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Green Supply Chain Network Design: A Literature Review Focused on Carbon Policy

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Abstract: With the growing size of the market for carbon trading and the development of carbon trading mechanism, carbon emissions should be considered in supply chain network design. Many scholars are interested in the design of green and sustainable supply chain network to reduce the emission of greenhouse gases. The purpose of this paper is to review the relevant literature on green supply chain network design (GSCND), from 2011 to 2019, and analysis the impact of relevant carbon policies on GSCND. At last, some future research directions are also discussed in this review.

1. Introduction

Since the Kyoto Protocol came into force in 2005, the global carbon trading market has seen explosive growth. As the atmosphere of global warming, many countries have adopted a series of policies to reduce the emission of greenhouse gases (GHG). According to the World Bank [1], there are 25 sub-national and 42 national governments having the carbon policy or planning to put into effect, which is 1/4 global GHG emission. Because of carbon trading market started relatively late in China, following the quota trading mechanism of EU's carbon market, the carbon policy exists many deficiencies and needs to be improved. Thus, it is one of the critical goals for supply chain network design to reduce carbon emission. GSCND is a new emerging approach that arouse in order to congregate economic efficiency and environmental benefits.

The major emission sources in supply chain network are between transportation, which accounts for about one third, raw material procurement, and construction and operation of facility and distribution center [2]. Samir et al. develop a GSCND model that simultaneously minimizes logistics costs and the environmental cost of CO_2 emissions [3]. In green supply chains, carbon policies play a key role in decreasing carbon emissions. After reading these researches, five policies are generally considered by the government: carbon tax, carbon offset, carbon cap, and cap-and-trade and carbon subsidy. We mainly study three dimensions in GSCND, including carbon tax, carbon cap and cap-and-trade.

This paper is divided into four sections. The carbon policy is detailed in Section 2. Section 3 discusses important findings over major decisions over carbon policy in GSCND. Finally, Section 4 presents the conclusion and the suggestions for future research in this paper.

2. Carbon policy

This paper presents 41 researches and a content analysis studies from 2011 until 2019. The results are as following in the Table 1.

Table 1 Summary of carbon policy in GSCND researches from 2011 to 2019.

Research Work	Year	Carbon Policy		
		Carbon Tax	Carbon cap	Cap-and -Trade
Chaabane et al.[4]	2011			◆
Paksoy et al.[5]	2011	◆		
Akgul et al.[6]	2012	◆		
Abdallah et al.[7]	2012			◆
Chaabane et al.[8]	2012			◆
Kannan et al.[9]	2012			◆
Abdallah et al.[10]	2013			◆
Diabat et al.[11]	2013			◆
Benjaafar et al.[12]	2013		◆	
Mirzapour et al.[13]	2013		◆	
Abdallah et al.[14]	2013			
He et al.[15]	2014		◆	
Paksoy et al.[16]	2014	◆		
Zeballos et al.[17]	2014	◆		
Zhang et al.[18]	2014	◆		
Choudhary et al.[19]	2015	◆	◆	◆
Fahimnia et al.[20]	2015	◆		
Fareeduddin et al.[21]	2015	◆	◆	◆
Liotta et al.[22]	2015	◆		
Martí et al.[23]	2015	◆	◆	
Niakan et al.[24]	2015	◆		
Rezaee et al.[25]	2015		◆	◆
Zakeri et al.[26]	2015	◆		◆
Hammami et al.[27]	2015	◆	◆	
Martí et al.[28]	2015		◆	
Tao et al.[29]	2015		◆	
Alhaj et al.[30]	2016	◆		
Liotta et al.[31]	2016	◆		

Peng et al.[32]	2016	◆	◆	
Xu et al.[33]	2017	◆	◆	◆
Arampantzi et al.[34]	2017			◆
Entezaminia et al.[35]	2017	◆		
Mohammed et al.[36]	2017	◆	◆	◆
Soleimani et al.[37]	2017		◆	
Zhou et al.[38]	2017	◆	◆	
Qi et al.[39]	2017			◆
Li et al.[40]	2017			◆
Shu et al.[41]	2018	◆		
Yi et al.[42]	2018	◆		
Olsen et al.[43]	2018	◆		
Wong et al.[44]	2019	◆		

2.1 Carbon tax

There are 25 articles surveyed in the Table 1, all of which are divided into two aspects, including the process in supply chain applying the carbon tax and the determination of tax rate. Most of these articles apply the carbon tax into transportation emission, attaching to other emission sources such as raw materials, production, and storage and so on.

Many scholars such as Paksoy, Özceylan, Zeballos, Liotta and Niakan, considered only the process of transportation into carbon emission [5] [17] [22] [24]. Paksoy and Özceylan propose an integer non-linear programming model of a supply chain network with a bi-objective function that not only considers the transportation costs, but also takes the costs for the amount of greenhouse gas emissions, fuel consumption into account [5]. Zeballos tackled the costs of different transportation, relating to the realistic requirements in closed-loop supply chain design [17]. Besides, the electricity emission in the production process can't be ignored, because of the result in the United States Environmental Protection Agency: there are 29% global GHG emission from electricity production. Mohammed et al. accounted for the emissions due to manufacturing, storage at distribution centers, disposal, handling, and recycling in the closed-loop supply chain [37]. Furthermore, both Choudhary et al., Fareeduddin et al., Xu et al. and Mohammed et al. considered all or part of the emission from in the disposal, recycling and burning [19] [21] [33] [36].

