



The effect estimation and channel testing of the technological progress on China's regional environmental performance



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ABSTRACT

To study the effects of and approaches to technological progress on China's regional environmental performance, this study first estimates China's regional environmental performance and its variation indexes by applying a slack-based model (SBM) and an entropy-based model (EBM). The results indicate that the environmental performance in different regions of China has improved, but the rate of improvement differs greatly. This may be attributed to heterogeneous characteristics and changes in the green technology innovation level in different regions. Considering the overflow effect of environmental pollution among different regions, we study the impact of various technological progress patterns on China's regional environmental performance using spatial econometrics, and we find that there are significant spatial effects of technology innovation, technology transfer, and imitative innovation on China's regional environmental performance. Also, different technological progress patterns have different effects. Specifically, independent innovation has failed to effectively improve regional environmental performance, whereas the introduction of technology and imitative innovation have significantly improved this performance. Moreover, after the cross-items of independent innovation and human capital are introduced, the effects of technology introduction and imitative innovation on China's regional environmental performance through the absorptive capacity of human capital remain significant, whereas the effect of independent innovation on regional environmental performance via the absorptive capacity of human capital becomes more obvious. Based on this and from the perspective of environmental enhancement, we believe that China should strengthen human capital accumulation and give consideration to imitative innovation and technology introduction while emphasizing independent innovation.

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1. Introduction

In recent years, the problem of global climate change has increasingly attracted the attention of scholars and officials. China's annual economic growth rate of 9% since the reform and opening-up policy in 1978 has inevitably led to a rapid increase in energy consumption and environmental pollution. Auffhammer and Carson (2008) believed that China's per-capita carbon emissions would continue to rise rapidly for a long time and exceed the range stipulated in the *Tokyo Protocol*, imposing significant negative effects on China and the world. For this reason, the *Copenhagen Accord* was reached by China, the United States, India, and other countries on December 9, 2009. There, the Chinese government announced that China's carbon emission intensity would be 40–45%

lower in 2020 than in 2005, fully demonstrating the sincerity and determination of China in response to global climate change.

However, China still lacks a set of scientific and complete evaluation systems to accurately estimate environmental performance.¹ Most studies have initially focused on energy consumption and future carbon dioxide emissions development trends. Relative to these studies, an increasing number of studies have started to review influencing factors. Cole et al. (2008) studied the key impact factors of environmental pollution based on industry-

¹ Generally speaking, environmental performance refers to changes in the environment. The center for environmental law and policy at Yale University developed a standard environmental performance index (EPI) to measure environmental performance. According to the characteristics of China, this study uses industrial output, waste gas emissions, wastewater discharge, and waste discharge for 30 provinces (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2000 to 2011 as desirable and undesirable output indexes. The environmental performance of each region from 1997 to 2011 is estimated and analyzed using the entropy-based model (EBM)–Luenberger index.

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level data from 1997 to 2003, concluding that energy use and human capital have a positive impact on emissions at the industry level that are mainly attributed to productivity improvements and R&D activities that reduce carbon emissions. Alternatively, [Ang \(2007\)](#) first attempted to combine the environmental impact equation with endogenous growth theory and shifted his attention to the impact of R&D activities and technology transfer on environmental pollution reductions. He found that energy use, high income, and trade openness would create more environmental pollution, whereas technology transfer, R&D activities, and absorptive capacity would reduce environmental pollution.

Overall, technological progress is a key factor influencing economic growth and environmental performance. The reasons are as follows: first, technological progress is the mainspring of sustainable economic growth; second, technological progress may increase or decrease environmental pollution ([Popp et al., 2009](#)). This can affect environmental pollution in two ways: (1) technological progress drives economic growth, influencing environmental pollution indirectly (i.e., “technological progress – economic growth – environmental pollution”) (2) technological progress affects environmental pollution directly (i.e., “technological progress – environmental pollution”). However, because technological progress relies on certain paths, the direction of the direct effect is uncertain. If an enterprise uses unclean technology to gain profits at the initial phase, the new technology it develops may remain unclean and increase carbon dioxide emissions and weaken environmental performance; by contrast, if the enterprise relies on clean technology at first, it may further develop clean technology, reducing carbon dioxide emissions ([Acemoglu et al., 2009](#)) and improving environmental performance. Thus, we seek the combined effect of technological progress on environmental performance and under what conditions we can guarantee economic growth while reducing environmental pollution. Furthermore, we would like to determine the effect of China's technological progress on environmental performance. On the basis of a theoretical model, this study makes full use of province panel data to conduct empirical testing and resolve these issues.

