Reducing UK's carbon footprint in food supply chains

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Abstract

UK food supply is reliant on the EU and the rest of the world, leading to huge CO_2 emissions embedded in food consumption due to food miles. This paper investigates the key factors contributing to CO_2 emissions in the UK food supply chain (FSC) precisely in fruits and vegetables supply using FAOSTAT and ONS data. Our empirical findings show that two key factors i.e. Transport and Sales and Distribution channel and related processes contribute to CO_2 emissions in UK FSC. This study provides managerial implications that policymakers and business managers can explore to mitigate CO_2 emissions in UK FSC.

Keywords: Food Supply Chain (FSC), Carbon Dioxide Emissions (CO_2e), Sales and Distribution channel and related processes

Introduction

Forty percent of UK fresh food supply is reliant on imports from Europeans countries (e.g. France, Spain, Germany, Netherlands and Ireland). Other nations namely South Africa, Chile, China, Ghana, Colombia and India are also supplying varieties of fresh fruits and vegetables. Twenty-five countries count for ninety percent of the total UK fruits and vegetables supply in 2011 (Defra, 2012; ABHD, 2016). In all these, UK Food Standards Agency play an important role in maintaining food quality and food security. Notwithstanding that, Michalský and Hooda (2015) criticise that importation of UK fresh food generates a significant amount of CO_2e contributing to huge consumption-based emissions of UK. Meanwhile, sustainable food supply chains that reduces food miles have been advocated by many food supply chain players and researchers (Edwards-Jones et al., 2008). Nevertheless, UK Sustainable Development Commission are continuously working with all actors to achieve sustainable food supply chain that is internationally applicable. Food supply chain (FSC) provides the link from production to consumption. Its life cycle involves the stages of the farming process and its inputs, through to manufacturing, distribution, preservation, retailing, food preparation and waste disposal (Mintcheva, 2005). In the year 2010, UK's food supply chains emitted between 152Mt CO_2e and 159Mt CO_2e (Audsley et al., 2010), which makes 20% of overall UK consumption. Further, in 2014, UK FSC emissions increased and is responsible for 176 million tonnes of CO_2e (Tassou et al., 2014). This is a significant contribution to overall UK's GHG emissions, and that calls for attention.

Therefore, the purpose of this paper is twofold. Firstly, it identifies the key factors of CO_2e in UK FSC and ranks them through empirical analysis. Complementing the approach, this paper develops a conceptual framework based on the knowledge from the literature to suggest the factors of CO_2e and estimates the carbon footprint. Significant emissions hotspots that lie in the life cycle of FSC are taking into consideration e.g. farm produce, overseas storage, storage in UK, transportation, cold storage, distribution and sales. Secondly, this paper links the significant carbon emissions factors of UK FSC to measures that policymakers and business managers can explore in mitigating CO_2e. This opens options for achieving reduction of carbon footprint in the UK food supply chains.

The rest of the paper is organised as follows. The next section provides a literature review (background study) on food supply chain (FSC), food miles and carbon footprint. It also provides clue for available policies and measures for mitigation purposes. Section three explains the methodology, conceptual framework, data and model. Section four presents empirical results and analysis. Section five provides managerial implications for mitigating CO_2e. Finally, the study concludes highlighting research findings, research limitations and future research opportunities.

Background study

Literature on food supply chain ranges from production, transportation, distribution to consumption in the UK. This section first considers discussions on UK FSC. The second part of this section discusses food miles and carbon footprint. Policies and measures available are also discussed to provide clue for mitigation purposes in the UK FSC.

