

Comparing the sustainability of local and global food products in Europe

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Highlights

- 14 food products in four sectors were characterized by their degree of localness
- Multi-criteria outranking analysis was based on sustainability indicators
- Local products outperform global products in the majority of rankings
- Global products perform better than local products for climate change and food security

Abstract

In the debate surrounding the sustainable future of food, claims like “buy local” are widespread in publications and the media, supported by the discourse that buying “local food” provides ecological, health and socio-economic benefits. Recognising the lack of scientific evidence for this claim, this paper aims to compare the results of sustainability assessments for 14 local and global food products in four sectors within four European countries. Each sector has been analysed independently using sustainability indicators across five dimensions of sustainability: environmental, economic, social, health and ethics. In order to determine if local products generally perform better, an outranking analysis was conducted to rank the products relative to their sustainability performance. Outranking is a multi-criteria decision aid method that allows comparison of alternatives based on quantitative and qualitative indicators at different scales. Each product is also characterized by a degree of localness in order to relate sustainability and localness. The results are given in the form of phi flows, which are relative preference scores of one product compared to other ones in the same sector. The rankings showed that global products consistently come last in terms of sustainability, even when the preference functions and weighting of the

indicators were varied. The first positions of the rankings were taken either by the most local or an intermediary product. Moreover, detailed rankings at the attribute level showed the relative strengths and weaknesses of each food product along the local-global continuum. It appeared that the strength of local and intermediary products was mainly in health and socio-economic dimensions, particularly aspects of care and links to the territory such as biodiversity, animal welfare, governance or resilience. In relation to global food products, they presented substantial advantages in terms of climate change mitigation and affordability to consumers. This contrasts with the food-miles ecological claim. Thus, we conclude that distance is not the most critical factor in improving sustainability of food products, and that other criteria of localness (identity, governance or size) play a more critical role.

Key-words

Local food, global food, sustainability, multi-criteria analysis, outranking, localness

1 Introduction

The increase in the interest for local food in the last decades among consumers, social movements, the media and academia has been based on strong beliefs that local food is more sustainable, more ecological and healthier (Adams and Salois, 2010; Thilmany et al., 2008). In fact, some scholars have argued that these assumptions are based more on perception than evidence (Born and Purcell, 2006) because rigorous studies of the benefits of local foods remain limited. Moreover, two aspects are problematic and often confused: i) the definition of “local food” is often unclear (Pearson et al., 2011), and ii) the best ways to measure their impact on sustainability are contested and still much debated. Concerning the first aspect, it has been recognized that the local-global distinction is dichotomous and that a continuum between each pole is a more realistic representation (Brunori, et al. 2016; Smith Taillie and Jaacks 2015). The food miles concept has been widely cited as a measure of localness, but it has also been criticized for over-simplifying the sustainability of food and for providing a narrow comparison of performance (Coley et al., 2011; Edwards-Jones et al., 2008). A study in the US by Weber and Matthews (2008) also found that shifting diets would be more efficient than focusing on food miles to reduce the impact of food consumption. However, Pretty et al. (2005) found that food miles are a significant contributor to the UK food basket’s hidden environmental costs.

An extended form of sustainability comparison is represented by life-cycle assessments (LCA) studies, which often compare domestic and imported food products (Brodt et al., 2013; Farmery et al., 2015). The examples of New Zealand apples imported to Europe and Spanish greenhouse tomatoes imported to other European countries have been flagship products to study, but scientists come to different conclusions (Edwards-Jones et al., 2008). Indeed, Rothwell et al. (2015, p. 421) concluded that the evidence behind the claims regarding the advantage of low food miles “may be equivocal and dependent on a diverse range of system boundaries, produce types, varied assumptions and a multiplicity of footprinting methods”. LCAs typically include a limited number of environmental impact indicators, such as carbon footprint, eutrophication potential, energy use, water use or land use, with each detailed at specific levels of the supply chain (ISO 14040, 2006). LCA studies should include a whole supply chain perspective, going beyond the farm gate for agricultural products (Tasca et al., 2015). Some studies are starting to integrate socio-economic considerations (Cucek et al., 2012), but most remain focused on the environmental side of sustainability assessments.

On the other hand, a range of rural sociology studies have examined the societal significance of local and short food chains (Hinrichs, 2000; Milestad et al., 2010; Renting et al., 2003; Wiskerke, 2009) and/or the economic benefits of direct sales for small to medium-sized

producers (Timmons and Wang, 2010). However, the sustainability of food production and consumption is inherently multidimensional, combining all the fundamental pillars of sustainability (i.e. economic resilience, environmental integrity, social well-being and good governance) (FAO, 2014). However, studies implementing this principle of multi-dimensionality in sustainability assessment and food product comparison remain limited. In response to this evidence gap, the European research project “Global and Local food chain Assessment: a Multidimensional performance-based approach” (GLAMUR) has assessed the sustainability of 39 value chains along the local to global continuum (Brunori et al., 2016). This project included sustainability assessments in five dimensions: social, environmental, economic, health and ethics. A participatory process and extended media and literature review led the project to the identification of 24 attributes (i.e. areas of concern/debate) of sustainability performance covering the five dimensions (Brunori, et al. 2016). Research teams within the project subsequently selected attributes and measurement indicators (i.e. qualitative or quantitative metrics) to apply to product-based case studies. This selection of attributes was necessary as they need to be adapted to local and sectorial contexts for feasibility and relevance (Morrison-Saunders and Pope, 2013; Pinter et al., 2012). For example, the attribute “animal welfare” would be applicable only in the animal product sectors and would be measurable by different indicators if applied in a dairy or a pig meat sector.

Comparisons have been done among pairs of countries and among pairs (or trios) of local-global cases in six food sectors (ham, bread, cheese, wine, fruits and vegetables). These comparisons have been realized at the indicator level, choosing a non-reductionist perspective (Claudia R. Binder et al., 2010). In a review of the GLAMUR case studies, Brunori et al. (2016) analysed which attributes of sustainability are to the advantage of local or global products but did not include any quantification in terms of performance differences. However, they concluded that a wide range of supply chain characteristics should be considered in order to assess performance and that local versus global comparison should be done with caution.

Some indicator weights and stakeholder perceptions have been collected through participatory processes but an actual aggregation of performance has only been attempted in the Italian bread case, which was done to compare differing visions of stakeholders in terms of what counts as ‘sustainable food’ (Galli et al., 2016). In this case and others, a clear conclusion as to whether local chains perform better or not has been very difficult to achieve. Results at the indicator level have revealed trade-offs between dimensions but product comparisons have not been conclusive. There are numerous challenges that arise in indicator-based sustainability assessments when trying to either aggregate indicators’ performances or to extract a single overarching performance indicator. Subjectivity in the indicators’ selection and weighting is often criticized (Böhringer and Jochem, 2007), but it is difficult to avoid. Mitigation of subjectivity includes the integration of multi-dimensional methods and stakeholders participation (Gasparatos et al., 2008). The consideration of uncertainty or ambiguity in the weights applied is also a challenge in practice, although solutions exist in the form of sensitivity analysis and transparency (Munda and Nardo, 2009; Van Asselt et al., 2015). Aggregating the indicators in the form of a weighted arithmetic mean has the advantage of simplicity for communication to decision-makers (Van Asselt et al., 2015) and is often used for ranking countries in terms of their sustainability achievements (Böhringer and Jochem, 2007; Singh et al., 2009). However, there are issues with aggregation procedures, especially in multi-dimensional assessments. The first issue relates with aggregating indicators that are actually not comparable, because they are measured at different scales or have been generated qualitatively (Munda and Nardo, 2009). To deal with this problem, indicators are usually normalized according to different rules (Böhringer and Jochem, 2007) and placed on an artificial scale of performance to allow

averaging with other performance criteria. The second issue relates to the aggregation of weights, which are often meant as coefficients of importance, but aggregating them has the effect that low scores can be compensated by good scores in another dimension. The weightings thus just serve to define which dimensions are more easily compensated for (Munda and Nardo, 2009).

Multi-criteria decision aid (MCDA) methods have been increasingly used in sustainability assessments because they allow multiple points of view to be considered and the integration of multi-dimensional criteria (Sadok et al., 2008). MCDA has been used to evaluate environmental management strategies, such as nuclear waste or alternative land use or to rank enterprises (Behzadian et al., 2010). Carbone et al. (2014) used it to evaluate the performance of a series of Protected Designation of Origin (PDO) products in Italy. The MCDA approach is applied in this paper to answer the following research question: how do selected local or global food products compare and which rank first in terms of sustainability performance? The case studies are presented in more detail in the next section, while the outranking method is presented in section 3. This methodological section also includes the description of the weighting and preference functions used for comparison.

