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The impacts of policy mix for resolving overcapacity in heavy chemical industry and operating national carbon emission trading market in China

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HIGHLIGHTS

- A STIRPAT embed dynamic CGE model is utilized to evaluate the whole impact.
- Economy and trade increased slightly under scenario shock.
- Global carbon emission reduction rate ranges from 3.33% to 7.46%.
- Carbon emission peaks in 2022, 2024, 2026 beyond simulating scenarios.
- Energy intensity decreases 19.58–23.71% upon 2020 in contrast with 2015.

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ABSTRACT

In place to reduce greenhouse gas emission efficiently and accomplish carbon emission peak destination ahead of 2030, a variety of policy-based interventions grounded in optimizing energy structure and boosting emission mitigation have been put forward to target carbon-and resource-intensive enterprises across China. Both defusing overcapacity in heavy chemical industry and constructing national carbon trading market are recently attached with a stronger significant importance. A STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) embed dynamic CGE (computable general equilibrium) model is applied in this study to evaluate the simulation effects focusing on China's economy, energy, and household lifestyle. We devise nine scenarios in terms of the two aforementioned mitigation strategies. The results indicate that, the optimal policy mix, balancing economic improvement, energy mix readjustment, and emission reduction to the maximize value, is founded to be declining the proportion of heavy chemical industry capacity with an annual average level of 3%, 1%, 1%, stipulating carbon price in 5.8 dollar/ton, 11.6 dollar/ton, 14.5 dollar/ton, and distributing annual carbon allowance as 3.5 billion ton, 7 billion ton, 9 billion ton during 2017–2020, 2021–2025, and 2026–2030 respectively.

1. Introduction

Global overcapacity problem has been the prominent common challenges in all of the large manufacturing countries. The global steel industry capacity was exceed 230 million ton in 2015 while the apparent consumption was merely 150 million ton according to the data from OECD and WSA (World Steel Association). Thus, there was approximately 80 million ton overcapacity in steel industry in 2015. As the biggest development country in the world, the overcapacity phenomenon has recently been especially remarkable in China. The capacity utilization rate of steel, cement, electrolytic aluminum, flat glass, and vessel industry were significantly lower than the international average level with 72%, 73.7%, 71.9%, 73.1% and 75% in 2012. Based on that seriously overcapacity circumstances, the guidance on resolving serious excess capacity contradictions was released in 2013. Targeted official documents of defusing overcapacity in steel, coal, construction materials, and petrifaction industry were unveiled successively. Herein resolving overcapacity is projected to be the critical emphasis on promoting industrial restructuring.

Zhang et al. [1] studied China's coal overcapacity from coal enterprises and local government, illustrated that the primary cause of the overcapacity is due to government's excessive interventions, and pointed out the coal enterprise's optimal strategy. Wang et al. [2] considered that the overcapacity in PV industry was caused by policy guidance and government's support and

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incentive measures. Nie et al. [3] proposed a system dynamics model to simulate China's coal production capacity under three scenarios with corresponding values, and realized that the overcapacity in coal industry would be a huge challenge for China.

Stabilizing the global temperature rise at 1.5–2 °C is required for unprecedented jointly endeavors concentrating on carbon emission reductions. China submitted the "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions" to Secretariat of the United Nations Framework Convention, announced that China would achieve carbon emission peak around 2030. In view of the reduction effects of EU ETS and CCX, carbon trading market is undoubtedly seen as yielding substantial emission mitigation benefits. A national carbon emission trading market is confirmed to be constructed in 2017 at Paris climate conference. Additionally, substantial correlated policy guidelines have been issued by NDRC (National Development and Reform Commission) preparing for national carbon market.

Tang et al. [4] used a multi-agent-based model to design the initial carbon allowance distribution mode, and analyzed different impacts in environmental and economic aspects. Yang et al. [5] made a survey about factors influencing China's companies' awareness and perceptions of the carbon emission trading market, and indicated that companies didn't regard the emission trading scheme as a cost-effective reduction tool. Munnings et al. [6] pointed out that China's unique institutions need different and deft adjusting instances through finding the carbon emission trading pilots' design. Agnolucci et al. [7] put forward a real-option based investment decision model to research the impacts on low carbon energy investment under the carbon emission trading scheme.