Food Supply Chain (FSC): UK Fruits and Vegetables

The UK imports of fruits and vegetables are estimated at £5.2billion in the year 2015 as against export of £199million. Out of the imports, 40% are supplied by EU members mainly France, Netherlands, Spain and Germany. The remaining 60% make the imports from Asia, Africa and the rest of the world (AHBD, 2016). Legge et al. (2008) assert that large portion of fruits and vegetables are supplied to retailers (59%) e.g. Tesco, Marks and Spencer and Sainsbury, wholesale markets (18%) and food service (23%), which are mostly supplied by air freight. However, Garnett (2011) argues that the supply chain of fresh food generates greenhouse gas (GHG) emissions at all the stages in its life cycle, starting from farming processes through to transportation, distribution, retailing and waste disposal. UK food production is lower than 60 percent of consumption, giving rise to reliance on food supply from EU countries and other countries (Lang and Schoen, 2016). All things considered, Parson (2013) stresses that UK food supply from a diverse range of local and global suppliers assist to maintain price stability and resilience of food supply. Meanwhile, Smith et al. (2005b) argue that UK sourcing food from the global supply chains means food must travel long distances before sales and consumption. Otherwise, food should be grown locally and manufactured locally to improve food quality and safety in the UK market and reduce emissions in the FSC (Yang and Campbell, 2017). Notwithstanding these arguments, the UK fruits and vegetables supply is responsible for about 2.5% of the UK GHG emissions (Garnett, 2006). Tassou et al. (2014) put it that UK's food supply chains are responsible for 176 million tonnes of CO_2e. This is a significant contribution to overall UK's CO_2e of 423.4Mt of CO_2e for the year 2014 (Defra, 2016), and that calls for attention.

It is said that due to lack of statistical data, the impact of the fruit and vegetable sector is still underestimated (Garnett, 2006). de Ruiter et al. (2016) add that there are complexities of current UK FSC and lack of availability of data. Despite this, transport is mentioned and estimated to generate the highest GHG emission in UK food supply (Defra, 2013). Studies by some researchers (Cowell and Parkinson, 2003; Yang and Campbell, 2017) stress for the promotion of more localised food supply system, limiting the use of transport, logistics and distribution channels in FSC. Therefore, to promote sustainable food supply chain that reduces carbon emissions, there is need to measure food miles or carbon footprint of UK imported fruits and vegetables considering all the factors of the lifecycle of FSC and their contributions to UK CO_2e.

Food miles, Carbon footprint, Policies and Measures for Mitigation

Food miles is a term first created by the Sustainable Agriculture Food and Environment (SAFE) Alliance in a 1994 report (Paxton, 1994), to indicate the food travel distance from the place of production to place of consumption. Thereafter, the concept has been widely discussed by scholars, researchers and authors (Smith et al., 2005b; Edwards-Jones et al., 2008; Coley et al., 2009; López et al., 2015; Yang and Campbell, 2017). Food transportation consumes a huge amount of fossil fuel releasing GHG that affect global climate change (Smith et al., 2005b). Edwards-Jones et al. (2008) conclude that fool miles is a poor indicator of the environment and ethical effects of food production. The discussion on food miles has however raised huge concerns of governments, agencies, businesses and food supply chain professionals to estimate the carbon footprint of food supply chain (Litskas et al., 2017). Carbon footprint of a food item is the total amount of greenhouse gases (GHGs) emitted during its production, processing, transportation, distribution and retailing (López et al., 2015). An increase in the carbon footprint of a food item can be caused by food miles or the factors in several processes in the production to retailing line. Therefore, in estimation of carbon footprint, food miles, all factors in the FSC life cycle need to be considered. Measurement of carbon footprint of UK fruits and vegetables supply chain have been attempted few researchers (Mason et al., 2002; Marriott, 2005; Garnett 2006; McKinnon, 2007; Coley et al., 2009; Defra, 2013). Coley et al. (2009) estimation use a case study approach. They compare the carbon dioxide emissions resultant from operating a large-scale vegetable box system and local farm shop supply. Their findings show that a consumer's travel (6.7km) by heavy-duty vehicle to buy the organic vegetable generate emissions more than emissions from storage, packing and distribution to a regional hub by suppliers. Further, heavy-duty transport records 25.7% of total system emissions, followed by cold storage and packing (21.4%) and then intermediate storage and distribution at the hub (2.8%). In 2013, Defra estimate shows that food transport is responsible for 12Mt of CO_2e yearly. Out of the figure, it is mentioned that 6Mt of CO_2e is for food freight emissions in the UK, which 80% of it is produced heavy-duty vehicle transport emissions (Defra, 2013). However, a gap still remains between theoretical emphasis and empirical studies in the relation to estimating carbon footprint of UK FSC particularly fruits and vegetables supply taking into account all FSC life cycle, global food supply, food miles and food sustainability practices.