2 Case studies

The analysis presented in this paper covers 14 case studies from four sectors (cheese, ham, bread and wine) that were selected from the 39 GLAMUR case studies. Table 1 summarizes the degree of localness of the case studies on a local-global gradient according to the criteria developed in Schmitt et al. (2016a), where an overall degree of localness between 0 and 100% is assessed. The degree of localness is calculated as the average of seven criteria, each evaluated on a scale from 0 to 100%. Each of these criteria is presented in a column of table 1. Criteria 3 to 6 have a weighting of 50% in the final average. How the scale of each criterion is standardized on a percentage scale is shown in table 4 in the annex of this paper. The case studies have been chosen with the objective to maximize difference in localness between comparable products. The data presented in table 1 has been elaborated from previous publications on the case studies and thus relies on partially representative data for each. The evaluations are case specific and should not be considered as representative of a general product (e.g., cheddar production in the UK), but rather estimations from the typology of value chains represented in the case study publications. The primary goal is to order the case studies from the most local to the most global along a continuum based on available evidence.

Table 1 – Selected case studies in the cheese, ham, bread and wine sectors (data for the criteria of localness according to Schmitt et al. (2016a) and final degree of localness using data from Galli et al., 2016; Oostindie et al., 2016; Schmitt et al., 2016b; Touzard et al., 2016))

Case	Distance (km)	Supply chain size (tons in 2014)	Number of intermediaries by typology of sales channels	Direct sales (%)	Local Know-how	Product identity in reference to the territory	Governance (degree of control of local actors)	Degree of localness
L'Etivaz PDO (Swiss cheese)	Inputs: 2865 Processing: 13 Sales: 333 TOTAL: 3210	445	National market (63%): 1.5 Export (30%): 3.5 Total: 2	7%	Traditional process, limited mechanization	Regional identity (PDO)	High	56%
Farmhouse PDO cheeses ¹ (UK cheeses)	Inputs: 3969 Processing: 0 Sales: 283 TOTAL: 4251	12'000 (1993)	Farm shops (20%): 1 Wholesale (55%): 2 Export (5%): 3 Total: 1.5	20%	Traditional process, limited mechanization	Sub-Regional identity (PDO)	High	53%
Le Gruyère	Inputs: 4718	29'342	National market (54%): 2.5	4%	Modern	Country	Medium	31%

PDO (Swiss cheese)	Processing: 39 Sales: 711 TOTAL: 5469		Export (42%): 4.5 Total: 3.2		process, mechanized	specialty (PDO)		
Cheddar (UK cheeses)	Inputs: 24'673 Processing: 407 Sales: 811 TOTAL: 10'615	279'000 (incl. Westcountry)	Wholesale (84%): 3 Export (16%): 4 Total: 3.2	0%	Very modern process and technology	Generic product	Very low	9%
Cornalin (Swiss red wine, under PDO Valais Wine)	Inputs: 0 Processing: 0 Sales: 312 TOTAL: 312	935	Wine shop or restaurant (30%): 1 Wholesale (6%): 2 Export (6%): 3 Total 0.6	59%	Traditional process, average mechanization	Sub-Regional identity (PDO)	Very high	71%
Languedoc local PDO wine (French red wine)	Inputs: 0 Processing: 0 Sales: 17 TOTAL: 17	5'987	Wine shop or restaurant (50%): 1 Total: 0.5	30%	Traditional process, average mechanization	Regional identity (PDO)	Very high	69%
Languedoc exported PDO wine (French red wine)	Inputs: 0 Processing: 0 Sales: 4395 TOTAL: 4395	13'969	Wine shop or restaurant (5%): 1 Wholesale (30%): 1.5 Export (60%): 2.5 Total: 2	5%	Traditional process, average mechanization	Regional identity (PDO)	High	46%
Variety wine brand (French red wine)	Inputs: 0 Processing: 485 Sales: 4295 TOTAL: 4756	791'616	Wholesale (25%): 3 Export (70%): 3.5 Total: 3.2	5%	Very modern process and technology	Generic Product	Very Low	11%
Cinta Senese PDO (Italian cured ham)	Inputs: 173 Processing: 237 Sales: 150 TOTAL: 481	66	Restaurants (4%): 2.5 Wholesale (87%): 2.5 Export (4%): 3.5 Total: 2.4	5%	Traditional process, limited mechanization	Sub-Regional identity (PDO)	High	65%
Parma Ham PDO (Italian cured ham)	Inputs: 1677 Processing: 150 Sales: 1285 TOTAL: 3903	84'621	Restaurants (7%): 4.5 Wholesale (60%): 4.3 Export (32%): 5 Total: 4.5	1%	Traditional process, average mechanization	Country specialty (PDO)	Medium Low	27%
Generic Ham (cured ham processed in Italy)	Inputs: 5295 Processing: 935 Sales: 977 TOTAL: 9933	141'865	Restaurants (12%): 4 Wholesale (69%): 5 Export (19%): 5 Total: 5	0%	Modern process, mechanized	Generic product	Very low	7%
Pane Floriddia (Italian bread)	Inputs: 0 Processing: 22 Sales: 11 TOTAL: 33	21	Small bakeries (70%): 1 Total: 0.7	30%	Traditional processes and mechanized technology	Specialty product very little known	Very high	81%
Pane Toscano PDO (Italian bread)	Inputs: 204 Processing: 113 Sales: 0 TOTAL: 317	200	Small bakeries (100%): 3 Total: 3	100%	Traditional processes and mechanized technology	Regional identity (PDO)	High	66%
Pan Bauletto (Italian bread)	Inputs and Processing: 1004 Sales: 1000 TOTAL: 2004	19'815	Wholesale (100%): 5 Total: 5	0%	Very modern process and technology	Generic product	Very low	12%

¹ Name grouping Single Gloucester PDO and Westcountry Farmhouse Cheddar PDO

2.1 Cheese

The cheese case studies cover four value chains, two in the UK (cheddar and farmhouse PDO cheeses) and two in Switzerland (Le Gruyère PDO and L'Étival PDO). They all follow a value chain starting with a dairy farmer (who also process the cheese in local cheese cases), followed by a primary and secondary processing phase (maturing), and by multiple sales channels (further details in Maye et al. (2016)). Data collection for the sustainability assessment, covering eight attributes (table 2), was conducted through interviews with actors at each stage of the value chain, including input provision, and consumption through consumer focus groups. Stakeholder workshops were also conducted to discuss the results and weight the attributes and indicators. Comparisons between the cheeses at the indicator level revealed critical issues and trade-offs (Schmitt et al., 2016b). One major issue impairing

the localness of cheese is the origin of inputs such as animal feed and rennet (Schmitt et al., 2016a).

2.2 Ham

The ham case studies cover three Italian value chains. The Cinta Senese PDO system is an example of small-scale territory-based product, depending on a traditional local pig breed and extensive grazing on agro-forest settings. The high-quality meat, processed with traditional techniques, is mostly consumed locally (Oostindie et al., 2016). The Parma ham PDO is processed in Parma, while pigs are bred and slaughtered in ten Italian regions. The 150 Parma ham processors produce around 9 million hams per year. The most global product is a generic cured ham produced in the same region, using know how and the same facilities used for PDO production, but using mostly foreign meat (Dentoni et al., 2012). The three value chains include pig farms, slaughterhouses, ham processing and maturing (over different time periods), and marketing (national or export markets). A major issue identified from the analysis is the spill-over of reputation from the Parma ham PDO to the global chain product, and differences in environmental impact linked to economies of scale or to land use (Oostindie et al., 2016). Seven attributes (table 2) have been analysed combining quantitative methods, such as LCA, with qualitative assessment techniques.

2.3 Bread

The bread value chains comprise three cases based in Italy, covering wheat cultivation, milling, dough making, baking, and marketing. A local case (Pane Floriddia) is represented by a farmer-miller processing and selling bread from his organically farmed wheat (suing ancient varieties). The intermediate case is a Tuscan bread made from sourdough out of Tuscan wheat sourced through a consortium, which recently obtained PDO status. The Tuscan bread PDO has distinct nutritional and organoleptic quality (wheat germ preservation, no salt, lower gluten content, etc.). The most global case is a convenience soft bread processed by a multi-national company using both national and imported wheat. This industrial bread, which is sold sliced and has a longer shelf life, is made of soft wheat flour, water, salt yeast and vegetable oil and is marketed at a national level. Having screened for distinctive features of local and global wheat-to-bread chains based on available literature (Galli et al., 2015), a set of attributes were analysed mainly through participatory methods. Contribution to biodiversity preservation, environmental impact, transparency, creation and distribution of value added and nutritional contents linked to ingredients and baking properties were identified as the most critical sustainability performance issues (Galli et al., 2016).

2.4 Wine

The wine case studies include four value chains: one local case in Switzerland and one local case in Languedoc (France), and two global value chains exporting wine from Languedoc. The Swiss local wine is made from a local grape variety (Cornalin) and marketed by the grape grower/wine-maker using mostly direct supply chains. The local Languedoc wine is also made and sold by small family estates using a blend of traditional varieties (Mouvèdre, Cinsault, etc.). They follow PDO and/or organic certification and have developed strategic relations with local actors via tourism, gastronomy, fairs and cultural events. One of the global wines studied comes from estates or small cooperatives, with grape varieties grown on the hillsides of Languedoc and relying on local resource management, according to PDO specifications. The wine is bottled in the PDO area and is then exported to specialist wholesalers. The most global wine uses international grape varieties (e.g., Merlot, Cabernet-

Sauvignon) and is cultivated in Languedoc plains by grape-growers' cooperatives according to an intensive production model. The wine is sold in bulk to an international wine company, who manage the logistics, blending and bottling, before exporting to large scale retailers. Worldwide consumers identify this wine by the name of the variety and a trade-brand (i.e. "variety wine brand").

