Marion Drut*, Federico Antonioli, Michael Böhm, Ruzica Brečić, Liesbeth Dries, Hugo Ferrer-Pérez, Lisa Gauvrit, Việt Hoàng, Kamilla Knutsen Steinnes, Apichaya Lilavanichakul, Edward Majewski, Orachos Napasintuwong, An Nguyễn, Konstadinos Mattas, Bojan Ristic, Burkhard Schaer, Torvald Tangeland, Marina Tomić Maksan, Peter Csillag, Áron Török, Efthimia Tsakiridou, Mario Veneziani, Gunnar Vittersø and Valentin Bellassen

Foodmiles: The Logistics of Food Chains Applied to Food Quality Schemes

https://doi.org/10.1515/jafio-2019-0040
Received September 13, 2019; accepted September 12, 2020

Abstract: This paper estimates the foodmiles (embedded distances) and transport-related carbon emissions of 27 Food Quality Scheme (FQS) products – Protected Designation of Origin (PDO), Protected Geographical Indications (PGI) and organic – and their reference products. It goes further than the existing literature by adopting a value chain perspective, instead of the traditional consumer perspective, and focusing on FQS products. The same methodology is applied across all the case studies. The article specifically investigates the determinants of differences between FQS and their references. FQS products travel significantly shorter distances (–30%) and generate significantly lower transport-related emissions (–23%) than conventional food products. The differences are even greater for vegetal and organic products. The relationship between distance and transport-related emissions is not exactly proportional and highlights the importance of transport modes and logistics, in particular for exports and imports. Finally, we stress the importance of the spatial distribution of the different stages in the value chains (e.g. production, processing). PDO technical specifications delimit a geographical area for production and processing, thereby limiting distances and transport-related emissions compared to conventional food products, but also compared to other types of FQS.

Keywords: foodmiles, food quality schemes (FQS), transport, logistics, carbon emissions

1 Introduction

Long gone are the days when people grew their own vegetables and bred their own cattle on their doorstep.

***Corresponding author: Marion Drut**, CESAER, AgroSup Dijon, INRAE, University Bourgogne Franche-Comté, Dijon, Bourgogne, France, E-mail: marion.drut@agrosupdijon.fr
Federico Antonioli and Mario Veneziani, University of Parma, Parma, Emilia-Romagna, Italy, E-mail: federico.antonioli1@gmail.com (F. Antonioli), mario.veneziani@unipr.it (M. Veneziani)
Michael Böhm, Lisa Gauvrit and Burkhard Schaer, ECOZEPT, Freising, Germany, E-mail: Boehm@Ecozept.De (M. Böhm), gauvrit@ecozept.com (L. Gauvrit), schaer@ecozept.com (B. Schaer)
Ruzica Brečić and Marina Tomić Maksan, University of Zagreb, Zagreb, Zagreb, Croatia, E-mail: rbrecic@efzg.hr (R. Brečić), matomic@agr.hr (M.T. Maksan)
Liesbeth Dries, Wageningen Agricultural University, Wageningen, Gelderland, Netherlands, E-mail: liesbeth.dries@wur.nl
Hugo Ferrer-Pérez, Center for Agro Food Economy and Development, Catalonia Polytechnic University, Barcelona, Spain, E-mail: hugo.ferrer@upc.edu
Việt Hoàng and An Nguyễn, University of Economics Ho Chi Minh City, Ho Chi Minh City, Viet Nam, E-mail: viet.hoang@ueh.edu.vn (V. Hoàng), quynhan1995@gmail.com (A. Nguyễn). https://orcid.org/0000-0001-7842-4637 (A. Nguyễn)
Kamilla Knutsen Steinnes, Torvald Tangeland and Gunnar Vittersø, HiOA, National Institute for Consumer Research, Oslo and Akershus University College, Oslo, Akershus, Norway, E-mail: kamillak@oslomet.no (K.K. Steinnes), Torvald.Tangeland@sifo.hioa.no (T. Tangeland), Gunnar.Vitterso@sifo.hioa.no (G. Vittersø)
Apichaya Lilavanichakul and Orachos Napasintuwong, Kasetsart University, Bangkok, Thailand, E-mail: apichaya.l@ku.ac.th (A. Lilavanichakul), orachos.n@ku.ac.th (O. Napasintuwong)
Edward Majewski, SGGW, Warsaw University of Life Sciences, Warszawa, Poland, E-mail: edward_majewski@sggw.pl
Konstadinos Mattas and Efthimia Tsakiridou, Aristotle University of Thessaloniki, Thessaloniki, Central Macedonia, Greece, E-mail: mattas@auth.gr (K. Mattas), efitsaki@agro.auth.gr (E. Tsakiridou)
Bojan Ristic, University of Belgrade, Beograd, Beograd, Serbia, E-mail: risticbj@gmail.com
Peter Csillag, ECO-SENSUS Research and Communication, Szekszárd, Hungary, E-mail: csillag.peter@ecosensus.hu
Áron Török, Corvinus University of Budapest, Budapest, Hungary, E-mail: aaron.torok@gmail.com
Valentin Bellassen, CESAER, AgroSup Dijon, INRA, University Bourgogne Franche-Comté, Dijon, Bourgogne, France, E-mail: valentin.bellassen@inrae.fr. https://orcid.org/0000-0001-8581-2814

Nowadays, our plate contains foodstuffs that have traveled varying distances. Foodmiles are defined as the distance food travels along the value chain, from the production stage through to retail distribution or even delivery to the end consumers. To that effect, the distances traveled from cradle to plant by all the feedstocks necessary to produce one ton of product are cumulated and added to the travel of the product itself from plant to plate. Foodmiles increased in the second part of the 20th century (Pirog et al. 2001; Saunders and Hayes 2007), driven by enhanced agricultural productivity and the liberalization of trade, but also by reduced travel costs along with the expansion of refrigerated long-haul trucks. As an example, on the East Coast of the United States, food travels an average of 2,800 km from farm to plate, a distance that increased by 25% from 1980 to 2000 (Halweil and Grown 2002). At the same time, Food Quality Scheme (FQS) products are booming: the number of registered and applied designations in the European Union (EU) has doubled over the last decade, from 867 products in 2009 to 1713 products in 2019 (Door database 2020), and the EU organic market has increased almost fourfold from 2004 to 2018 to exceed € 40 billion (Agence BIO 2019). FQS products include, among others, Geographical Indications (GI), such as Protected Geographical Indications (PGI) products and Protected Designation of Origin (PDO) products, and also organic products. FQS products are expected to have a different value chain organization from conventional products. For this reason, analyzing the foodmiles and their contribution to the carbon footprint is of particular interest.

This article aims to discuss the following questions: do FQS products travel shorter distances and generate less transport-related emissions than their standard references? At which levels in the value chain does the transport-related carbon footprint differ most between a FQS product and its reference? What are the determinants of the transport-related carbon footprint and of the differences in distance between FQS products and their references?.

Two indicators were designed. First, a distance indicator, expressed in ton.km ton^{-1}, sticks to the concept of foodmiles and gives an idea of how far the product has traveled. Second, a transport-related carbon emission indicator, expressed in $kgCO_2e\ ton^{-1}$, provides a detailed contribution of the transport stage to the carbon footprint of products as estimated by Bellassen (2020).

