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**The role of environmental collaborative strategies in greening supply chains: insights from a case study analysis**

**1. Introduction**

Strategic cooperation among companies involved in the production of a good/service allows firms to obtain bigger environmental improvements and reductions of costs (Melander, 2017) from reorganizing existing processes in the supply chain (Carbon Trust, 2008). From this perspective, competence shifts from companies to supply chains (Ketchen and Hult, 2007; Krantz, 2010) and green supply chain management (GSCM) is a useful tool for improving cost managing of green products considering the whole supply chain of a product.

In particular, carbon management has received attention from organizations and practitioners, interested in reducing the carbon emissions produced on the supply chain (e.g. Theiben et al., 2014; Singh et al., 2015; Giannarakis et al., 2017) to advance in the development of green products (Zhao et al., 2017).

However, carbon management research at supply chain level is still in its initial phase. While prior research has underlined that collaborative strategies have a big potential for reducing the carbon footprint (CF) of products (e.g. CDP, 2013; Pagell and Shevchenko, 2014), there is a lack of studies which examine how different decisions with regard to the supply chain would impact products’ CF and, by extension, the environment. There is a need to 1) quantify in what extent collaborative strategies are more effective to reduce CF of products than internal or organization level actions; 2) determine which actions have a strong effect impact on the final product of specific supply-chains and 3) decide in what part of the supply chain these actions should be implemented to have the greatest impact on products’ CF. These tasks are especially encouraging for products obtained in global supply chains, comprised by multiple intermediaries placed in different countries all over the world (Pagell and Shevchenko, 2014).

This article aims to contribute to the detection of such circumstances by assessing the impact of different CF reduction strategies on a supply chain. The objective is to determine if collaborative strategies have more potential than isolated actions taken at an organizational level to achieve low carbon products. In addition, this research also examines the contribution of different actions aimed to reduce the CF in different stages of the supply chain.

The remainder of the paper is organised as follows. The following section reviews the concepts of sustainable and green supply chain, analysing the importance of inter-organizational collaboration to reduce carbon emissions along the supply chain. The third section is devoted to the explanation of the materials and methodology used in this paper. The main results are presented in section four. Finally, conclusions are included in the last section.

**2. Theoretical background**

Supply chains can be defined as a set of upstream and downstream linkages between suppliers of materials and services which affect different processes and activities that produce goods and services delivered to the final consumers (Teng et al., 2006). Those linkages often involve flow of products, services, finances, and/or information from a source to a customer (Mentzer et al., 2001). Supply chain management (SCM) aims to integrate and control the normal flow of material across the supply chain, considering multiple tiers among suppliers and customers (Monczka et al., 1998).

Theories such as the purchasing portfolio model (Kraljic 1983), stakeholder theory (Freeman, 1984), the resource-based view (Wernerfelt, 1984) the natural resource-based view (Hart, 1995), institutional theory (Jennings and Zandbergen, 1995) or the dynamic capabilities view (Teece et al., 1997) have been used to support supply chain management research. More recently the relational view (RV) has been used to analyse the role of collaborative environmental strategies to improve the environmental performance of supply chains (Theiben et al., 2014).

RV notes that supply chain relationships among suppliers and partners can be seen as an intangible resource which enables value creation (Priem and Swink, 2012). In particular, collaboration among supply chain partners involves benefits (e.g. knowledge sharing, complementary resources, access to partners’ experience or relation specific assets) which are difficult to achieve if organizations does not work together (Gold et al., 2010; Theiben et al., 2014). Relational view approach is well suited to analyse the role of collaborative strategies in achieving low carbon products, forming the theoretical foundation of this study.

*2.1. Sustainable supply management, green supply chain management and carbon management*

Sustainable supply chain management (SSCM) brings the sustainability triple bottom line approach of economic, environmental, and social performance into the supply chain analysis (Tseng et al., 2015). SSCM is defined as “the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, economic, environmental and social, into account which are derived from customer and stakeholder requirements” (Seuring and Müller, 2008, p.1700). From this perspective, sustainable supply chains should be able to maintain economic viability without harming social or natural systems during an extended period of time (Pagell and Wu, 2009; Pagell and Shevchenko, 2014).

One of the main interests for researchers in SSCM is the management of environmental issues within a supply chain (Lintukangas et al., 2015). As environmental impacts of products do not occur in only one of the companies involved in their production, some firms are aware of the importance of managing environmental aspects that occur out of the boundaries of their facilities (Kogg, 2003).

Green or environmental supply chain management (GSCM) is focused on environmental questions that affect a product along the supply chain. Although researchers have proposed different definitions, previous studies have pointed out that GSCM aims to minimize the environmental impacts (e.g. emissions, wastes, hazardous chemicals…) along the whole supply chain (Chin et al., 2015), through different actions in response to concerns related to the natural environment (Kogg, 2003). Those actions are intended to greening the supply process or the products obtained in that process (Seuring, 2004, 2011) and implementing green development strategies while managing the external environmental pressures (Zhao et al., 2016). The efficient management of environmental issues in many supply chains is a complex and challenging task. Supply chains are complex networks that involve different activities, operations and relationships among the members of the supply chain (Harms et al., 2013). Besides environmental objectives, organizations need to satisfy contradicting economic and social objectives, and dealing with tensions between them.

