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# Sustainability assessment of food supply chains: an application to local and global bread in Italy

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## Abstract

Over the 2000s', consumers' food purchases have been increasingly informed by supply chain-related issues, with growing concerns about the sustainability of chains differing for their geographical scope. As a result, short food supply chains and local food systems have risen to policymakers and food chain stakeholders' attention as more sustainable alternatives to mainstream food networks. However, associating food chain's geographical scope and sustainability performance may not be straightforward. This paper aims at shedding lights on the connection between geographical scope and sustainability by comparing and discussing 19 attributes owing to different sustainability dimensions. The analysis anchors on the wheat-to-bread chain, due to its global relevance. Bread is a worldwide staple food and wheat is (generally) a commodity traded globally. However, wheat processing often occurs locally and baking is influenced by local heritage and consumption patterns, particularly in the EU and in Italy, where gastronomy is culturally embedded. The paper identifies critical aspects and provides a qualitative assessment of the performances of local vs global wheat-to-bread chains. The assessment is carried out on Italian case studies.

**Keywords:** Sustainability assessment; Food supply chain; Local; Global; Bread

**JEL:** Q18 Agricultural Policy; Food Policy; Q10 General

## Background

The emerging evidence of global food chains' negative sustainability and nutritional performance are among the underlying determinants of raising consumers' concern about food origin (Ilbery and Maye, 2005; Goodman et al., 2010). That trend has somewhat strengthened the position of policymakers and food chain stakeholders supporting food "relocalization" world-wide (e.g. Forssell and Lankoski, 2014; Ilbery and Maye, 2006; Selfa and Qazi, 2005, O'Hara and Stagl, 2001). Business, concerned citizen organizations, and policy initiatives have boosted the diffusion of short food chains and local food systems, which, in turn, have stimulated research and policymaking (see, for example, Martinez et al., 2010; Kneafsey et al., 2013). Many academic studies have

assessed the sustainability of food chains, but no agreement has been reached about the overall sustainability performance of local food systems (see Hand and Martinez, 2010 and Durham et al., 2009).

Indeed, those assessments are challenging in their attempts to integrate food production-to-consumption impacts in comprehensive decision making tools, able to highlight tradeoffs and ethical dilemmas. However, the scientific community has not yet agreed on a shared methodology, allowing robust and simultaneous comparisons over all sustainability dimensions. Despite the global importance of food chain alternatives to the mainstream (global) food system, here, we concentrate on the EU context. We propose a multidimensional sustainability assessment based on a set of 19 criteria. Provided the impact of food choice on human health and ethical concerns associated to food consumption, we considered those two social issues as autonomous dimensions of sustainability, thus ending with five sustainability dimensions. After a preliminary literature review, we develop a comparative case study research considering two Italian wheat-to-bread chains differing for their geographical scope, and summarise research findings into a matrix, that helps discriminate local and global chains for their relative sustainability performance. The paper is structured as follows: firstly, we introduce the methods; secondly, we describe the Italian bread sector and introduce the two case studies; thirdly, we present and discuss the comparative assessment matrix. The concluding paragraph summarises our findings, highlighting strengths and weaknesses of our work, and providing insights for further research.

## Methods

This paper has the objective of exploring the sustainability dimensions relevant for the performance assessment of the supply-chains, with a special focus on the wheat-to-bread supply chains. It aims at providing a qualitative assessment on the expected performance contrasting local versus global wheat-to-bread chains, based on evidence gathered on two case-studies.<sup>1</sup> This contribution represents the first step, preliminary to the further assessment of the most critical attributes here identified, that shall be based on evidence provided by indicators selection and measurement.

The methodology used entails three main steps: i) analysis of academic literature to identify the critical links between a pre-defined set of sustainability attributes and the wheat-to-bread chain ii) mapping of a local and a global bread supply chain in terms of globalness/localness. iii) Expert qualitative assessment of the supply chains case-studies with regard to the ability of the selected sustainability attributes to discriminate between local and global, and preliminary evaluation on the best performing supply chains.

Regarding the first step, the identification of sustainability attributes stems from the work of Kirwan et al. (2014). The authors, based on national level reports carried out a European wide systematic analysis on how both local and global food and the performance of food chains are perceived, defined and communicated in the public, scientific, market and policy spheres (regarded as arenas of interaction and debate) across the five mentioned sustainability dimensions. A set of 24 attributes, representing the most relevant societal expectations on food supply chain performances, has been identified through a process of selection and aggregation of the attributes identified at national level in the countries examined. Out of the 24 general attributes we have selected 19

suitable to discuss the sustainability of the wheat to bread supply chain<sup>2</sup> (Table 1). The allocation of the attributes within the five dimensions of sustainability reflects the one suggested by the authors.

