Will China's building sector participate in emission trading system? Insights from modelling an owner's optimal carbon reduction strategies

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\section*{A R T I C L E  I N F O}

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\section*{A B S T R A C T}
Building sector is a significant contributor to the global warming and thus the control of carbon emissions from buildings has received unprecedented attention. While China is pioneering in including building sector in its Emission Trading System (ETS) pilots, there is few practical trading. This study investigates the reasons of lack trading via exploring a building owner's optimal strategy that is based on a multi-objective optimization model to achieve required carbon emissions reduction with minimal incremental costs. The investigated emissions reduction strategies include adopting low-carbon technologies, purchasing emission permits from ETS market, and non-compliance. A typical four-star hotel in Shenzhen, China is selected as an empirical case to validate the proposed model. The result shows that non-compliance is the preferable strategy by the owners, and there is no permits trading from the carbon market. Key influencing factors that affect the owners' strategic choice are further investigated with various scenarios and it is found that the probability of government environmental inspection, the penalty for non-compliance, and an owner's reputation loss will to a large extent change an owner's strategy. These findings provide a quantitative rationale for policymakers to reformulate existing initiatives and mechanisms to invigorate the ETS market in the building sector.

\section*{1. Introduction}

China has witnessed an unprecedented increase in carbon emissions in recent years, with the record that nearly three-quarters of the growth in global carbon emissions from the burning of fossil fuels and cement production between 2010 and 2012 took place in China (Liu et al., 2015). Notably, the emissions from the building sector, China's second largest carbon emitter only after the industry sector (Chau et al., 2015), are mainly driven by the country's large population, unprecedented development of urbanization, and continuously increasing demand in energy service (Shuai et al., 2017). According to Ma et al. (2017), carbon emissions in China's buildings are almost equal to total carbon emissions in the Middle East, or two times that in Africa, or the sum of Japan and South Korea's emissions. Furthermore, the growing trend of carbon emissions in China's building sector is projected to continue to increase by an average of 2.4% per year from 2012 to 2040, which makes China the largest residential carbon dioxide emitter in the world by 2040 (EIA, 2016).

With increasing concern for carbon emissions mitigation, the emphasis of the low carbon transition policies in China has gradually shifted from mandatory regulations to market-based mechanisms in recent years (Lo, 2014; Shen et al., 2016). Emission Trading System (ETS) (hereinafter referred to carbon trading or carbon emissions trading interchangeably) has been increasingly recognized and promoted by the Chinese authority (Cong and Lo, 2017). China launched a regional carbon trading market in 2013 for a total of seven pilots including Shenzhen, Shanghai, Tianjin, Beijing, Guangdong, Hubei and Chongqing, collectively covering 16% of China's carbon emissions. After 4-years’ experience, the national ETS has been officially launched in December 2017 and it will surpass the European ETS (EU ETS) to become the world's largest carbon trading system.

As carbon reduction is primarily driven by the energy saving, the building energy efficiency policies have also gradually shifted from traditional regulatory approaches, such as mandatory building codes and standards, to market-driven mechanisms. China decided to include buildings into its ETS markets due to the awareness that there is the...
Building owners, as part of the sector into the ETS at the city level. The successful inclusion of this development in China is significant. Globally, only Japan has included building sector in their ETS. The study is essential to both the literature and the ETS market development. The last section concludes the paper.

This study has two prominent theoretical contributions to the existing knowledge and one policy implication. First, the decision-support model proposed in this paper provides a new perspective by considering both ETS permit trading and non-complying emissions as available emission reduction strategies for building owners. Previous research adopting multi-objective optimization is primarily concentrated on the evaluation of LCT choices, but seldom consider corporate strategies that especially incorporate important aspects such as emission violation and ETS trading too. Our model makes the owners’ decision more reliable and closer to normal business conditions than previous ones. Second, this study innovatively assesses the value of violation penalty and reputation loss. Additionally, the findings from this study also provide a reference of the Chinese policymakers to improve the performance of ETS in the building sector, which could also be useful for other countries who intend to include buildings into their ETSs.

This paper is structured into seven parts. Followed by the introduction, we conducted a comprehensive review on building owners’ emission reduction strategies and decisions. In Section 3, the optimization model for each emissions reduction strategy was established. An empirical study based on an actual building in Shenzhen, China was carried out in Section 4. We discussed the effects of four respective ETS market and industrial factors on reducing carbon emissions under each strategy in Section 5. Section 6 discusses the implications for the China ETS market development. The last section concludes the paper.

2. Literature review

Facing increasingly severe pressure to shoulder responsibility in abating carbon emissions, building sector has been given considerable attention by the Chinese authorities. In recent years, an array of market-oriented policies and relevant measures have been gradually endorsed by different levels of authorities to prepare the implementation of ETS in the China’s building sector. For example, building regulations on energy efficiency have been issued since 2007 to specify the requirements on energy statistics, energy audit, energy consumption information disclosure, and dynamic energy monitoring system for large-scale public buildings (ERI, 2015). In 2015, the Greenhouse Gas
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