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The effect of technological factors on China's carbon intensity: New evidence from a panel threshold model

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ABSTRACT

Despite the wealth of literature, there is no consensus regarding the effects of the technological factors, including indigenous research and development investment (R&D), foreign direct investment (FDI) and trade, on carbon intensity in China. In this study, using panel data consisting of 30 Chinese provincial-level regions between 2000 and 2014, an extension of the CH-LP framework is first employed to control for the disparity between different proxy variables for FDI and trade in the previous literature. The effects of both indigenous R&D and technology spillovers in the formation of FDI and trade on carbon intensity are investigated in depth by utilizing both linear and nonlinear analyses. The linear empirical results indicate that both indigenous R&D and import's technology spillover play a significant role in decreasing China's carbon intensity. The technology spillovers originating from FDI and export are also beneficial to the reduction of China's carbon intensity. Further estimation results based on the nonlinear analysis indicate that the local technology absorption capacity affecting factors such as human capital, indigenous R&D and the full-time equivalent of R&D personnel are crucial for determining the level of carbon intensity.

1. Introduction

Energy is vital to all economic activities and human well-being. Since launching a nationwide economic reform and open-door policy in 1978, China has experienced rapid economic growth, with the average annual growth rate of its gross domestic product (GDP) being 9.66% during the period 1978–2015 (National Bureau of Statistics of China, 2016). In addition, China has a rich endowment of coal resources. The rapid economic growth and endowment in coal resources to some extent has caused the extensive use of fossil energy and high CO_2 emissions in China (e.g., Lin and Moubarak, 2014; Liu et al., 2016). As of 2011, China overtook the US as the world's largest energy consumer. Moreover, China has been the biggest CO_2 emitter since 2007, and China's emissions of various air pollutants, particularly SO_2, have long been the highest in the world. As such, China's energy policies and environmental policies on CO_2 and SO_2 emissions have become hotly debated issues that attract worldwide attention.

Because the carbon intensity (calculated as the ratio of CO_2 emission to GDP) is one of the most important indexes and references to control for CO_2 emissions (Su and Ang, 2015; Liu et al., 2015), the Chinese government at various levels (including the State Council, National Development and Reform Commission, etc.) have formulated a series of national environmental protection goals to lower carbon intensity (Yang et al., 2014; Liu et al., 2015, 2016; Dong et al., 2016; Zhang et al., 2017). Therefore, to fulfill these ambitious national goals of controlling CO_2 emissions, it is critical to analyze the change mechanisms and dynamics of the carbon intensity, which may help China's policymakers better understand the influential factors and obtain detailed information for future reasonable and suitable energy strategies and CO_2 emissions reduction policies.

For the literature concerning the driving forces of the carbon intensity, most of the extant studies have come to a consensus that the

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major changes in carbon intensity could result from energy intensity reduction or sectorial composition involving economic and energy consumption (e.g., Lan et al., 2012; Xu et al., 2014; Yang et al., 2014; Su and Ang, 2015; Liu et al., 2015; Dong et al., 2016 Wang et al., 2016). However, very few studies have specified the mechanisms through which the carbon intensity could be reduced with solid empirical evidence, because the declining energy intensity may also be affected by many factors such as innovations in technology or an upgrade in energy mix and economic structure. Moreover, technological progress plays a significantly important role for improving environmental performance, and technology spillover is an important source of technological progress.[2] Specifically, the technological factors include indigenous R&D activities and technology spillover coming from openness in the form of foreign direct investment (FDI) and trade that may enhance the environmental quality were identified by existing studies (e.g., Ang, 2009; Perkins and Neumayer, 2011; Guo et al., 2012; Ren et al., 2014; Yang et al., 2014; Seker et al., 2015; Shao et al., 2016; Liu et al., 2017; Behera and Dash, 2017; Huang et al., 2017a, 2017b). However, to the best of our knowledge, how and to what extent the technology spillovers can influence the carbon intensity is still an open question.

Moreover, the effect of these technological factors on the environmental performance could be heavily affected by the host country's specific characteristics, such as the technological gaps, the human capital stocks, and the financial development (Ang, 2009; Lan et al., 2012). Ang (2009) also argues that the increase in domestic R&D activities could help the domestic economy assimilate technology developed in the leading countries more effectively. Thus, the indigenous R&D activities exert both direct and indirect beneficial influences on abating the carbon intensity. Lan et al. (2012) investigate the effect of FDI on pollution emissions intensity in China. The researchers report that FDI is negatively associated with pollution emissions in provinces with higher levels of human capital, whereas it is positively related to pollution emissions in provinces with the lower levels of human capital. Yang et al. (2014) investigate the effects of indigenous R&D and R&D spillovers in the form of FDI and trade on China's industrial carbon intensity. The researchers find empirical evidence that the effect of R&D spillover on carbon intensity depends on local R&D expenditure. In a recent study, Huang et al. (2017a) find that the effects of technology spillovers on energy intensity are highly related to indigenous R&D activities.

