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# Economic growth model, structural transformation, and green productivity in China

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## HIGHLIGHTS

- Two total factor productivities of China are estimated by super-DEA models.
- Investment-driven growth model produces the negative effect on green productivity.
- Various structural transformation have different impacts on green productivity.

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## ABSTRACT

This study investigates the impacts of investment-driven economic growth model, as well as rationalization and upgrading of the industrial structure on green productivity in 30 Chinese provinces over the period 1997–2010. Two total factor productivities (TFP), namely energy adjusted TFP and energy and carbon dioxide emissions adjusted TFP (denoted as *TFEE* and *TFCE* respectively), are estimated using super-efficiency DEA models, and used as indices to reflect green productivity performance in China. The main results of the empirical study are as follow: (1) China's economic growth model does not improve both *TFEE* and *TFCE*; (2) the flow of laborers from the primary, secondary, and tertiary industries helps to improve *TFEE* and *TFCE*, while capital transformation does not produce the same effect; (3) the structural changes in the manufacturing industry produce negative and positive effects on *TFEE* and *TFCE* respectively.



## 1. Introduction

It is well known that China's economic growth is mainly driven by huge investment, with investment growth is higher than output growth, and contributing to economic growth more than consumption and net exports. Correspondingly, China's industrial structure is dominated by the industrial sector, particularly energy-intensive industries. According the National Bureau of Statistic of China, fixed asset investment, total industry output, and heavy industry output of the country increased by 18.3%, 10.8%, and 22.7% respectively over the period 1997–2010. These exceeded the annual growth rate of GDP (9.9%), agriculture output (3.9%), services output (10.7%) and light industry output (17.7%). These figures show that the heavy industry is a key player in the industrial sector. In 1997, heavy industry output accounted for 51.0% of the total industrial output, which increased to 71.4% in 2010.

The concepts of the 'Low-Carbon Economy', or 'Green Economic Growth' has received increasing policy and media attention in recent years [1]. Enhancing green productivity is an important way of achieving 'Green Economic Growth'. However, the investment-driven economic growth model and the energy-intensive industrial structure of China have increased energy consumption and deteriorated the environmental resources of the country, thereby undermining green productivity [2–5]. Because of rapid increase in energy consumption, China's $CO_2$ emissions became the highest in the world in 2007 [6]. The need for green development has propelled the government to switch from an extensive economic growth model to an intensive one, and to speed up the rate of industrial structural transformation [7]. This study aims to investigate how the investment-driven economic growth model and structural transformation contribute to the enhancement of green productivity. It also seeks to determine how a country can switch from an economic growth model to

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another, and how the industrial structure can be adjusted to enhance green development.

Energy conservation and emissions abatement is an inherent requirement for green development. Enhancing total factor productivity (TFP), especially the energy and carbon dioxide emissions adjusted TFP, is consistent with the connotation of energy conservation and emissions abatement. In this sense, improving TFP while considering energy input and carbon dioxide emissions reflects green development.

The effect of investment-driven economic growth model on green productivity is among the critical economic issues faced by China. Enhancing energy efficiency is one of the aspects of green productivity improvement. The investment-driven economic growth model in China reduces economic value added (EVA) rate and raises energy consumption growth rate. This makes the growth model unfavorable for the enhancement of energy efficiency [8]. In 1995, the Chinese government claimed that the economic growth model of the country must be gradually switched from extensive to intensive. Cai et al. [9] believed that low per capita income and rapid industrialization and urbanization may hinder the necessary transformation, and undermine energy conservation and $CO_2$ emission reduction. Lin and Su [10] argued that long-term interest and cost of energy should be maintained at low levels to benefit investment-driven economic growth, which would subsequently increase energy consumption and reduce energy efficiency. Chen and Golley [11] believed that much investment and energy consumption was undertaken by large, inefficient state-owned enterprises, and thereby undermined green TFP. Previous studies on investment-driven economic growth model are merely qualitative and conceptual, and neglect its effect on energy and carbon dioxide emissions adjusted TFP or green productivity, which presents a research gap that this study aims to fill.