Different carbon rates applied in different countries, years and analysis. For example, based on the Australian environmental policy in 2015, Zakeri et al. apply a tax rate of 23 AUD/t of CO_2 in carbon emissions trading from supply chain design view [26]. At the same time, Fahimnia et al. mention how the tax rate in Australian influences the SCND. The result is that a tax rate of 30–40 AUD/t can bring worthy change and it is necessary for the tax rate to suit variations in fuel price [21]. Akgul et al. use a carbon tax rate of £15/t, which in the BBC, for a case in the U.K. [6]. Liotta et al., who use projected tax rates reported in Canada, take capacity limitation and multi-model into account [22]. When referred to set a carbon tax, authors always make use of a marginal abatement cost curve. A marginal abatement cost curve is utilized to determine the tax to achieve the carbon reduction targets [23]. If subsidy and carbon tax policies play a role in a two- echelon supply chain in the same time, it can encourage both the producer and the retailer to reduce emissions [42].

2.2 Carbon cap

The carbon cap policy is generally defined the upper bound of carbon emission and must be enforced. The common carbon cap policy has been taken into consideration in some studies for the GSCND. Many authors set a limitation in the manufacture [28] [38], warehousing [28] [32], transportation [13] [19] [21] [28] [32] [36] [37] [38], and recycling [19] [21] [36] [37], in order to control the carbon emissions from the transportation, set a maximum of the CO_2 emissions for every manufactured and recycled one. Martí et al. mention CO_2 emissions from many aspects, including raw materials, production, storage, and transportation [28]. Other scholars consider the periodic or global carbon cap on the GSCND [12] [18] [27] [29] [33]. Zhang et al. conclude that a global carbon cap has a better effect, compared with the periodic carbon cap [18]. Moreover, Tao et al. mention that different emission limits can use different polices [29]. If the emission limit is high, the global cap is superior. On the contrary, the periodic cap is prevalent. Benjaafar et al. integrate carbon caps into different models for single and multiple firms [12].

2.3 Cap-and-trade

Because of incomes or offsets, the cap-and-trade policy are considered more clearly than other carbon policies. There is a focus on manufacturing and transportation emissions in the Table 1, as easy measurement to make. All articles related to the cap-and-trade include transportation emissions [4] [9] [11] [25] [40], in which also include raw material [10] [11], open facilities [9] [19], manufacturing [4] [11] [25] [40], distribution centers [11] and the electricity consumption [11]. Diabat et al. take all aspects into count, capping emissions due to materials from the supplier and transportation, power consumption of plants and distribution centers [11].

Some researches, such as Chaabane et al. and Rezaee et al., propose a linear programming model, which contacts the carbon emissions of production and transportation with scale of production [4] [25]. The main source of GHG emissions is raw materials, considered by Abdallah et al. in every stage during the lifecycle of a product [14]. Kannan et al. mention emissions in open facilities and transportation and set a mixed integer linear model based reverse logistics network design, which aims at minimizing the CO_2 footprint [9]. Li et al. propose a two-echelon supply chain and examine the production and transportation outsourcing problems under the cap-and-trade policy [40]. They find that the incorporation cap-and-trade and carbon tax policy is more effective for emissions reduction. Qi et al. presents a model under carbon cap-and-trade, aiming to incorporate carbon emissions into production inventory and routing decisions. The result is the model has the potential to reduce emission levels of carbon dioxide and operational costs [39]. Other authors, such as Fareeduddin et al., Zakeri et al., Arampantzi et al. and Xu et al. utilize unit emission intensity [21] [26] [35] [21] [33].

3. Results and Discussion

Between carbon tax, carbon cap and cap-and-trade, carbon tax exerts a financial pressure to the enterprises, so that it may be more effective [41]. Many common conclusions are found in these researches. For example, with a carbon tax policy, the total cost in the supply chain can't increase sharply. Wong et al. show that carbon tax can not only reduce emission and waste resource, but also help to develop a better policy reform about carbon. It is prudent to set the standard of carbon tax because the rang for the policy is small [44].

Compared carbon cap with carbon tax policies, the former is usually inflexible [35] but it can contribute to a lower total cost [18] [23]. A higher carbon cap has an obvious influence on the supply chain. We find that the emissions sharply reduce in the carbon cap, only resulting the total costs increase a little. Obviously, the reason is the application of the optimal production technology, recycle and reuse the product in the foreword, reverse and the closed-loop supply chain.

As excepted, the higher cap in cap-and-trade, the lower cost in the supply chain, similarly to carbon cap. Carbon emissions and total costs could be reduced at the same time with the cap-and-trade policy. In fact, the cap-and-trade policy is useful to encourage the industry to pursue GSCND. In addition, the carbon credit is imperative to GSCND.

4. Conclusions and future research

This paper focus on the researches for the GSCND. We find articles to analysis the carbon policy and carbon tax, carbon cap and cap-and-trade are mainly applied. Table 1 shows that the number of papers is increasing from 2012, because the environmental concerns are emerging constantly.

After carbon tax policy mainly affects the design of green supply chain and the formulation of strategy. Different policies can minimize the cost rising involving the carbon emissions. Most researches are focused on the transportation mode, facility location, manufacturing, electricity and the choice of suppliers, to reduce emissions in close-loop supply chain. It is worthy to note that, the better effect can be achieved if two or more policies, like cap and tax, are considered in the same time.

There are many shortages in the exciting literature and the future research can be focused on the following tips.

- The impact of carbon credits in cap-and-trade on GSCND should be explored further.
- The influence of carbon emissions on customers demand is rarely taken into account.
- A comprehensive research on international carbon policies on a GSCND is deficient.

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