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Industrial structural transformation and carbon dioxide emissions in China

Xiaoyan Zhou [a,*], Jie Zhang [b], Junpeng Li [c]

[a] School of Business, University of International Business and Economics, Beijing 100029, P R China
[b] Institute of China's Economic Reform & Development, Renmin University of China, Beijing 100872, P R China
[c] Department of Sociology, Columbia University, NY 10027, USA

HIGHLIGHTS

- ► Relationship between the transformation of industrial structure and CO_2 emissions in China.
- ► Dynamic panel data model.
- ► Industrial structural adjustments can effectively reduce current CO_2 emissions.
- ► Technical progress leads to decreasing CO_2 emissions through upgrading of industrial structure.

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ABSTRACT

Using provincial panel data from the period 1995–2009 to analyze the relationship between the industrial structural transformation and carbon dioxide emissions in China, we find that the first-order lag of industrial structural adjustment effectively reduced the emissions; technical progress itself did not reduce the emissions, but indirectly led to decreasing emissions through the upgrading and optimization of industrial structure. Foreign direct investment and intervention by local governments reduced carbon dioxide emissions, but urbanization significantly increased the emissions. Thus, industrial structural adjustment is an important component of the development of a low-carbon economy. In the context of industrial structural transformation, an effective way to reduce a region's carbon dioxide emissions is to promote the upgrading and optimization of industrial structure through technical progress. Tighter environmental access policies, selective utilization of foreign direct investment, and improvements in energy efficiency can help to reduce carbon dioxide emissions.

1. Introduction

Over the past century, in particular the last three decades, there have been significant global climate changes, of which global warming is the most alarming. With the increasing pace of global economic development, there has been a rise in demand for energy for human activities. More and more studies have demonstrated that the rising level of carbon dioxide (CO_2) emissions may be the leading contributing factor in global climate change (Intergovernmental Panel on Climate Change, 2007). As a consequence, CO_2 emissions have attracted a great deal of attention from various government agencies, academia, and the general public. According to data from the United Nations (2011), China's CO_2 emissions have surpassed those of the United States, becoming the highest in the world in 2006. Although China's per capita emissions only account for one-fifth of those of the United States and one-half of those of the United Kingdom, and are below the global average (4.3 t), with China's rapid and sustained economic growth, emissions will predictably keep increasing. This prediction has brought mounting pressure from the international community.

As part of the national strategy to change China's mode of economic growth, in recent years, the Chinese government has adopted an array of aggressive measures to reduce CO_2 emissions, and has set both short-term and long-term reduction goals. Due to China's size, its industrial structure and technology display huge discrepancies between regions, thus the rapid increase in emissions should not be solely attributed to the increase in fossil fuel consumption—it has a deeper set of roots. Therefore, to reduce CO_2 emissions, the first step should be to analyze the long-term, structural driving forces behind them. The research of Roberts and Grimes (1997) showed that the level of economic development is a major determinant of CO_2 emission intensity. If that is the case, we expect the ongoing transformation of China's industrial structure to be a structural factor that affects the CO_2 emission intensity. In this paper, we seek to test this hypothesis.

* Corresponding author. Tel.: +86 10 13811919800.
E-mail addresses: njulily@126.com (X. Zhou), zhangjie0402@ruc.edu.cn (J. Zhang), jl3023@columbia.edu (J. Li).

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More specifically, we make the following contributions. First, we are the first to employ the widely recognized framework developed by the Intergovernmental Panel on Climate Change (IPCC) to estimate the intensity of China's CO_2 emissions from the consumption of coal, petroleum, and natural gas in 1995–2009. Second, we are the first to study the relationship between industrial structural transformation and the intensity of CO_2 emissions in China. Third, we improve previous methods by introducing an interactive effects model. We use technical progress as the moderator variable to investigate the effect of the interaction between technical progress and industrial structural transformation on CO_2 emissions. We apply the system generalized method of moments (SYS-GMM), and compare the fitted values of different models, which enable us to more accurately determine the effect of industrial structural transformation and technical progress on China's CO_2 emissions.

2. Literature review

Existing research on CO_2 emissions in social sciences focuses on the determinants of per capita emissions, as well as the relationship between economic growth and various indexes of environmental quality, using the environmental Kuznets curve (EKC) (Grossman and Krueger, 1995). The index of environmental quality that is adopted in most empirical studies is sulfur dioxide (SO_2), rather than CO_2, and these two approaches often come to different conclusions.

Grossman and Krueger (1995) argued that economic growth affects the environment by expanding the scale of economic activity, altering the industrial structure, and improving the techniques of production. Many studies have shown that the industrial structure is an important determinant of the intensity of CO_2. A number of studies conclude that secondary industry is the leading producer of CO_2 emissions (Cole, 2008; Panayotou, 1997; Fisher-Vanden et al., 2006; Talukdar and Meisner, 2001), although some have challenged this assertion (Jorgenson, 2007; Stefanski, 2009).