Food Quality Scheme (FQS) products travel significantly shorter distances (−30%) and generate significantly lower transport-related emissions (−23%) than conventional food products. The results highlight the importance of product distribution, and particularly exports, when considering transport along the value chain: more than 80% of foodmiles and transport-related emissions occur after the processing plant. However, the relationship between foodmiles and transport-related emissions is not linear. The larger the share of exports and imports, the more the foodmiles, but not necessarily the higher the emissions. Finally, we stress the importance of the spatial distribution of the different stages in value chains (e.g. production, processing). PDO technical specifications delimit a geographical area for production and processing, thereby limiting distances and transport-related emissions compared to conventional food products, but also compared to other types of FQS products.

The paper is organized as follows. Section 2 provides a brief review of the literature on foodmiles. Section 3 details the methodology and data sources. In section 4, we present the results and discuss them in section 5. Section 6 stresses methodological issues and limits. The last section draws conclusions.

2 Literature Review on Foodmiles

2.1 Distance and Carbon Emissions: Contributions and Relationship

It is usually estimated that transport represents about 15% of the carbon footprint of a product. For France, Barbier et al. (2019) found that 19% of the carbon footprint is due to freight transport and households' transport when buying food, against 67% from agriculture and 5% from processing. Weber and Matthews (2008) on U.S. data showed that freight transport represents about 11% of the carbon footprint of a product over the value chain, and 4% for final delivery, against 83% from the production stage. Similarly, the carbon footprint varies between food groups: transport represents only 7% of the carbon footprint of red meat and dairy, against 29% for fruits and vegetables (Weber and Matthews 2008). The carbon footprint of animal products, and in particular red meat, is mainly driven by the production stage (e.g. cattle). On the contrary, the relative impact of transport can be considerale for root crops, cereals and vegetables (Röös, Sundberg, and Hansson 2014). Transport can even become the major contributor to the carbon footprint, as is the case for fruit (Barbier et al. 2019). Yet, transport of animal feed is not negligible as it represents for France one third of food-related traffic and 19% of CO_2 emissions for France, and concerns mainly soy cakes, most of which are imported (Barbier et al. 2019). Lopez et al. (2015) on Spanish data showed that the carbon footprint of food products can double when emissions from products traveling long distances at the distribution stage are included.

However, it is not only the distance between different stages, but also the organization of the logistics (collection and distribution stages), that impacts transport-related carbon emissions. Economies of scale may contribute to reducing emissions per ton due to a more efficient organization along the value chain, but small businesses that rely on small-scale transport need more energy to distribute their products, compared with bigger units (Schlich and Fleissner 2005). Moreover, different transport modes (sea, air, road) imply different emission rates. Sea transport exhibits by far the lowest carbon content per kilometer traveled among transport modes. Barbier et al. (2019) estimated that sea transport is used for 57% of the ton.kilometers traveled by food products consumed in France. However, 83% of the carbon emissions from transport of food products are generated by road transport. Similarly, air transport is used only for 0.5% of the ton.km traveled but generates 5% of the carbon emissions from transport of food products consumed in France (Barbier et al. 2019).

Furthermore, there is a lack of consensus in the literature about the environmental impact of Short Food Supply Chains (SFSC), and of short-distance value chains more generally. Schlich and Fleissner (2005) pointed out the role of value chain organization and found a larger carbon impact of SFSC compared to conventional value chains, while Pimentel et al. (2008) and Mundler and Rumpus (2012) supported the lower carbon impact of SFSC. Coley, Howard, and Winter (2009) defined threshold distances between producer and consumer above which the carbon impact of SFSC products exceeds that of conventional ones. Shortening distances along food value chains may imply shorter distances downstream, as in SFSC with farm sales for instance, and/or shorter distances upstream, as for PDO products whose production and processing must occur in a geographically limited area.

2.2 From a Consumer Perspective to a Value Chain Perspective

Interestingly, foodmiles have mainly been dealt with from a consumer perspective rather than from a value chain perspective. Most articles and studies refer to food products consumed in a given meal or country, and consider only the transport related to the domestic production that is consumed nationally and imports of food products, while transport related to exports of food items is not systematically accounted for. Barbier et al. (2019) considered French household diets and left out flows relating to food items that are produced in France and exported, i.e. both international and domestic transport of products to be exported. Moreover, most estimates in the literature have been applied to single-ingredient and non-processed food products such as fresh fruit and vegetables. One exception is the study by Pirog and Benjamin (2005), in which they estimated the foodmiles and carbon impact for a multiple-ingredient food product. In this case, the distance traveled by each ingredient of the product was accounted for proportionally to the contribution of the ingredient to the final product.

As a complement to the existing literature, this article estimates foodmiles and the associated carbon emissions, along particular food supply chains. In that respect, both exports of the final product and imports of raw products required to produce the final product are considered. In addition, it estimates foodmiles for fresh and non-processed food products, as well as for processed ones. This article goes beyond the existing literature in that it focuses on the value chain of particular food products, namely geographical indications (PDO, PGI) and organic products, in comparison with conventional products (non-certified products).

3 Material and Method

3.1 Method

3.1.1 Estimating Indicators

Two indicators were computed for each FQS case study and its standard reference: a distance indicator and a transport-related carbon emission indicator.

3.1.1.1 The distance indicator

The distance indicator sticks to the basic idea of the concept of "food miles" as it gives an idea of how far the product and its components have traveled. It estimates the distance *embedded in* a unit of the final product and is expressed in ton.km per ton of final product (ton.km ton^{-1}). A ton.km, sometimes also abbreviated as tkm, is a unit of measurement of freight transport, representing the transport of one ton of goods (including packaging and tare weights of transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one km (Eurostat 2019) (Equation (1)).

$$ton.km = TLC.TDC \tag{1}$$

Where TLC is the Total Load Carried measured in tons and TDC is the Total Distance Covered measured in km. In a value chain perspective, using the ton.km ton^{-1} as a unit seems more appropriate (Equation (2)).

$$ton.km\ ton^{-1} = \frac{TLC.TDC}{TLC} \quad (2)$$

In addition, Equation (2) removes the reliance on information about the accurate weight of goods carried over each value chain segment. We used the distribution of the production over the different segments of a value chain to weight the distances traveled by one ton of final product.[1]

3.1.1.2 The transport-related carbon emission indicator

The transport-related carbon emission indicator translates the distance indicator into an environmental impact of transport. However, it is not only the distance that is central to estimating the transport-related carbon emission indicator but also the transport modes and organization of the logistics (empty return trip or single journey of vehicles). The transport-related carbon emission indicator is expressed in kilograms of CO_2 equivalent per ton of final product (kg CO_2e ton^{-1}) and as such allows a comprehensive and precise estimate of transport in the carbon footprint indicator (Bellassen 2020). It corresponds to a part of SAFA indicator E 1.1.3, with a focus on transportation and logistics (FAO 2013).

3.1.2 Defining the Value Chain

We identified each step in the value chain associated with each section a distance, a transport mode, information on logistics, and a share of the total production transiting through (e.g. 98% for the national market and 2% for exports). Three main levels can be distinguished: farm level (from input producers to farmers), processing level (from farmers to processors or packers),[2] and distribution or retail level (from the last processor to wholesalers on the domestic market and abroad for exports). Additional steps may be identified at retail level, from wholesalers to downstream retailers or even end consumers.