Nevertheless, policies, measures and approaches that can mitigate CO_2e in the UK FSC have been implemented, adopted or suggested by the government, key food supply chain players and researchers. Two major policies that can curb carbon emissions implemented by the UK government are carbon price and cap-and-trade (Brand and Preston, 2010). Carbon price requires retailers of food supply that use heavy energy to purchase permit for units of GHG they emit whereas cap-and-trade schemes strengthen businesses to achieve emissions target more effectively (DECC, 2014). Further, Carbon labelling and carbon footprinting are voluntary policies in the UK that inform consumer decisions, resulting to lower carbon emissions. These policies have been adopted by some key FSC chain players in the UK such as Tesco and Asda (Gadema and Oglethorpe, 2011; Ramanathan et al., 2014). In addition to that, Li and Hewitt (2008) advocate for education and creating awareness can cause a shift in consumers' choices, therefore reducing food miles. Furthermore, policy-oriented research is suggested (Barrett et al., 2013). Policy research can enable the UK to improve sustainable consumption and production policies. Sundarakani et al. (2010) also stress for designing green buying and supplying policies for mitigation of carbon emissions. Summarising the discussions, there is need to consider all factors of UK FSC life cycle and investigates the factors that matter to CO_2e in UK FSC. This facilitates finding what policy, measure or approach most suitable for mitigating purposes. However, whereas there are few literatures on food supply chain which focus on food miles and carbon footprint (Coley et al., 2009), empirical studies on carbon footprint in UK fruits and vegetables supply is limited. The existing literature is characterised by few samples (e.g. Kenya and UK, Spain and UK) and fewer factors of fruits and vegetables supply chain life cycle (e.g. transport, storage and waste). Due to such limitations, researchers are motivated to fill an empirical gap in the literature by estimating carbon footprint of UK FSC taking account of the life cycle in the fruits and vegetables supply from the global food supply.

Therefore, this study develops a conceptual framework based on the knowledge gained through the literature and present research questions as follows. What key factors that contribute to carbon dioxide emissions in UK food supply chain? How significant is the key factors that contribute to carbon dioxide emissions in the UK food supply chain? Are there measures available for policymakers and business managers to explore in mitigating carbon dioxide emissions in UK food supply chain?

Methodology

To facilitate this study, an attempt to answer the questions, a quantitative research approach is used to provide benefits of corroboration and elaboration (Cresswell and Plano-Clark, 2007). Firstly, a conceptual framework is developed based on the literature of Pretty et al. (2005), Smith et al. (2007) and Edwards-Jones et al (2008) to suggest key factors contributing to CO_2e in UK food supply chain, focusing on fruits and vegetables import. Secondly, we carried out the empirical study that, based on data collected from FAOSTAT (2017) and Office for National Statistics (ONS) (2017) that span from 1990 to 2014, to determine the contributing factors of CO_2e in UK FSC. The study focuses on the fruit and vegetable sector, due to high public interest in the sector (Foster and Lunn, 2007). Particular categories of fruits and vegetables selected are the field and fresh vegetables, tree fruits and soft fruits due to high imports by the UK and good quality control and system maintain by Defra and UK Food Standards Agency. The fruits and vegetables selected include lettuce, pepper, tomatoes, pear, mango, apple, banana, grapes, pineapples and melons. Two of these fruits and vegetables are selected as imported foods from China, India, South Africa, Ghana, Colombia, Costa Rica, France and Spain covering four continents (Asia, Africa, South America and Europe). It is estimated that twenty-five countries accounted for 90% of UK fruits and vegetables supply in 2011 (Defra, 2012). However, due to high quality and safety, good logistics and transport and year-round supply (Dolan and Humphrey, 2004), these eight countries are selected.

