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Game Theory-Based Research in Green Supply Chain Management: A Review

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Abstract: A vast literature has been developing on the topic of Green Supply Chain Management (GSCM) during the last two decades. Focusing on coordinating the decision making and the activities of the supply chain partners, game theory emerged as an essential methodological tool for analyzing GSCM. This paper presents a review the research that used game theoretical approaches in analyzing the Green Supply Chain (GSC). We first give an overview of this literature and classify papers based on the problems investigated. Then, we give a brief review and highlight the contribution of the papers. We include also a discussion of our findings where we point out the different achievements and limits of the existing literature and the opportunities for future research.

Keywords**:** Green Supply Chain Management, Game Theory, Coordination, Literature Review.

1. INTRODUCTION

A supply chain could be defined as a set of entities directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer (Mentzer et al. 2000). Effective management of the supply chain requires different partners to adopt common goals and coordinate their activities accordingly to achieve these common goals and share the corresponding benefits (Fawcett et al. 2008). Therefore, game theory has become an essential tool to improve decision making and optimize the overall chain performance. A considerable literature on the applications of game theoretic approaches in supply chain management has accumulated in the last few decades and comprehensive reviews of this literature have been published. Cachon and Nentessine (2004) highlighted game theory related concepts and techniques that are used in supply chain analysis. Leng and Parlar (2005) covered a broad scope and reviewed the use of game theoretic analysis in different supply chain management related areas: inventory management, production and pricing competition, capacity decisions, service quality, advertising and new product introduction. It is no surprise that the nascent topic of Green Supply Chain Management (GSCM) has not been included in these reviews, as this topic has not yet established enough in the literature (Fahimnia et al., 2015).

Driven by various market and non-market pressures (Zhu et al. 2013), managing the operations of the supply chains in an environmentally friendly manner has gained attraction of the practitioners and researchers, and a vast body of literature on GSCM rapidly developed in the past two decades (Fahimnia et al., 2015). Several reviews of this literature were published. Some of these reviews (Srivastava, 2007; Seuring and Müller, 2008; Hassini et al., 2012; Fahimnia et al., 2015) present a wide perspective and cover the entire GSCM field or even the broader area of "Sustainable Supply Chain Management (SSCM)". Other reviews focus on specific topics such as the organizational theories used in GSCM literature (Sarkis et al., 2011), the modelling approaches for sustainable supply chain management (Seuring, 2013) or the analytical models for green supply chain management (Govindan et al., 2015). Even though a large number of research studies on GSCM follow a game theoretic approach, to the best of our knowledge, a literature review of the applications of game theory in the area of GSCM has not been published yet. Our study tends to fill this gap.

Our review study will help to highlight the main research questions in GSCM that were discussed using a game theoretic approach, show the progress of the academic knowledge in this area and provide insights for future research directions and needs. We note that green or environmental issues in supply chain management could be viewed as one aspect of sustainable supply chain management that addresses the social dimension in addition to the environmental impact. However, to further bound and focus our efforts, only papers studying the environmental issues in supply chain management are considered.

The paper is organized as follows. Section 2 describes the methodology used in searching the literature and performing

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the content analysis and the resulting classification of the literature. Section 3 presents a detailed analysis of the papers. Section 4 provides a discussion of the main findings and directions for future research. Section 5 concludes our study.

2. RESEARCH METHODOLOGY

To ensure the objectivity and validity, a literature review should follow a systematic, explicit, and reproducible design (Fink, 2001). The objective is to identify, evaluate and classify the works in a body of literature so as to map the knowledge in the field and uncover gaps and opportunities for future research (Tranfield et al., 2003). For this purpose, we use a structured process that ensures the objectivity of the findings and the reproductibility of the research. Similar to those used in previous reviews on GSCM (Srivastava, 2007; Seuring and Müller, 2008; Govindan et al., 2015), our review process consists of the following steps:

- Collecting the material: this step consists of defining the unit of analysis, delimiting the scope of the literature review, determining the resources to be searched, collecting and cleaning the material to be analysed.
- Producing a descriptive analysis of the collected material: assessing and analysing some formal aspects of the collected material and providing descriptive statistics, such as the distribution of publications through the time and on journals.
- Selecting categories and classifying the literature: establishing selected categories for structuring the literature and classifying the collected material.
- Evaluating the material: analysing the papers in each category and interpreting the results to provide insights and identify future research directions.

2.1 Delimiting and searching the literature

Defining clear boundaries for the literature to be searched is a crucial step in any literature review. For the purpose of our study, we search literature on the intersection of GSCM and game theory published in English language in peer-reviewed scientific journals with a management focus. We consider only the journal articles and exclude the books. We exclude also the publications that have a technical, political or ethical focus, the papers that address single firm-level problems and those that do not focus on environmental issues.