Within GSCM, carbon management aims to reduce life cycle carbon emissions of products and organizations and move toward a low-carbon business model (Zhao et al., 2017). By focusing on a single environmental impact, carbon management makes easier the transmission of information along the supply chain. The CF is a well-known indicator, easy to understand, globally communicable and easy to implement (Alvarez et al., 2016). It can be estimated at an organization and product levels, being a valid indicator for the eco-label of goods and services (Carbon Trust, 2006; Coto-Millán et al., 2010). CF methodologies allow for obtaining the CO2 emissions of each stage in a supply chain, helping firms to prioritize those stages where the emissions are higher and making easier to obtain the products’ CF (McKinnon, 2010).

As a consequence, CF management has received increased attention from a number of upstream and downstream firms on the supply chain, which are interested in reducing their greenhouse emissions and move toward a low-carbon business model (Singh et al., 2015; Zhao et al., 2017).

Figure 1 The relationship between supply chain management (SCM) and Carbon management (CM)

[PLEASE, INSERT FIGURE 1 HERE]

SSCM: sustainable supply chain management; GSCM: Green supply chain management

*2.2. Interorganizational collaboration aimed at greening products*

Many companies interested in managing the environment have improved their environmental performance by focusing on organizational intra-firm activities related to applied technologies, pollution preventing activities, waste management or rethinking the design of their products. These activities are often costly, limit the potential benefits of managing the environment and often discourage firms from reducing their environmental impacts (Vermulen and Ras, 2006).

Strategic cooperation between companies in product chains increases the opportunities of improving environmental performance by allowing companies to look beyond their organizational boundaries to find new ways to reduce environmental burdens along the supply chain (Giurco and Petrie, 2007; Theiben et al., 2014). Strategic cooperation can arise in two different ways: on the initiative of a focal company with an influential position on the supply chain or through collective cooperation between various parties which participate in a supply chain (Cramer, 1996).

The first form of cooperation is particularly interesting for large firms closer to the downstream end of supply chains which are involved in the manufacture and distribution of products who sell to final customers. As customers associate these powerful companies with the products they buy, firms’ reputation is specially exposed to environmental risks associated with the products they sell, although the origin of these problems could be in other stage of the supply chain. Hence, leading companies are interested and have the power to encourage their suppliers to improve the environmental management of their products (Cramer, 1996).

Collective forms of cooperation among supply chain members often arise when they realize that that coordination involves mutual benefits for the cooperating companies, or any of them have enough resources to lead the necessary change process (Cramer, 1996). Some members of a supply chain could realize that they are not able to manage environmental burdens independently and they enjoy synergies from collaborating with other partners (Seuring, 2004).

Researchers have noted that a collective approach is more effective for encouraging supply chain members to engage in environmental management and learn from each other (e.g. Carter and Rogers, 2008; Fynes et al., 2008; Müller et al., 2012; Theiben et al., 2014). Working closely with other partners could involve different benefits from accessing to partner’s expertise, sharing knowledge, or exploiting the synergies that flow from combining expertise and experience. Partnership-building promotes more environmentally friendly products than other forms of cooperation, being a way of creating advantages such as better product quality (Chiou et al., 2011; Theiben et al., 2014).

The importance of inter-organizational collaboration to reduce CO2 emissions along the supply chain has been recently underlined. Collaborative CO2 reduction management aims that the members of a supply chain work together to maximize CO2 reduction in order to “better meet customer expectations, mitigate risks related to climate change, lower energy costs, and improve public reputation” (Theiben et al., 2014, p.44). Collaboration to reduce CO2 emissions involves sharing emissions data, knowledge, people and assets, allowing carbon savings from both internal efficiencies and change and reorganisation of external process (Carbon Trust, 2006).

**3. Material and methods**

*3.1. The studied case*

A case study approach is adopted to examine the role of different carbon reduction strategies in a supply chain comprised of four companies. Case study analysis is well suited for areas of research such as ours which are still in an exploratory phase, because they can increase our understanding of phenomena that have not been analysed in deep such as CO2 management of supply chains. In addition, case studies enable direct interactions with relevant subjects (e.g. managers of the studied companies) and include multiple data sources, which helps to produce more robust results (Theiben et al., 2014).

The developed case study assesses the impact of different actions aimed at reducing products’ CF, providing information on the contribution of collaborative strategies comparing them with isolated actions taken an organizational level.

First, we selected a local supply chain which produces canned-mussels in Galicia (Spain). As it is shown on Figure 2, the selected local supply chain comprises four companies, which produce different mussel-based products: fresh (stage 1), boiled/frozen (stage 2), and canned mussels (stage3 and stage 4). Hence, we assess the effect of different actions aimed at reducing the canned mussels’ CF. Table 1 shows some economic and environmental information of the studied companies.

Figure 2. The studied supply chain

[PLEASE, INSERT FIGURE 2 HERE]

Table 1. Economic and environmental information on the studied organizations

[PLEASE, INSERT TABLE 1 HERE]

Source: Own elaboration.

Second, a total of 5 scenarios have been defined. Scenarios include actions that could be carried out to reduce canned mussels’ CF. Each scenario has in turn two objectives which could be achieved with individual or collaborative strategies. For instance, scenario 1 analyses the impact on products’ CF of two different strategies: working at an organizational level to reduce the consumption of electricity by a 15% in every organization or working together to reduce the CF of the company with the highest electricity consumption by a 60%.

Finally, the effects of every strategy on product’s CF along the supply chain are assessed and reported.

*3.2. Method*

Organizational and products CF were calculated using the Compound Method Based on Financial Accounts (MC3). The MC3 is a hybrid method used to estimate the CF of organisations, goods and services.