Table 2 – Attributes selected and analysed by sustainability dimension in each product sector (Number of indicators in parentheses; the list and description of the indicators by attribute is available in the supplementary material).

Dimension	Cheese	Ham	Bread	Wine
Economic	Affordability (2) Creation and distribution of added value (3)	Affordability (3) Resilience (25) Creation and distribution of added value (2)	Creation and distribution of added value (2)	Creation and distribution of added value (3)
Social	Information and communication (3)	Territoriality (7) Governance (3)	Information and communication (2)	Information and communication (2) Territoriality (2) Governance (2)
Environmental	Biodiversity (2) Resource use (4) Pollution (2) ²	Resource use (3) ³ Pollution (2) ³	Biodiversity (2) Resource use (1) Pollution (1) Technological innovation (4)	Biodiversity (2) Resource use (2) Pollution (3)
Health	Nutrition (4)		Nutrition (2)	Food safety (2)
Ethics	Animal welfare (3)			

² Assessed only in Switzerland

³ The indicators concerning the impacts for the intermediary stages of the supply chain from Oostindie (2016) were not taken into account in this analysis. Only the impacts « per kg sliced ham » for the final product are included (concerns water use, energy use, and land use for attribute « resource use » ; and indicators GHG emissions and eutrophication for attribute « pollution »).

Given that the selection of attributes and indicators was made independently per sector, the list of attributes analysed in each sector is different, as can be seen in table 2. Furthermore, if the same attribute (e.g., "biodiversity") appears in several sectors, it does not mean that it was assessed using the same indicators or the same methods. This difference also explains why some attributes have a variable number of indicators. The 25 indicators composing the "resilience" attribute in the ham sector, for example, are qualitative indicators covering specific aspects of resilience whereas the two pollution indicators (GHG emissions and eutrophication potential) are quantitative indicators that cover a large portion of the pollution issue. Further justification of the indicators' selected is available through the sector-specific studies: cheese (Schmitt et al., 2016b); ham (Oostindie et al., 2016); bread (Galli et al., 2016) and wine (Touzard et al., 2016). The supplementary materials section of this paper also provides a complete list of the indicators selected and a brief description of each. The difference in indicators' selection between sectors is the reason why the outranking analysis described in the next section was conducted only within each sector.

3 Method

Several methods exist to apply the outranking approach, but the "preference ranking organization method for enrichment evaluations" (PROMETHEE) is applied in this study because it takes weights as coefficients of importance, makes it possible to define threshold

values and it can integrate qualitative and quantitative data (Cinelli et al., 2014). PROMETHEE is based on pair-wise comparisons between different alternatives (in our case, food products). The first step is to compile the evaluation matrix that contains the indicators' performance scores for each indicator and for each food product to be compared (within sectors). This evaluation matrix contains all the indicator results that will be used to perform all pair-wise comparisons. Second, preference functions and preference thresholds are defined to obtain an outranking flow for each alternative on each indicator (Brans and De Smet, 2016). The outranking flows have been calculated according to the preference functions described below with the software Visual Promethee (Mareschal, 2016). In the third and final step, each outranking flow is weighted according to the indicators' importance and they are summed to calculate the overall net phi flows that serve to establish rankings. The evaluation matrixes, the weights and thresholds for each indicator are available in the supplementary material.

3.1 Preference functions

The preference function is a function of the difference in performance among the alternatives or options (i.e., the food products). Thus, the resulting phi flows represent a relative way of comparing alternatives, but should not be taken as an absolute reference of the sustainability performance of products. Six types of preference functions exist (Brans and De Smet, 2016), but three have been applied in this paper, after consideration of similar designs and applications (Carbone et al., 2014; Podvezko and Podvezko, 2010) :

1. Linear preference function: this function was assigned to the quantitative continuous indicators and it corresponds to a linearly increasing outranking flow, based on the difference in performances d between each pair of alternatives (figure 1). Two thresholds can be defined: the indifference threshold q below which d is considered insignificant and the strict preference threshold p from which the difference is considered a full preference of product a over product b . A special case of linear function is the V-shape function when q is set to 0.
2. Usual preference function: this was used for the few binary indicators (yes/no) used in the study. It simply attributes a full score of 1 in case of any difference in performance and 0 in case of no difference between the alternatives, as no quantification of preference can be evaluated. The preference thresholds do not play any role for this function.
3. Level preference function: this type of function is an intermediary type and was used for categorical indicators that present performances in levels such as rating scales from 1 to 5. If the difference in the performances d is below the indifference threshold q , the function will return 0, and 1 if it is above the strict preference threshold p . For d in between q and p , the function will return a value depending on the number of levels (see figure 1).

The selection of the thresholds p and q can potentially change the results of the outranking analysis, especially the magnitude of preference of one alternative over the others. No strict rule exists for the selection of the thresholds and one could rely on the decision-maker to define them or select values according to the scale and type of data (Sultana and Kumar, 2012). Different values have been tested by Podvezko and Podvezko (2010) and they state that q and p should be between the minimum and the maximum of the differences observed within the indicators' performances. Carbone et al. (2014) have set p at 50% of the maximum difference in performance values and q at 0. Most importantly, different threshold levels should be tested to evaluate their effects on the ranking (Rogers and Bruen 1998). Our analysis was tested with several levels of q and p in order to test the stability of the rankings. Threshold p has been set to three levels: (i) 50% of the maximum difference,

(ii) the maximum difference, and (iii) the optimal value in terms of sustainability. The higher the p threshold, the harder it is for each alternative to reach an outranking flow of 1. The threshold q has each time been set alternatively to (i) 0 (the linear preference functions become V-shape functions), meaning that any difference in indicators' performance values is significant, and (ii) to 20% of p , meaning that the difference in the indicator's performance values have to show a difference of at least 20% to count. In total six combinations of thresholds have been tested.

FIGURE 1 HERE

Figure 1: Two examples of preference function types from Brans and De Smet (2016) to calculate the net phi flows of products in the outranking analysis. (P : Preference; d : difference in performances; q : indifference threshold; p : strict preference threshold).

The application of the preference functions on each criterion results in unicriterion outranking flows for each alternative. These unicriterion flows are then aggregated over all criteria (weighted by their weight w_i), which results in outranking flows for each pair of alternatives (comparison of alternatives a over b and b over a , for each pair). There are two types of outranking flows resulting from this iteration (Brans and De Smet, 2016): (i) the positive outranking flow $\phi^+(a)$ expresses how an alternative a is outranking all the others (the higher $\phi^+(a)$ the better the alternative); and (ii) the negative outranking flow $\phi^-(a)$ expresses how an alternative a is outranked by all the others (the lower $\phi^-(a)$ the better the alternative). The PROMETHEE I partial ranking method compares ϕ^+ and ϕ^- of all alternatives and ranks one alternative first only if both flows are favourable. If one alternative a has a higher ϕ^+ , but also a higher ϕ^- than b , then the two alternatives are incomparable. The PROMETHEE II complete ranking method overcomes this by calculating the net outranking flow $\phi(a) = \phi^+(a) - \phi^-(a)$. The higher the net flow, the better the alternative, although the "incomparabilities" in the ranking are sometimes arbitrarily erased by this method. The net phi flow results can be between -1 and 1 and the closest to 0, the smaller the preference to other alternatives (Brans and De Smet, 2016). Results of both ranking methods are presented in the results section below.

3.2 Weighting

The weight that is given to the indicators used to operate the outranking can greatly influence the results (Sultana and Kumar 2012; Rogers and Seager 2009). Attributing no weight implicitly gives equal weights to all indicators, which is as subjective as giving different weights. However, determining which aspects of sustainability are the most important concerning food production and distribution remains a major challenge and is subject to different points of views. Each weighting method contains biases and cannot include a consensus of all points of view. This is why several weighting systems are tested in this analysis:

- 1) Equal Attributes: The weight of all attributes is set equal (see table 2 for a list of attributes) so that if an attribute contains 3 indicators, its indicators' weight will be twice higher than the ones of an attribute containing 6 indicators.
- 2) Equal Dimensions: the weight of the indicators is set so that the total weight of each dimension (economic, social, environment, health and ethics) is equal. There is no other balancing within indicators so that all indicators within one dimension have the same weight.