Development of conceptual Framework of Key Factors of CO_2e and Explanation of Variables

The conceptual framework of the study explains the inputs that generate the key factors of CO_2e in the UK FSC life cycle (see figure 1). The inputs describe the processing activities and factors involved in the FSC life cycle. From the framework, Farm Produce is the emissions from the average aggregate of overseas land use, synthetic fertiliser, manure applied, crop residues, organic soil and burning residues emissions. FAOSTAT provides the understanding of inputs that dominate Farm produce. However, the use of machinery and electricity emissions data that can be added to the inputs of Farm produce are not available. Therefore, excluded from the framework. In-country Logistics outside UK is the emissions from the summation of inputs such as farm produce logistics, overseas storage and port logistics. Xue-gong (2007) provides insight of inputs of this factor. Transport is the transport emissions of fruits and vegetables from all the selected countries to the UK. It is the aggregate emissions of all modes of transportation to the UK particularly by heavy-duty vehicles, planes, train and transoceanic. Kemp et al. (2010) assert that transportation of food is mainly done by plane, train (rail), transoceanic and heavy-duty vehicles. Sales and Distribution channel and related processes are the emissions from logistics, storage in UK and distribution of the fruit and vegetables to the point of sales. Estampe et al. (2013) suggest the inputs that consist of Sales and Distribution channel and related processes. However, other input factors e.g. packaging, retailing storage and waste are not included due to lack of availability of data. The utilisation of data is consistent with the work of Elhedhli and Merrick (2012) and Edwards-Jones et al (2008) that provide kg CO_2 (direct) per ton*km by a different mode of transportation, safe fruit and vegetable trade in UK and estimation of CO_2e considering food miles. All final values of variables are in tonnes of CO_2 e except for the dependent variable which is in thousand tonnes.

Current literature suggests key factors of CO_2e as plant production emissions, logistics, transport (road, air freight and cargo freight emissions), storage and sales and distribution emissions (from large warehouse to sales point).