To collect the materials, we conducted a structured keyword search in the data bases provided by the main publishers: Elsevier (www.sciencedirect.com), Emerald (www.emeraldinsight.com), Wiley (www.wiley.com). Keywords used include “Supply Chain”, “Green”, “Environment*”, “Game”, “Contract” and “Coord*”. Combinations of these terms were searched in the titles, abstracts and keywords of the papers. In total, we used six combinations of keywords that guarantee the presence of the term “Supply Chain” along with the term “Green” or “Environment*” and one of the terms “Game”, “Contract” or “Coord*” in the searched fields. Thus, keywords combinations used in the search were: Supply chain AND Green AND Game; Supply chain AND Green AND Contract; Supply chain AND Green AND Coord*; Supply chain AND Environment* AND Game; Supply chain AND Environment* AND Contract; Supply chain AND Environment* AND Coord*.

Our search attempt came out with a big number of papers of which several appeared in more than one list of results. A first step in cleaning the data was to eliminate the duplications. This left a unique record for each paper in the search results. A further check was performed using mainly the abstracts and sometimes the main text to decide whether to include exclude the paper. To increase the reliability of this step, papers were examined by two researchers separately, their final lists of papers were compared and exceptions solved to agree on one single list of papers that constitute the body of the literature.

2.2 Descriptive analysis and initial statistics

The body of literature identified comprises 67 papers. Fig. 1 shows the distribution of this number according to the year of publication until 2017. The oldest paper that we found in our review was published in 2005. Publications before 2011 are scant. Out of the 67 papers we found only 4 were published between 2005 and 2010. Since 2011, yearly publications follow an increasing pattern and reached a maximum of 28 in 2017. This shows that through the recent years, game theory has been taking attention and gaining popularity in analysing the GSC. As the peak is reached at the end of the period under consideration, we expect that the number of publications will continue to increase in the coming years. So, we might say that the use of game theory in GSC analysis is still at development/growth phase.

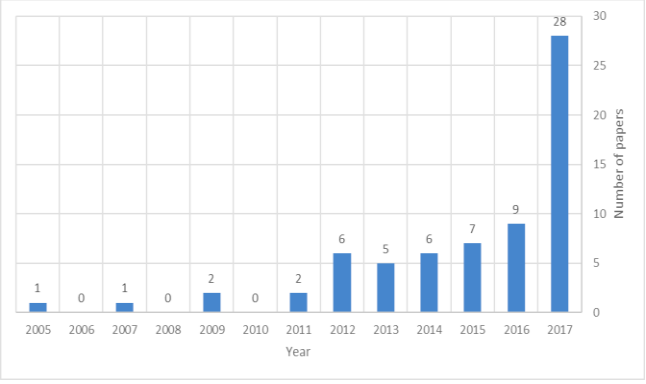

Fig. 1. Distribution of publications per year across the period studied.

Our research shows that 20 journals contributed to this literature. Among journals a large variation is observed regarding the contribution (Table 1).

11 of these journals published a single paper each, while 3 journals published more than half of the articles (39 papers

out of 67). These are the Journal of Cleaner Production (19 papers), the European Journal of Operational Research (11 papers) and the International Journal of Production Economics (9 papers). It is not surprising that the highest contribution comes from the Journal of Cleaner Production as this journal is fully specialized in sustainable production and mainly publishes quantitative research work.

Table 1. Distribution of publications according to the journals

Journal's title	Number of Articles
Journal of Cleaner Production	19
European Journal of Operational Research	11
International Journal of Production Economics	9
Computers & Industrial Engineering	5
Transportation Research Part E: Logistics and Transportation Review	4
Omega	2
Supply Chain Management: An International Journal	2
Transportation Research Part D: Transport and Environment	2
Energy Policy	2
Other journals with 1 paper each	11
Total	**67**

2.3 Classifying the literature

Selecting categories for classifying the literature can be done using deductive or inductive approach (Seuring and Müller, 2008). We first used the deductive approach and established an initial set of problem context-based classes (Srivastava, 2007) that included the green design, green operations, reverse supply chain and government interventions. However, this classification has quickly appeared to be too limited, and couldn't express all the questions addressed by the identified literature. So, the classes were further refined and augmented through an inductive approach based on content analysis of the papers. The final set of classes that we found representative and could cluster all the identified literature for further analysis is presented in Table 2.