In terms of China's CO_2 emissions, Ang et al. (1998) used the logarithmic mean Divisia index (LMDI) method to study CO_2 emissions in China in 1985–1990, and identified a large positive effect associated with the change in industrial production, and a large negative effect associated with the change in sectoral energy intensity. Wu et al. (2005) decomposed the driving forces behind China's CO2 emissions, and showed that the effect of economic scale contributed to intensifying CO_2 emissions, while technical progress and economic structural adjustment inhibited CO_2 emissions. Wang et al. (2005) decomposed CO_2 emission intensities in China from 1957 to 2000, and found that technical progress, represented by improving energy intensity, was the most significant factor leading to emission reduction; the structural adjustments of the energy sector also decreased CO_2 emissions, while economic growth had a positive effect on emissions. Xu et al. (2006) and Wang et al. (2010) employed similar methods to investigate the contributing factors to per capita CO_2 emissions in China, but came to different conclusions. Xu et al. showed that economic development had exponentially contributed to China's per capita CO_2 emissions, while the contributions from both energy efficiency and energy structure to decreasing per capita CO_2 emissions displayed an inverted-U shape. Wang et al. decomposed China's CO_2 emissions from energy consumption into 11 driving forces, identifying per capita gross domestic product (GDP), number of vehicles, total population, economic structure, and average annual household income as positive forces, and energy intensity in the productive sector, length of transportation routes per vehicle, and household energy intensity as negative forces.

Liu et al. (2007) examined CO_2 emissions from 36 industrial sectors in China in the period 1998–2005, and claimed that industrial activity and energy intensity were the major factors contributing to the changes in the emissions. Cole (2008) analyzed data on Chinese industry specific emissions in 1997–2003, and found that an industry's energy use and human capital had a positive effect on its emissions, while an industry's productivity and research and development expenditure had a negative effect on its emissions. Feng and Zou (2008) used the modified Kaya identity to conduct decomposition without residues on China's CO_2 emissions from 1971 to 2005, and pointed out that economic development and demographic growth were the major factors accounting for the emissions, while improvement in energy efficiency contributed to emission reductions. Zhang et al. (2009) found that economic development had the most significant positive effect on the emissions from major economic sectors, while decreasing energy intensity had a significant negative effect on emissions. Ang (2009) analyzed China's CO_2 emissions in 1953–2006 in the framework of endogenous growth, and found that emissions were negatively associated with research intensity, technology transfer, and the absorptive capacity of the economy to foreign technology, and that emissions were positively associated with energy use, income, and trade openness. Song and Lu (2009) emphasized the varied effects of different modes of economic growth. Using cointegration methods, Lin and Liu (2010) found that China's CO_2 emissions were affected by energy intensity, carbon intensity of energy use, and urbanization level.

While technical progress makes the reduction CO_2 emissions possible, its exact impact is difficult to fathom because of the rebound effect (Khazzoom, 1980).[1] In general, technical progress is considered to be conducive to the improvement of energy efficiency of a single product or service. However, when the economy is taken as a whole, technical progress does not necessarily lead to the reduction of energy consumption, and may even increase energy demand (Brookes, 1990). To make sense of the rebound effect, researchers have reached a certain consensus, which Saunders (1992) named the "Khazzoom–Brookes postulate." According to the postulate, from a macroeconomic perspective, reductions in energy intensity may be counterbalanced by increasing energy demand. More specifically, although technical progress improves energy efficiency and consequently reduces CO_2 emissions, it creates new demand for energy, which partly cancels out the effect of energy saving. Therefore, the rebound effect greatly adds complexity to the measurement of the effect of technical progress on CO_2 emissions.

The assertion that industrial structural transformation is conducive to energy efficiency has been confirmed by many studies. Sue Wing and Eckaus (2007) showed that industrial structural change and technical progress largely accounted for the declining energy intensity in the United States during the last four decades of the 20th century. Xu and Jiang (2007) concluded that structural changes had the most profound impact on energy efficiency in the United States during the period 1980–2004. Similarly, Shi (2002) claimed the importance of industrial structural change on energy efficiency in China. In brief, improvement in industrial structure facilitates the flow of various factors, including energy, from low-efficiency sectors to high-efficiency sectors, and therefore reduces energy intensity and carbon emissions.

In this paper, we use cross-regional panel data from the period 1995–2009 to investigate the relationship between the industrial structural transformation and CO_2 emissions in China. Rather

[1] The rebound effect was first raised by Jevons in 1865, but was not widely discussed and brought to the policy level until the early 1990s.