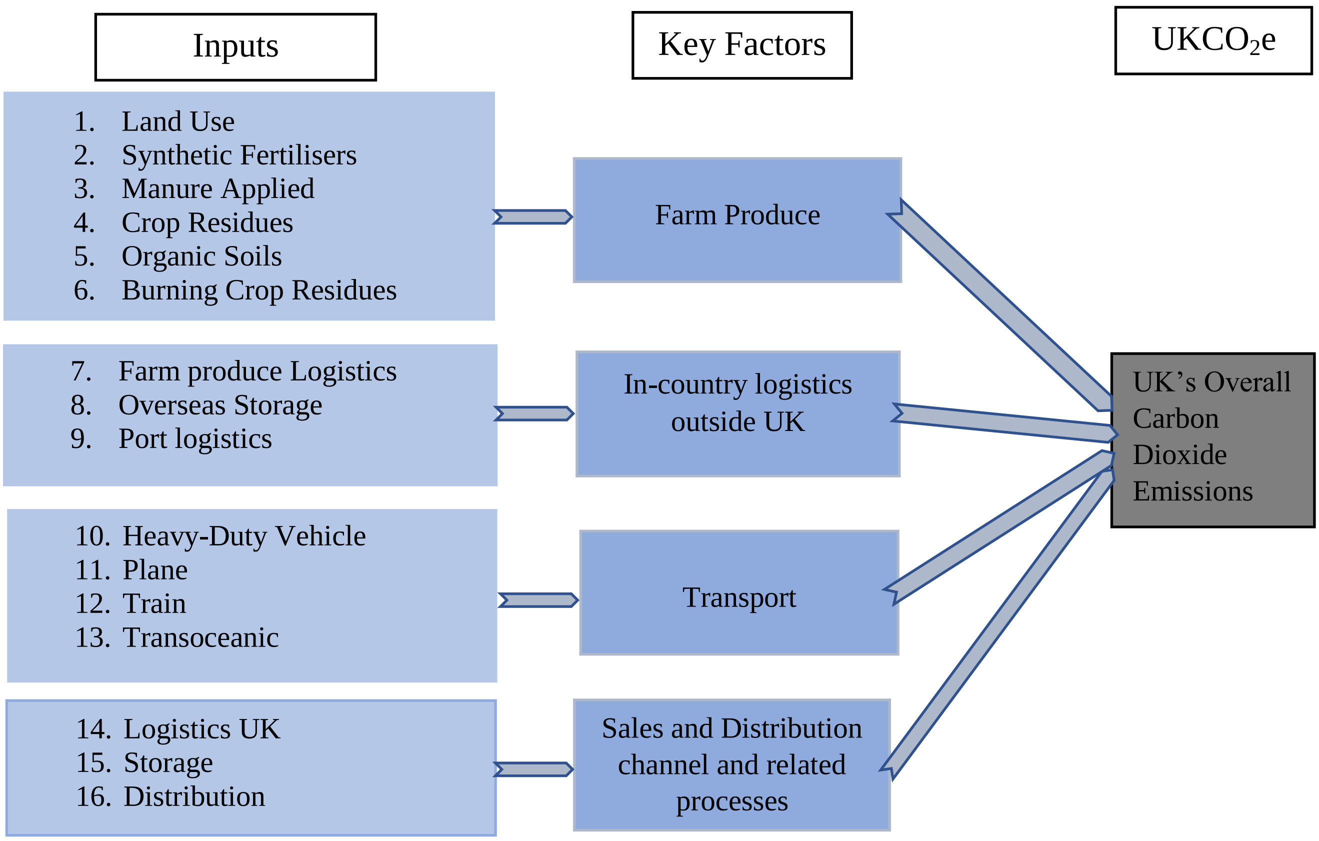


Figure 1 - Conceptual Framework of Key Factors of CO_2e

Data Description

In order to test the conceptual framework, we use the secondary data collected from FAOSTAT (2017) and ONS (2017). The sample observations cover from 1990 to 2014, is determined by lack of availability of current data for the year 2015 and year 2016 for most of the selected countries. The result is a panel (unbalanced) data with 320 observations, covering 8 countries presenting 4 continents (namely China and India for Asia; Colombia and Costa Rica for South America; France and Spain for Europe; Ghana and South Africa for Africa). The key factors are the explanatory variables and the dependent variable is the Overall UK CO_2e. For our regression variables, we consider both observations with and without missing values.

Model

To estimate the key factors, a multiple linear regression model is used for the panel data constructed using Eviews software version 6.0 (Thomsen et al., 2010; Anghelache et al., 2015). Multiple linear regression model has one dependent variable and many explanatory variables.