This study aims at making several scientific contributions to the literature. First, the primary objective of our research is to investigate how much does defusing heavy chemical industry overcapacity and how the carbon allowance quantity and carbon price performed in national carbon trading market should be the integrated optimal scheme including for promoting economic growth, reducing energy consumption, reaching carbon emission peak earlier and so forth. Second, in order to facilitate global emission reduction, we also observe how the decreasing proportion of carbon emission from China affects global carbon emission. Third, an improved STIRPAT regression technique is incorporated into our empirical CGE approach. Both CGE and STIRPAT method are highly popular and commendably suited to macro simulations. Aimed at observing whether the tested error is controlled within reasonable range, results are manifested before comparison. Fourth, China pledged to peak around 2030 and designed the roadmap of energy production and consumption revolution upon 2030. We thus use our approach to predict energy consumption and carbon emission to the year of 2030.

This article is organized as follows: Section 2 is literature review. Section 3 concretely displays the CGE method with STIRPAT model. The model data source is provided in Section 4. Section 5 showed the simulating results. Section 6 take stack of the conclusions as well as recommend several policy implementations.

2. Literature review

As pointed out in earlier researches, a sheer scale of quintessential studies should be cited as follows. Zheng et al. [8] discussed the subsidy level on Chinese renewable energy enterprises by applying a threshold regression model, revealed that an increasing subsidy could be conducive to solve the overcapacity in wind energy enterprise. Yuan et al. [9] employed power plan model to demonstrate that a rational range from 50 GW to100 GW is the coal power's suitable capacity addition space, and highlighted that the overcapacity 200 GW would exert disastrous influence to China. Carbon sequestration is also identified as a significant mitigation technology and has been researched over different countries. Andrew and Freddie [10] studied the effects of carbon sequestration with dissolved oxygen on lipid production from accumulated biomass, and found that Algal technology strategies was successfully. Arshe et al. [11] analyzed the experimental effects of steelmaking slag on carbon sequestration using the world's first mineral carbonation pilot data of Finland. Kim et al. [12] used the artificial neural network that proved to be in a high accuracy to predict storage efficiency of CO_2 sequestration in deep saline aquifers. Other researches also discussed carbon sequestration [13–15].

A dynamic CGE model, which is used to be described, emulated and forecasted the influences of macro economy under a specific policy shock to observe the simulation effects, will be employed in this study. CGE model, owing to its quantitative and qualitative combining character, is identified as a widespread applied method which adopted in environment, low carbon, and public policy analysis fields. Shi et al. [16] built a dynamic CGE model to explore the fitted carbon cap, permit allocation and some additional policies relative to carbon emission trading market to fulfill China's Copenhagen pledges. Liu et al. [17] used CGE model to simulate the economic and environmental impacts of the Hubei Pilot ETS. Dai et al. [18] evaluated the impact of renewable energy (RE) development in China by CGE model. Wu et al. [19] estimated economic impacts of ETS policy through using a static computable general equilibrium (CGE) model in Shanghai. Shivika et al. [20] assessed the implication of aligning renewable energy deployment target with national emission reduction target for mitigation cost utilizing AIM/CGE model. Liu and Lu [21] explored the impact of a carbon tax and different tax revenue recycling schemes on China's economy over operating CGE model, and also alternative fields [22–26]. Qi et al. [27] employed a CGE model to analyze a multi-region integrated carbon trading scheme including China, US, Europe, Australia, Japan and South Korea, evaluating the influences on international competitiveness between these countries. Several scholars also studied the emission trading market of European and others, for example, Bryant [28] researched the European Union Emissions Trading System, Song et al. [29] estimated the Korea emission trading market, and also some others [30–39].

STIRPAT model is utilized to study the drivers of carbon emission [40–44]. The embed STIRPAT CGE model, as the employed model constructing innovation in this study, is proposed to improve the accuracy and rationality while quantifying carbon emission drivers. A variety of other research areas, as a spectrum of subjects targeting climate mitigation which including environmental sustainable development and comprehensive ecological improvement, energy low carbon economic technology, carbon mitigation systematical design, energy supply and demand prediction, energy consumption mode and renewable energy utilization, are also supported by this dynamic CGE model due to its synthesis with STIRPAT method.

3. Methodology

A dynamic recursive CGE model is used to study the policy implementations. Profit maximization is hypothesized as the decision objective of producers and consumers. China is supposed as a small country in external trade. Chinese government, enterprises, household, and foreign country are assumed to be the four major economic entity in this model. The model contains production module, trade module, income and expenditure module, investment and save module, carbon emission module, welfare module, and general equilibrium module. The production sectors is divided into heavy chemical industry (coal industry, petrifaction industry, chemical industry, steel industry, non-ferrous metallurgy industry,