Following a common practice in Life Cycle Assessment, for value chain levels producing several co-products, foodmiles and emissions from upstream levels were allocated to each coproduct proportionally to its economic value. For exports and imports, we built typical journeys: we assumed that the goods were transported by truck to the closest port, shipped to the port closest to the importing country's most populated city, and then transported by truck to this city (Barbier et al. 2019).

3.1.3 Using Cool Farm Tool

We used the *transport* section of the Cool Farm Tool (CFT) version 2.0 beta 3 (Hillier et al. 2011) to estimate the transport-related carbon emission indicator. Table 1 presents the carbon emission rates for different types and sizes of vehicles on which the CFT calculator is based. More details on the carrying capacity of the transport modes listed below are available in Appendix A.

In addition, the Cool Farm Tool allows a vehicle weight to be addedfor road transport, assuming that truck weight is one third of laden weight. Consequently, adding the vehicle weight to a single journey means the laden weight is multiplied by 1.333, while adding vehicle weight to a truck returning empty means the laden weight is multiplied by 1.667.

The calculator estimates the following equation (Equation (3)).

$$\sum_{i=0}^{n} tons.km.CER^{i}.Logis = kg\ \ CO_2e \quad (3)$$

Table 1: Carbon emission rates for different types and sizes of vehicles.

Type of vehicle	Carbon emission rate (in kg CO_2e ton.km^{-1})
Road – Heavy goods vehicle	0.12
Road – Light goods vehicle – Diesel[a]	0.34
Road – Light goods vehicle – Petrol	0.94
Rail	0.021
Air – Very short haul	1.94
Air – Short haul	1.42
Air – Long haul	0.60
Ship – Small tanker	0.20
Ship – Large tanker	0.005
Ship – Very large tanker	0.004
Ship – Small bulk carrier	0.011
Ship – Large bulk carrier	0.007
Ship – Very large bulk carrier	0.006
Ship – Small container vessel	0.015
Ship – Large container vessel	0.013

[a]This value is substantially lower than other sources such as French Government (MEDDE 2012) but light goods vehicle is only a minor mode of transportation in our cases.
Source: Cool Farm Tool (Hillier et al. 2011).

1 For instance, in a case where 3% of the total production is exported and travels 100 km, and where 97% is sold in the domestic market and travels 10 km, we estimate that one ton of product travels $0.03 \times 100 + 0.97 \times 10 = 12.7$ ton.km·ton^{-1}.

2 In the case where there are two processing stages, we distinguish the first processing stage (from farmers to the first processor) from the second processing stage (from the first to the second processor).

Where *CER* stands for the Carbon Emission Rate of a selected transport mode *i*, and *Logis* refers to the organization of the logistics relative to road transport when concerned (add vehicle weight or not, single journey or returning empty). The Cool Farm Tool estimates the environmental impact of tons.km. We normalized the quantity moved (tons) to one in order to obtain results measured in kg CO_2e ton^{-1}, i.e. an amount of carbon equivalent per ton of product.

3.2 Data

3.2.1 Data Sources and Collection Strategy

The data collection strategy focused on two main sources: secondary data from technical documents on farming and processing practices, regional or national statistics, and primary data from interviews of a few key stakeholders of the value chain. Partners were asked to fill in variables for each indicator. The variables used to compute the foodmiles indicators are presented in Appendix A. Then, the corresponding author in charge of a particular set of indicators was responsible for checking the consistency of the data and for estimating the indicator(s). Finally, he/she provided a first interpretation of the results for each case study, which was then completed and corrected when necessary by the partner in charge of the case study. This article presents a synthesis of the results obtained from the 27 cases studied, while case by case results are provided in Arfini and Bellassen (2019).

3.2.2 Case Studies

This article analyzes data on 27 FQS products and 27 reference products.[3] There are 9 PDO products, 10 PGI products and 8 organic products. As far as sectors are concerned, there are 14 vegetal products (cereals, fruits, beans), 9 animal products (dairy, meat) and 4 seafood products (fish, unfed fish, seafood). Table 2 provides basic information for each case study. Further details on reference products at each value chain level, as well as data sources, are available in Appendix B. A description of each case study, including a description of the value chain and of the governance, as well as its sustainability performance, is provided in Arfini and Bellassen (2019).

The processing level, from producer to processor or packer, and the retail level from processor to wholesaler on the domestic market or abroad (exports) were the most complete, with data for more than 85% of case studies. On the contrary, the farm level, from input producer to farm, and the downstream level of retail, from wholesaler to retailer or end consumers, relied on partial data, for 50 and 15% of the case studies, respectively. Moreover, data before the farm gate was sometimes partial, with only international transport of animal feed considered, in addition to inputs other than animal feed in a few cases (seeds, crates). However, what is important in this analysis of the differences is that at a given level data should be available for both the FQS and its reference.

Data at processing level came mostly from field interviews of experts. Data on domestic market distribution were derived either from expert interviews, or from product/sector specific national statistics. Data on exports usually stemmed from national statistics databases.

3.2.3 Data Analysis Strategy

The case studies are very heterogenous, in size, sector and country. Similarly, products from different food sectors (animal, vegetal, seafood) have very different value chain characteristics, which is expected to lead to different impacts in terms of foodmiles and transport-related carbon emissions. The case studies also cover a wide geographical scope in Europe, and also outside Europe (Thailand and Vietnam) for a few cases. Country-specific features may also influence results. For all these reasons, the objective was not to compare absolute results, i.e. results in terms of embedded distance or transport-related carbon emissions in a product, but to analyze relative results, i.e. the difference between a FQS and its reference. Analyzing differences allows us to focus on the factors driving the difference between FQS and non FQS products.

We used the Wilcoxon signed rank test on paired samples to assess the significance level of the median differences. The null hypothesis is H_0 = the median difference between pairs of observations is zero. This non-parametric test allows work to be performed on small samples that do not follow normal distribution. However, for a sample size under 6 observations, the signed-rank test cannot be significant at the 5% level.[4] In addition, we performed the Kruskal–Wallis test to examine whether different groups belonged to the same populations. Then,

3 The same reference product was used for the two Greek FQS cases (Kastoria apples and Zagora apples). Moreover, national product/sector data were sometimes used, at some levels of the value chain and for a few cases. Further details in Appendix B.

4 Among the categories and subcategories of products analyzed below, only the "seafood products" category comprised fewer than 6 cases and therefore could not become significant at the 5% level.

Table 2: Case studies and reference products.