- 3) Quality: during the data collection process, each indicator has been attributed a data quality score between E (very bad) and A (very good), following the data quality “pedigree matrix” commonly used in LCA (Ciroth, 2009; Weidema, 1998). Each indicator was thus attributed a weight according to the quality score obtained across the case studies using that indicator.
- 4) Society Relevance: the method presented in Hak et al. (2012) was followed to extract the societal relevance of the attributes and indicators sourced through Internet searches. The relevance of attributes and indicators is evaluated by the number of hits in specific research strings in the search engine google.search. Hak et al. (2012) found that this is influenced by the number of words and concreteness of the searched terms. In this case, we searched for attributes relevance using only one keyword, in order that attributes of one word (e.g., biodiversity) are not advantaged. The keywords returning 100% relevance like “information” were avoided and transformed (e.g., the attribute “information and communication” was rephrased as “transparency”). The terms were combined with the general search for “food” and “sustainability” to remain in the relevant theme and to be able to give the hits in relative terms. “Sustainability”AND”food”AND”keyword_attribute” search strings were used for attributes, adding two keywords describing the indicator when searching for the indicator’s relevance.
- 5) Scholar relevance: The same procedure as for Society relevance was performed in the search engine google.scholar.
- 6) Stakeholder weighting: taking the point of view of stakeholders in assessing the importance of indicators has become common in sustainability assessment that attempt to consider varying and sometimes opposing viewpoints (Binder et al., 2010; Peano et al., 2014). In this case, the weights were assigned by stakeholders (actors taking some part in the value chain such as farmers, processors or retailers) during the data collection phases (workshops and interviews) performed in each sector. This process depends on the methodologies followed by each research team and they are different for each sector. When several weightings were available for each sector, the most complete set of weights was chosen.

With six weighting systems and the previous six combinations of preference thresholds (three different p associated each time to two different q), 36 outranking analyses have been performed for each food sector (30 for ham because stakeholder weighting was not performed for this case).

4 Results

4.1 Rankings

Table 3 presents the rankings obtained with the PROMETHEE I method. As this method considers both net phi flows ϕ^+ and ϕ^- to determine whether one alternative is better than the other, it is possible to identify alternatives which are incomparable (equals) in the rankings. The rankings in table 3 are presented for the preference functions thresholds set at p equal to the maximum difference observed in the data and q at 0, which was observed as the most average ranking within the combinations of parameters tested.

Figures 2a-d show the results of the PROMETHEE II method which uses the net phi flows ($\phi^+(a) - \phi^-(a)$) of each product. In total, 18 points are shown per product, representing each one of the 18 combinations of preference parameters (6 weights x 3 combinations of p thresholds, q at 0) that were used for the outrankings. Figures 2a to 2d show the results for one sector. The net phi flow are to be read on the y axis and the x-coordinate shows the

degree of localness for each product. The net phi flows for one product thus form a vertical line at this x-coordinate.

Table 3 – Rankings of food products per sector with the PROMETHEE I method (left to right from most local to globally-oriented).

Weighting System	CHEESE			
	L'Etivaz PDO	Farmhouse PDO cheeses	Le Gruyère PDO	Cheddar
Equal Attributes	1	2	3	4
Equal Dimensions	1	3	2	4
Quality	1	2	3	4
Scholar Relevance	1	2	2	4
Society Relevance	1	2	3	4
Stakeholders	1	2	3	4
	HAM			
	Cinta Senese PDO	Parma Ham PDO	Generic Ham	
Equal Attributes	1	2	3	
Equal Dimensions	1	2	3	
Quality	1	2	3	
Scholar Relevance	1	2	3	
Society Relevance	1	1	3	
	BREAD			
	Pane Floriddia	Pane Toscano PDO	Pan Bauletto	
Equal Attributes	1	2	3	
Equal Dimensions	1	2	3	
Quality	1	1	3	
Scholar Relevance	1	2	2	
Society Relevance	1	2	2	
Stakeholders	1	1	3	
	WINE			
	Cornalin	Languedoc local PDO wine	Languedoc exported PDO wine	Variety wine brand
Equal Attributes	3	1	2	4
Equal Dimensions	2	1	3	4
Quality	2	1	3	4
Scholar Relevance	2	1	3	4
Society Relevance	3	1	2	4
Stakeholders	2	1	3	4

Results from both PROMETHEE I and II rankings clearly show that globally-oriented chains are always on the last position of the ranking and have the lowest net phi flows for all sectors across all weighting systems and all threshold levels tested. The top of the ranking is thus always occupied by either the most locally-oriented product or an intermediary product.

In the case of cheese, the most local cheese – L'Etivaz – usually comes first, and the English local cheeses –Farmhouse PDO cheeses –come first on other occasions. The second position in the ranking is taken either by L'Etivaz or the intermediary-global case (Gruyère). Gruyère and Farmhouse PDO cheeses score well, and so it is not possible to determine which is more sustainable. This is visible on figure 2a: phi flows for Farmhouse PDO and Gruyère are close to 0 and within the same range, so the preference for any of them is hardly conclusive.

In the case of ham, the most local ham – Cinta Senese –always comes first, but sometimes the intermediary case also scores well.

In the case of bread, the first place is always taken by the most local bread (Pane Floriddia), but sometimes the intermediary case scores equally well. This intermediary case (Pane Toscano) is also sometimes equal with the global bread and thus in last position (with the “society” and “scholar” weighting systems). Hence, we can conclude that the local case is more sustainable than the global case but the position of the intermediary bread is unclear in comparison with the other two bread cases.

In the case of wine, first place is always taken by the local French wine (the Languedoc PDO red wine). The local Swiss wine (Cornalin) and the intermediary French wine (exported Languedoc PDO wine) share the second and third ranking. They are both shown within the same range of phi flows on figure 2d.

FIGURE 2a-d HERE

Figure 2a-d: Net Phi Flows of each product per sector (cheese (a), ham (b), bread (c), wine (d)) resulting from the PROMETHEE II outranking method. The 18 points per product represent the 18 combinations of weighting systems and varying p thresholds tested.

4.2 Results by sustainability attribute

However, when the products were examined at the indicator and attribute levels, global chains in some instances scored well. Figure 3 shows the positive and negative phi flows aggregated at attribute level with the same thresholds as in table 3 and for the “equal attributes” weighting. The attributes that scored well for the most globally-oriented products studied are: affordability (ham and cheese), food safety (wine) and technological innovation (bread). Pollution and resource use alternate between positive or negative scores for global products. Other attributes mostly score favourably for local products: nutrition, biodiversity, information and communication, creation and distribution of added value, territoriality, resilience, animal welfare and governance.

FIGURE 3 HERE

Figure 3: The positive and negative phi flows of each food product aggregated by sustainability attribute (Preference parameters used: Threshold p set at “maximum difference”, q at 0, weighting system “equal attributes”)

4.3 Stability of the rankings

The variation of thresholds and weighting was conducted to test the stability of the rankings and they appear very stable. The most global products come last in every ranking, except on one occasion for cheese and two occasions for bread. The variation of phi flows is most affected by the weighting. The weighting based on data quality is the clearest pattern and reinforces the suggestion that such comparisons should be based on a sufficient number of indicators and reliable data. No weighting system showed very contradictory results, even with the weighting systems “society relevance” and “scholar relevance”, which contain some strong varying weights. The change of thresholds only created a small variation. The change of threshold q had limited impact on the rankings, hence why they are not represented on figure 2a-d. This suggests that the advantage of local or intermediary products is related to

important differences in performance (at least 20% superior). Still, the relative instability of the ranking (between weighting systems) is the strongest with the harshest thresholds (p at highest value, q at 20%). This could mean that more globally-orientated cases sometimes have considerable advantage for a few indicators (for quantitative indicators assessed with a linear function).

In the case of cheese, cheddar comes third instead of fourth with the “society relevance” weighting for the strictest preference function parameters (p at maximum value, q at 20%). This is because in the “society relevance” weighting, the importance of the indicator “price” is very high. Its weight is set at 14%, which is 3% higher than the stability interval of the weight for this indicator (i.e., if the weight was 11%, cheddar would still come fourth). This reveals the biggest advantage of cheddar in comparison to the other cheeses studied: its low price, but that still makes it only gain one position and it does not reach the top of the ranking. It is also with the strictest parameters that L’Etivaz loses its first place. This could mean that it has only a small advantage over the others.

The ranking of hams is the most stable of all the products examined and also the one based on the most indicators. It is in the bread sector that there is significant variation that impedes giving a clear ranking result. Indeed, Pane Toscano occupies all three positions of the ranking. The most globally-oriented bread remains on the last position, but Pane Toscano also scores less well for “society relevance” and “scholar relevance” weighting with p at 50% and 100% of the maximum difference. These two weighting systems put an especially high importance (19 and 32%, respectively) on the indicator “share of farmer’s price on the final bread price”. For this indicator, Pane Toscano PDO performs a little worse with a value of 4%, whereas Pan Bauletto is at 5.1%. For wine, the variation mostly appears between weightings; the thresholds do not generate any variation. Still, this variation only appears for the second and third position shared by the Swiss local wine Cornalin and the French exported PDO wines. The first position is always occupied by the French local wine and the last position is always taken by the French more globally-orientated wine.

5 Discussion

5.1 Degrees of Localness

The degrees of localness calculation showed that the case studies are distributed along a continuum which reflects well the value chains’ characteristics (table 1). No product reaches close to 100% of localness. This is because most of surveyed products present relatively low rates of direct sales, except for Pane Toscano PDO, which, at the time of the survey was advertised as sold in the local bakeries¹. The other products rely mainly on conventional sales channels.