MC3 follow an integrated approach which first calculates organizational CF and then distributes it among the products dispatched to the market (Alvarez et. al., 2016). Organizational footprints include Greenhouse gas (GHG) emissions from any organization and its products, expressed in tons of CO2 equivalent and caused by: a) the purchase of all kinds of goods and services; b) the occupation of space; and c) waste generation (Domenech, 2010). This method was described in detail in different studies (e.g. Carballo-Penela and Doménech, 2010; Coto-Millán et al., 2010; Carballo-Penela et al., 2012; Alvarez et al., 2014).

Figure 3. Organizational and products’ footprint

[PLEASE, INSERT FIGURE 3 HERE]

OP: Outgoing products; IP: Incoming products

Source: Cagiao et al. (2014)

The information to determine organizational CF though the MC3 is mainly obtained from accounting documents such as the balance sheet and the profit and loss account, so all activities linked to each organization are perfectly defined. In addition, MC3 could need information provided by the studied companies with regard to wastes generation and certain specific items (e.g. water, fuel, electricity and fuel consumption) (Carballo-Penela et al., 2012; Pereira et al., 2016).

The CF of an organization is estimated from the sum of the footprint of goods and services purchased in the studied year (incoming products). Scope 1 and Scope 2[[1]](#footnote-1) emissions are estimated by applying Exiobase2[[2]](#footnote-2) emission factors (KgCO2eq/litre of fuel and KgCO2eq/ kWh) to the amount of fuel and electricity consumed in the studied year. Scope 3 consider the emissions from the energy needed to produce the goods and services consumed by every organization, applying Exiobase2 emission factors (KgCO2eq/Kg of product) for every category of product.

Once organizational footprints are estimated, MC3 distributes it among the products produced by every company in the studied year (outgoing products), obtaining unitary footprints. The organizational CF of the studied companies was examined in previous studies (e.g. Carballo-Penela and Doménech, 2010; Carballo-Penela and Castromán, 2016). However, organizational footprints were recalculated for this study using Exiobase2 emission factors.

Unitary footprints (tCO2/t of product) are obtained dividing the total footprint of every company by its production. Unitary footprints collect the CO2 emissions/t mussel in every stage of the supply chain of the studied product.

When each of the participants in the supply chain acquires different goods from the company situated in the previous phase, they are also acquiring the CF incorporated in that good. If every participant communicates the unitary footprints of the goods and services that produce to the following phase of the supply chain, the needed connection is made (Carballo-Penela and Castroman-Diz, 2016). If anything that a company buys has a footprint, companies could demand that suppliers leave the smallest footprint possible. In addition, what an organization sells goes with the footprint to their customers (Cagiao et al., 2014). If information on product CF is incorporated to eco-labels, final customers could consider GHG emissions when making purchasing decisions. In practice, initiatives such as Carbonfeel[[3]](#footnote-3) provide technological solutions to store and communicate information of unitary footprints among the participants in a supply chain.

Following MC3 approach, companies interested in reducing the CF of their products could consider different strategies to reduce scope 1, 2 and 3 emissions. A first group of strategies could be focused in reducing the consumption of goods and services (e.g. electricity, fuels, raw materials and any other resource) made by the companies. This could be done by removing those expendable resources or using necessary resources in a more efficient way. A better organization and design of processes; acquiring clean technologies and equipment; reducing the number of transport operations and their length; optimizing machinery performance; increasing the life of products; establishing fuels and electricity and fuel consumption controls; focusing the design of products on reducing resource consumption and waste generation could be useful practices to reduce the consumption of goods and services.

In addition, companies interested in lowering the CF of their products could select suppliers that offer less-carbon intense products, if they include emissions information of the products they sell. Low carbon supplier selection could be an interesting strategy, especially for those organizations which buy and sell products without transforming them (Carballo-Penela, 2010).

*3.3. Data collection*

Organizational CF of every company is obtained by considering the consumed amount of every product purchased by organizations in the studied year in terms of mass units (e.g. tons). These data were obtained from three sources 1) semi-structured interviews with managers; 2) questionnaires developed by the researchers and 3) financial statements of the studied companies.

Interviews with managers provided us with detailed information on the activities developed by every company and the available data for assessing organizational CF. Once the results were obtained, the feasibility of putting in practice by a single organization some measures aimed to reduce the CF of their organizations was discussed with them.

Interviews also allowed us to design specific questionnaires for every firm, asking for information on those consumptions considered relevant by the managers and available in tons or other units, including information on electricity, fuels and water consumption, the wastes generated and different raw materials.

Since firms’ information on some materials and resources consumption is hardly expressed in tons, the money expenditure in every product from financial statements was also used. The conversion into tons is made by considering the specific product average prices in the studied period or foreign trade statistics which include data about exports and imports of the different tariff chapters expressed in monetary units and tons, allowing us to obtain a monetary unit/ton factor.

**4. Results**

Tables 2-6 show the canned mussels’ CF at every stage of the supply chain, including the scenarios results. The baseline scenario show the results of the current canned mussels’ CF, estimated following the method described in section 3. The “Added” column shows the CF added at every stage while the total column shows the accumulated CF after every stage. “Change” column shows how canned mussels’ CF would change with regard to baseline scenario if participants decide to implement actions to reduce CF according to stablished goals. Some of these actions could be consequence from individual actions from every company, while other actions will be more feasible if participants collaborate with other to achieve stablished goals.

First scenario focuses on electricity and compares the effects in canned mussels’ CF of a 15% reduction in the electricity consumption of each participant with concentrating the reduction efforts on a single company (a 60% reduction in the electricity consumptionof *Beta*). *Beta* was chosen due to its high electricity consumption. Second scenario focuses on fuels, making a similar approach to the first scenario. In this case, the isolated reduction (60% of the consumption of fuels) is made in *Alpha*, the company with the highest fuel consumption.