Case studied	Type of FQS	Sector	Country	Reference product
Buon Ma Thuot coffee	PGI	Vegetal	Vietnam	Conventional coffee beans and ground and roasted coffee from Dak Lak province in Vietnam
Dalmatian prosciutto	PGI	Animal	Croatia	Conventional prosciutto from pigs raised in Croatia
Olive oil	PDO	Vegetal	Croatia	Conventional olives and conventional olive oil produced in Croatia
Saint-Michel bay bouchot mussels	PDO	Seafood	France	Conventional Bouchot mussels or mussel sector in France
Organic flour	Organic	Vegetal	France	Conventional soft wheat, conventional soft wheat flour, and conventional bread, France
Comte cheese	PDO	Animal	France	Emmental cheese produced in France, or national average from the French cheese industry
Camargue rice	Organic	Vegetal	France	Conventional rice from Camargue region in France, or from France.
Gyulai sausage	PGI	Animal	Hungary	Conventional sausage from Gyulai region, in Hungary
Kalocsai paprika powder	PDO	Vegetal	Hungary	Conventional dried paprika from raw paprika produced abroad and conventional paprika powder
Parmigiano Reggiano cheese	PDO	Animal	Italy	Biraghi cheese (similar non-PDO cheese)
Kastoria apples	PGI	Vegetal	Greece	Conventional apples produced by the Kissavos cooperative, in Agia, Greece
Zagora apples	PDO	Vegetal	Greece	Conventional apples produced by the Kissavos cooperative, in Agia, Greece
Phu Quoc fish sauce	PDO	Seafood	Vietnam	Conventional fish sauce from Phu Quoc island in Vietnam
Organic pasta	Organic	Vegetal	Poland	Conventional cereals produced by 14 model conventional farms
Kaszubska Strawberry	PGI	Vegetal	Poland	Conventional strawberries from Poland
Organic pork	Organic	Animal	Germany	Conventional pork from Germany
Organic raspberries	Organic	Vegetal	Serbia	Conventional raspberries from Serbia
Sjenica cheese	PDO	Animal	Serbia	Conventional cow cheese from Serbia
Organic tomato from Emilia Romagna	Organic	Vegetal	Italy	Conventional processed tomato from Northern Italy (Emilia Romagna region).
Organic yoghurt	Organic	Animal	Germany	Natural cow milk yoghurt (unflavored) from Germany
Opperdoezer Ronde potatoes	PDO	Vegetal	The Netherlands	Conventional fresh consumption potato from The Netherlands
Lofoten stockfish	PGI	Seafood	Norway	Clipfish produced in More og Romsdal, or in Norway
Organic salmon	Organic	Seafood	Norway	Conventional salmon from Norway, or salmon from Norway
Sobrasada of Mallorca	PGI	Animal	Spain	Both PGI Sobrasada de Mallorca, Mallorca, Spain and PGI Sobrasada de Mallorca de Porc Negre, Mallorca, Spain
Ternasco de Aragon	PGI	Animal	Spain	Conventional lamb from Aragon region, in Spain
Thung Kula Rong-Hai (TKR) Hom Mali rice	PGI	Vegetal	Thailand	Conventional rice seeds, paddy rice and milled rice from the TKR region, Thailand.
Doi Chaang Coffee	PGI	Vegetal	Thailand	Conventional coffee cherries and roasted coffee beans from Doi Phahee in Chiang Rai province, Thailand

we performed the Dunn test to identify which sectors were different from the others. Both tests are appropriate for groups with unequal numbers of observations.

4 Results

4.1 Most Foodmiles and Emissions occur after the Processing Plant

Figure 1 represents the contribution of each value chain level to the foodmiles embedded in products and to the CO_2 emissions from the transport stage, for FQS products, and displays the sector breakdown for distances. More than 80% of the foodmiles and the transport-related carbon emissions occur after the processing plant or collecting/packing unit. More precisely, about 20% of the impacts are attributable to exports, about 30–35% to domestic markets (to wholesalers), and about 30% to downstream retail (to retailers or end consumers). However, the contribution of each value chain segment is highly sector-dependent. Impacts of seafood products are highly driven by exports (more than 80% of distances), while most impacts of animal products occur before the farm gate due to

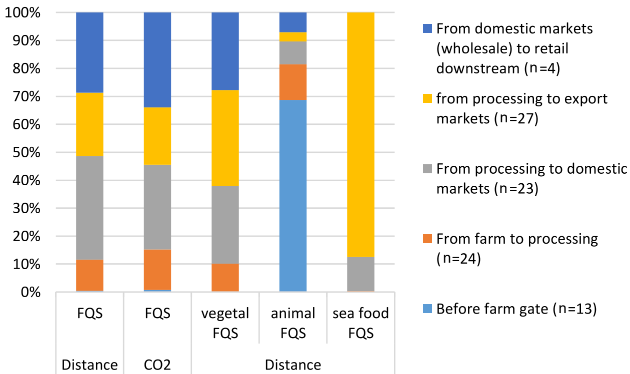

Figure 1: Contribution of supply chain segments to embedded distances and transport-related CO_2 emissions (in %).
NB: n indicates the sample size on which the median contribution (median values) was built

international transport of animal feed (mainly soy products from Brazil).[5]

Due to missing data, median contributions per segment were built on different sample sizes (n). Particular caution is required on the downstream retail and farm levels, since the results are based on data from only 4 and 13 cases respectively, and do not cover all sectors or all types of FQS.

4.2 Shorter Distances traveled by FQS

The distance traveled by FQS products along the value chain is clearly shorter than the distance traveled by their reference: the median difference is 30% shorter (p-value < 0.05) (Table 3). The difference is larger and statistically significant (p-value < 0.01) for vegetal cases, with a median difference of 61% in favor of FQS. The difference is similar (30%) and significant (p-value < 0.01) for organic products, too. For GI products, only the vegetal subgroup shows a significantly shorter distance (66%, p-value < 0.01) than that for the reference group. The difference between PDO products and their reference is also large (78%) and in favor of FQS, but not significant (p-value = 0.13) along the value chain. However, distances at processing level (i.e. from farms to processors) are significantly shorter (37%, p-value < 0.05) for PDO products than for their reference. At processing level, the difference in terms of foodmiles is not significant taking into account all types of FQS. Similarly, the difference at farm level (i.e. before the farm gate) is not significant, even for PDO products. Furthermore, the median distance traveled by animal and seafood, as well as by GI, for FQS products is not statistically different from the distance traveled by their reference products along the value chain.

4.3 Lower Emissions from the Transport Stage for FQS

In line with the results for distances, FQS products generate lower emissions at the transport stage than their reference. Along the value chain, the median difference shows that emissions are 23% lower (p-value < 0.1) (Table 4). The difference is larger and statistically significant (p-value < 0.01) for vegetal cases, with a median difference of 31% in favor of FQS, though less marked than the difference in distances. The difference is smaller (18%) and significant (p-value < 0.05) for organic products. For GI products, only the vegetal subgroup shows significantly shorter transport-related emissions (51%, p-value < 0.01) than the reference group. The difference between PDO products and their reference is not significant along the value chain, nor at processing level, despite the significantly shorter distances traveled. Furthermore, the median transport-related carbon emissions generated by animal and seafood, as well as by GI, for FQS products are not statistically different from the emissions generated by their reference products.

4.4 A Non-linear Relationship between Distance and CO_2

Figure 2 presents the relationship between the differences in distances and the differences in transport-related carbon emissions. The trend line reveals an obvious correlation between the two indicators. A negative difference in distances is likely to be associated with a negative difference of the same order of magnitude for carbon emissions. This is coherent with the idea that, all other things being equal, more foodmiles generate more emissions.

However, a closer look at this relationship shows that all other things are not necessarily equal and that the linearity of the relationship is distorted. We can observe in the top left corner that some FQS products (organic pasta, Lofoten stockfish and Phu Quoc fish sauce) travel shorter

5 Long distances before the farm gate do not mean that animal products travel several times around the planet Earth, but that the final product is a result of several inputs that have traveled long distances. Indeed, the lower transport cost of grains by non refrigerated bulk carriers compared to the higher transport cost of final products by refrigerated long haul trucks foster long distances traveled by animal feed.

Table 3: Difference in foodmiles for different categories.