The sustainability dimensions considered by the authors aim at encompassing not only the social, economic and environmental and but also ethical and health dimensions. Although ‘localness’ of food is connected to ‘healthiness’ by association with freshness, seasonality and trust (IGD 2008) the health aspect of the local–global dimension in food is poorly communicated and remains implicit rather than explicit. Similar arguments are valid for the analysis of ethical performance in the food chain, which has concentrated on values-based purchasing and alternative economic experiments, notably alternative food networks (AFNs), fair trade practices, product certification schemes (i.e. animal welfare), and Slow Food and food sovereignty movements (Barnett et al., 2010; Maye and Kirwan, 2010). Given the difficulty in defining ethical issues, so far few attempts have been made to assess the performance of supply chains on the ethical dimension.

The review of academic literature referred to the wheat to bread chain is developed according to a systematic approach (Fink, 2014; Pfau et al., 2014). To this end, we created suitable strings by combining each attribute (and synonyms) with the terms “bread”, “wheat” “soft wheat” and integrated results from Scopus, Ageconsearch and Google Scholar databases. The search was performed in September 2014. We selected 92 references based on the pertinence and relevance with respect to each attribute. This allowed framing the most critical issues emerging in the wheat to bread supply chain

**Table 1** Attributes for sustainability assessment

Dimensions of sustainability	Attributes
Economic	Affordability
Environmental	Biodiversity
Social	Connection and labour relations
Social	Consumer behavior
Economic and environmental	Economic and ecological efficiency
Economic	Farmers income and value added received
Social and ethical	Food security
Economic and ethical	Governance/even distribution of power
Social	Information and Communication
Health	Nutrition
Economic	Profitability/competitiveness
Economic	Resilience and local development
Environmental	Resource use and pollution
Ethical	Responsibility
Health	Safety
Economic	Technological innovation
Social and ethical	Territoriality
Health	Traceability
Environmental and economic	Waste

Source: adapted from Kirwan et al. 2014

for each attribute (see Gava et al., 2014 for a review). In the second step, we identified two wheat to bread chains differentiated on the basis of four key criteria drawn from academic literature to distinguish between global and local food chains: i) the physical/geographical distance between production and consumption (i.e. the food miles concept, Pretty et al., 2005; Hogan and Thorpe, 2009). This is a primary distinction, with emphasis on the place of cultivation of wheat with respect to milling and baking and consumption. ii) The type of governance and organization of the supply chain, in particular the degree of control on the chain exerted by “local actors” vs “global actors” (Marsden, 2000; Ménard and Valceschini 2005; Gellynck and Molnár 2009). iii) The type of resources, knowledge and technologies employed (Wiskerke, 2003), in particular the technology used for flour milling and baking technique. Also the ingredients and the complexity of the recipe often discriminate among industrial and artisanal breads. iv) The way supply chain actors shape product identity with regard to territory of reference: quality attributes of bread vary in relation to territorial typologies, traditions, local culture (Marsden and Smith, 2005; Tregear, et al., 2007, Barham and Sylvander 2011). The selected case studies were then analysed on the basis on in-depth interviews with stakeholders at each step of the chain (agricultural production, storage, milling, baking and retailing), and integrated with secondary data readily available (i.e. company reports, newspapers, websites).

In the third step we turned to selected experts asking them to formulate an assessment on the ability of each selected sustainability attributes to discriminate across local and global chains, and to give a preliminary assessment on the best performing supply chain (local or global) in relation to each attribute. We interviewed eight experts, chosen to cover as many scientific domains as possible: one academic in plant genetics, one in food technology, an NGOs active in seed saving networks, a regional policy maker, one expert artisanal baker and one expert industrial baker, an innovation manager for industrial bakery, a quality manager for a large retailing company.

The output of this preliminary analysis is given by a synthetic, qualitative assessment on the performance variability of two chains with respect to each attribute and an assessment on which out of the chains studied shows the best expected performance.

## Results

### The bread sector in Italy

Bread is a staple food of worldwide importance. Bread basic ingredients are cereal flour, water, a leavening agent, and salt. The bread supply chain involves both global and local phases, from input production to consumption. The production process involves wheat grinding and baking; both processing stages can occur in small scale (artisan) or large scale (industrial) plants. Apart from the difference in scale (amount of raw material and end-product handled and delivered) the artisan production systems normally differ from the industrial ones for technology and environmental impact (Espinoza-Orias et al., 2011; Andersson and Ohlsson, 1999; Mondal and Datta 2008).

Italy is a country where bread baking has a long standing cultural tradition (Pagani et al., 2014).