The classification of papers is intended for providing a clear picture of the literature and a better understanding of the problems addressed rather than establishing a rigid partition of the literature. There exist overlaps between the identified classes. While the problem class of some papers could be clearly identified, many papers present various aspects that allow for assigning them into two or more classes. To give an example, a paper could investigate the problem of pricing the green product concurrently with the question of determining the green level of the product. Therefore, it could be assigned either to "Pricing the green product" or "Coordinating the product/operations greening efforts" class. However, as it is possible to identify the main problem emphasized in each paper, we made the classification choice considering the main problem addressed in the paper.

Table 2. Distribution of publications according to the categories

Journal's title	Papers (Ordered wrt Publication Year)
Green product design	Subramanian et al. (2009), Wu (2013), Liu and Song (2017), Zhu and He (2017)
Coordinating the operations greening efforts	Corbett et al (2005), Barari et al. (2012), Ghosh and Shah (2012), Nagurney and Yu (2012), Liu et al. (2012), Zhao et al. (2012), Swami and Shah (2013), Ghosh and Shah (2015), Zhang et al. (2015), El Ouardighi et al. (2016), Huang et al. (2016), Kellner (2016), Wang et al. (2016), Basiri and Heydari (2017) Chen et al. (2017), Chen and Wang (2017), Dai et al. (2017), Ji et al. (2017), Xie et al. (2017), Xing et al. (2017), Xu et al. (2017), Yang et al. (2017a), Yang et al. (2017b), Yang and Chen (2017)
Pricing the green product	Zhang et al (2014), Gan et al. (2015), Li et al. (2016), Liu and Yi (2017), Ulku and Hsuan (2017) Zhao et al. (2017)
Coordinating the closed-loop Supply chain	Mafakheri and Nasiri (2013), De Giovanni & Zaccour (2014), Govindan and Popiuc (2014), Savaskan et al. (2014), Hong et al. (2015), Fallah et al. (2015), Wu and Wu (2016), Yi et al (2016), Cheng et al. (2017), He (2017) Hong et al (2017), Huang and Wang (2017), Jafari et al. (2017)
Diffusion and performance measurement	Zhu and Dou (2007), Naini et al. (2011), Tian et al. (2014), Zhang et al. (2016)
Governmental interventions and policy making	Chen and Sheu (2009), Sheu (2011), Sheu and Chen (2012), Du et al (2013), Chung et al (2013), Sheu and Chen (2014), Sheu and Gao (2014), Hafezalkotob (2015), Xie (2015), Hafezalkotob (2017), Heydari et al. (2017), Li and Li (2017), Madani and Rasti-Barzoki (2017), Wang et al. (2017), Yang and Xiao (2017), Zhou et al. (2017)

3. PRESENTATIONS OF THE PAPERS CATEGORIES

In this section, we present the different categories of papers that we have established throughout our analysis. Due to the limited space, we don't analyze the content of the papers in each category.

3.1 Green product design

This category includes papers that address decisions taken during the design phase of the product and which affect its environmental impact. Such decisions could be related to an assessment of the product environmental impact through its whole life-cycle or to a specific technology or features incorporated in the product through an environmentally conscious design.

3.2 Coordinating the operations greening efforts between supply chain members

Greening the operations imposes costs to the companies which take the initiative of doing it while it benefits to the whole supply chain by attracting the environmentally sensitive consumers who are generally willing to pay a premium price for greener products. This raises many questions on the coordination of the greening efforts and the distribution of the resulting rewards among the supply chain partners. Works in this category attempt to formulate such questions and answer them under several conditions and assumptions which mainly address the contribution of each supply chain member; the power structure in the chain; the competition between the green and the standard product on the market or between different entities of the same supply chain or between different supply chains, and; the existence of regulations regarding the green aspect of the products, especially regulations regarding carbon emission such as cap-and-trade regulation. This class of problems is strictly different from the green product design, as this later is concerned only with specific decisions and choices made during the design phase that are related to the green characteristic of the product.

3.3 Pricing the green product

Studies in this category investigate pricing the green product under various conditions and settings regarding the power structure between the chain members, the decision mechanisms, and the existence or not of a substitutable standard product in addition to other marketing conditions.

3.4 Coordinating the closed-loop supply chain

This category regroups all studies that investigate questions related to product return, recycle and reuse.

3.5 Diffusion and performance measurement

Diffusion refers to the processes spread over time through which supply chain members adopt the green practices. As well as the enterprises, the stakeholders, including governments and consumers take important roles in the adoption process. Game theory has been used to model the strategic relationships among the stakeholders and describe the diffusion process.

3.6 Governmental interventions and policy making

Government regulations and policy changes have considerable effects on the management of supply chains. Governments play an important role in the markets through taxes and tariffs. They substantially affect the decisions taken for the design of the chain and the planning of the operations. Studies that focus on governmental interventions cover the coordination of both the forward and the reverse green supply chains and the emission trading.

