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

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ABSTRACT

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.

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

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Table 1
The coverage scope of the seven ETS pilots in China.

ETS Pilots	The sectoral coverage	The coverage for building sector	
		Building type	Building criteria
Beijing	Industrial sectors: electric-power, heating, cement, petrochemical, other industrial sectors Non-industry sectors: **building**, transport, service, etc.	Office buildings, malls, hotels, restaurants, supermarkets, hospitals, and other large-scale public buildings	Above 5000 tCO2/year
Shenzhen	Industrial sectors: 26 sectors such as power, manufacturing. Non-industry sectors: **building**, aviation, bus, subway	Large office buildings, shopping centers, hotel buildings, multifunctional integrated buildings	Government buildings: above 10,000 m^2 Commercial buildings: above 20000 m^2
Shanghai	Industry sectors: iron and steel, power, textile, rubber, material, petrochemical, chemical, non-ferrous metals, etc. Non-industry sectors : Aviation, **building**, transport	Hotels, restaurants, exhibition centers, multifunctional integrated buildings	Above 10000 tCO2/year
Guangdong	Industry sectors : power, cement, iron and steel, petrochemical, ceramic, textile, non-ferrous metals, plastics, paper Non-industry sectors: **building**, service, etc.	Hotels, restaurants, financial buildings, business buildings, public institute buildings	Above 5000 tCO2/year
Tianjin	Iron and steel, chemical, power, heating, petrochemical and exploitation, **building**	Civil buildings (especially focused on heating units)	Above 20000 tCO2/year
Hubei	Industry sectors : 12 sectors such as power, steel, petrochemical, cement, auto production, nonferrous metal, glass, paper	N.A.	N.A.
Chongqing	Industry sectors: iron and steel, power, textile, rubber, etc.	N.A.	N.A.

enormous number of large-size buildings. The market-driven carbon trading mechanism in the building sector was initially proposed in 2011, and until 2014, five out of the seven ETS pilots, except Hubei and Chongqing, extended the sectoral coverage to buildings (Swartz, 2016). Most of large-scale public buildings, such as office buildings, shopping centers, hotels, and restaurants, have been covered and regulated by these five ETS pilots (see Table 1). However, no practical carbon trading of building projects had been conducted at present (Wang et al., 2017). In fact, the transaction cost is critical for building owners when they decide to participate in the ETS market. The lack of ETS trading in the building sector is mainly attributed to the reasons such as relatively high transaction costs due to smaller quantities of carbon reduction from an individual building compared to other industry sectors (e.g. power plant) (Lam et al., 2015) and scattered ownership of individual units in a building (e.g. residential house) (Raines et al., 2005).

With the introduction and promotion of ETS in the China's building sector, building owners are allowed to flexibly trade their excess or saved carbon emissions in the trading market. When a building releases excess carbon dioxide above the required baseline, the building owner may consider one or more options from three carbon mitigation strategies: adopting low-carbon technologies (LCTs), purchasing carbon emission permits through ETS, and irresponsibly releasing emissions at the risk of being punished (non-compliance). The non-complying emissions are essentially referring to those false carbon reductions reported to the government, yet without any abatement efforts made by the building owner. That is to say, it is just the sense of “accounting” rather than “real reduction”. Selection of any of these options imposes an additional burden on building operational cost (Yang et al., 2016). Building owners, as profit-motivated decision makers, would therefore opt to minimize their operating cost while meeting the required emissions reduction target.

This paper aims to propose a multi-objective optimization model that simulates a building owner's strategy to achieve emissions reduction target. Specifically, three objectives are expected to achieve: (1) to quantify the amount of carbon emissions mitigated by each of above three strategies to meet the reduction goal, (2) to understand corresponding emission strategies due to the change in the ETS market (i.e. carbon price) and government regulations such as probability of environmental inspection, penalties, and emissions baseline for buildings, and (3) to explore policy implications for improving China's ETS in the building sector. The study is essential to both the literature and the ETS development in China. Globally, only Japan has included building sector into the ETS at the city level. The successful inclusion of the building sector in the China's national ETS is substantial for the global community since the scale of emission is significant. Given few ETSs incorporate buildings in the sectorial coverage scope across the world, there is scarcely prior experience that China can learn and thus theoretical simulations can help China to improve its ETS for the building sector.

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