However, many products still reach the consumer with information about their identity and connection to the territory, which has been elsewhere described as “extended short food supply chains” (Renting et al., 2003). Brunori et al. (2016) describe this category of products as “locality” foods and Ilbery and Kneafsey (2000) refer to them as “typical” food emerging against a “placeless foodscape”. Most of our case studies use PDO as mechanism to promote the link with the territory and to valorise their identity. In general, the PDO products analysed tended to rely more on short value chains than generic products, with fewer supply chains links.

The analysis shows that the overall distance covered by food during its production, processing and distribution was higher than expected. This is due to the fact that production

¹ The recent PDO recognition means the bread is now also sold in supermarkets

inputs, such as animal feed, salt, oils, enzymes or yeast, have been included. Indeed, these inputs are commonly sourced on global markets even for locality products, and often for local products as well. Some of them, like salt, are often available at a national scale but others come from countries dominating the global market (e.g., Brazil and Argentina for soy). This reality greatly impacts the distance, or food miles, of animal food products. This is the main reason why the cheese and ham products surveyed are all below a degree of localness of 60% and 65%, respectively, while bread and wine, which are plant-based products and rely less heavily, in terms of mass, on production inputs, show higher degrees of localness. Other important inputs often sourced globally were not included: labour, machinery, energy, seeds and capital.

The product with the highest degree of localness in our sample, Pane Floriddia, also stands out as it is produced in very small quantities and oriented to local markets (with no PDO). It is the best example of a local farm product sold directly by its producer, who manages the whole supply chain, growing traditional wheat varieties, managing milling, baking, and selling directly to local consumers (an element of which includes Internet sales).

On the basis of the data in table 1, degrees of localness could be calculated, although uncertainties still exist and therefore the degree on figures 2a-d should be taken as indications. Thus, a difference of 3% in the case of the two most locally-oriented cheeses (56 and 53% respectively) is not significant. They are equivalent in terms of localness and close in their sustainability performance. The two most locally-oriented wines have also close degrees of localness (69 and 71%) and convergent results in terms of sustainability. These degrees of localness are also evolving, as illustrated with the evolution in sales types seen with the adoption of PDO by Pane Toscano, so the figures calculated in table 1 are only representative of the situation in 2014.

From the products placed on figure 2 and figure 3 with their degree of localness on the x-axis and their net phi flow obtained from the sustainability ranking on the y-axis, four groups emerge:

4. Global (degree of localness < 20%), low phi flows: Pan Bauletto, non-PDO Cheddar, Variety wine brand and generic ham
5. Major Locality products (degree of localness 20-50%), intermediary ranking: Le Gruyère PDO, Parma Ham PDO, Languedoc exported PDO wine,
6. Small locality products (degree of localness 50-80%), top-intermediary ranking: Farmhouse PDO cheeses, L'Etivaz PDO, Pane Toscano PDO, Cinta Senese Ham PDO, Languedoc local PDO wine, Cornalin PDO Valais Wine
7. Local farm product (degree of localness > 80%), top ranking: Pane Floriddia

5.2 Strengths and weaknesses in Sustainability

In line with Brunori et al. (2016), the results show that a higher number of attributes perform better in local product value chains compared to global ones. Local products perform better in areas of sustainability that are mostly concerned with quality and place (e.g., territoriality, nutrition, animal welfare, biodiversity) and global products outperform local products in areas related to quantity management (e.g., affordability, food safety). Global products also tend to have an advantage in pollution mitigation as well as in resource use and efficiency, although evidence is sometimes unclear. The following sub-sections discuss the results for each sustainability dimension with reference to targeted attributes.

Economic performance The creation and equitable distribution of added value is strong in value chains where the farmers hold a dominant position in the governance of the chain (in groups 3 and 4, and group 2 for cheese). Brown et al. (2013) also found that farmers involved in short value chains and direct sales could significantly improve their income, although the effect on economic growth at regional level was not visible. On the contrary,

affordability (mostly measured as the retail price) is clearly an asset of the global products in group 1, together with the two larger-scale locality products surveyed (Parma Ham and Gruyère). Affordability was considered a positive aspect due to its importance for food security in terms of availability and accessibility to (healthy) food for middle and low-income consumers (Kneafsey et al., 2013). However, as described by the “creation and distribution of added value” attribute, a sustainable price should cover production costs and provide decent wages for farm workers rather than mere provision of “cheap food”. This aspect of sustainability is therefore dependent on perspective and displays a major trade-off. From a systemic perspective, lower food prices can also imply that measures to protect the environment or repair damage from food production would need to be covered by public funds. In some countries, such as Switzerland, public direct payments are necessary to compensate the low wages that farmers face as a result of low international food prices. Consumers are thus paying more for food and environmental protection through their taxes. This is only one example but it shows how sustainability in food systems needs to be assessed beyond the performance of a single attribute.

5.2.1 Environmental performance

In our case studies, greenhouse gases (GHG) emissions, as part of the attribute “pollution”, were lessened in global supply chains when measured in quantitative terms (pork, bread) and when measured in relative practices (bread, partly for cheese and wine). The reasons explaining this higher performance of the global products were: more efficient transport (bulk wine on trains rather than single bottles by car), shorter maturing periods (cheese and ham) or baking technology (bread). In the literature, authors have also shown that distance is not correlated to an increase of emissions because the mode of transport, the efficiency of the distribution system and the loading capacity of vehicles have a larger impact (Coley et al., 2011, 2009; Wallgren, 2006). A small number of studies have tried to model the impact of re-localizing major sectors of food production and tested changes in GHG emissions. The common conclusion is that emissions from farming (land use, soil emissions, productivity) are more important than transport emissions and that relocalization, if practiced globally would actually increase GHG emissions (Avetisyan et al., 2014; Kastner et al., 2011; Kreidenweis et al., 2016). The impact is similar for land use: a shift to local production would increase worldwide agricultural land use because of yield differences (Kastner et al., 2014). It is thus quite clear that if one’s goal was purely to preserve the climate, turning to efficient food production with large economies of scales and low GHG emissions per production unit would be the best strategy. However, this would severely prejudice other sustainability dimensions of the food system, such as biodiversity, distribution of added value, animal welfare, etc. The influence on dietary quality of the resulting food choice available could also be negative (Vieux et al., 2012). In order to override these aspects and position the global cases high in the rankings, the weight of the GHG indicators would have to be increased in the ham and bread cases to 30% and 50%, respectively. This would not be coherent with considering all dimensions of sustainability equally important but highlights the risk of considering a single indicator in comparative studies.

The trend for resource use across the local-global continuum is however less clear. For ham, the global one had the lowest scores in terms of water use and medium scores in relation to energy and land use. Water and energy use are an advantage of the local ham case, although it performed less well for land use because its production system is closely interwoven with marginal forest areas as part of a wider system of ecosystem management (Oostindie et al., 2016). Resource use has been measured in efficiency per unit of outputs in volumes (kg), but Oostindie et al. (2016) (see also Notarnicola et al. (2016) for bread) showed that if it was measured in efficiency per unit of added value, the results could be very different.

All global cases are outperformed in the biodiversity attribute. However, in the case studies included, only in-situ biodiversity was considered through indicators like “diversity of productions” or “presence of rare breeds”. If biodiversity in inputs-providing countries were considered, the result would even be worse for global cases because these regions often experience high rates of deforestation (Kastner et al., 2014).

5.2.2 Ethical performance

The trend is the same for animal welfare (assessed in the cheese sector), where the two most local-oriented cheeses (in group 3) outperform the global cases. It has been shown that the feeding regime based on grassland has the highest benefits for animal welfare, but also for the nutritional quality of the milk (Schmitt et al., 2016b). The attribute “animal welfare” is the only one of ethical dimension considered explicitly in this study and this is a limitation. Having an ethical dimension in the sustainability assessment was thus only the first step into attracting attention about the links of other dimensions with human values. Other attributes, like “information and communication”, “creation and distribution of added value” and “governance” also touch on aspects of ethics and deal with issues which are often difficult to translate into measurable indicators. The more explicit inclusion of ethics into sustainability assessments should be enhanced by attributes that “establish the extent to which food chain actors are organising themselves to address ethical dilemmas” (Kirwan et al., 2017, p. 14). This especially concerns attributes relating to transparency, responsibility and governance patterns. Indeed, an ethical food chain actor would demonstrate engagement past a good performance in animal welfare, and would be prepared to question its operations, its communication and its internal governance structures in what Kirwan et al. (2017) call “reflexive governance”. More studies are needed in this field in order to be able to integrate such important aspects touching on the intentions of actors into indicator-based sustainability assessments.

5.2.3 Health performance

The nutrition attribute follows a positive pattern for the local cheese cases, and also for the local bread cases (positive in groups 2, 3, 4 and negative for cheddar and Pan Bauletto). However, the indicators considered for nutrition were mainly at the levels of potentially harmful nutrients like salt or fat, or the presence of one mineral in the case of cheese. The intake of essential vitamins or other elements was not assessed. Edwards-Jones et al. (2008) stated that this is important for fruits and vegetables and that it depends more on time between harvest and consumption than place. Another study by Notarnicola et al. (2016), found that the environmental impact of breads based on their calorific value was lower for breads containing ingredients like vegetable oil, which is also the case in the two Italian local breads studied here.

