e.g., land use and urbanization) can be incorporated into the model according to the study requirements (York et al., 2003). Therefore, the empirical results based on the STIRPAT model are more reasonable and credible.

The contribution of this study is as follows. First, we examine the relationship between CO_2 emissions and their drivers by incorporating representative IILU indicators into the basic STIRPAT model. Second, we estimate and compare the contribution of changes in each driver to the growth of CO_2 emissions from 2006 to 2015 at national and regional levels in China. Finally, based on the perspectives of labor, energy, capital and R&D investments, targeted policy implications for each region (east, central and west) are proposed to upgrade the IILU mode in the industrial sector.

[2] See http://www.ccchina.gov.cn/Detail.aspx?newsId=28013.
[3] See http://www.cnca.gov.cn/bsdt/ywzl/zyxcprz/tzgg_1079/201507/t20150706_39872.html.
[4] See http://www.cnca.gov.cn/bsdt/ywzl/flyzcyj/bmgz/201512/t20151230_43682.html.
[5] http://www.mlr.gov.cn/zwgk/zytz/201409/t20140926_1331065.htm (in Chinese).
[6] http://f.mlr.gov.cn/201702/t20170206_1437212.html (in Chinese).