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Integrated impact of the carbon quota constraints on enterprises within supply chain: Direct cost and indirect cost

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ABSTRACT

Emission Trading Scheme (ETS) has become one of the most popular ways to meet CO_2 reduction targets owing to its flexibility and cost effectiveness. This paper applies game theory to analyze the impacts of direct and indirect costs derived from ETS on enterprise's competitiveness and supply partnership. By emphasizing the role of carbon intensity, the results illustrate that an enterprise with lower carbon intensity will have stronger capability to ease the pressures of both direct and indirect costs. From the perspective of direct cost, when reducing carbon intensity to a certain extent, the enterprise will take the advantage of carbon competitiveness to further expand the market share. The enterprise with low carbon intensity can even increase its product output amount instead of damaging it. From the perspective of indirect cost, a downstream manufacturer with lower carbon intensity is more likely to obtain the favor of suppliers. If choosing a downstream partner with high carbon intensity, the supplier may need to reduce the price of its product to ensure the product's demand and profits. Therefore, the implementation of ETS will drive suppliers to choose low-carbon partners, resulting in low-carbon supply partnerships replacing the original one. Based on a numerical example combing with the investigation in Hubei ETS pilot, this research argues for the enlightenment, and implications, of carbon quota constraints as a part of China's emission reduction policies.

1. Introduction

Climate change, in the most recent five decades, has been mainly caused by greenhouse gas emissions from anthropogenic activities, according to the fourth report of the *International Panel on Climate Change* [9]. The greenhouse effect has affected the natural, social, and ecological environment on which human rely, with both its speed and extent already exceeding popular expectation. In response to climate change, various countries have explored many methods, among which carbon emission trading scheme (ETS) has become one of the most popular ways to meet CO_2 reduction targets owing to the flexibility and cost effectiveness [11,17,33]. As a developing country with rapid economic growth and the largest CO_2 emissions in the world, China's reactions to environmental issues have drawn considerable attention. At the Paris UN Climate Conference, China clearly proposed that it would reduce its carbon intensity by 60–65% by the end of 2030, compared with 2005. To achieve its CO_2 emission reductions targets and to identify ways to build a unified carbon emissions trading scheme—by drawing on the experience of developed countries—China has gradually established seven pilots since 2012 specifically for Beijing, Shanghai, Tianjin, Chongqing, Guangdong, Hebei, and Shenzhen. In this way, the government has implemented initiatives to put emissions trading plans into effect. Based on practice from these pilot programs, China has also promised to steadily establish a national carbon market.

Now at a learning-by-doing stage, there is keen interest from both policy makers and business managers in China to understand the impacts of ETS on an enterprise's production operational strategy. Under ETS, a CO_2 permit becomes a kind of commodity that can be exchanged on the carbon market. In an allowance-based ETS, participants face a certain free carbon quota. No extra permit is needed until emissions exceed the free quota. To cover actual emissions, enterprises will start to purchase carbon permits and carbon exchange will occur. Along with carbon price fluctuations, the cost structure will change such that operational decisions will be adjusted correspondingly.

Regarding costs, ETS exerts pressure on enterprises by increasing both direct and indirect costs. So-called direct cost arises from the purchase of permits. Moreover, when an upstream supplier associated with a product has a carbon quota constraint, indirect cost will arise.

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The upstream supplier may then transfer part of the cost increment caused by the carbon quota constraints to the price of its product, which will indirectly raise the raw material costs of the downstream manufacturer. If both upstream and downstream enterprises are incorporated in the ETS, the situation becomes more complicated, where the downstream manufacturer will face dual cost pressures as a result of increases in carbon costs and raw material prices.

That, ETS affects enterprises from different levels. Owing to the direct cost, carbon intensity becomes a new competitiveness indicator that influences other competitiveness performance indicators, such as production output, market share, and profit. An enterprise with lower carbon intensity then has stronger carbon competitiveness, resulting in a greater advantage in industrial competition. The indirect cost affect the supply partnership between upstream and downstream enterprises by improving the raw material purchasing costs. Currently, the literature has focused on the effects of ETS on regional economies or industries [15,18]; however, few studies have analyzed the impacts of direct and indirect costs caused by ETS on industrial competition and supply cooperation relationships. More important, from the perspective of practical implementation, many enterprises in China's ETS pilots have not realized the impacts of ETS. Moreover, they neglect the importance of carbon management, as they have not realized the government's seriousness in building a carbon market. At the budding stage of ETS, it is important to discuss the influence from both industrial competition and supply partnership perspectives. In this context, this research aims to address the following three questions:

(1) How does the direct cost derived from ETS affect an enterprise's competitiveness?
(2) Regarding indirect cost, what are the potential effects of ETS on the supply partnership between upstream and downstream enterprises?
(3) How can enterprises manage such with the effects?