Third scenario show the effect of actions aimed to reduce the CF in different stages of the supply chain. To this end, the effects of a 50% fuel and electricity reduction in *Delta*, the last stage of the selected chain, is compared to a 40% reduction of fresh mussels’ CF (*Alpha*). The purpose of this analysis is to examine what objective is more interesting for the retailer: achieving a 50% reduction in electricity and fuel consumption at the retail stage or working with the other participants to achieve a 40% CF reduction at the mussel harvest stage of the supply chain.

Fourth scenario considers the role of supplier selection to reduce products’ CF. As in the third scenario; the first simulation shows the effects of a 50% reduction in electricity and fuel consumption at the retailer stage. This scenario assesses if this objective produce better results than acquiring greener canned mussels from *Gamma* or another supplier. That is *Gamma* reduces canned mussels’ CF by 25%.

Finally, considering that *Gamma* have the highest organizational CF of the studied companies (Table 1), the fifth scenario considers two different objectives for the canned mussel stage. Purchasing 25% greener frozen mussels from *Beta* and purchasing 25% greener frozen mussels from *Beta* plus reducing by 25% Scope 3 emissions associated to tins used to package the canned mussels. The aim of this scenario is the assessment of reductions in what could be considered “hotspot emissions”.

Table 2. Electricity scenario (t CO2eq / t of product)

[PLEASE, INSERT TABLE 2 HERE]

Table 3. Fuels scenario (t CO2eq / t of product)

[PLEASE, INSERT TABLE 3 HERE]

Table 4. First and last stage scenario (t CO2eq / t of product)

[PLEASE, INSERT TABLE 4 HERE]

Table 5. Strategies at the retailer stage (t CO2eq / t of product)

[PLEASE, INSERT TABLE 5 HERE]

Table 6. Canned mussel stage scenario (t CO2eq / t of product)

[PLEASE, INSERT TABLE 6 HERE]

Table 2 shows that a 60% reduction of the consumption of electricity at the second stage (company *Beta*) produces a canned-mussels’ CF reduction of 5.83%, almost three times higher than the reduction obtained by reducing electricity consumption by a 15% in each company (2.05%). Thus, a high reduction in a single company with high electric consumption could provide better results than soft reductions in each company.

Table 3 shows the results for the second scenario. In this case, the difference is not as prominent as the described for the previous scenario: a high fuel reduction in a single company with high fuel consumption (*Alpha*) produces a 2.29% reduction in products’ CF, slightly better than results from soft reductions in each company (1.82%).

Tables 4 and 5 show results for the third and fourth scenarios. Results show that reducing fresh mussels’ CF at the beginning of the supply chain (a 40% reduction) strongly reduces canned-mussels’ CF (a reduction almost 5 times higher than reducing Scope 1 and 2 emissions at the retailer stage by 50%, Table 4).

In addition, results show that collaboration between the retailer and the canned mussel company could be a successful strategy to reduce the canned mussels’ CF. The purchase of 25% greener canned mussels by the retailer would reduce the final CF by 24.11%, 20 times more than a twofold higher reduction of fuel and electricity at the retailer stage (table 5). This objective could be also attained by selecting a greener supplier.

Finally, results from the last scenario are shown in table 6. Results show how effective could be some actions aimed to reduce canned-mussels’ CF by reducing *Gamma* CF. If *Gamma* acquires 25% greener frozen mussels from *Beta*, canned mussels’ CF decreases 9.65%. A 15.60% reduction is obtained if, in addition, actions to reduce by 25% emissions from tins used to package the canned mussels are implemented (table 6).

**5. Conclusions**

Prior research has underlined that strategic cooperation among companies involved in the production of a good/service have a big potential for reducing the carbon footprint of products. However, researchers have not examined in what extent different environmental decisions made at different stages of a specific supply chain impact final products.

This study considers different CF reduction objectives which can be met with different environmental strategies. Our objective is to provide information on the contribution of collaborative strategies comparing them with isolated strategies taken an organizational level.

Five different scenarios have been proposed. In practice, MC3· method allows companies to do as many simulations as they need to decide on what stage and category of products they should focus the actions aimed to reduce products’ CF. Budget and other organizational limitations should be taken into account to determine what measures they put in practice.

Considering the academic purpose of this research and that the optimal package of measures highly depends on contextual and internal factors of the supply chain members, our analysis does not intend to show which practices minimize the CF of the final product but just illustrating the effect of different actions.

Results underline that concentrating reduction efforts in some stages of the supply chain is more effective than implementing individual actions by the participants. Hence, collaboration among the participants is needed to decide what practices are implemented, in what stage are needed and also how they are going to be implemented.

First, the effect of actions to reduce the canned-mussels’ CF through reducing electricity consumption of the firms involved in the supply chain is examined. The effect of individual measures from every company is compared with the effect of a strategy in which companies decide to concentrate the effort on the company with the highest electricity consumption (*Beta*). Second, a similar simulation focused on the consumption of fuels is made. In this case, the effects on the canned mussels’ CF of individual actions to reduce fuels consumption by every company are compared with concentrating the efforts on the company with the highest consumption of fuels (*Alpha*). Actions aimed to reduce emissions associated to electricity and fuel consumptions were chosen since many organizations focus their efforts in reducing scope 1 and 2 emissions.

