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Research article

Changes to pollutants and carbon emission multipliers in China 2007–2012: An input-output structural decomposition analysis

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ABSTRACT

This study performed an input-output structural decomposition analysis on changes in COD, ammonia nitrogen, SO_2, NOx, soot and dust, industrial solid waste, and CO_2 emission multipliers for 41 final products over the period 2007–2012 in China. The results show that during the examined period, emission multipliers were, in general, decreasing. The main driver of this was technical effects. The effects that made a significant contribution were concentrated in eight sectors: coal mining and washing; metals mining and quarrying; food and tobacco products; paper printing manufacturing; the chemical industry; non-metallic mineral products; metal smelting and rolling processing; and electricity, heat production, and supply. Moreover, the technical effects presented an obvious spillover. Although the contribution of the structural effects was far less than the technical ones, there were still some structural adjustments that led to significant synergistic mitigation. For example, the decrease in the direct demand of the agriculture products, electricity, and heat for food and tobacco products commonly reduced SO_2, NOx, and CO_2. In addition, four technical effects and most of the structural effects with high efficiency made small contributions. More than one third of the structural effects that showed obvious contributions played a positive role.

1. Introduction

The high-speed economic growth of China has been accompanied by an over-reliance on the consumption of material resources and serious environmental problems. In 2014, China accounted for approximately 11% of the world's oil consumption, 49% of its coal consumption, 26% of the world's sulfur dioxide (SO_2) emissions, and 28% of its nitrogen oxide (NO_x) emissions; almost all kinds of pollutants emitted in China rank the highest in the world and far exceed the country's own environmental capacity limit (Xue and Zhao, 2014). This results in fog and haze, urban malodorous black water, unsafe drinking water, and other severe environmental issues.

In fact, the Chinese government has emphasized the importance of environmental problems for a long time. As early as 1980, the "Sixth Five-year Plan" stressed that environmental protection must be strengthened to prevent further pollution of the environment. Subsequently, starting in the "Seventh Five-year Plan," quantified emission reduction targets were established; for example, 50%–70% of the main industrial pollutants were to achieve national emissions standards by 1990. The severity of the mitigation targets has gradually increased in recent years. The "Thirteenth Five-year Plan" (Ministry of Environment Protection of the People's Republic of China, 2016) states that chemical oxygen demand (COD) and ammonia nitrogen emissions are to be reduced by 10% and SO_2 and NO_x emissions by 15% by 2020 compared to 2015 levels. The government has also proposed many mitigation measures. For example, the "Thirteenth Five-year Plan" proposed the acceleration of ultra-low emissions and an energy-saving renovation project for coal-fired power plants, the comprehensive up-to-standard discharge treatment project for key industries, the "coal to gas" and "coal to electricity" project in Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta.

However, the overall deteriorating environmental situation has

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not yet been ameliorated in China. For example, water pollution is still serious in key areas such as the Bohai Sea, the Huai River, and the Taihu Lake. Emissions of major pollutants in some regions such as Beijing-Tianjin-Hebei and the Yangtze River Delta still exceed environmental capacity and frequently cause severe haze (Ministry of Environment Protection of the People's Republic of China, 2011).

One important reason behind the current difficulties in implementing environmental management is that, at present, the idea of end-of-pipe treatment still prevails in China. The essence of end-of-pipe treatment is "pollution first, treatment later"; thus, it only cures the *symptoms*, not the *disease*. On the one hand, the limitation of existing technologies makes it difficult to thoroughly eliminate environmental emissions. On the other hand, the sustained relatively high-speed growth of China's economy continues to drive the quantity of emissions generated and hence places greater pressure on the end-of-pipe treatment. To facilitate solutions to environmental problems, it is necessary and probably more critical to determine how to alleviate or avoid the occurrence of environmental emissions. For this purpose, the key influential factors of environmental emissions should be examined and employed.

These influential factors are both direct and indirect. The direct factors include economic size, structural change, and technical progress (Carvalho and Almeida, 2009; Grossman and Krueger, 1995; Verbeke and Clercq, 2002). The indirect factors include environmental damage, environmental awareness, the structure of government (or environmental regulation), trade, and market imperfection (Mc Ausland and Millimet, 2012; Verbeke and Clercq, 2002). Studies show that the indirect factors generally affect environmental quality by changing the direct factors. For example, Copeland and Taylor (2003) claimed that international trade indirectly affects the environment via direct factors that produce environmental emissions such as scaling up production and changing trade structures while promoting technical progress. Porter and Linde (1995) believed that rational environmental regulation policy could signal possible resource inefficiency or potential technical innovation to companies and motivate them to generate innovative compensation methods in the face of higher pollution control costs, thereby indirectly affecting emissions. Given that the direct factors play a leading and more straightforward role in the environmental quality situation, indirect factors are not addressed in this study.