To address these three issues, this research first uses a duopoly model to analyze the impact of ETS on enterprises within the same industry. In this way, the production output change caused by ETS implementation is mainly discussed. Then, a Stackelberg model is applied to analyze the impact of the indirect cost caused by carbon quota constraints, including the pricing strategy of upstream suppliers and production strategy of downstream manufacturers. The answers to these issues can make up for the deficiency of academic research on the impacts of ETS. On the other hand, we hope that this paper can provide some enlightenment for China's enterprises with respect to carbon management.

2. Literature review

As ETS has received growing attention, many studies have investigated operational decisions to reduce carbon emissions and to maximize benefits under carbon quota constraints. The research related to this paper can be classified into two categories: the impacts of ETS on enterprises' competitiveness and the impacts of ETS on the operational decisions regarding the supply chain.

2.1. The impact of ETS on enterprises' competitiveness

The ETS has been complained by some energy-intensive industries since firms believe that carbon quota constraints would reduce their competitiveness. In fact, before the implementing of the carbon emissions trading regime, many scholars have analyzed its potential impacts on business competitiveness. At present, the measurement of competitiveness indicators is not entirely consistent in the literature, as studies have examined costs, profits, output, market share, employment, and so forth. Smale et al. [25] evaluated the potential impact of carbon trading on profit, cost, and market share by using a Cournot model; Lund [13] assessed the EU-ETS impact on the cost of energy intensive manufacturing industries and found that the EU-ETS exerted different influences on different industrial sectors; Kara et al. [10] investigated the impacts of the EU-ETS implementation on energy intensive industries in Finland; Chen et al. [4] studied the implications of CO_2 emissions trading for short-term electricity market outcomes in northwestern Europe; Tsai and Yen [27] analyzed the influence of ETS on power units' operation and dispatch; and Park et al. [16] aimed to assist private companies in establishing proper investment strategies for CDM projects under uncertain energy policies. Finally, Wang et al. [28] examined the effect of ETS on firms' production planning, such as optimal production quantity, optimal allowance selling price, and maximum profit.

Among the studies on competitiveness changes, some scholars have considered the indirect cost caused by ETS. Based on cost structure, CO_2 emissions, electricity consumption, and allocated allowances, Tomas et al. [26] used survey data from four representative businesses in the Portuguese chemical industry to analyze the effects of ETS. In this paper, not only the direct cost derived from purchasing quotas but also the indirect production costs derived from the power sector were considered in constructing the cost structure. Chan et al. [3] used panel data from 5873 enterprises in ten countries during the period from 2001 to 2009 to analyze the changes in unit material costs, employment, and revenue before and after the implementation of carbon trading regimes. The analysis results suggested that rising material costs could reflect the costs to fulfill obligations under the ETS, that is, the indirect cost. The determinants of firm's competitiveness have been discussed in the research of Meleo [14], who considered the possibility of passing through the environmental costs onto the final price as an important part of the determinant framework.

It is of great significance to study the impact of ETS on the enterprise's competitiveness. On one hand, such an examination can help enterprises who have carbon quota constraints to achieve reasonable production and a mitigation plan, and thus gain maximum benefit therefrom [12]; On the other hand, such an examination can provide a reference for policymakers to design more reasonable and effective carbon trading policies.

2.2. The operational decisions regarding the supply chain with carbon quota constraints

In recent years, research into the operational decisions regarding the supply chain under the background of carbon constraints has gradually received more attention. On the one and, pressure from carbon constraints motivates businesses to reduce CO_2 emissions across the entire supply chain; on the other hand, consumer concern regarding environmental issues and consumers' desire for environmentally friendly products make enterprises redesign their supply chain within such carbon constraints. Some scholars consider the supply chain to be a whole in studying the optimal strategy [20,24]. For example, Abdallah et al. [1] developed a mixed integer program that minimized emissions throughout the supply chain by considering green procurement with respect to the carbon-sensitive supply chain. Chaabane et al. [2] designed sustainable supply chains under the emission trading scheme, which suggests that the legislation must be strengthened and harmonized at a global level to develop a meaningful environmental strategy.

In addition to the research on the optimal operation decision of the whole supply chain under ETS, the interconnected, restrictive relationship between different actors in the supply chain has also been the focus of scholars. By providing a mathematical background for modelling a rational system and for generating solutions in competitive or conflicting situations, game theory method has been widely used to verify the relationship between different actors in the supply chain. Sheu [22] studied the problem of negotiations between producers and reverse-logistics suppliers in cooperative agreements under government intervention. Based on evolutionary game theory, Sikhar et al. [23]

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