Sector	Type of FQS	Value chain level	Number of cases	Median difference	p-value
All	All	All	27	−30%	0.0245
Vegetal	All	All	14	−61%	0.0001
Animal	All	All	9	−37%	0.7344
Seafood	All	All	4	−11%	0.125
All	PDO	All	9	−78%	0.1289
All	PGI	All	10	−20%	0.8457
All	Organic	All	8	−30%	0.0078
All	GI	All	19	−60%	0.2413
Vegetal	GI	All	9	−66%	0.0039
All	All	Farm	27	−59%	0.8339
All	PDO	Farm	9	−76%	0.5896
All	All	Processing	27	−1%	0.8373
All	PDO	Processing	9	−37%	0.0156

GI (Geographical Indication) is a subgroup made of PDO products and PGI products.

Table 4: Difference in emissions from the transport stage for different categories.

Sector	Type of FQS	Value chain level	Number of cases	Median difference	p-value
All	All	All	27	−23%	0.0859
Vegetal	All	All	14	−31%	0.0009
Animal	All	All	9	−31%	0.8203
Seafood	All	All	4	+10%	0.625
All	PDO	All	9	−51%	0.25
All	PGI	All	10	−16%	1
All	Organic	All	8	−18%	0.0391
All	GI	All	19	−38%	0.418
Vegetal	GI	All	9	−51%	0.0039
All	All	Farm	27	−51%	0.8339
All	PDO	Farm	9	−50%	0.7874
All	All	Processing	27	0%	0.5135
All	PDO	Processing	9	−16%	0.3125

distances than their reference products but yet release more transport-related emissions. Similarly, in the upper part of the bottom left corner, some cases (TKR Hom Mali rice, organic raspberries, PDO olive oil, Sobrasada Porc Negre and Comte cheese) perform much better on foodmiles than they do for carbon emissions. This can be explained by a difference in the transport mode used, and thus in the carbon content per kilometer traveled.

4.5 FQS Products Travel Shorter Distances but generate proportionally more Emissions

The environmental benefits gained by FQS products traveling shorter distances are partly offset by higher carbon content per kilometer traveled (Figure 3). On the contrary, reference products release proportionally less emissions compared to the distance they travel. Such a result indicates that transport of FQS is less carbon efficient.

The FQS cases presented in this study, and PDO cases in particular, are generally smaller in scale. They involve a smaller number of farms and processing units, and lower production volumes compared to their reference cases. For this reason, the logistics may be less optimized (more empty runs) and transport may rely to a larger extent on light goods vehicles that are more carbon-intensive per ton of product moved than heavy goods vehicles. Therefore, similar or even fewer foodmiles may lead to more emissions, indicating that variables other than the distance impact the level of emissions, namely the logistics and the transport mode.

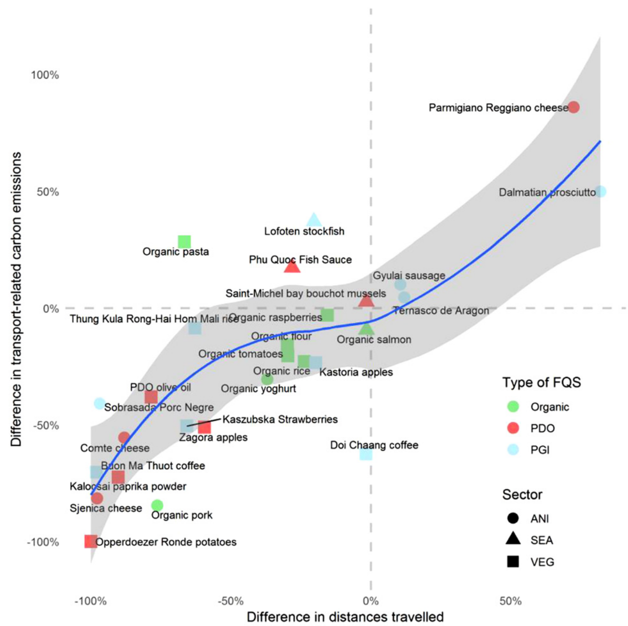

Figure 2: Relationship between the distance indicator and the emission indicator
NB: We use median values.

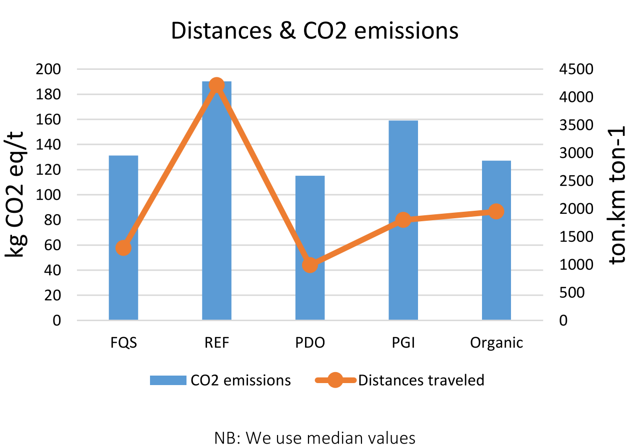

Figure 3: Cross-analysis of both distances and emissions. NB: We use median values.

4.6 Importance of Animal Feed

A closer look at animal feed allows the results to be consolidated. The differences between FQS products and their reference are less marked for animal products and PDO products when international transport of animal feed is excluded. This makes sense since animal feed concerns animal products only, and the geographical restrictions PDO products must comply with as regards animal feed are likely to increase the difference between the FQS and their references. PDO products usually rely to a larger extent than their reference on fodder crops from a delimited local area. Excluding data on animal feed decreases the difference between PDO and their references by 18% points as regards foodmiles and by 13% points as regards transport-related carbon emissions. Similarly, excluding data on animal feed decreases the difference between animal FQS products and their references by 25% points for foodmiles and by 17% points for transport-related carbon emissions, although the median differences are still not statistically significant.

The Kruskal–Wallis test examines whether different groups belong to the same populations. The results indicate that sectoral groups have different populations in terms of foodmiles (p-value < 0.1). The Dunn test then identifies which sectors are different from the others. The results show that the animal sector is significantly different from the vegetal sector (adjusted p-value < 0.1).

5 Discussion

This section identifies the main drivers of the difference. The variables that impact foodmiles and CO_2 emissions from the transport stage are the following: the share of exports of the final products and imports of raw products, product concentration and the value of the co-products, the logistics, the transport mode and energy used, and the technical specifications defining a particular geographical area.

5.1 The Larger the Exports, the Higher the Foodmiles, but not Necessarily the Higher the Emissions

Variables related to exports are expected to significantly impact the results, given that exports, and especially exports outside Europe, generate a lot of miles and emissions. Nevertheless, export miles may have different carbon intensity, according to the logistics and transport mode used, especially for the long distances of exports outside the EU (sea or air transport).

Food Quality Scheme (FQS) products are less frequently exported than their reference, and also less frequently exported outside Europe. The median value for FQS exports is 10% of total production (against 17.5% for reference products) and the median value for extra-EU exports is 7% (against 27% for reference products). Most FQS products are sold on domestic markets, and when they are exported, they are sold primarily in European markets.

Yet, a few cases are export oriented (the Norwegian cases, PGI Kastoria apples and organic raspberries).

