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Scenario-based potential effects of carbon trading in China: An integrated approach

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HIGHLIGHTS

- Carbon dioxide shadow price shows a negative asymmetrical correlation with carbon dioxide emissions in China.
- The implements of carbon trading can bring *Porter Hypothesis* effect significantly.
- Provincial carbon trading can reduce carbon intensity by 19.79–25.24% in China.

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ABSTRACT

Using China's provincial panel data and national panel data of OECD (Organization for Economic Co-operation and Development) and BRICS (Five major emerging national economies: Brazil, Russia, India, China and South Africa), this paper simulates the scenario-based potential effect of carbon trading in China. Analysis methods included Stochastic Frontier Analysis, Difference-in-differences Model, and Nonlinear Programming Technique. Results indicated that in a theory-based view of carbon trading, the shadow price of carbon dioxide generally rises, with a non-linear negative correlation with carbon dioxide emissions. In different regions, the shadow price of carbon dioxide presents a digressive tendency among eastern, central, and western areas, with divergent gaps between and within areas. When the greatest goal is assumed to reduce national carbon intensity as much as possible at the given national GDP (Gross Domestic Product) (Scenario I), carbon trading has the effect of reducing carbon intensity by 19.79%, with the consideration of *Porter Hypothesis* effect. If the rigid constraint of national GDP is relaxed, and the dual constraint of both economic growth and environment protection in each region is introduced (Scenario II), the resulting effect is a reduced carbon intensity of 25.24%. China's general carbon intensity in 2012 was higher than goals set at the Copenhagen Conference, but lagged behind the goal of Twelfth Five-Year Plan for National Economy. This study provides realistic and significant technical support for the government to use in designing and deploying a national carbon trading market.

1. Introduction

Whether viewed from the perspective of environmental protection or politics, controlling greenhouse gas emissions – represented by carbon dioxide – is a worldwide concern for academia and governments. As the largest emitter of carbon dioxide, China was one of the earliest developing countries to integrate environmental protection into basic national policy. China is also one of the member states and advocates of the *UN Framework Convention on Climate Change* (1992) and the *Kyoto Protocol* (1997). At the Copenhagen Conference, China not only promised to substantially reduce carbon intensity, but also specifically brought the goal of cutting down carbon intensity into the national economic plan. However, there are still many poor people in China and the social welfare level is fairly low. Urbanization and industrialization have not been fully achieved, and the country must consider economic growth while also reducing carbon dioxide emissions. Therefore, China needs to invest significant effort in the difficult tasks of achieving both environmental protection and economic development.

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The current reality requires China to promptly implement and improve emission reduction measures based on market mechanisms. These mechanisms include carbon emissions trading, characterized by controlling the amount of emissions. China does not yet have a unified national carbon trading market, nor a mature system that can connect with the other countries' systems. However, the government has recently attached great importance to the domestic carbon trading market construction. Seven areas, including Beijing, Shanghai, Tianjin and Guangdong, have initiated carbon trading pilots. Their goal is to present and explore schemes and models to connect and integrate cross-regional carbon markets.

One discussion topic relates to what *reform dividends* can be achieved through a national carbon trading market. Existing literature addresses this question by applying different methods to simulate and analyze related effects in implementing national carbon trading mechanisms. These studies generally recognize the remarkable results of carbon trading in promoting energy conservation and emissions reduction and reducing Gross Domestic Product (GDP) losses [1–3]. However, the challenge in simulating the relative effect of China's carbon trading is that while models are often based on the cost function of carbon dioxide emissions, these models overlook the role of carbon dioxide as a factor input (essentially serving as fossil energy). Carbon dioxide is actually a power source to product economic output, and has substitution effects with other elements [4,5]. Existing literature on simulation analysis only analyze the direct effect of carbon trading. As such, they only address the degree that implementing the carbon trading mechanism directly reduces the cost of reducing carbon dioxide emissions. This approach does not account for the indirect effect of *Porter Hypothesis* caused by carbon trading. Based on a dynamic standard, Porter holds that a reasonable environmental regulation communicates information to enterprises, by highlighting resource allocation inefficiencies and needs for improved technology. This inspires the *innovation compensation effect*, offsetting the *compliance cost* of enterprises, and increasing their productivity and international competitiveness [6,7]. Carbon trading is an environmentally-regulated policy tool based on market mechanisms; as such, is it assumed to cause the corresponding *Porter Hypothesis* effect, by improving technology level, technical efficiency, and by optimizing the proportions of factor inputs.