Results show that a high reduction of electricity and fuels consumption in *Beta* and *Alpha*, respectively, helps to obtain higher reductions in the canned mussels’ CF than individual actions taken by every company. *Beta* uses electricity mainly for powering the machinery used in the production process of this company and for illuminating purposes. Reducing the consumption of electricity could involve measures such as renewing some machinery and acquiring low-energy light bulbs and devices. *Alpha* mainly uses fuels for powering ships, needed to move to the rafts where mussel is harvested. Measures such as replacing ships engines for more efficient engines could be effective measures for reducing fuels consumption and emissions.

In both cases, *Alpha* and *Beta* considered that they could not afford themselves many some of the proposed practices without financial support and external help. Collaboration from the other members of the supply chain could be useful to encourage them to put in practice the recommended actions.

Third, this research examines the effect of actions led to different stages of the supply chain. Sometimes firms closer to the downstream end of supply chains are interested in leading initiatives to achieve greener products. It is interesting to analyse the impact on product’s CF of actions aimed to reduce the CF in the retailer phase of the supply chain in comparison with actions focused on the first stages of the chain.

Results show that actions implemented in the first stage of the supply chain could have a stronger influence in caned mussels’ CF than actions aimed to reduce scope 1 and 2 emissions in the retailer phase. The reduction of CF at the stage 1 reduces the footprint of the product in the different stages of the supply chain, and the effect in the final product is stronger than even more intense measures implemented in the retailer phase. Hence, in the studied case, retailers could be interested in working with mussel producers to reduce the emissions in the initial stage of the chain.

The fourth simulation tries to illustrate the role of supplier selection in greening products. In this simulation, different actions aimed at lowering the CF at the retailer stage are considered. As in the previous simulation, some actions are focused on scope 1 and 2 emissions form the retailer. In addition, it is analysed what would happen if the retailer acquire canned mussels from suppliers which sell less-intense carbon canned mussel. Our findings show the power of acquiring products which are produced in a more sustainable way, showing that is the most efficient of analysed measures. The retailer of this case study (*Delta*) could work with the other participants in the supply chain to reduce the CF in the canned mussel production stage. It could be also interested in buying canned-mussel from different canned producers which offer low carbon products.

Taking into account the importance of reducing the emissions produced in the retailer stage, a final simulation is made to compare the power of different reducing actions at this stage. Our findings show that *Gamma* could contribute to achieve relevant reductions in the product by reducing the emissions associated with purchased frozen mussel. This could be done by using in a more efficient way frozen mussels (e.g. reducing the frozen mussel wastes during the production processes) and/or acquiring less-intense carbon frozen mussel (e.g. working with *Beta* to reduce the emissions at the freezing stage or replacing *Beta* for a more efficient supplier). In addition, results also show that purchasing less-intense carbon tins or reducing the amount of tins needed are effective measures to reduce canned-mussels’ CF (e.g. reducing the number of tins which are lost during the packaging process).

5.1 *Practical implications*

These findings have practical relevance for companies and organizations. First, prior research has noted the need of analysing in what extent supplier selection could contribute to greening products (Theiben et al., 2014; Reizer et al., 2016). This work provides insights to this question, showing that supplier selection could play a relevant role for greening the product obtained in the studied supply chain.

Second, although some studies on CF are focused on Scope 1 and Scope 2 emissions, our findings also confirm the importance of Scope 3 emissions, as some studies previously have pointed out (Alvarez et al., 2015; Carballo-Penela and Castromán, 2016). Hence, organizations interested in reducing the CF of their products should consider actions aimed at reducing Scope 3 emissions when designing environmental strategies.

Third, our study proposes different measures that help companies to achieve the established emissions reduction goals. For instance, replacing ships engines for more efficient engines could be help *Alpha* to reduce fuels consumption and associated emissions. However, this analysis does not quantify in what extent the proposed measures help to achieve stablished goals.

We want to note that MC3 is based in the footprint analysis. Footprint analysis tries to connect consumption and waste generation with environmental impact (Wackernagel and Rees, 1996). Considering this premise, our aim is to help organizations to see the environmental side of their consumption patterns, underlining what activities have more impact in terms of emissions. At a supply chain level, this kind of information is very useful, providing a way of quantifying how the products’ CF at the final stage is affected by different actions implemented along the supply chain. This information helps organizations to set the appropriated objectives. Since some of them are difficult to achieve through individual initiatives, collaboration among the members of the supply chain could help companies to produce greener products.

*5.2. Limitations of the study and future research*

The current study has some limitations. First, a case study approach is well suited for the purpose of this research. However, this approach opens the question of generalizability of results. The studied case is focused on a specific supply chain, being debatable if the obtained findings can be generalized to other supply chains.

Although results of the simulations could be different when considering a different supply chain, the information provided by this study is useful for both academic purposes and also for companies interested in reducing the CF of the studied product. Information on how different collaborative actions with regard to the supply chain would impact products’ CF is still very scarce and our findings provide knowledge on the impact of different actions that need of collaboration among the participants in the studied supply chain, also showing in what stages reduction measures are more efficient.

In addition, it is interesting to develop a similar analysis in more complex supplier chains. Working with a local short supply chain focused in one product involves some advantages in order to understand the proposed analysis and the followed approach. However, supply chains usually involve more complexity, for instance, for not being linear processes (Zhu and Sarkis, 2004) or the participation of a high number of organizations placed in different locations. As Carbonfeel provides the technology to store and communicate environmental information among the members of any supply chain, with independence of their number and location, future research should develop a similar analysis in more complex supply chains.