Nevertheless, the healthiness of individual products says little about their impact on consumers’ health because it all depends on both the quantities consumed and the diet composition. This aspect is, however, very important because consumers describe taste as the most important driver for buying local foods (Feldmann and Hamm, 2015), which is in contrast with global food which is sometimes described as tasteless (Seyfang, 2006). The better taste of local food could be linked to the higher nutritional quality found, which is in line with perceptions that local food is healthier (Miroso and Lawson, 2012). The only counter-example from the present study is provided by farmhouse PDO cheeses that show higher levels of fat and salt, although the healthier levels found in non-PDO cheddar are partly due to marketing “trendy” low-fat, low-salt cheese ranges.

Food safety and technological innovation are also typical attributes that are emphasized in value chains where high quantities of products are managed (group 1). Food hazard is closely monitored, and innovations are easier because of large investment capacity. It has

also been shown that hygiene regulations can be a barrier for food processing at a local scale (Ilbery and Maye, 2005).

5.2.4 Social performance

Nutritional values are communicated on labels and it appears that global cases in group 1 also lag behind in terms of information and communication. The exception is the cheese sector, where the intermediate cheese Gruyère is at the top of the ranking in terms of communication. Local products do not necessarily rely on conventional information on labels. For example, in the wine sector, the labels on bottles sold locally contain very little information. This is compensated by the way information is communicated either directly by the producer or by other means (websites, social media, pamphlets, etc.). The global wine, however, also puts very little information on the label, targeting mostly consumers who focus on price. The most information is offered by locality products that have to convince consumers of the product's quality which is of a higher price.

In the processed food sector assessed here, the link local products' value chains and actors have with their territory shapes the attributes territoriality, governance and resilience, as it does for the creation of added value to some extent. The "terroir" concept is strongly promoted in social events and tourism aspects in product groups 2 and 3 (territoriality assessed for ham and wine). These sectors were also observed for governance dynamics in terms of trust, decision-making mechanisms and market management. This pattern reflects the necessity for locality products to differentiate themselves in order to create added value. This strategy is often triggered by local actors in order to preserve or defend their product, in our cases through the adoption of PDOs. In the process, producers or processors have to re-think their governance and production in relation to place (Maye et al., 2016) and have created "a more collaborative, territory-based governance" that builds resilience (Oostindie et al., 2016, p. 12).

5.3 Methodological discussion

Previous papers focusing at the indicator level of performance have highlighted nuances and multiple trade-offs between attributes. This analysis has had the advantage of aggregating the performances, without resorting to an arithmetic mean, and indicates that more globally-oriented products perform worse in the case studies selected here and based on the indicators chosen. This conclusion could still be criticised for being an oversimplification of complexity. This is why the phi flows at the attribute level have been detailed in the discussion and the limitations and nuances they have exposed should be kept in mind. The testing of different weighting systems has also provided an opportunity to test different points of view. The inclusion of six different weighting systems is considered sufficient to reveal major instabilities in the ranking, which did not happen. The gradient from highest to lowest phi flows along the local-global continuum was clearest for the weighting system "quality", suggesting that indicators measured with the highest accuracy show most clearly that local food in most instances is the most sustainable. It was useful to include the weighting systems "society" and "scholar relevance", as adopted from Hak et al. (2012), because they involved more extreme weighting, sometimes assigning up to 30% of the weight to one indicator. This allowed testing for the stability of rankings even under very unequal weights. These weighting systems also revealed that, from a societal perspective, climate change, price and the distribution of added value were the most important concerning the sustainability of food systems. This could have been expected from a weighting operated by stakeholders, but the ones consulted in our case studies tended to be consensual and attributed equal weights to all attributes or indicators. Different weightings

for individual stakeholders were not considered here and instead reflect stakeholder group appreciation, which probably has the effect of flattening variation. Another approach was applied in Gamboa et al. (2016), where even the selection of indicators assessed varied according to different perspectives (with only three indicators for each perspective). The approach adopted here was to keep all indicators in each outranking analysis and this has offered a broader assessment to identify the strengths and weaknesses of local versus global food products. One can argue that the selection of indicators is never completely exhaustive, but extensive work has been conducted in selecting the most relevant attributes for each context and sector, using participatory methods to do so. This is why the indicators used to assess the attributes are different in each sector and the direct comparison of products from different sectors has been avoided with the outranking analysis performed only within sectors. In future studies, broader comparisons could usefully include more food products from more sectors and other continents. For example, the conclusion on GHG emissions could be different for fruits or vegetable products, especially if the global product surveyed is transported by plane.

6 Conclusion

A multi-criteria analysis of the outranking type was performed to compare processed food products along a local-global continuum. The method proved very useful and moved beyond an indicator-level trade-off analysis to a multi-dimensional and multi-sectorial synthesis. Whilst it was possible to maintain a broad scope in terms of sustainability assessment, covering whole value chains and including a large number of indicators in the assessment, two limitations remain. The first is that a high level of measurement precision is not possible for every aspect of the assessment and all indicators of sustainability. The second is that any selection of indicators will not cover all aspects of sustainability. These two limitations (precision and coverage) represent a constant trade-off in sustainability assessments. For the purpose of comparison and outranking, as performed in this study, having a higher number of indicators, as per the ham cases, does help to increase the robustness of the results. The inclusion of the health and ethics dimensions was innovative for a sustainability assessment of food value chains but remained limited and should be encouraged in future studies.

Results showed that the most global products in each sector (cheese, ham, wine and bread) consistently appear last in the rankings. However, they also presented at least two strengths (low prices and lower GHG emissions) that are considered important in the society and scholar relevance weighting systems. They are very important in terms of food security and climate change and thus prevent a full embrace of the “local is best” message and demonstrate the importance of assessments that account for different perspectives and social values. However, the food miles concept (e.g., distance and associated GHG) should also not be used as a single indicator for sustainability, but rather as a descriptive variable as applied in this study. The analysis presented here supports the argument that local processed food products are more sustainable; however, the common assumption that it is because of a lower carbon footprint is not supported. The main factors improving sustainability in local products are linked to localness criteria such as identity, know-how, size and governance, rather than distance.

Furthermore, local and global foods are not separate from each other but are instead part of the one food system and the case studies show that products often have mixed local-global value chain profiles; as most of the food products studied had a degree of localness in the middle of the continuum. A good example of this inherent hybridity is “locality” products, which typically emphasise links to the territory through a PDO label and local governance but sell a good percentage of product through world markets, using both conventional and

short chain/ direct sales. These products are either re-localizing products or up-scaling local products and show how both types are learning and taking from the other. This is just one example of how these food products are changing and evolving and unfortunately our assessment gives only a static picture.

The outranking could be seen as guidance for food choices, but it is merely an indication of the strengths and weaknesses related to each scale and should only be considered as such. The only certainty is that there is a big margin for improvement and that measures are necessary to make the whole food system greener and fairer. Policies also have their part to play to direct the future governance of food value chains in a more sustainable direction (Smith et al., 2016). Focusing on how food is produced and consumed might be a more efficient and purposeful agenda than focusing on where it comes from.

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8 References

- Adams, D.C., Salois, M.J., 2010. Local versus organic: a turn in consumer preferences and willingness-to-pay. *Renew. Agric. Food Syst.* 25, 331–341. doi:10.1017/S1742170510000219
- Avetisyan, M., Hertel, T., Sampson, G., 2014. Is Local Food More Environmentally Friendly? The GHG Emissions Impacts of Consuming Imported versus Domestically Produced Food. *Environ. Resour. Econ.* 58, 415–462. doi:10.1007/s10640-013-9706-3
- Behzadian, M., Kazemzadeh, R.B., Albadvi, A., Aghdasi, M., 2010. PROMETHEE: A comprehensive literature review on methodologies and applications. *Eur. J. Oper. Res.* 200, 198–215. doi:10.1016/j.ejor.2009.01.021
- Binder, C.R., Feola, G., Steinberger, J.K., 2010. Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. *Environ. Impact Assess. Rev.* 30, 71–81. doi:10.1016/j.eiar.2009.06.002
- Binder, C.R., Feola, G., Steinberger, J.K., 2010. Considering the normative , systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. *Environ. Impact Assess. Rev.* 30, 71–81. doi:10.1016/j.eiar.2009.06.002
- Böhringer, C., Jochem, P.E.P., 2007. Measuring the immeasurable - A survey of sustainability indices. *Ecol. Econ.* 63, 1–8. doi:10.1016/j.ecolecon.2007.03.008
- Born, B., Purcell, M., 2006. Avoiding the Local Trap: Scale and Food Systems in Planning Research. *J. Plan. Educ. Res.* 26, 195–207. doi:10.1177/0739456X06291389
- Brans, J.-P., De Smet, Y., 2016. PROMETHEE Methods, in: Greco, S., Al, E. (Eds.), *Multiple Criteria Decision Analysis*. Springer Science+Business Media New York, pp. 1–14. doi:10.1007/978-1-4615-1495-4
- Brodts, S., Kramer, K.J., Kendall, A., Feenstra, G., 2013. Comparing environmental impacts of regional and national-scale food supply chains: A case study of processed tomatoes. *Food Policy* 42, 106–114. doi:10.1016/j.foodpol.2013.07.004
- Brown, J.P., Goetz, S.J., Ahearn, M.C., Liang, C. -I., 2013. Linkages Between Community-Focused Agriculture, Farm Sales, and Regional Growth. *Econ. Dev. Q.* 28, 5–16. doi:10.1177/0891242413506610