Why are FQS exported less? First, lack of label recognition: GIs only capture a price premium on their domestic market. This is the case of the PDO Zagora apples that benefit from label recognition and therefore better prices on the domestic market in Greece. Second, the volumes produced by FQS supply chains are generally smaller, and may not be large enough for opening international markets to become a necessity, once domestic demand has been met. Third, the difference in taste of products and in consumers' preferences may explain why FQS is exported less or exported to geographically closer countries. For example, as the taste and the smell of the PDO Phu Quoc fish sauce are stronger, this product primarily targets neighboring Asian markets, while European and USA consumers have different preferences and may prefer the reference product.

5.2 The Larger the Imports of Raw Products or Animal Feed, the Higher the Foodmiles and the Emissions

Here, we distinguish imports of raw products (e.g. import of fresh meat to be processed) from imports of animal feed. First, imports of raw products concern only a few cases (PGI Dalmatian prosciutto, PGI Gyulai sausage and its reference, and the reference paprika powder). For this reason, the mean contribution of imports of raw products to foodmiles and their associated emissions is small. The supply chains studied in this article that rely on imports get 95–100% of their raw products from abroad. Imports usually occur at the processing stage: meat parts from slaughterhouses located abroad to sausage or prosciutto producers located in the PGI country, conventional dried paprika from abroad to grinding and milling units in Hungary. Raw products are imported when they are cheaper when produced abroad, and when the technical specifications do not prohibit foreign procurement of core inputs.

Second, part of the animal diet is imported, especially as far as soy products are concerned. Long distances traveled by animal feed are further multiplied by the quantity of animal feed required to produce a unit of final product, in order to get distances and thus transport-related emissions embedded in the final product. The quantity of animal feed required per ton of final product is particularly large for dried or cured meat, such as Dalmatian prosciutto and Ternasco de Aragon, as well as their references, which drives foodmiles and emissions up. A marked difference appears when conventional animal products rely on imported animal feed whereas their FQS sources feed locally or nationally (Comte cheese, Sobrasada Porc Negre and Sjenica cheese).

5.3 The More concentrated the Product, the Higher the Foodmiles and the Emissions Embedded in the Final Product

The product concentration indicates the quantity of raw products required to obtain a unit of final product, due either to processing (e.g. milk to cheese) or to losses along the value chain (e.g. mussels). The median value for product concentration of FQS products is 0.53 (against 0.68 for reference products),[6] meaning that about 1.5–2 tons of raw products are required to get 1 ton of final product. FQS products are slightly more processed and concentrated than their references, but product concentration varies more widely among the different sectors and types of FQS. PDO products show a far higher concentration (0.18), contrary to organic products that are less processed (0.9). Similarly, animal products are more processed and exhibit a high product concentration (0.29) while vegetal and seafood products are much less concentrated (0.65 and 0.9 respectively). A higher product concentration is expected to drive foodmiles and emissions up, since the miles and CO_2 emissions from an intermediate or final product are multiplied by the number of units of core inputs needed to obtain a given unit of this product over the distance between core input providers and the processing plant. The higher product concentration of FQS products is expected to result in more impacts, compared to their reference.

The same rationale applies to co-product values. Only the share of the process (intermediate consumption of food, transport, etc.) related to the final product investigated in the case study is considered. The share of the process related to co-products is excluded from the results.

5.4 Transport Mode and Logistics

The transport mode (road, air, sea) and energy used (petrol or diesel) have an impact on the carbon content per kilometer traveled. The emission rates proposed by Cool Farm Tool are clearly differentiated. Sea transport emits almost 50 times less CO_2 than air transport. Similarly, road transport

6 These values are at farm level and do not take animal feed into account, since it is considered earlier in the calculations.

has a higher carbon content than sea transport, with a distinction between light goods vehicles (less than 3.5 tons) and heavy goods vehicles (more than 3.5 tons) – the latter have a lower carbon content than the former.

National trips and exports within Europe usually rely on road transport, whereas exports outside Europe rely mainly on sea transport. Only some fresh and highly perishable products (mussels and yoghurt) rely on air transport, as well as products that are exported in very small quantities (in parcels), like organic pasta. Therefore, exports within Europe usually have a higher carbon content than exports outside Europe. For this reason, the greater number of foodmiles resulting from oversea exports do not necessarily imply more transport-related emissions: long-distance exports result in a less than proportional increase in CO_2 emissions. This result supports the idea that exports are not necessarily environmentally unfriendly, although they do lead to more foodmiles.

The logistics (empty return trip or single journey) impact the foodmiles embedded in the final product, and to a lesser extent the emissions from the transport stage. An empty return trip doubles the embedded distance but less than doubles the emissions released, given that empty vehicles emit less carbon per kilometer traveled than full ones. The logistics options concern road transport, as it is considered that sea and air transport are optimized and do not return empty. In this study, when no specific data was available, trucks were considered to be returning empty.

5.5 PDO Technical Specifications Delimit a Geographical Area for Production and Processing, therefore Limiting Distances and Emissions

GI technical specifications may delimit a geographical area for production and processing. This is the case for all PDO and some PGI products. Indeed, although PDO products are more processed than other types of FQS in our sample, therefore exhibiting a higher median product concentration (0.18 *vs* 0.53), they involve fewer foodmiles (–78%, median value, compared to –30% for all types of FQS) and lower emissions (–51%, median value, compared to –23% for all types of FQS) embedded in the final product. The only variable that seems to drive the difference in terms of foodmiles and consequently in terms of emissions, though to a lesser extent, is the delimitation of a geographical area for production and processing. This specificity of PDO products allows foodmiles from farms to the processor gate to be cut, where product concentration multiplies the foodmiles. Foodmiles from farms to the processor gate are 37% shorter (median value, p-value < 0.05) for PDO than for their reference, whereas at this stage they are similar (1%, median value) and not significantly different for all case studies. The effect of geographical area delimitation is particularly clear-cut at processing level for PDO Bouchot mussels, PDO Zagora apples, PDO Sjenica cheese, and of course for PDO Kalocsai paprika powder whose reference product relies on imports of core inputs.

In addition, GI technical specifications may impose local sourcing for animal feed and may limit concentrate feed as well. The difference is all the more marked when reference products rely on imported feed. Foodmiles before the farm gate are 76% shorter (median value) for PDO products than for their reference, whereas they are 59% shorter for all case studies. As an illustration, PDO Comté cheese, PDO Sjenica cheese and PGI Sobrasada de Porc Negre exhibit large differences in favor of the FQS.

6 Methodological Issues & Limits

6.1 System Boundaries and Major Hypothesis

This section presents the major methodological issues surrounding the hypothesis used to compute the foodmiles indicators. Both FQS products and their references are treated in a similar way. As such, most of the possible biases likely cancel out when analyzing the difference as we are doing here.

Regarding animal feed, information on the precise origin of inputs was not easily available. For this reason, we only computed distances for animal feed assumed to come from abroad, for instance soy-based feed assumed to originate from Brazil, or palm kernel from Indonesia. International transport implies long distances, and as such is a major component of the foodmiles from animal feed.