**References**

Alvarez S, Blanquer M, Rubio A. 2014. Carbon footprint using the Compound Method based on Financial Accounts. The case of the School of Forestry Engineering, Technical University of Madrid. *Journal of Cleaner Production* **66** 224-232. DOI: 10.1016/j.jclepro.2013.11.050

Alvarez S, Carballo-Penela A, Mateo-Mantecón I, Rubio A. 2016. Strengths-Weaknesses-Opportunities-Threats analysis of carbon footprint indicator and derived recommendations. *Journal of Cleaner Production* **121** 238-247. DOI: 10.1016/j.jclepro.2013.11.050

Alvarez S, Planelles R, Rubio A. 2015. Carbon footprint from helitankers: sustainable decision making in aerial wildfire fighting. *International Journal of Wildland Fire* 24(7): 983-988. DOI: 10.1071/WF15011#sthash.H9UWDuI4.dpuf

Cagiao J, Meijide BG, Carballo-Penela A, Labella S. 2014. Carbonfeel Project: Calculation, Verification, Certification and Labeling of the Carbon Footprint. *Low Carbon Economy* **5**: 65-79. DOI: [10.4236/lce.2014.52008](http://dx.doi.org/10.4236/lce.2014.52008)

Carballo-Penela A. 2010. *Ecoetiquetado de bienes y servicios para un desarrollo sostenible*. AENOR Ediciones: Madrid

Carballo-Penela A, Castromán-Diz JL. 2016. *Responsabilidad social y gestión de las cadenas logísticas*. AENOR ediciones: Madrid.

Carballo-Penela A, Doménech J. 2010. Managing the carbon footprint of products: the contribution of the method composed of financial statements (MC3). *The International Journal of Life Cycle Assessment* **15**(9): 962-969. DOI: 10.1007/s11367-010-0230-1

Carballo-Penela A, Mateo-Mantecón I, Doménech JL, Coto-Millán P. 2012. From the motorways of the sea to the green corridors' carbon footprint: The case of a port in Spain. *Journal of Environmental Planning and Management* **55**(6): 765-782. DOI: 10.1080/09640568.2011.627422

Carbon Trust 2006. *Carbon footprints in the supply chain: the next step for business*. The Carbon Trust: London.

Carbon Trust 2008. *Product carbon footprinting: the new business opportunity pack*. The Carbon Trust: London.

Freeman RE. 1984. *Strategic Management: A stakeholder Approach*. Pitman: Boston, MA

Carter CR, Carter JR. 1998. Interorganizational Determinants of Environmental Purchasing: Initial Evidence from the Consumer Products Industries. *Decision Sciences* **29**(3) 659-684. DOI: 10.1111/j.1540-5915.1998.tb01358.x

CDP (Carbon Disclosure Project). 2013. *Reducing Risk and Driving Business Value*. https://www.cdp.net/cdpresults/cdp-supply-chain-report-2013.pdf. (accessed May 20, 2017).

Chin, T.A., Tat, H.H. and Sulaiman, Z. 2015. Green supply chain management, environmental collaboration and sustainability performance. *Procedia CIRP* **26** 695-699. DOI: [10.1016/j.procir.2014.07.035](https://doi.org/10.1016/j.procir.2014.07.035)

Chiou T-Y, Chan HK, Lettice F, Chung SH. 2011. The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transportation Research Part E: Logistics and Transportation Review* **47**(6) 822-836. DOI: 10.1016/j.tre.2011.05.016

Coto-Millán P, Mateo-Mantecón I, Quesada JLD, Carballo-Penela A, Pesquera, M. A. 2010. Evaluation of port externalities: the ecological footprint of port authorities. In *Essays on port economics*, Coto P, Pesquera MA, Castanedo J, (eds.), Essays on port economics*,* Springer: London, pp. 323-340. DOI: 10.1007/978-3-7908-2425-4\_20

Cramer J. 1996. Experiences with implementing integrated chain management in Dutch industry. *Business Strategy and the Environment* **5**(1) 38-47. DOI: 10.1002/(SICI)1099-0836(199603)5:1<38::AID-BSE36>3.0.CO;2-O

Fynes B, De Burca S, Mangan, J. 2008. The effect of relationship characteristics on relationship quality and performance. *International Journal of Production Economics* **111**(1) 56-69. DOI: 10.1016/j.ijpe.2006.11.019

Giannarakis, G., Zafeiriou, E. Sariannidis, N. 2017. The Impact of Carbon Performance on Climate Change Disclosure. *Business Strategy and the Environment.* Early view. DOI: 10.1002/bse.1962

Giurco D, Petrie J. 2007. Strategies for reducing the carbon footprint of copper: New technologies, more recycling or demand management? *Minerals Engineering* **20**(9) 842-853. DOI: 10.1016/j.mineng.2007.04.014

Gold S, Seuring S, Beske P. 2010. Sustainable supply chain management and inter-organizational resources: a literature review. *Corporate Social Responsibility and Environmental Management* **17**(4) 230-245. DOI: 10.1002/csr.207

Harms D, Hansen EG, Schaltegger S. 2013. Strategies in Sustainable Supply Chain Management: An Empirical Investigation of Large German Companies. *Corporate Social Responsibility and Environmental Management* 20(4) 205-218. DOI: 10.1002/csr.1293

Iribarren D, Moreira MT, Feijoo G. 2010. Revisiting the life cycle assessment of mussels from a sectorial perspective. *Journal of Cleaner Production* **18**(2) 101-111. DOI: 10.1016/j.jclepro.2009.10.009

Ketchen, DJ, Hult GTM. 2007. Bridging organization theory and supply chain management: The case of best value supply chains. *Journal of Operations Management* **25**(2) 573-580. DOI: 10.1016/j.jom.2006.05.010

Kogg B. 2003. Power and incentives in environmental supply chain management. In *Strategy and organization in supply chains*, Seuring S, Müller M, Goldbach M, Schneidewind U. (eds.), Essays on port economics*,* Springer: London, pp. 65-81.