Specifically, by referencing relevant literature at home and abroad and combining the research framework of [Ang \(2007\)](#), this study divides technological progress into independent innovation capability, technology transfer, and imitative innovation and then introduces the concept of environmental performance. Thereafter, it evaluates and analyzes environmental performance and how it varies for each region from 2001 to 2011 using EBM–Luenberger indexes. To obtain more robust measurements and calculations and to ensure follow-up empirical analysis, this study follows robustness requirements for performance measurement of [Cooper et al. \(2007\)](#). It applies a non-radial slacks-based model (SBM) of undesirable outputs and a hybrid-radial EBM model of undesirable outputs to measure environmental performance and its variation index. Considering the overflow effect of environmental pollution among different regions, this study reviews the spatial effect of technology innovation, technology transfer, and imitative innovation on China's regional environmental performance and further describes the channels of technological progress that affect regional environmental pollution. Next, it provides relevant policy suggestions by constructing an equation based on endogenous growth theory that analyzes the impact of technological progress on environmental performance using the estimated results and applying a spatial econometric panel data model.

2. Literature review

Studies on technological progress, economic growth, and environmental performance can be grouped into two types. The first type is theoretical research that incorporates pollutant

discharge in growth models. Early studies have paid more attention to the impact of economic growth on the environment within the framework of the neoclassical growth model based on technological progress. [Nordhaus \(1977\)](#) analyzed the effect of economic growth on environment and built a dynamic integrated model of climate change and economy (DICE model) to analyze the relationship between economic growth and the environment. [Selden and Song \(1995\)](#) and [Dinda \(2005\)](#) analyzed the impact of economic growth on pollutant discharge within the framework of the neoclassical growth model.

The other type is empirical research, which involves the analysis of an environmental impact model based on population, affluence, and technology (IPAT) and the verification of the environmental Kuznets curve (EKC). [Ehrlich and Holdren \(1971\)](#) first proposed the IPAT model. They believed that environment-influencing factors include population (P), affluence (A), and technology (T). [Dietz and Rosa \(1994\)](#) introduced a random factor based on the IPAT model and extended the model. Some researchers used this extended model to explore the impact of technological progress and economic growth on carbon dioxide emissions. The hypothesis of the EKC was derived from the empirical analysis of [Grossman and Krueger \(1991\)](#) on the relationship between economic growth and pollutant discharge. Their claim, called the EKC hypothesis, was that the relationship between economic growth and pollutant discharge was in an inverted U shape. Grossman and Krueger believed that the reduction in pollutant discharge resulted from an enhanced technological effect. [Holtz-Eakin et al. \(1995\)](#), [Richmond and Kaufmann \(2006\)](#) verified the relationship among technological progress, economic growth, and carbon dioxide emissions using the EKC hypothesis. However, because they used different data and methods, the results varied greatly.

A number of empirical studies confirmed the existence of endogenous technological progress ([Newell et al., 1999](#); [Popp, 2004](#)), which has revealed the analysis of the relationship between economic growth and the environment. Ignoring endogenous technological progress may exaggerate the environmental impact of economic growth. A number of studies have started to explore the relationship between economic growth and the environment within the framework of the endogenous growth model. Representative literatures include [Nordhaus \(1977\)](#), and [Grimaud et al. \(2008\)](#). [Acemoglu \(2009\)](#) divided the growth model into two sectors, clean and polluted, and probed into the impact of economic growth on carbon dioxide emissions. They believed that technological progress relied on certain paths. If an enterprise intonates in the polluted sector, it continues technological innovation in the polluted sector, leading to increased carbon dioxide emissions. These studies all follow the path of “technological progress – economic growth – environmental pollution,” but give no consideration to the direct effect of technological progress on environmental performance.

Although, these studies help us understand the relationship among technological progress, economic growth, and environmental pollution, they were based on data and lacked a theoretical basis. Moreover, as technological progress is unobservable, most studies used proxy variables to represent technological progress, failing to accurately reflect the effect on environmental performance. Simply, existing studies have failed to fully consider the overflow effect of regional environmental pollution and the direct effect of technological progress on environmental pollution and its impact channels, so it is impossible to determine which technological progress model better promotes China's environmental performance. Thus, to measure this effect, a formula is created in this study based on the basic features of Chinese economic development and current

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