- Brunori, G., Galli, F., Barjolle, D., van Broekhuizen, R., Colombo, L., Rougoor, C., Giampietro, M., Kirwan, J., Lang, T., Mathijs, E., Maye, D., De Roest, K., Schwarz, J., Schmitt, E., Smith, J., Stojanovic, Z., Tisenkopfs, T., Touzard, J.-M., 2016. Are local food chains more sustainable than global food chains? Considerations for assessment. *Sustainability* 8, 449. doi:10.3390/su8050449
- Carbone, A., Caswell, J., Galli, F., Sorrentino, A., 2014. The Performance of Protected Designations of Origin: An Ex Post Multi-Criteria Assessment of the Italian Cheese and Olive Oil Sectors. *J. Agric. Food Ind. Organ.* doi:10.1515/jafio-2013-0017
- Cinelli, M., Coles, S.R., Kirwan, K., 2014. Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. *Ecol. Indic.* 46, 138–148. doi:10.1016/j.ecolind.2014.06.011
- Ciroth, A., 2009. Cost data quality considerations for eco-efficiency measures. *Ecol. Econ.* 68, 1583–1590. doi:10.1016/j.ecolecon.2008.08.005
- Coley, D., Howard, M., Winter, M., 2011. Food miles: time for a re-think? *Br. Food J.* 113, 919–934. doi:10.1108/00070701111148432
- Coley, D., Howard, M., Winter, M., 2009. Local food, food miles and carbon emissions: A comparison of farm shop and mass distribution approaches. *Food Policy* 34, 150–155. doi:10.1016/j.foodpol.2008.11.001
- Cucek, L., Klemes, J.J., Kravanja, Z., 2012. A review of footprint analysis tools for monitoring impacts on sustainability. *J. Clean. Prod.* 34, 9–20. doi:10.1016/j.jclepro.2012.02.036
- Dentoni, D., Menozzi, D., Capelli, M.G., 2012. Group heterogeneity and cooperation on the geographical indication regulation: The case of the “Prosciutto di Parma” Consortium. *Food Policy* 37, 207–216. doi:10.1016/j.foodpol.2012.02.003
- Dunne, J.B., Chambers, K.J., Giombolini, K.J., Schlegel, S.A., 2011. What does “local” mean in the grocery store? Multiplicity in food retailers’ perspectives on sourcing and marketing local foods. *Renew. Agric. Food Syst.* 26, 46–59. doi:10.1017/S1742170510000402
- Edwards-Jones, G., Milà i Canals, L., Hounsome, N., Truninger, M., Koerber, G., Hounsome, B., Cross, P., York, E.H., Hospido, A., Plassmann, K., Harris, I.M., Edwards, R.T., Day, G. a. S., Tomos, a. D., Cowell, S.J., Jones, D.L., 2008. Testing the assertion that “local food is best”: the challenges of an evidence-based approach. *Trends Food Sci. Technol.* 19, 265–274. doi:10.1016/j.tifs.2008.01.008
- FAO, 2014. Sustainability Assessment Of Food and Agriculture Systems. Guidelines Version 3.0. Rome, Italy.
- Farmery, A.K., Gardner, C., Green, B.S., Jennings, S., Watson, R.A., 2015. Domestic or imported? An assessment of carbon footprints and sustainability of seafood consumed in Australia. *Environ. Sci. Policy* 54, 35–43. doi:10.1016/j.envsci.2015.06.007
- Feldmann, C., Hamm, U., 2015. Consumers’ perceptions and preferences for local food: A review. *Food Qual. Prefer.* 40, 152–164. doi:10.1016/j.foodqual.2014.09.014
- Galli, F., Bartolini, F., Brunori, G., 2016. Handling Diversity of Visions and Priorities in Food Chain Sustainability Assessment. *Sustainability* 8, 305. doi:10.3390/su8040305
- Galli, F., Bartolini, F., Brunori, G., Colombo, L., Gava, O., Grando, S., Marescotti, A., 2015. Sustainability assessment of food supply chains: an application to local and global bread in Italy. *Agric. Food Econ.* 3, 21. doi:10.1186/s40100-015-0039-0
- Gamboa, G., Kovacic, Z., Di Masso, M., Mingorría, S., Gomiero, T., Rivera-Ferré, M., Giampietro, M., 2016. The Complexity of Food Systems: Defining Relevant Attributes and Indicators for the Evaluation of Food Supply Chains in Spain. *Sustainability* 8, 515. doi:10.3390/su8060515
- Gasparatos, A., El-Haram, M., Horner, M., 2008. A critical review of reductionist approaches for assessing the progress towards sustainability. *Environ. Impact Assess. Rev.* 28, 286–311. doi:10.1016/j.eiar.2007.09.002

- Hak, T., Kovanda, J., Weinzettel, J., 2012. A method to assess the relevance of sustainability indicators: Application to the indicator set of the Czech Republic's Sustainable Development Strategy. *Ecol. Indic.* 17, 46–57. doi:10.1016/j.ecolind.2011.04.034
- Hinrichs, C.C., 2000. Embeddedness and local food systems: notes on two types of direct agricultural market. *J. Rural Stud.* 16, 295–303.
- Ilbery, B., Kneafsey, M., 2000. Registering regional speciality food and drink products in the United Kingdom: the case of PDOs and PGIs. *Area* 32, 317–325. doi:10.1111/j.1475-4762.2000.tb00144.x
- Ilbery, B., Maye, D., 2005. Alternative (shorter) food supply chains and specialist livestock products in the Scottish - English borders. *Environ. Plan. A* 37, 823–844. doi:10.1068/a3717
- ISO 14040, 2006. Environmental Management - Life Cycle Assessment - Principles and Framework. Geneva, Switzerland.
- Kastner, T., Erb, K.-H., Haberl, H., 2014. Rapid growth in agricultural trade: effects on global area efficiency and the role of management. *Environ. Res. Lett.* 9, 34015. doi:10.1088/1748-9326/9/3/034015
- Kastner, T., Kastner, M., Nonhebel, S., 2011. Tracing distant environmental impacts of agricultural products from a consumer perspective. *Ecol. Econ.* 70, 1032–1040. doi:10.1016/j.ecolecon.2011.01.012
- Kirwan, J., Maye, D., Brunori, G., 2017. Reflexive Governance, Incorporating Ethics and Changing Understandings of Food Chain Performance. *Sociol. Ruralis.* doi:10.1111/soru.12169
- Kneafsey, M., Dowler, E., Lambie-Mumford, H., Inman, A., Collier, R., 2013. Consumers and food security: Uncertain or empowered? *J. Rural Stud.* 29, 101–112. doi:10.1016/j.jrurstud.2012.05.005
- Kreidenweis, U., Lautenbach, S., Koellner, T., 2016. Regional or global? The question of low-emission food sourcing addressed with spatial optimization modelling. *Environ. Model. Softw.* 82, 128–141. doi:10.1016/j.envsoft.2016.04.020
- Mareschal, B., 2016. Visual Promethee software [WWW Document]. URL <http://www.promethee-gaia.net/academic-edition.html> (accessed 9.1.16).
- Maye, D., Kirwan, J., Schmitt, E., Keech, D., Barjolle, D., 2016. PDO as a Mechanism for Reterritorialisation and Agri-Food Governance: A Comparative Analysis of Cheese Products in the UK and Switzerland. *Agriculture* 6, 54. doi:10.3390/agriculture6040054
- Milestad, R., Bartel-Kratochvil, R., Leitner, H., Axmann, P., 2010. Being close: The quality of social relationships in a local organic cereal and bread network in Lower Austria. *J. Rural Stud.* 26, 228–240. doi:10.1016/j.jrurstud.2010.01.004
- Mirosa, M., Lawson, R., 2012. Revealing the lifestyles of local food consumers. *Br. Food J.* 114, 816–825. doi:10.1108/00070701211234345
- Morrison-Saunders, A., Pope, J., 2013. Conceptualising and managing trade-offs in sustainability assessment. *Environ. Impact Assess. Rev.* 38, 54–63. doi:10.1016/j.eiar.2012.06.003
- Munda, G., Nardo, M., 2009. Noncompensatory/nonlinear composite indicators for ranking countries: a defensible setting. *Appl. Econ.* 14, 1513–1523. doi:10.1080/00036840601019364
- Notarnicola, B., Tassielli, G., Renzulli, P.A., Monforti, F., 2016. Energy flows and greenhouses gases of EU (European Union) national breads using an LCA (Life Cycle Assessment) approach. *J. Clean. Prod.* doi:10.1016/j.jclepro.2016.05.150
- Oostindie, H., van Broekhuizen, R., de Roest, K., Belletti, G., Arfini, F., Menozzi, D., Hees, E., 2016. Sense and Non-Sense of Local–Global Food Chain Comparison, Empirical Evidence from Dutch and Italian Pork Case Studies. *Sustainability* 8, 319. doi:10.3390/su8040319