In terms of direct factors, here, the factor of economic size is not addressed. It is obvious that there is a positive correlation between economic size and environmental emissions: the larger the economy, the more input and resource consumption, and thus, more emissions. However, it is unreasonable to achieve emissions reduction by compressing a country's economic size, especially for a developing country such as China. Although the idea of moderate and new-normal economic development is currently promoted in China, emissions mitigation achieved by such moderate economic growth policies would be limited. The Chinese economy still has much room for growth considering the accelerating urbanization process, upgrading of infrastructure, and services becoming a new growth engine. Therefore, at least in the near future, emissions mitigation will have to rely on economic restructuring and technical progress, which are the two effects this study focuses on.

There have been many studies about the influence of technical progress and structural change on environmental emissions. Most of these focused on either one or the other. However, it is meaningful to focus on both (Akpan et al., 2015; Marsiglio et al., 2016; Zhang and Qi, 2011) as technical progress addresses the emissions efficiency of each sector, while structural change addresses the interrelationship among different sectors. A comprehensive analysis of these two can help pinpoint the emissions delivery channels throughout the whole economic system. Until now, only a few studies have focused on the effects of both structural change and technical progress (Llop, 2007; Pasche, 2002; Philip et al., 2012). Wang et al. (2013) found that industrial restructuring promoted economic development but increased pressure on the environment, while technical advancement and innovation offered important reductions in emissions into the environment. Guo et al. (2015) studied the optimal economic development roadmap for the manufacturing sector on the basis of the constraints of environmental emissions reduction and indicated that technical progress makes it possible to reduce pollution, and industrial structure adjustment is also crucial. Lei et al. (2012) studied the influential factor of COD and ammonia nitrogen using the logarithmic mean Divisia index decomposition method and found that structural change helped to reduce two pollutants to a small extent, and the technical level of each sector effectively promoted the reduction of pollutant discharge. In general, there are few such studies, and most have not been refined to the sector level. This study contributes to the existing literature by performing a sector level analysis and comparing the effects of structural change and technical progress on the environmental quality of China.

As for the indicators describing environmental quality, most existing studies use total emissions or emissions per unit of output. This study uses neither an indicator of total emissions, which inevitably includes the effect of economic size, nor an indicator of emissions per unit of output, which is production-based. Here, a consumption-based (or demand-side) indicator is adopted, which is called the emission multiplier. The emission multiplier represents the amount of emissions generated by an exogenous change in final use and thus, can measure the direct and indirect effects of this change. Final use refers to the troika of a country's economic development, namely, consumption, investment, and exports. Adopting such an indicator not only eliminates the effect of economic size, and thereby, reflects the efficiency of mitigation, but also further reflects the effects of the factors that fundamentally drive up various environmental emissions. Such consumption-based indicators have been attracting increased attention in the field of climate change, but they still lack attention in the field of local pollution. Thus, employing such an indicator is a second contribution of this study.

Another potential contribution is that multiple types of environmental emissions are considered simultaneously. Most related studies focus on only one pollutant. However, environmental pollution in China is "compound" and "extruding" (Liang, 2006). That is, because of China's rapid economic growth in recent decades, a variety of pollutants are being discharged and generating superposed effects, which leads to composite pollution that is difficult to solve by relying on the control of a single pollutant. Moreover, taking multiple environmental emissions into account helps to achieve co-benefits and avoid duplication of governance, thereby realizing the emission control goals more cost-effectively and lowering corresponding socio-economic shocks.

Accordingly, this study examines the change in the multiple emissions multipliers (COD, ammonia nitrogen, SO_2, NO_x, soot and dust, industrial solid waste, and CO_2) for 41 final use products over the period of 2007–2012 and then analyzes and compares the contribution of structural change and technical progress among various sectors on different emission multipliers. The rest of the paper is organized as follows. Section 2 describes the methods and data sources used. Section 3 describes the results. Section 4 provides the main conclusions.

2. Methods and data

The core method of the study is a combination of an input-output model with structural decomposition analysis techniques.