Information on retail points was not easily available. As far as the domestic market is concerned, we used the largest city (most populated city) in a region as the destination point to compute weighted distances according to the volumes consumed in the different regions. As regards exports, the largest city (in general the capital) of destination countries was used as destination point to compute distances. We assumed first that the largest city was also the largest consumption basin. Barbier et al. (2019) also used a theoretical distance from capital cities to port of departure to estimate transport-related carbon emissions of imported food products in France. Second, we assumed that the largest city in a region or country hosted wholesale markets and might be a transit point for goods that are then distributed within the region or country. Halweil and Grown (2002) described the case of large warehouses in Upper Marlboro, Maryland, United States of America, that centralize food products for the whole Mid-Atlantic region. A similar rationale was followed for imports of raw food products: the largest city of the countries of origin was taken as the origin. For imports of animal feed, only the sea distance from port of departure to port of destination[7] and the road distance from port to producers were used.

In addition, information was often lacking on logistics for road transport. When no such information was available, we assumed that vehicles returned empty. This option doubles the foodmiles and multiplies carbon emissions by 1.333 at a given value chain level, leading to overestimating foodmiles and transport-related emissions. Eurostat (2018) estimated that in 2017 at EU-28 level, 40% of vehicles were returning empty on average. Empty running rates vary among countries and also differ according to the type of freight trips (national or international). Applying country-specific empty running rates would have allowed us not to overestimate foodmiles and transport-related emissions in absolute values, and may slightly alter the contribution of the supply chain segments to foodmiles and transport-related CO_2 emissions (Figure 1). However, the results presented here would remain unchanged, as we are focusing on the relative difference between FQS and their reference.

Similarly, when no information was available on the energy used for light goods vehicles, we used the national energy mix provided by the ACEA (2018) to allocate part of the trip to each energy mode: petrol, diesel or CNG/LPG (Compressed Natural Gas/Liquid Petroleum Gas).

6.2 A Small and Heterogeneous Data Set

This article is based on a limited number of case studies: 27 FQS products and 27 reference products. In addition, the data set is quite heterogeneous, since it is made up of different types of FQS (PDO, PGI and organic) and different sectors (animal, vegetal and seafood). As a result, each category (e.g. PDO products) and even more each subcategory (e.g. vegetal PDO products) consist of a small number of individuals.

The case studies are also heterogeneous in terms of volumes produced (9000 tons of PDO paprika against 90,000 tons for organic raspberries) or in terms of producers and processors involved in the value chain (2500 producers of milk for PDO Comté cheese against 14 organic cereals farmers surveyed and one pasta processor).

Moreover, the difference between PDO and PGI products is sometimes blurred. PGI products often involve a processing stage that is geographically separated from the production stage, and technical specifications are largely focused on the process. Yet, several PGI products in our data set do not include any processing stage and show similarities with PDO products. As an illustration, PGI Kastoria apples and PGI Kaszubska Strawberries are not processed but only packed, and within the same geographical area.

Last but not least, reference products may be more or less appropriate to their FQS products. First, the size of the FQS sometimes differs from that of its reference product, which may impact variables related to logistics, as it is usually agreed that the greater the size, the more optimized the logistics. Second, the geographical scope is sometimes different between the FQS and its reference. For example PDO products such as Comté cheese are produced within a limited geographical area, whereas the reference products may be produced over a much larger geographical area (e.g. Emmental cheese produced nationally) when they are not purely replaced by national values of the sector (e.g. cheese manufacturing sector). We can suspect that regional or geographical-dependent features may be altering the results.

7 Conclusion

FQS products travel significantly shorter distances (–30%) and generate significantly lower transport-related emissions (–23%) than conventional food products. The differences are even greater for vegetal and organic products. The results highlight the importance of product distribution since more than 80% of foodmiles and transport-related emissions occur after the processing plant. However, the relationship between foodmiles and emissions is not systematically proportional. The larger the share of exports and imports, the longer the foodmiles, but not necessarily the higher the emissions. Indeed, the carbon content of the transport mode and the logistics (single journey or empty return) play a key role. Besides, the more concentrated the product, the longer the foodmiles and the higher the transport-related emissions embedded in the final product. Finally, we stress the importance of the spatial distribution

7 We used an online tool (https://www.searates.com/maritime/) to identify the main container terminal of a country or the closest one to the largest city.

of the different stages in value chains (e.g., production, processing). PDO technical specifications delimit a geographical area for production and processing, therefore limiting foodmiles and transport-related emissions compared to conventional food products, but also compared to other types of FQS products.

However, a number of methodological issues call for caution. First, the system boundary is sometimes restricted to part of the value chain and varies across cases. Second, some strong hypotheses are made at retail level to overcome the lack of fine data as regards consumption basins and logistics. Third, this analysis is conducted on quite a small, heterogeneous data set. However, the quite simple, transparent methodology followed in this article suggests that these results can be enriched and consolidated by further case studies at a lower cost.

Acknowledgments: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 678024. Partners listed as co-authors in this article were responsible for collecting data related to two case studies on average, i.e. two FQS products along with two reference products over the value chain. The authors would like to thank all the people and institutions who collected or provided raw data for this publication. Statistical analysis were conducted using the R software.

Appendices

Appendix A

A detailed description of the variables used is presented below. These variables are to be completed for each transport mode used in a given section of the value chain. Indeed, different transport modes have different emission rates associated. Please refer to Bellassen et al. (2019) for more details.

- **Distance**: either directly given in kilometers by case study conductors (usually from expert interviews) or computed by the corresponding author using online tools based on an origin point and a destination point. The shortest distance proposed is systematically selected when using online tools to estimate distances (https://www.maps.google.com for road transport, https://sea-distances.org/ for sea distances, and https://www.worldatlas.com/travelaids/flight_distance.htm for flight distances).
- **Transport mode**: the Excel data file provides the following options from a drop-down list: Road – Light Goods vehicle – Petrol; Road – Light Goods vehicle – Diesel; Road – Heavy Goods vehicle; Rail; Air; Ship – Small tanker; Ship – Large tanker; Ship – Very large tanker; Ship – Small BC; Ship – Large BC; Ship – Very large BC; Ship – Small CV; Ship – Large CV. Detailed description helps choosing the appropriate mode. Light goods vehicles are vehicles carrying loads less than 3.5 tons (3.9 US tons), while heavy goods vehicles are vehicles carrying loads greater than 3.5 tons (3.9 US tons). A tanker is a ship designed to transport or store liquids or gases in bulk. Small tankers carry about 1000 tons, while large tankers carry 20,000 tons and very large tankers carry 100,000 tons. BC states for Bulk Carrier, a ship especially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement. Small bulk carriers carry up to 2000 tons, while large bulk carriers carry 15,000 tons and very large bulk carriers carry 70,000 tons. CV states for Container Vessel, a cargo ship that carries its load in truck-size intermodal containers, in a technique called containerization. Small container vessels carry 2500 tons, while large container vessels carry about 20,000 tons. When no further information is available about sea transport, the ship category "large CV" is selected. Indeed, today about 90% of non-bulk cargo worldwide is transported by container ships. Different sizes of transport modes correspond to different carbon emission rates.
- **Logistics**: the Excel data file provides the following options from a drop-down list: single journey; returning empty. The logistics variable indicates when a transport mode runs back empty or not. Only road transport modes may run back empty, air and sea transport are assumed to travel single journeys and to run back or further to another destination full of another commodity. When no information is available on logistics for road transport, we assume trucks run back empty.
- **Share of the product concerned**: the share of the product traveling with a given transport mode and between two steps of the value chain. This variable is used to weight the distance when several modes are used for a given segment of the value chain, or when the value chain divides into several segments at a

given level (e.g., exports and domestic market at retail level).