4. DISCUSSION

This paper provides a first review of publications that apply the game theoretic approach for analyzing the GSC. Our main contribution lies in identifying classes of problems in the related literature and aggregating the so far scattered research in these classes. Our work allows for a better understanding of the literature by identifying the various contributions in each class of problems and uncovering the existing gaps. Several points could be highlighted regarding the current state of the literature and the potential developments. We summarize our discussion under two main titles: the scope of the problems addressed and the types of the games modelled.

4.1 The scope and depth of research using game theoretic approach in GSCM analysis

A broad scope of GSCM problems investigated.

Our review reveals that a wide range of the problems that have been traditionally studied in GSCM literature (see Srivastava, 2007; Seuring and Müller, 2008; Hassini et al., 2012; Fahimnia et al., 2015 for comprehensive reviews) have been addressed using the game theoretic approach. However, GSCM topics are disproportionately represented in the literature, and there is a lack of research on some specific issues in GSCM.

Imbalanced distribution of GSCM topics.

Traditionally, GSCM problems have been investigated under two wide groupings (Srivastava, 2007). The first one contains the green design problems that emphasize the environmental effects of the products through both product environmentally conscious design of the product and life-cycle analysis of the product. The second one covers green operations that embraces both the forward and reverse supply chain operations, such as manufacturing, distribution, collection, disposal and remanufacturing. While the green operations categories -which have been discussed under “Coordinating the operations greening efforts between supply chain members” and “Coordinating the closed-loop supply chain”- are addressed by many game theory studies, only four papers focus on green design decisions. Among them only one explicitly adopted a product life-cycle approach (Liu and Song, 2017). Thus, we believe that green design in general (design for material and product recovery and disassembly,

design for waste minimization, design for replacing hazardous materials) and more specifically green design based on life-cycle analysis, constitute very promising areas for future game theoretic-based investigations.

Performance assessment and evaluation metrics design is under represented in the reviewed literature, as only two papers focused on it (Naini et al., 2011; Zhang et al., 2016). This is not surprising considering the scarcity of the supply chain metrics studies (Gunasekaran et al., 2004) and particularly of GSC metrics (Hassini et al., 2015). Nevertheless, this topic is promising for research using game theoretic approach, especially for games with asymmetric information.

Finally, our review points out that most studies investigate two echelon of the supply chain (such as a manufacturer and a retailer). There is a lack of studies that deal with the extended supply chain that includes more than two echelons. Therefore, we think that using game theoretic-based approach for analyzing GSCM issues in the extended supply chain constitute an important research avenue in the future.

Lack of addressing specific greening practices and environmental impacts.

Greening operations could take several forms such as implementing green manufacturing by using techniques for minimizing energy and resource consumption, proper management of inventory and production planning that take into account the environmental impact, pollution preservation and waste minimization (Beamon, 199; Sarkis, 2003). However, except for carbon emissions reduction, and energy efficiency, most papers in this category are vague about the type of environmental impact under consideration. We think that specific aspects of operations greening such as resource consumption, inventory management, production planning and scheduling, and waste minimization constitute very promising topics for future investigations and research using game theoretic approach.

4.2 The types of games modelled

Most of the reviewed papers apply non-cooperative games and use Stackelberg or Nash equilibrium concepts. Many of these papers examined also coordination and cooperation issues through contracts. However, very few studies used cooperative game solution concepts. This is not surprising as previous reviews of the wider body of literature on game theory applications in supply chain management pointed out the same phenomenon of scarcity of the research that uses cooperative games concepts involving the characteristic function form such as such as the core, shapley value, nucleolus etc. (Cachon and Nentessine, 2004; Leng and Parlar, 2005). Nevertheless, these concepts are very powerful tools for analyzing a big number of potential situations in GSCM where the supply chain members can achieve better if they cooperate with each other and act collectively. Similar to cooperative games, we observe that dynamic games and games with asymmetric information have been rarely used in analyzing GSCM issues and could be applied more widely in this domain.

5. CONCLUSION

In this paper we presented a systematic review of the literature that uses the game theory for analyzing the GSC. Our paper presents the first review work of game theory-based research in GSCM. Our analysis shows a rapid expansion of these studies in the last five years demonstrating that game theory is more and more adopted for analyzing the GSC. The reviewed literature covers a large span of GSC-related issues. The classification of the literature in 6 categories allowed us to show that some topics are more represented than others and that there is a lack of studies that investigate specific aspects of the GSC. Our study demonstrates also that cooperative games and games with asymmetric information are scarce in the existing literature. Finally, this study allowed us to underline the research gaps and provided insights for future research directions.

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