Empirical Results and Analysis

Table 1: Key Factors of Carbon Dioxide Emissions

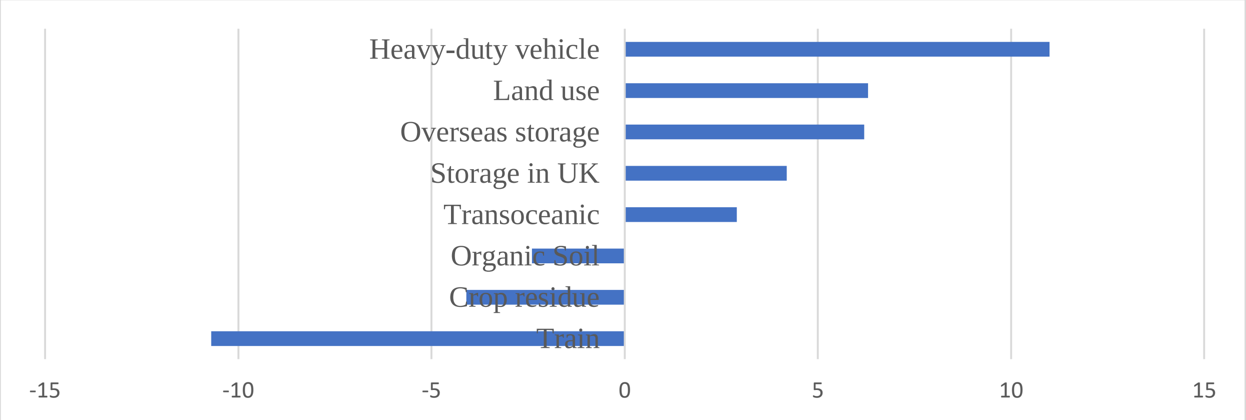
Dependent Variable: UK CO_2e

Independent Variable	**Coefficient**
Farm Produce	-0.000 (0.001)
In-country Logistics outside UK	0.003 (0.004)
Transport	0.100** (0.009)
Sales and Distribution	-0.013* (0.005)
Summary Statistics:	
Observation	320
R-squared	0.585
Adjusted R-squared	0.577
Prob(F-statistic)	0.007

Table 1 presents the results of the fixed effects estimator as a preferred model by Hausman test (Hausman, 1978) to indicate the key factors of CO_2e. Hausman test investigates the preferred model between and random effects and fixed effects estimator. When fixed effects estimator is preferred, it means null hypothesis is rejected. Fixed effects estimator has the benefit of capturing any effects that vary over time but are common across the whole panel. However, multicollinearity test is carried and the model is free from multicollinearity. *, ** and *** are 1%, 5% and 10% significance level respectively. The standard errors are the values in the parentheses. Prob (F-statistic) showing the overall significant predicative capacity of the model. The R-squared value of 0.585 explains that 58.5% of the variation in log of CO_2e can be explained by this model. However, this paper finds Farm Produce and In-country Logistics outside UK not significant but finds Transport and Sales and Distribution channel and related processes significant. The results show that an additional increase in import by the modes of Transport of fresh food predicts an increase in UK CO_2e by 10 tonnes of CO_2e at 5% significant level. This is due to the burning of fossil fuel and long-distance travels of fresh food from global supply to the UK. This result is consistent with results from Defra (2013) that explains that significant proportion of overall UK CO_2e is contributed by food transport. Previous study by Marriott (2005) estimate that fresh strawberries transport generates nearly 3.6 tonnes of CO_2e per tonne of strawberries. While Defra estimated tomatoes transport emissions to be 0.1 CO_2e per tonne of tomatoes from Spain to UK (Garnett, 2006). Considering the global supply of fresh fruits and vegetables to the UK, increased importation and changes in FSC factors over the period, this study predicts transport emissions of 10 CO_2e per tonne of fresh fruits and vegetables to the UK.

Again, this study predicts decrease of UK CO_2e by 1.3 tonnes of CO_2e from Sales and Distribution channel and related processes per tonne of fresh fruits and vegetables from global supply, ceteris paribus. This is due to the efficiency processes and measures used in the supply chain in the UK. Research by Hulthén and Gadde (2009) stress that modified distribution facilities (e.g. trucks and distribution centres) efficiently utilized can reduce fuel consumption and emissions.

Finally, the study finds that some factors in the life cycle of UK FSC (thus, land use, overseas storage, heavy-duty vehicle transport, transoceanic transport and storage) have a significant positive relationship with UK carbon emissions, contributing to CO_2e increase in the UK FSC. Whereas train transport, organic soils and crop residue farming reduce CO_2e in the UK FSC. Figure 2 presents ranking of all significant factors that contribute to UK CO_2e in fruit and vegetable supply chain life cycle identified by the study. It shows that heavy-duty transport has high emissions in food supply chain and train transport has the highest potential to reduce carbon emissions in UK FSC.