Lintukangas K, Hallikas J, Kähkönen AK. 2015. The Role of Green Supply Management in the Development of Sustainable Supply Chain. *Corporate Social Responsibility and Environmental Management* 22(6) 321-333. DOI: 10.1002/csr.1348

McKinnon AC. 2010. Product-level carbon auditing of supply chains: environmental imperative or wasteful distraction? *International Journal of Physical Distribution & Logistics Management* **40**(1/2) 42-60. DOI: 10.1108/09600031011018037

Melander L. 2017. Achieving Sustainable Development by Collaborating in Green Product Innovation. *Business Strategy and the Environment*. Early view. DOI: 10.1002/bse.1970

Mentzer JT, Dewitt W, Keebler JS, Soonhong M, Nix, NW, Smith CD, Zcharia, CJ. 2001. Defining supply chain management. *Journal of Business logistics* **22**(2) 1-25. DOI: 10.1002/j.2158-1592.2001.tb00001.x

Monczka, R.M., Handfield, R.B., Giunipero, L.C. and Patterson, J.L. 2015. *Purchasing and supply chain management*: Cengage Learning, Hampshire.

Muller C, Vermeulen WJV, Glasbergen P. 2012. Pushing or Sharing as Value-driven Strategies for Societal Change in Global Supply Chains: Two Case Studies in the British–South African Fresh Fruit Supply Chain. *Business Strategy and the Environment* **21**(2) 127-140. DOI: 10.1002/bse.719

Pagell M, Wu Z. 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of Supply Chain Management* **45**(2) 37-56. DOI: 10.1111/j.1745-493X.2009.03162.x

Pagell M, Shevchenko A. 2014. Why research in sustainable supply chain management should have no future. *Journal of Supply Chain Management* **50**(1) 44-55. DOI: 10.1111/jscm.12037

Pereira Á, Carballo-Penela A, González-López M, Vence X. 2016. A case study of servicizing in the farming-livestock sector: organisational change and potential environmental improvement. *Journal of Cleaner Production* **124** 84-93. DOI: 10.1016/j.jclepro.2016.02.127

Priem RL, Swink M. 2012. A demand‐side perspective on supply chain management. *Journal of Supply Chain Management,* **48 (2)**. 7-13. DOI: 10.1111/j.1745-493X.2012.03264.x

Seuring S. 2004. Industrial ecology, life cycles, supply chains: differences and interrelations. *Business Strategy and the Environment* **13**(5) 306-319. DOI: 10.1002/bse.418

Seuring S. 2011. Supply chain management for sustainable products – insights from research applying mixed methodologies. *Business Strategy and the Environment* **20**(7) 471-484. DOI: 10.1002/bse.702

Seuring S, Müller M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* **16**(15) 1699-1710. DOI: 10.1002/bse.418

Singh A, Mishra N, Ali SI, Shukla N, Shankar R. 2015. Cloud computing technology: Reducing carbon footprint in beef supply chain. *International Journal of Production Economics* **164** 462-471. DOI: 10.1016/j.ijpe.2014.09.019

Teng GS, Jaramillo H. 2006. Integrating the US textile and apparel supply chain with small companies in South America. *Supply Chain Management: An International Journal* **11**(1) 44-55. DOI: 10.1108/13598540610642466

Theiben S, Spinler S, Huchzermeier, A. 2014. Reducing the Carbon Footprint within Fast‐Moving Consumer Goods Supply Chains through Collaboration: The Manufacturers' Perspective. *Journal of Supply Chain Management* **50**(4) 44-61. DOI: 10.1111/jscm.12048

Tseng M, Lim M, Wong WP. 2015. Sustainable supply chain management: A closed-loop network hierarchical approach. *Industrial Management & Data Systems* **115**(3) 436-461. DOI: 10.1108/IMDS-10-2014-0319

Vermeulen WJ, Ras P. 2006. The challenge of greening global product chains: meeting both ends. *Sustainable Development* **14**(4) 245-256. DOI: 10.1002/sd.270

Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* **5** (2):171-80. DOI: 10.1002/smj.4250050207

Zhao R, Liu Y, Zhang N, Huang T. 2017. An optimization model for green supply chain management by using a big data analytic approach. *Journal of Cleaner Production* **142** 1085-1097. DOI: 10.1016/j.jclepro.2016.03.006

Zhu Q, Sarkis J, Lai KH. 2008. Confirmation of a measurement model for green supply chain management practices implementation. *International Journal of Production Economics* **111**(2) 261-273. DOI: 10.1016/j.ijpe.2006.11.029

Table 1. Economic and environmental information on the studied organizations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Organization | Obtained product | Tonnes of produced product | Turnover (thousands of €) | Organizational  footprint  tCO2eq |
| *Alpha* | Fresh mussels | 4,928 | 2,937 | 1,111,84 |
| *Beta* | Frozen mussels | 1,268 | 3,032 | 4,026.28 |
| *Gamma* | Canned mussels and other canned products | 1,776 | 11,294 | 24,210.44 |
| *Delta* | Different products for home | 378,34 | 1,891 | 1,078,95 |