Thus, this paper is distinct from the previous studies in the following three aspects. First, the effects of indigenous R&D, technology spillovers in the formation of FDI and trade on carbon intensity are accessed within a comprehensive framework. Second, by employing the panel threshold model, this study fully accounts for regional heterogeneity and examines whether and how the influences of technology spillovers on China's provincial carbon intensity vary over time. Third, by fully considering the characteristics and situations of various technology spillovers, the diversified policies and measures aimed to encourage a low carbon route for China are presented.

The structure of the rest of this paper is as follows. Section 2 reviews the related literature. In Section 3, the methodology and the data management are briefly discussed. The results based on linear and nonlinear regression methods are presented in Section 4. The final section concludes and provides relevant policy implications on carbon reduction in China.

2. Literature review

The sustained increase in greenhouse gas (GHG) emissions, particularly CO_2 emissions, has inspired an extensive amount of studies. Literature that addresses factors influencing carbon emissions can be roughly classified into two categories according to their methods.

The decomposition method is an important tool. Both structural decomposition analysis (SDA) and index decomposition analysis (IDA) are popular decomposition analysis approaches (Zhang et al., 2009; Choi and Ang, 2012; Lv et al., 2014; Zhang and Da, 2015). These studies have been conducted in various countries and regions or industries, which serve as an effective tool for identifying factors influencing changes in carbon emissions. Nobuko (2004) finds that changes in production technology contribute to the decrease in CO_2 emissions by employing the SDA for Japanese industries during 1985–1995. Zhang (2010) analyses the impact of economic development mode transformation on China's carbon intensity between 1987 and 2007 based on SDA, and the results illustrate that the economic development mode has caused China's carbon emission intensity to decline by 66.02%, while the remaining 33.98% has for the most part resulted from structural changes. Zhu and Zhang (2011) use the logarithmic mean divisia index (LMDI, one of the most important IDA methods) method to analyze the carbon intensity of Shanghai (one of the most important China's municipalities) from 1995 to 2008 and show that the reduction in energy intensity is the main reason for the decline in carbon intensity; however, the adjustments in energy mix and industrial structure are minor driving forces behind the decline in carbon intensity. Xu et al. (2014) investigate five driving factors: energy intensity, energy mix, economic output, industry structure and population scale on carbon emissions using the LMDI method. The result indicates that the economic output effect is a main driver of carbon emissions, while the energy intensity effect is the major inhibitory factor. Zhang and Da (2015) utilize the LMDI method to decompose the changes in China's carbon emissions intensity over the period 1996–2010. The results report that economic growth appears to be the major driver of carbon emissions, while energy intensity is the main source of the decline in carbon intensity. Most of the decomposition literature has reached a consensus that energy intensity reduction should be responsible for the declining carbon intensity and that the structural changes are also important factors affecting the carbon intensity. However, many other factors behind energy intensity such as technological progress and urbanization, etc. are difficult to incorporate into these studies; consequently, no further detailed contributions of these factors can be included.

Econometrics analysis is another critical and popular approach in carbon intensity research. In contrast to the decomposition analysis, econometrics not only incorporates the variables omitted in the decomposition analysis but also avoids the administrative intervention conclusions drawn by the decomposition approach to a great extent (Zhu et al., 2014). According to the empirical evidence provided by this literature, due to technological progress and economic structure or energy mix adjustment, the carbon intensity in most countries and regions has declined to some distinct extent.

Regarding the net effect of technological progress, it could be influenced by indigenous R&D, technology spillovers through FDI and trade. Hence, the effects of indigenous R&D and technology spillovers on environmental performance have received great attention in empirical studies.

Indigenous expenditures on R&D have been recognized as one of the major avenues to accelerating technological progress and improving production efficiency in the endogenous growth literature. Indigenous expenditures on R&D can be expected to lead to the development of new technologies, and the R&D activities related to the creation of clean technology will better protect the environment. Generally, R&D efforts have a wider scope than improving environmental performance; however, they may still have measurable effects on energy or carbon intensity. Cole et al. (2008) examine the determinants of environmental pollution for China using industry-level data between 1997 and 2003. The researchers show that productivity improvements and research activities can reduce emissions. Tamazian et al. (2009) report that

[2] According to the previous work of Coe and Helpman (1995), the technology spillover could be defined as follows: in a world of rapid globalization, the more advanced technologies and managerial experiences of foreign countries may have positive externalities through their interactions with domestic firms, which in turn would lead to productivity improvement in the host country.