In tonnes of CO_2e

Figure 2: Ranking of factors contributing to UK CO_2e in fruits and vegetables supply chain

Managerial Implications

Following the findings and analysis of this paper, we propose more feasible policy and legal-related measures and technological and operations-related measures to policymakers and business managers to explore in mitigating CO_2e in the UK FSC.

On transport, improving efficiency is one of the technological and operation-related measures that can be considered. The use of solar, biogas, wind or hydrogen fuel cells is more efficient energy sources that businesses can shift to. Further, on board energy management, smart voyage planning and propeller optimization in transoceanic transport are additional efficient operational measures. Businesses operations can also shift to rail transport especially for inter-city transport and long distances transport, due to high carbon emissions associated with heavy-duty vehicles transport. Alternatively, heavy-duty vehicles transport operations can resort to hybrid electric vehicles that have significant carbon emissions reduction impact (Fontaras et al., 2008). Also, training and development of staff on programmes such as fuel-efficient driving have the benefit of reducing fuel consumption and emissions in the atmosphere. On the other hand, key possible policy and legal-related measure that can be explored is incorporating green objectives and goals in transport operations. This enables businesses to control operations that have high carbon emissions and to achieve corporate-level targets in transport emissions reduction.

On Sales and Distribution channel and related processes, improving storage energy systems can be one technological and operation-related measure business managers can take. This can cause more carbon emissions reductions in the UK FSC. The use of light-emitting diode lighting and innovative technologies in refrigeration, ventilation and heating equipment. Managers can increase the use of renewable energy such as biomass boilers and solar power. Further, using wastes for energy and biomass can significantly reduce carbon dioxide emissions. Also, it is recommended that proper training for staff on behavioural changes in energy use is very important (Tassou et al., 2014). Alternatively, the study of Rodrigues et al. (2014) can be utilised. Rodrigues et al. (2014) research stress that shifting freight from road to rail in container movements between ports and inland destinations in the UK reduce carbon dioxide emissions. Adding that rerouting containers away from usual large ports in the UK southeast and making use of the north-west and north ports for the distribution of imports or food reduce CO_2e. Notwithstanding the use of rerouting technique, practices and principles of decarbonisation of logistics can be used (McKinnon and Piecyk, 2012). For example, managers can set emissions reduction targets in logistics operations by redefining logistics emissions targets and applying to the entire logistics operations in respect of the carbon trade-offs that exist between all logistical operations and activities. To add to that, policy and legal-related measure that can be utilised is the greener objectives and goals. This includes making green supply chain management and green logistics (Ahi and Searcy, 2013) part of the policy framework. These can enable businesses to achieve environmental sustainability goals that include carbon emissions reduction targets.

Conclusions, limitation and framework work

This study finds that Transport and Sales and Distribution channel and related processes are the two key factors of CO_2e in UK FSC. This paper contributes to the existing literature and fills an empirical gap by identifying that Sales and Distribution channel and related processes can reduce carbon emissions in the UK FSC by 1.3 tonnes of CO_2e from every logistics, storage and distribution of fresh food (fruits and vegetables) from global supply. This paper also supports the previous studies by McKinnon (2007), Defra (2013) and Tassou et al. (2014) that estimate that Transport contributes a significant amount of CO_2e in UK FSC. Future studies can extend this research to capture other significant factors of UK FSC such as packaging, retail storage, household storage and waste that are not included in the research due to lack of availability of data.

Brexit means that UK must look elsewhere other than EU for food supply. Further studies can consider research opportunities in a comparative study of carbon footprint of the UK food supply chain from different countries to assist implementation of specific green policies and measures.

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