Source: Own elaboration from Carballo-Penela (2010)

Table 2. Electricity scenario (t CO2eq / t of product)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Baseline | |  | 15 % electricity reduction in each company | | |  | 60 % electricity reduction in *Beta* | | |
|  | Total | Added |  | Total | Added | Change |  | Total | Added | Change |
| *Alpha* | 0.23 | 0.23 |  | 0.23 | 0.23 | -0.11% |  | 0.23 | 0.23 | 0.00% |
| *Beta* | 3.18 | 2.95 |  | 3.05 | 2.83 | -3.82% |  | 2.70 | 2.47 | -15.10% |
| *Gamma* | 8.60 | 5.43 |  | 8.45 | 5.39 | -1.84% |  | 8.08 | 5.39 | -6.04% |
| *Delta* | **8**.**92** | 0.32 |  | **8.74** | 0.29 | **-2.05%** |  | **8.40** | 0.32 | **-5.83%** |

Table 3. Fuels scenario (t CO2eq / t of product)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Baseline | |  | 15 % fuel reduction in each company | | |  | 60 % fuel reduction in *Alpha* | | |
|  | Total | Added |  | Total | Added | Change |  | Total | Added | Change |
| *Alpha* | 0.23 | 0.23 |  | 0.22 | 0.22 | -3.25% |  | 0.20 | 0.20 | -12.98% |
| *Beta* | 3.18 | 2.95 |  | 3.07 | 2.85 | -3.27% |  | 3.00 | 2.80 | -5.65% |
| *Gamma* | 8.60 | 5.43 |  | 8.45 | 5.38 | -1.80% |  | 8.40 | 5.40 | -2.37% |
| *Delta* | **8.92** | 0.32 |  | **8.76** | 0.31 | **-1.82%** |  | **8.72** | 0.32 | **-2.29%** |

Table 4. First and last stage scenario (t CO2eq / t of product)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Baseline | |  | 50 % fuel and electricity reduction in *Delta* | | |  | 40 % fresh mussel CF reduction (*Alpha*) | | |
|  | Total | Added |  | Total | Added | Change |  | Total | Added | Change |
| *Alpha* | 0.23 | 0.23 |  | 0.23 | 0.23 | 0.00% |  | 0.14 | 0.14 | -40.00% |
| *Beta* | 3.18 | 2.95 |  | 3.18 | 2.95 | 0.00% |  | 2.62 | 2.49 | -17.42% |
| *Gamma* | 8.60 | 5.43 |  | 8.60 | 5.43 | 0.00% |  | 7.97 | 5.35 | -7.32% |
| *Delta* | **8.92** | 0.32 |  | **8.81** | 0.21 | **-1.21%** |  | **8.29** | 0.32 | **-7.06%** |

Table 5. Strategies at the retailer stage (t CO2eq / t of product)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Baseline | |  | 50 % fuel and electricity reduction in *Delta* | | |  | 25 % canned mussel CF reduction (*Gamma*) | | |
|  | Total | Added |  | Total | Added | Change |  | Total | Added | Change |
| *Alpha* | 0.23 | 0.23 |  | 0.23 | 0.23 | 0.00% |  | 0.23 | 0.23 | 0.00% |
| *Beta* | 3.18 | 2.95 |  | 3.18 | 2.95 | 0.00% |  | 3.18 | 2.95 | 0.00% |
| *Gamma* | 8.60 | 5.43 |  | 8.60 | 5.43 | 0.00% |  | 6.45 | 3.28 | -25.00% |
| *Delta* | **8.92** | 0.32 |  | **8.81** | 0.21 | **-1.21%** |  | **6.77** | 0.32 | **-24.11%** |

Table 6. Canned mussel stage scenario (t CO2eq / t of product)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Baseline | |  | 25 % frozen mussel CF reduction (Beta) | | |  | 25 % frozen mussel CF reduction and reducing by 25% emissions associated to tins | | |
|  | Total | Added |  | Total | Added | Change |  | Total | Added | Change |
| *Alpha* | 0.23 | 0.23 |  | 0.23 | 0.23 | 0.00% |  | 0.23 | 0.23 | 0.00% |
| *Beta* | 3.18 | 2.95 |  | 3.18 | 2.95 | 0.00% |  | 3.18 | 2.95 | 0.00% |
| *Gamma* | 8.60 | 5.43 |  | 7.74 | 4.57 | -10.00% |  | 7.21 | 4.04 | -16.17% |
| *Delta* | **8.92** | 0.32 |  | **8.06** | 0.32 | **-9.65%** |  | **7.53** | 0.32 | **-15.60%** |

1. Scope 1 emissions account for direct emissions that are produced as a result of burning fossil fuels directly when the companies perform their economic activity. Scope 2 relates to indirect emissions from the generation of purchased electricity, heat or steam consumed by the companies. Scope 3 refers to all other indirect emissions that are consequence of the activities of the company not included in scopes 1 and 2. [↑](#footnote-ref-1)
2. Exiobase2 is a detailed Environmentally Extended MRIO database that has been recently developed and not yet as implemented as other databases. It currently consists of tables for 27 EU countries, 16 major economies and 5 rest of world regions in industry by industry (163 sectors) as well as product by product (200 products) classification. [↑](#footnote-ref-2)
3. Carbonfeel (carbonfeel.org) is a collaborative initiative focused on providing methodological and technological solutions to the processes of calculation, verification, certification and labelling of the CF. It provides the technology to create a repository of those footprints based on real businesses data. [↑](#footnote-ref-3)