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Exploring the effect of cap-and-trade mechanism on firm's production planning and emission reduction strategy

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ABSTRACT

Cap-and-trade mechanism has a significant effect on firm's production and operation decisions and carbon emissions. This study develops a mathematical model to examine the effect of cap-and-trade mechanism on firm's production planning and emission reduction strategy. Based on the model, the firm's critical production planning decisions, such as the optimal production quantity, optimal allowance selling price and the maximum profit under the cap-and-trade mechanism are derived firstly. Then based on the cost-benefit analysis, the conditions under which the firm makes the optimal emission reduction strategy between buying carbon allowance from the carbon trading market and conducting low-carbon processing are identified. The result suggests that when the low-carbon processing cost is greater than the potential opportunity benefit, the firm is inclined to purchase carbon allowance from the carbon trading market, and vice versa. Finally, a numerical analysis is conducted to investigate the effects of relevant factors, such as carbon quotas, carbon emission rate, low-carbon processing cost and transaction cost on firm's production and operation decisions. The results indicate that under the cap-and-trade mechanism, the transaction cost has a positive effect on allowance selling price. The firm's optimal production quantity and maximum profit is positively related to carbon quotas, while negatively related to carbon emission rate and low-carbon processing cost. This research contributes to enrich related literature and knowledge with regard to carbon emissions reduction at the firm level and highlight the critical importance of cap-and-trade mechanism in reducing carbon emissions.

1. Introduction

There is an increasing consensus that carbon emissions associated with the rapid development of industrialization are one of the main causes of global climate change (Hashim et al., 2015; Kamyaba et al., 2015; Repar et al., 2017). To alleviate the global climate change and curb the carbon emissions, some low-carbon policies, regulations and mechanisms have been implemented by government authorities and non-governmental organizations, such as shutting down the energy-intensive industries, improving the energy consumption efficiency, developing renewable energy and promoting cleaner production (Hashim et al., 2015; Zhou et al., 2016). Currently, cap-and-trade mechanism has been widely adopted and regarded as an effective mechanism to control the carbon emissions (Kamyaba et al., 2015; Wang et al., 2017). Compared with command-and-control mechanism, cap-and-trade mechanism is a market-based mechanism which can achieve a given level of emission reductions at lower cost without much government intervention (He et al., 2015; Wang et al., 2017). Under the cap-and-trade mechanism, firms initially obtain a predetermined amount of carbon allowances (carbon quotas) from the government agencies and the total carbon emissions generated at a certain period should be lower than the carbon quotas (He et al., 2015). Firms could buy/sell carbon allowances in the carbon trading market when they have lack/surplus allowances where allowance price is determined by the trading market (Singh and Weninger, 2017).

European Union Emission Trading Scheme (EU-ETS), which was launched in 2005, is the first and the largest international scheme for carbon emission trading and covers more than 40% of carbon emissions in European Union (Demailly and Quirion, 2008; Grüll and Taschini, 2011). In 2009, ten of the north-eastern US States signed the Regional Greenhouse Gas Initiative (RGGI) and planned to implement a US-wide cap-and-trade mechanism (Grüll and

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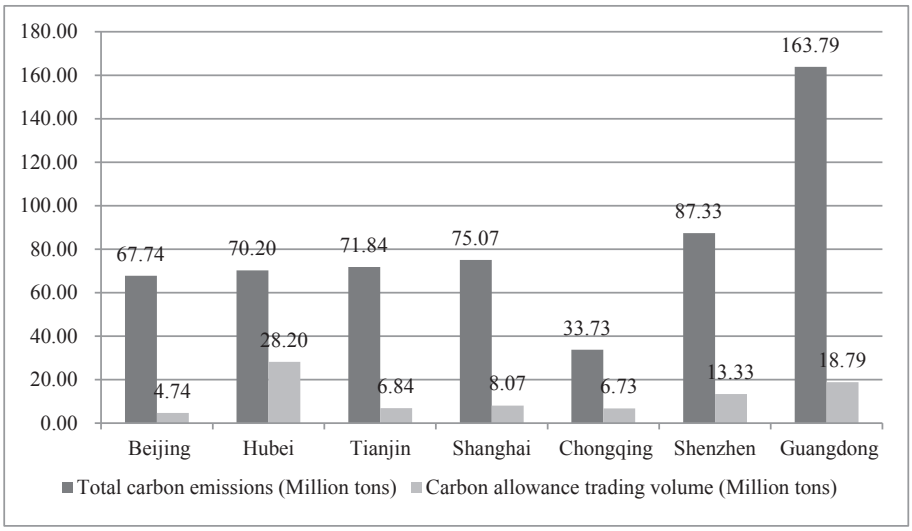

Fig. 1. Total carbon emissions and carbon trading volume in seven pilot regions.