- Peano, C., Migliorini, P., Sottile, F., 2014. A methodology for the sustainability assessment of agri-food systems: An application to the slow food presidia project. *Ecol. Soc.* 19. doi:10.5751/ES-06972-190424
- Pearson, D., Henryks, J., Trott, A., Jones, P., Parker, G., Dumaresq, D., Dyball, R., 2011. Local food: understanding consumer motivations in innovative retail formats. *Br. Food J.* 113, 886–899. doi:10.1108/00070701111148414
- Pinter, L., Hardi, P., Martinuzzi, A., Hall, J., 2012. Bellagio STAMP: Principles for sustainability assessment and measurement. *Ecol. Indic.* 17, 20–28. doi:10.1016/j.ecolind.2011.07.001
- Podvezko, V., Podvieszko, A., 2010. Dependence of multi-criteria evaluation result on choice of preference functions and their parameters. *Technol. Econ. Dev. Econ.* 16, 143–158. doi:10.3846/tede.2010.09
- Pretty, J.N., Ball, A.S., Lang, T., Morison, J.I.L., 2005. Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. *Food Policy* 30, 1–19. doi:10.1016/j.foodpol.2005.02.001
- Renting, H., Marsden, T.K., Banks, J., 2003. Understanding alternative food networks: exploring the role of short food supply chains in rural development. *Environ. Plan. A* 35, 393–411. doi:10.1068/a3510
- Rogers, K., Seager, T.P., 2009. Environmental Decision-Making Using Life Cycle Impact Assessment and Stochastic Multiattribute Decision Analysis: A Case Study on Alternative Transportation Fuels. *Environ. Sci. Technol.* 43, 1718–1723. doi:10.1021/es801123h
- Rogers, M., Bruen, M., 1998. Choosing realistic values of indifference, preference and veto thresholds for use with environmental criteria within ELECTRE. *Eur. J. Oper. Res.* 107, 542–551. doi:10.1016/S0377-2217(97)00175-6
- Rothwell, A., Ridoutt, B., Page, G., Bellotti, W., 2015. Environmental performance of local food: trade-offs and implications for climate resilience in a developed city. *J. Clean. Prod.* 114, 420–430. doi:10.1016/j.jclepro.2015.04.096
- Sadok, W., Angevin, F., Bergez, J.-E., Bockstaller, C., Colomb, B., Guichard, L., Reau, R., Doré, T., 2008. Ex ante Assessment of the Sustainability of Alternative Cropping Systems: Implications for using Multi-criteria Decision-Aid Methods – A Review. *Agron. Sustain. Dev.* 28, 163–174. doi:10.1051/agro
- Schmitt, E., Barjolle, D., Six, J., 2016a. Assessing the degree of localness of food value chains. *Work. Pap.*
- Schmitt, E., Keech, D., Maye, D., Barjolle, D., Kirwan, J., 2016b. Comparing the Sustainability of Local and Global Food Chains: A Case Study of Cheese Products in Switzerland and the UK. *Sustainability* 8, 419. doi:10.3390/su8050419
- Seyfang, G., 2006. Ecological citizenship and sustainable consumption: Examining local organic food networks. *J. Rural Stud.* 22, 383–395. doi:10.1016/j.jrurstud.2006.01.003
- Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2009. An overview of sustainability assessment methodologies. *Ecol. Indic.* 9, 189–212. doi:10.1016/j.ecolind.2008.05.011
- Smith, J., Lang, T., Vorley, B., Barling, D., 2016. Addressing Policy Challenges for More Sustainable Local–Global Food Chains: Policy Frameworks and Possible Food “Futures.” *Sustainability* 8, 299. doi:10.3390/su8040299
- Smith Taillie, L., Jaacks, L.M., 2015. Toward a Just, Nutritious, and Sustainable Food System: The False Dichotomy of Localism. *J. Nutr. issues Opin.* doi:10.3945/jn.115.212449.a
- Sultana, A., Kumar, A., 2012. Ranking of biomass pellets by integration of economic, environmental and technical factors. *Biomass and Bioenergy* 39, 344–355. doi:10.1016/j.biombioe.2012.01.027
- Tasca, A.L., Nessi, S., Rigamonti, L., 2015. Environmental sustainability of agri-food supply chains: An LCA comparison between two alternative forms of production and

- distribution of endive in northern Italy. *J. Clean. Prod.*
doi:10.1016/j.jclepro.2016.06.170
- Thilmany, D., Bond, C. a., Bond, J.K., 2008. Going Local: Exploring Consumer Behavior and Motivations for Direct Food Purchases. *Am. J. Agric. Econ.* 90, 1303–1309.
doi:10.1111/j.1467-8276.2008.01221.x
- Timmons, D., Wang, Q., 2010. Direct food sales in the United States: Evidence from state and county-level data. *J. Sustain. Agric.* 34, 229–240. doi:10.1080/10440040903482605
- Touzard, J.-M., Chiffolleau, Y., Maffezzoli, C., 2016. What Is Local or Global about Wine? An Attempt to Objectivize a Social Construction. *Sustainability* 8, 417.
doi:10.3390/su8050417
- Van Asselt, E.D., Van Bussel, L.G.J., Van Horne, P., Van der Voet, H., Van der Heijden, G.W.A.M., Van der Fels-Klerx, H.J., 2015. Assessing the sustainability of egg production systems in The Netherlands. *Poult. Sci.* 94, 1742–1750. doi:10.3382/ps/pev165
- Vieux, F., Darmon, N., Touazi, D., Soler, L.G., 2012. Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less? *Ecol. Econ.* 75, 91–101. doi:10.1016/j.ecolecon.2012.01.003
- Wallgren, C., 2006. Local or global food markets: A comparison of energy use for transport. *Local Environ.* 11, 233–251. doi:10.1080/13549830600558598
- Weber, C.L., Matthews, H.S., 2008. Food-Miles and the Relative Climate Impacts of Food Choices in the United States. *Environ. Sci. Technol.* 42, 3508–3513.
doi:10.1021/es702969f
- Weidema, B.P., 1998. Multi-user test of the data quality matrix for product life cycle inventory data. *Int. J. Life Cycle Assess.* 3, 259–265.
- Wiskerke, J.S.C., 2009. On Places Lost and Places Regained: Reflections on the Alternative Food Geography and Sustainable Regional Development. *Int. Plan. Stud.* 14, 369–387.
doi:10.1080/13563471003642803

9 Annex

Table 4. Criteria and scale for the assessment of the degree of localness (source: Schmitt et al. 2016a)

Criteria:	Data used	Formula for the degree of localness	Local end (100%)	80%	60%	40%	20%	Global end (0%)
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Geographical distance	Weighted Average Source Distance (WASD) (km)	$0.25(5 - \log_{10}(WASD))$	10 km	Logarithmic continuum					100'000 km
	Supply chain size	Tons produced in a year	$0.25(5 - \log_{10}(tons))$	10 t.	Logarithmic continuum				
Chain length (Average from 2 parameters)	Weighted average of number of steps in the supply chain	5- (average # steps)/5	0 steps (direct sales)	1	2	3	4	5 steps	
	Proportion of sales at production place	5* proportion	100%	80%	60%	40%	20%	0%	
Identity (Average from 2 parameters)	Local Know-how:	Qualitative categories	Artisanal (hand-made) tradition,	Traditional process, limited mechanization	Traditional process, average mechanization	Traditional processes and mechanized technology	Modern process, mechanized	Very modern process and technology	
	Product identity in reference to the territory of production:	Qualitative categories	Specialty product very little known	Sub-Regional identity (PDO)	Regional identity (PDO)	Country specialty (PDO)	specialty known worldwide	Generic product	
Governance	Degree of control of local actors	Qualitative categories	Very high	High	Medium	Medium	Low	Very low	

Notes to table 4: the framework presents the criteria and scale for the degree of localness calculation. Each line of the table lists one criterion and the columns show the data, the formula and the scale applied to each criterion. The first criterion is the total distance travelled by the product and its ingredients from cradle to point of sale (the step to the final consumer and waste could not be included due to a lack of data). The data in table 1 describes distance of “inputs”, which includes all ingredients and inputs necessary for production on the farm and/or for processing. The distance under “processing” lists the distances travelled during or in between processing e.g. the distance involved between primary processing and final maturation of surveyed cheeses. The distance under “sales” is the average distance from the final stage of processing to the final points of sale for the given product. All distances are weighted by units of mass.

The second criterion describes the size of the supply chain by an indicator of volumes produced in a year. The third and fourth criteria give indications about the supply chain’s length. The number of intermediaries varies from one sales channel to the other and the major sales channels and their weighting are presented for each channel as well as the average. The proportion of direct sales is given as the percentage of the product sold directly by actors operating at the final stage of processing.

The last three criteria are qualitative indicators and correspond to pre-established categories (see table 4) in relation to the degree of localness for each aspect (e.g. local know-how, reflects the way the product is processed in reference to traditional knowledge of the place). The final degree of localness is calculated as the average of the seven criteria, each resulting in a percentage score on a scale from 0 to 100%. Criteria 3 to 6 have a weight of 50% in the final average.