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How does industrial structure change impact carbon dioxide emissions? A comparative analysis focusing on nine provincial regions in China

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ABSTRACT

China as a whole is undergoing rapid industrial structure change, but this process is proceeding in a particularly unequal manner across regions. Understanding these changes and their associated impacts on CO_2 emissions in these regions is a vital step toward appropriately targeted policy making. In this paper, we conduct both regional analysis throughout the nation and case studies focused on nine typical regions in order to identify regional patterns of industrial structure change and CO_2 emissions. Results indicate that structural change in primary, secondary, and tertiary sectors was highly correlated, but structural change by industrial sector did not correspond well, with the stage of economic development. The disparity in regional industrial structure impacts regional CO_2 emissions substantially. First, industrial structure changes involving a shift from agriculture, mining, and light manufacturing to resource-related heavy manufacturing in many regions led to a rapid increase in CO_2 emissions at the national level. Second, production structure change, especially in construction and services sectors, is an important source of CO_2 emission growth in regions. Some developed regions with vastly improved input efficiency in resource-related heavy manufacturing demonstrate the immense potential for reducing CO_2 emissions in regions lagging in input efficiency. Third, regions with a more developed industrial structure avoided local CO_2 emissions by importing carbon-intensive products while exporting less carbon-intensive but higher-value-added products in the machinery and equipment and service sectors. Several policy implications are also discussed based on the main findings of this study.

1. Introduction

China has witnessed robust economic development during the last 30 years (IIE, 2008). The spectacular economic growth has become a key driver pushing China toward the top rank among the CO_2-emitting countries of the world (Peters et al., 2007; Minx et al., 2011). With widespread international concern recently expressed over China's negative role in its fast-growing CO_2 emissions (IEA, 2012), the country faces a big challenge: how to promote economic development in a way that is environment-friendly and reduces CO_2 emissions as well.

The economic system consists of industrial sectors that are transformed in their scale and structure with economic

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growth, as borne out by the history of economic development in the developed world, as well as developing countries such as China (Chenery et al., 1986; Fan et al., 2003). Meanwhile, industrial sectors are the ultimate emitters of CO_2 in their production process, while important consumers add their share by using products that embody CO_2 emissions. Moreover, CO_2 emission characteristics may differ among regions with different industrial structure because emission intensity varies among sectors (Tian et al., 2012). Thus, industrial structure is an important factor that relates economic growth with CO_2 emissions. Understanding how CO_2 emissions vary with industrial structure change is critical to providing information for the establishment of fine-grained CO_2 emission reduction policies in China.

China is characterized by highly uneven economic growth and industrial structures across its 31 provincial regions in its vast mainland. This great disparity is also reflected in the level of CO_2 emissions in each region (Tian et al., 2011). This situation suggests two key points. First, a regional perspective is important to understanding the industrial structure change and CO_2 emission issues in China. Second, a question arises whether and how changing industrial structure impacts CO_2 emissions across regions. The efforts to solve these questions may provide insights on how to help local governments control the rapid increase in CO_2 emissions from industrial structure change.

Both the rapid growth of CO_2 emissions and the dramatic industrial structure change in China has gained extensive critical attention from scientists. An increasing body of the literature has analyzed, by considering changes in several key driving forces, the reasons behind the rapid acceleration in China's varying CO_2 emission levels. Their results highlighted the tremendous incremental impact from rapid economic growth on increasing CO_2 emissions; the dramatic growth in export and investment was the key source of rising CO_2 emissions both at the national and regional levels (Peters et al., 2007; Weber et al., 2008; Guan et al., 2009; Zhang, 2009; Minx et al., 2011; Tian et al., 2013). Meanwhile, an increasing number of studies have explored how the industrial structure change affects economic growth. This research has indicated that reallocation of resources such as capital and labor from low- to high-productivity sectors promoted industrial structure change in China, which in turn contributed to productivity and economic growth (Chen et al., 2011). The structural shift from secondary to tertiary sectors led to moderate economic growth as the impact of resource reallocation decreased in the course of this shift (Gan and Zheng, 2009; Ji and Liang, 2011).

Although extensive studies have examined China's rapidly increasing CO_2 emissions and the dramatic industrial structure change, the relationship between these two important factors has not been adequately analyzed. Previous studies have merely mentioned the industrial structure viewpoint in a general way and have not provided an in-depth understanding of how structural change impacts CO_2 emissions in the regions of China. Existing studies have seldom considered the detailed effects of industrial structure change on CO_2 emission disparity across various regions of China.

This article aims to bridge the gap by providing a fine-scale analysis on how industrial structure change impacts CO_2 emissions in the regions of China. In this study, we extended previous analyses by (1) examining the general pattern of industrial structure change in the regions, (2) evaluating the impact of industrial structure change on CO_2 emissions in different regions, and (3) providing more detailed policy implications to identify how to balance regional disparities in CO_2 emission reduction under different processes of industrial structure change. This paper is organized as follows. The next section describes the methodology employed in the study and the data used. Section 3 gives an overall picture of industrial structure change pattern in regions of China. Section 4 examines the impact of industrial structure change on CO_2 emissions in regions of China. Section 5 discusses several key implications from our analysis. Section 6 concludes the paper.

2. Methodology and data

2.1. Measuring industrial structure change

Industrial structure change has long been discussed in the field of development economics, and previous theoretical analysis has confirmed widespread industrial structure changes with economic growth across countries (Akamatsu, 1962; Kuznets, 1963; Chenery and Syrquin, 1975; Petty, 1978; Syrquin and Chenery, 1989).

Considering the great disparity in the stages of economic development among regions in China, it is essential that an overall picture of industrial structure change across regions be provided. Previous studies have indicated that over a hundred countries, including China, have followed a logistic or S-type function of industrial structure change with economic growth (Chenery and Syrquin, 1975; Syrquin and Chenery, 1989). We therefore set up the following equation to fit the relationship between industrial structure change and economic growth in the regions of China:

$$x_i = \alpha + \beta_1 \ln y + \beta_2 (\ln y)^2 \quad (1)$$

where x is the dependent variable, representing the share of components in the economic structure (such as primary sector, secondary sector, and tertiary sector); y is the per capita gross regional product (GRP); the subscript i refers to different components in the economic structure; and α, β_1, and β_2 are fitted parameters.

Besides the general pattern of industrial structure change, the internal structure change within the secondary sector is also important to understand the industrialization process in the regions of China. Industries with larger shares in the local economic structure imply a dominant position, and the increasing trends in industrial shares also indicate their growing importance in the local economy. Thus, a simple and clear indicator to reflect these relative changes can be expressed as follows:

$$S = \frac{L_i}{\sum_i L_i} \quad (2)$$

where S refers to the industrial structure and L_i to the output in sector i.

Moreover, the ratio between the relative shares of different categories can reflect the degree of change in industrial structure. For example, a high ratio of heavy manufacturing to