- **Product concentration**: the final product ratio variable applies to value chains with at least one processing or packing stage. It gives an idea of the product concentration and of the degree of embeddedness of distance and emissions into the final product. For instance, a product ratio of 0.1 indicates that 10 units of raw product are required to produce 1 unit of final product. In this case, when raw products travel *x* kilometers upstream, there will be 10 times *x* kilometers embedded in the final product. When there are more than one processing stage, the product concentration for the (raw) product concerned at a given level is indicated with respect to the final product.
- **Co-product value**: the value of co-products compared to the value of final products. This variable allows to weight the foodmiles and transport-related carbon emissions by removing the foodmiles and emissions attributable to co-products.
- **Energy**: default hypothesis are made in Cool Farm Tool (e.g., heavy goods vehicles are necessarily powered by diesel) and the energy variable only makes a difference for road light goods vehicles. When no further information is available on the energy used by light goods vehicles, the national energy mix is considered.

Appendix B

Table 5 presents the most important data sources on which each case studied and reference product rely, as well as a detailed description of the reference products used along the value chain.

Table 5: Data sources and reference products.

Case studied	Type of FQS	Country	Reference product	Most important data sources
Buon Ma Thuot coffee	PGI	Vietnam	U3-P1 = conventional unsorted green coffee beans from Dak Lak province in Vietnam P1-P2 = conventional sorted green coffee beans from Dak Lak province in Vietnam P2-D1 = conventional ground and roasted coffee from Dak Lak province in Vietnam Exports (P1-D1) = conventional sorted green coffee beans from Dak Lak province in Vietnam	Interviews, accountancy data
Dalmatian prosciutto	PGI	Croatia	Conventional prosciutto made from pigs raised in Croatia	Interviews
Olive oil	PDO	Croatia	Conventional olives and conventional olive oil produced in Croatia	FQS: Interviews REF: Interviews, FAOSTAT (2015), Croatian Bureau of Statistics (2015)
Saint-Michel bay bouchot mussels	PDO	France	U1-U3 = conventional Bouchot mussels in France U3-P1 = conventional Bouchot mussels in France P1-D1 = mussel sector in France Exports = mussel sector in France	FQS: Interviews REF: Interviews, FranceAgriMer (2016)
Organic flour	Organic	France	U3-P1 = conventional soft wheat P1-D1 = conventional flour Exports = conventional soft wheat, conventional soft wheat flour, conventional bread	FQS: Interviews, ANMF (2016) REF: ANMF (2016), Passion Céréales (2017), France Export Céréales (2017)
Comte cheese	PDO	France	U3-P1 = national average from the cheese industry in France Exports = Emmental cheese, France.	FQS: Interviews, CIGC (2018) REF: CNIEL (2016), Maison du Lait (2016)
Camargue rice	Organic	France	U3-P1 = conventional rice from Camargue, France. P1-D1 = conventional rice from Camargue, France. Exports = conventional rice from France.	FQS: Interviews REF: Interviews, Eurostat (2015)

Table 5: (continued)

Case studied	Type of FQS	Country	Reference product	Most important data sources
Gyulai sausage	PGI	Hungary	Conventional (generic) sausage from Gyulai region, in Hungary	FQS: Interviews, company data REF: interviews, industry data, World Bank (2017)
Kalocsai paprika powder	PDO	Hungary	U1-U3 = conventional dried paprika from raw paprika produced abroad U3-P1 = conventional dried paprika from raw paprika produced abroad P1-D1 = conventional paprika powder Exports = conventional paprika powder	Interviews, World Bank (2017)
Parmigiano Reggiano cheese	PDO	Italy	Biraghi cheese (similar non-PDO cheese)	Interviews, ISTAT (2016)
Kastoria apples	PGI	Greece	Conventional apples produced by the cooperative Kissavos, in Agia, Greece	Interviews
Zagora apples	PDO	Greece	Conventional apples produced by the cooperative Kissavos, in Agia, Greece	Interviews
Phu Quoc fish sauce	PDO	Vietnam	Conventional fish sauce from Phu Quoc island in Vietnam	Interviews
Organic pasta	Organic	Poland	Conventional cereals produced by the 14 model conventional farms	Interviews
Kaszubska Strawberry	PGI	Poland	Conventional strawberries from Poland	Interviews
Organic pork	Organic	Germany	Conventional pork from Germany	ISN (2016)
Organic raspberries	Organic	Serbia	Conventional raspberries from Serbia	Interviews, National Institute of Statistics of Serbia (2016)
Sjenica cheese	PDO	Serbia	Conventional cow cheese produced in Serbia	Interviews, National Institute of Statistics of Serbia (2016)
Organic tomato from Emilia Romagna	Organic	Italy	U3-P1 = conventional processed tomato from Northern Italy (Emilia Romagna region). P1-D1 = conventional processed tomato from Northern Italy (Emilia Romagna region). Exports = processed tomato from Northern Italy (Emilia Romagna region).	Interviews, ISTAT (2017), ANICAV (2017)
Organic yoghurt	Organic	Germany	U3-P1 = natural cow milk yoghurt (unflavored) produced in Germany P1-D1 = natural cow milk yoghurt (unflavored) produced in Germany (both conventional and organic) Exports = natural cow milk yoghurt (unflavored and flavored) produced in Germany (both conventional and organic) D1-D2 = natural cow milk yoghurt (unflavored) produced in Germany (both conventional and organic)	Interviews, AMI (2018), Müller-Lindenlauf et al. (2014), Destatis (2017)
Opperdoezer Ronde potatoes	PDO	The Netherlands	Conventional fresh consumption potato from The Netherlands	Interviews, Central Bureau of Statistics (2016)
Lofoten stockfish	PGI	Norway	P1-D1 = clipfish produced in More og Romsdal, Norway Exports = clipfish produced in Norway	Interviews, Seafood Council (2016)
Organic salmon	Organic	Norway	U3-P1 = conventional salmon in Norway P1-D1 = conventional salmon in Norway Exports = salmon in Norway	FQS: Interviews REF: Interviews, Seafood Council (2016)
Sobrasada of Mallorca	PGI	Spain	U3-P1 = no data (assumptions) P1-P2 = no data (assumptions) Exports = both PGI Sobrasada de Mallorca, Mallorca, Spain and PGI Sobrasada de Mallorca de Porc Negre, Mallorca, Spain	Interviews, DGAR
Ternasco de Aragon	PGI	Spain	Conventional lamb from Aragon region, in Spain	FQS: Interviews, MAGRAMA (2016) REF: Interviews, DataComex (2016)

Table 5: (continued)

Case studied	Type of FQS	Country	Reference product	Most important data sources
Thung Kula Rong-Hai (TKR) Hom Mali rice	PGI	Thailand	U2-U3 = conventional rice seeds, Thailand. U3-P1 = conventional paddy rice produced in the TKR region, Thailand. P1-D1 = conventional milled rice produced in the TKR region, Thailand. Exports = conventional milled rice produced in the TKR region, Thailand.	FQS: Interviews REF: Interviews, Potchanasin et al. (2017), MOC (2017)
Doi Chaang Coffee	PGI	Thailand	U3-P1 = conventional coffee cherries produced in Doi Phahee in Chiang Rai province, Thailand P1-D1 = conventional roasted coffee beans produced in Doi Phahee in Chiang Rai province, Thailand	Interviews

NB: REF = reference product.

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