Energy efficiency is influenced by industrial structure [12–15]. Adjusting the industrial structure directly affects energy efficiency because the input factors, including the energy consumed by various industrial sectors, are reconfigured in the process. Numerous studies that apply the index decomposition method (IDM) have examined the effects of industrial structural changes on energy efficiency [16]. Numerous studies found that during structural changes, the main energy-consuming sectors were upgraded from low-efficiency to high-efficiency sectors, and their energy efficiency was improved as a "structural bonus" [17–22]. However, Lin and Su [10] argued that structural transformation in China, particularly in the manufacturing sector, might hinder or even diminish the enhancement of energy efficiency in the long term. As energy price and capital cost are maintained at low levels to promote extensive economic growth, various resources, including energy, iron, steel, nonferrous metals, and petrochemicals, are allocated to industries that consume large amounts of energy and emit large amounts of $CO_2$ [14].

Structural changes in the industrial sector can influence the input–output efficiency of industries. Timmer and Szirmai [23] found that such structural changes could affect economic growth rate and energy efficiency in the long run. Fan et al. [24] empirically discovered that structural changes could improve economic growth rate and significantly affect energy efficiency. Zheng, et al. [25] found that structural transformation had direct and indirect effects on economic growth and energy efficiency respectively. Zhou et al. [26] found industrial structural adjustments can effectively reduce current $CO_2$ emissions.

Although numerous studies have proven that industrial structural changes can affect the productivity of industries, they failed to describe how such changes affect green productivity through technology spillovers. Fagerberg [27] argued that a flexible industrial structure could promote technology spillover among different industries, which could improve their productivities. Ark and Timmer [28] and Oulton and Srinivasan [29] found that by improving their level of coordination with other industries, the effects of technology spillover from the information and communication industries could be extended to other industries, thereby enhancing their productivities. Isaksson [30] noted that structural changes usually improve the effects of reallocation, which could also increase productivity. By adopting an input–occupancy–output factor analysis model, Chai et al. [31] revealed that structural changes in the industrial sector could indirectly affect energy efficiency through technological spillovers. Yang et al. [32] found that indigenous R&D and interregional R&D spillovers can decrease $CO_2$ intensity, but this effect depends on local R&D expenditure. Boyd and Curtis [33] found most management techniques had beneficial spillovers on energy efficiency, but an emphasis on generic targets would result in decline in energy efficiency.

Schäfer [13] and Hofman and Labar [34] investigated the changes in the ratio of the primary, secondary, and tertiary industries to GDP, and Zhan et al. [35] investigated the structural changes in the manufacturing sectors. They proved that structural transformation could significantly affect energy efficiency in China. However, these studies did not completely cover the influence of structural changes on energy efficiency. Since the 1990s, the structural changes in China mainly occurred among three of its sectors and manufacturing, particularly from light to heavy industries.

Lü and Zhou [36] believed that structural changes could affect productivity through the optimization and upgrading of industries. Optimization affects productivity through allocation efficiency, which stems from the flow and transfer of laborers, capital, and other factors among industrial sectors. Upgrading influences productivity through the development of high-degree and high-value-added industries. An eccentric industrial structure distorts the configuration of resources among industries, which decreases the "structural bonus" of productivity and may even produce a "structural burden". Moreover, such a structure may be detrimental to the technology spillover among different industries, which diminishes the effects of technological progress on productivity.

This study aims to quantitatively analyze the effects of investment-driven economic growth model and energy-intensive industrial structure on green productivity using China as a case study. A simple but novel index is adopted to measure investment-driven economic growth model, which reflects the contribution of investment to economic growth. For structural changes, two aspects of structural transformation in China are considered. The first is the flow and transfer of inputs among sectors which reflects China's switch from an agricultural country to an industrial country. The second is the structural changes among manufacturing sectors which reveals the transformation and upgrading of industrial structure in China in recent years. This study distinguishes itself from previous literature by employing an econometric model or a quantitative analysis rather than a qualitative analysis to investigate the effects of investment-driven economic growth model and structural changes on green development in China.

## 2. Material and methods

This paper first provides the definitions of green productivity, investment-driven economic growth and structural changes, and then specifies the model.

### 2.1. Variables and data source

#### 2.1.1. Green productivity

There are different ways to measure green productivity. In the current study, we measure it by two indices of TFP—the energy