This paper uses provincial panel data as examples to advance theoretical research on carbon trading and to inform government policy-makers about the potential effect of carbon trading and formulate relevant policies. Further, on the basis of estimating the carbon dioxide shadow price in all provinces, the study analyzes two scenarios to assess the potential influence of interprovincial carbon trading on overall carbon dioxide emissions reduction, economic growth, and carbon intensity. It also discusses whether carbon trading can effectively support smooth accomplishment of the Copenhagen Conference commitment and the Twelfth Five-Year Plan for the National Economy.

There are several goals for this study. First, the paper introduces the new idea of energy duality, which differs from existing papers that apply the reduction cost function. Instead, the paper focuses on dynamic homogeneity and emission heterogeneity, evaluating energy's shadow price by examining the production function and calculating the carbon dioxide shadow price indirectly. With that analysis complete, the paper then carries out a simulation analysis. This analysis uses international carbon market information to identify the indirect effect of *Porter Hypothesis* caused by carbon trading, and also considers unconstrained and constrained national conditions respectively. Then, based on the differences between provincial aggregated data and national overall data, this paper applies a different approach to more correctly understand the current state and potential effect of reaching lower carbon intensity targets. The paper is organized as follows. The second part presents a literature review; the third part introduces the research methods; the fourth part explains the variables and data; the fifth part analyzes the empirical results; and the last part includes conclusions and policy implications.

2. Literature review

2.1. Is carbon trading more effective than other emission reduction mechanisms?

Studies have shown that market emission reduction mechanisms, compared with traditional administrative regulatory measures such as charging fees and penalties, save transaction costs, promote technology innovation in energy conservation and emission reduction, weaken political resistance, and motivate economic approaches [8,9]. As such, the current debate is not whether market emission reduction mechanisms are superior to administrative supervision measures. Rather, the debate is about the tax associated with reducing emissions and carbon trading [10]. If the information is complete and the transaction costs are zero, the policy effects of these two approaches are the same [11]. As such, the price or the upper emission limit must be set at the point where the marginal reduction cost and marginal reduction benefits are equal [12].

In reality, the demand assumptions are difficult to meet, leading to clear differences in the costs and incentive effects of the two kinds of mechanisms: taxation and trading. In terms of costs, carbon trading has a lower information cost than the carbon taxation; however, implementing the trading mechanism costs more than taxation. In terms of the incentives associated with emissions reduction, carbon trading is more effective than carbon taxation [13]. Under the carbon trading mechanism, once the total emission quota is defined, the government cannot dictate the measures used by discharging enterprises to reduce emissions; however, achieving environmental goals is generally assured [14].

Carbon trading and carbon taxation have advantages and disadvantages. Different emission reduction policies can be set based on specific targets and national characteristics, and these two emission reduction mechanisms are complementary rather than interchangeable. As such, establishing a reasonable joint mechanism is more important than choosing between carbon tax mechanism or carbon trading mechanism [10]. At the preliminary stage of emission reductions, carbon taxation can be promoted more easily because of its low implementation cost. Later, with the gradually popularization of emission reduction practices, carbon trading can then be adopted because of its well-defined overall emission reduction effect, and its potential for international management [14]. Some scholars propose that small businesses and residents pay a carbon tax for consuming carbon-containing fossil energy, while the big companies or big emission sources participate in carbon trading [15].

Internationally, although many countries and areas originally applied only carbon taxation or trading, an increasing number of countries and regions have more recently combined these two mechanisms into a composite policy. Denmark, Finland, the Netherlands, Norway, and other countries joined the European Union (EU) emissions trading scheme after introducing a carbon tax. Mandell's [16] study provided a mathematical model that government departments can use to achieve higher reduction efficiencies and economic efficiencies by adopting carbon trading and taxation at the same time, rather than just applying a single mechanism. Mckibbin and Wilcoxen [17] and Pizer [18] also advocate this approach.