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Imposing emission trading scheme on supply chain: Separate- and joint implementation

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ABSTRACT

In response to global warming, it is urgent to control and reduce greenhouse gas (GHG) emissions, especially from the supply chain perspective. The most often discussed topic in this domain indicates that emission trading scheme (ETS) could be employed as one of policy instruments for supply chain emissions management. Via mathematical models, scholars have shown that the employment of emission trading is affecting supply chain performances (both environmental and economic) in different levels. However, previous literature focus on the cost-effectiveness analysis only from the mathematical aspect. To provide policy-makers and companies with the theoretical bases on this hot topic, it is significant to discuss how ETS, one of market-based instruments, could be imposed in the context of supply chain from the mechanical point of view. By incorporating ideas from relevant literature, this paper generates two concepts/modes in imposing ETS on supply chain: jointly imposed supply chain emission trading (e.g., jointly imposed SC-ETS) and separately imposed supply chain emission trading (e.g., separately imposed SC-ETS). It illustrates the working principles of both concepts/modes and conducts a sandbox example to analyze the cost-effectiveness of them. Furthermore, this paper discusses the challenges and opportunities of implementing two modes from practical aspects. Results of quantitative analysis and discussion show that for the sake of both policy-makers and supply chain companies, the separately imposed SC-ETS allowing selling permits would be so far the better mode to manage supply chain GHG emissions compared to the jointly imposed SC-ETS.

1. Introduction

To curb climate change, greenhouse gas (GHG) emissions should be controlled from the supply chain perspective. Authorities are increasingly concerning the management of scope 3 emissions – the emissions created along with supply chain activities, beginning with identifying, measuring, and reporting. Supply chain GHG emissions account for around 75% of the whole GHG emissions from an industry sector while companies' direct emissions from their internal activities occupy up only 14% in average of their supply chain emissions prior to use and disposal across all industries (Huang et al., 2009). Besides, it is of huge potential to realize supply chain GHG emissions reduction, for example, to identify the hotspots along supply chain, to enhance the supply chain efficacy, and to increase the market competitiveness of supply chain companies, etc. (EPA, 2015). Therefore, it is both necessary and beneficial to control GHG emissions from the scope of products' life cycle or corporates' supply chain. Furthermore, it is being increasingly recognized that supply chain GHG emissions can best be managed through goal-oriented and market-based mechanisms such as emission trading scheme (ETS) that provide flexibility in choosing compliance levers to the targeted firms or industries (Diabat and Simchi-Levi, 2009).

Emission trading scheme (ETS), one of market-based instruments, works on the principle of 'cap and trade' (European Union, 2013). The 'trade' creates a market for carbon permits, helping liable entities innovate in order to meet, or come in under their allocated limit. The price of permits is jointly decided by the demand and supply of them in the market. In a word, entities under ETS are allowed to exchange the carbon permits via carbon market with a certain carbon price as needed. At the end of certain period, entities that emit less than its allocated permits may bank the spare permits to cover its future needs or else sell them to other entities that are short of permits. Entities whose cumulative emissions exceed allocated permits, after taking possible green potentials or

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not, may buy permits from carbon market in order to meet their excessive emissions. Since the compliance cost usually is much higher than the carbon price, carbon market may offer one solution to meet cap before suffering heavy fines.

ETS in recent years is gaining higher and higher concern from all over around the world to achieve the goals of environmental sustainability in a variety of fields. In 2015, Parties to the UNFCCC reached a landmark agreement – the Paris agreement – at the Conference of Parties (CoP) 21 in Paris to prevent global surface temperatures from rising above 2 °C (UNFCCC, 2015). The Paris Agreement builds upon the Convention and – for the first time – encourages all nations to submit intended nationally determined contributions (INDCs). Besides the Annex I countries living up to Kyoto Protocol targets, developing countries are also motivated to undertake ambitious efforts to combat climate change. Emission trading is being and going to be increasingly adopted around these nations as one essential strategy to control their national emissions. In the US, markets for Sulphur-Dioxide (SO2) permits now account for more than USD 8 billion a year in trade (Talberg and Swoboda, 2013); in the EU, the ETS is the cornerstone of the Kyoto Protocol implementation and affects more than 12,000 producers in 25 countries (European Union, 2013).