Taschini, 2011). In 2013, Chinese government has implemented the cap-and-trade mechanism in seven pilot regions[1] and the national level cap-and-trade mechanism is prepared to be launched in 2017 (Duan et al., 2014). Currently, cap-and-trade mechanism works well in the pilot regions (Wang et al., 2017; Zhao et al., 2017). As shown in Fig. 1 , by the end of 2016, the accumulative carbon emissions in seven pilot regions were 570 million tons and the accumulative carbon allowance trading volumes were 86.70 million tons.[2]

It is known that under the cap-and-trade mechanism, carbon allowance is a key factor (He et al., 2015; Singh and Weninger, 2017). Carbon allowance can be viewed as strategic asset of a firm which can significantly affect firm's sustained competitive advantages, business profits, and production and operation decisions (Du et al., 2015; He et al., 2015). Meanwhile, it is worth noting that carbon emissions are generated in almost all stages of firm's production process. Considering the constraint of carbon quotas, the firm is forced to reduce carbon emissions through managing the production process and implementing emission reduction strategy which will affect its production and operation decisions (Gong and Zhou, 2013). Hence, under the cap-and-trade mechanism, how to make production and operation decisions, implement emission reduction strategy and obtain benefits from the mechanism becomes a critical decision for the firm. As a result, a firm has to take all the factors such as production capacity, cost control, trade market and competitor's activities into consideration to respond to the mechanism. To be specific, under the constraint of carbon quotas, a firm has to make an optimal production planning to obtain the optimal production quantity and the maximum profit. Furthermore, a firm has to choose the optimal emission reduction strategy to maximize the profit. Understanding the effect of cap-and-trade mechanism on firms' production planning and emission reduction strategy can provide the insights for both firms and policy makers.

In this research, an optimization profit model has been presented to explore firm's production planning and emission reduction strategy problems under the cap-and-trade mechanism. Based on the model, the optimal production quantity, optimal allowance selling price, maximum profit and optimal emission reduction strategy are derived and analyzed. To make our findings complete and generalizable, the effects of some key parameters, such as carbon quotas, carbon emission rate, low-carbon processing cost and transaction cost, on the optimal production quantity, maximum profit and the allowance selling price are also investigated.

There are several theoretical and applied contributions of this research. Theoretically, this research enriches the literature on carbon emissions reduction at the firm level. Meanwhile, this research further highlights the critical importance of cap-and-trade mechanism in reducing carbon emissions. In practice, the findings of this research are useful and beneficial to government agencies and firms to reduce carbon emissions.

2. Literature review

Cap-and-trade mechanism is proposed to meet the public demands and soften the governmental pressures on environmental protection (Gong and Zhou, 2013). With the growing concerns of global climate change, the research on carbon emission trading has attracted wide attention both in theoretical and empirical studies.

Currently, the research on carbon emission trading mainly focuses on macro-effects. For example, Kuik and Mulder (2004) analyzed the absolute cap-and-trade mechanism and mixed cap-and-trade mechanism. They found that each mechanism has advantages and advantages and none of the mechanism is an advisable tool for emission reductions. Grüll and Taschini (2011) investigated the key design of existing cap-and-trade mechanisms and regarded the plain vanilla options as an alternative to reconcile the policy objectives. Comparing the advantages and disadvantages between carbon emission trading and carbon tax, it is found that carbon emission trading and carbon tax can substantially reduce the carbon emissions but in different degree and implementation cost (Elkins and Baker, 2001; Stavins, 2008). Carbon emission trading can lower the cost by 50% for the same emission reduction objective (Demailly and Quirion, 2008). The combination of two approaches can be more effective to reduce carbon emissions (Mandell, 2008).

However, the research focuses on micro-effects of carbon emission trading is limited, although its impact is significant. Letmathe and Balakrishnan (2005) studied the firm's optimal product mix and production quantity considering the

[1] These regions include Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Guangdong and Hubei.

[2] Please see detailed at http://www.tanpaifang.com/.