Scholars from academic areas and progressive practitioners are also showing their interests in employing ETS on the range of supply chain. All of these work can be generalized into the category of mathematical analysis (see Section 2). Though the mathematical models are able to optimize the supply chain and provide decision-making for companies, they didn't address how emission trading could be imposed in the context of supply chain considering different supply chain structures. For example, how should the responsibility of supply chain GHG emission be assigned in the supply chain? Based on this research gap, this paper aims to answer these research questions:

1) What kind of programs/mechanisms could be designed and applied to different supply chain structures?
2) How could the application of emission trading affect the supply chain performance?
3) How do these programs differ from each other in terms of cost-effectiveness?

Following the introduction section, this paper presents a brief overview of previous literature addressing this topic in Section 2. In Section 3, it introduces the two concepts/modes generated for the imposition of emission trading in the context of supply chain, and a sandbox example is provided as well to analyze the cost-effectiveness of these two modes. Furthermore, the challenges and opportunities involved in the practical implementation processes are also discussed in this section. Finally, the conclusion section is given in Section 4.

2. Literature review

Research from fields of green supply chain management (GSCM), sustainable supply chain management (SSCM), and environmental supply chain management (ESCM) consider mainly the negative impacts of supply chain activities on environment. Among them, it is not difficult to find literature addressing supply chain management (SCM) in line with emission trading. They take different carbon pricing policies, like cap, cap and trade, carbon tax into account within the supply chain network design (SCND). Different domains of supply chain are considered such as forward supply chain, reverse supply chain, and closed-loop supply chain (CLSC), with regard to operational adjustment, such as sourcing, subcontracting, manufacturing, transportation, allocation, distribution, recycling, remanufacturing, and reverse logistics. Mathematical models such as mixed-integer programing (MIP) and mixed-integer linear programing (MILP) are most often employed to solve the supply chain optimization problem. Some of them have also incorporated the concept of life cycle analysis (LCA) into constructing their mathematical models. A brief overview of some selected literature is provided in Table 1.

It could be so far easily derived that all of the literature work on the base of a common assumption, and that is, diverse supply chain nodes are owned and operated by a single firm. For example, Jin et al. (2014) suppose the retailer is in charge of carbon emissions from the whole supply chain nodes and processes, including manufacturing emissions from sources and transportation emissions from freight distribution (Jin et al., 2014). However, since supply chain design or optimization through operational adjustment may involve the participation from different supply chain partners, it requires close collaboration among supply chain partners to reach emissions reduction goals. There're rare literature addressing this problem from the mechanical aspect. Through the application of simple lot-sizing models under various scenarios, Benjaafar et al. (2013) find out imposing supply chain-wide emission caps is more cost-effective than individual cap installation on each firm and it also increases the value of collaboration (Benjaafar et al., 2013). Moreover, it could increase the cost and emissions of those firms left out from collaboration. Although they provide important insights to supply chain collaboration under emission trading, they still focus on the validation of mathematical models. Discussion of different mechanisms is missed in their paper. Considering the research gap, this paper aims to contribute in generating mechanisms for imposing emission trading on supply chain and discerning challenges and opportunities confronted in the implementation processes.

3. Imposing ETS on supply chain

3.1. Concepts & working principles

Inspired by the work of Benjaafar et al. (2013), this paper proposes two concepts/modes for imposing emission trading on supply chain (called SC-ETS for similarity): 1) jointly imposed SC-ETS, and 2) separately imposed SC-ETS. Working principles of both modes are described in detail as followed.

3.1.1. Jointly imposed SC-ETS

Jointly implemented SC-ETS program takes into account the GHG emissions from all supply chain activities and processes in the selected scope. Permits under this limit are allocated to supply chains for free, or for certain auction cost. One permit is the right to emit one ton of carbon dioxide equivalent (CO_2e). Supply chains have to surrender permits in equivalent to their accurate GHG emissions at end of a certain period. Supply chain GHG emissions have to be reduced under the regulated cap by emission abatement measures within the range of the selected supply chain. If not, the supply chain representative have to purchase emission permits from existing emission trading markets to cover the emissions exceeding the cap. Extra units reduced by emission abatement measures could be sold as permits to other organizations in trading markets. Emitting rights (i.e., permits) are exchanged between the supply chain representative and existing emission markets. Fig. 1 illustrates the working principle of this mode.

In other words, this mode appoints that supply chain work as a single company to perform emission abatement measures and to trade emission permits in current trading markets. Hence, one focal company (i.e., the representative of supply chain) coordinate actions among supply chain members, for example, calculating