Italy produces and consumes around 3.2 million tons of bread per year, worth 8 billion euro. Out of this, 90 % is produced in artisan bakeries, and the 10 % is

industrial, although in terms of value industrial bread retains a higher portion of turnover (over one billion euro). Traditionally, Italians buy bread directly from local bakeries, who pack the loaves in paper bags. Despite regional and local varieties, there are general features, such as crispy crust and relatively short shelf life. There are more than 300 varieties of local breads in Italy and each region has a particular recipe and tradition, which varies in relation to wheat cultivar, flour class and raising method, baking, shape and size of the loaves, along with salt quantity. Industrial bread is normally a soft loaf, with a shelf life up to 40 days. It is sliced, packed with plastic and mainly sold by supermarkets. It is mostly used as a substitute product (e.g. when running out of freshly baked bread) or for eating out. While the handcraft bread production is scattered on the Italian territory, the industrial baking sector is highly concentrated (the top three companies own a total share of 37.4 % of the market, while private labels account for 13.5 %). Over the last years, consumer prices have been highly variable (from € 1,70 to 3.94 per kg in the south and north of Italy), depending on bread type, quality and marketing channel. In recent years, re-localization initiatives have spread (Hills et al., 2013) also in Italy, as indicated by the emergence of geographical indications (PDO and PGI) as well as the proliferation of spontaneous initiatives promoting local wheat-to-bread chains and value added bakery products.

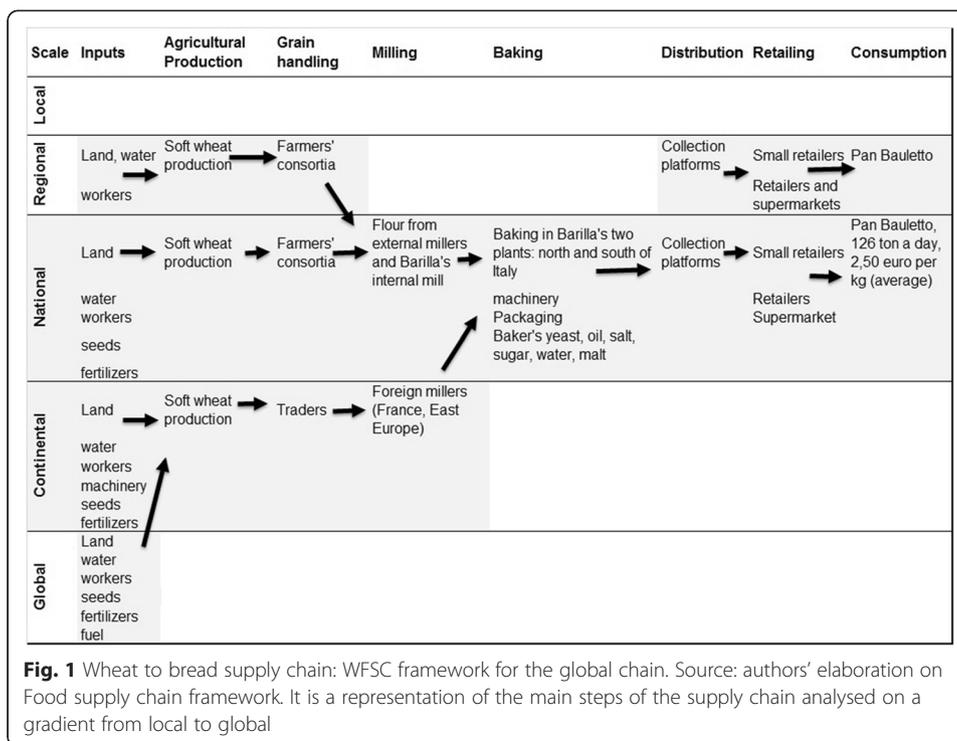
The case selected studies represent different types of production, consumption and governance of the wheat to bread chain: the global industrial chain is represented by the Barilla soft bread case and the local bread chain takes place on Floriddia family farm, in the province of Pisa, in all its stages from input production to distribution.

#### **Mapping the global chain case study**

The global wheat to bread chain is led by Barilla a multinational group that stands as one of the top Italian food groups, leading company for pasta production, bakery products and processed sauce market of continental Europe, and the flatbread market in Scandinavia. Out of its various brands, Mulino Bianco® Pan Bauletto (hereinafter Pan Bauletto) is a leader product in the sector of industrial pre packaged bread in Italy. Such industrially produced bread is made of soft wheat flour (obtained from grains produced in Italy and abroad), water, salt yeast and vegetable oil. This soft bread is marketed exclusively at national level, which is what normally happens on the bread markets. Indeed, this bread is in fact very different from the "local" bread we studied, in terms of consumption habit: Pan Bauletto is suitable for snacks or as a substitute of freshly baked bread whereas local bread is mainly consumed during meals.

Figure 1 is an elaboration on a framework by World Food System Center<sup>3</sup> (WFSC) that can help placing information on a gradient along the food supply chain. It shows the main steps occurring through the chain (in columns), and places them on a local to global scale (in rows) for a visual interpretation, identifying the different flows going through the steps at different scales.

The upstream stages of the Pan Bauletto bread chain (i.e. imports of soft wheat, and other primary inputs) occur at continental level while the following stages occur at the national level. Fuel supply, machinery and energy represent the most global inputs throughout the chain, although not as specific as wheat. Barilla company both sources



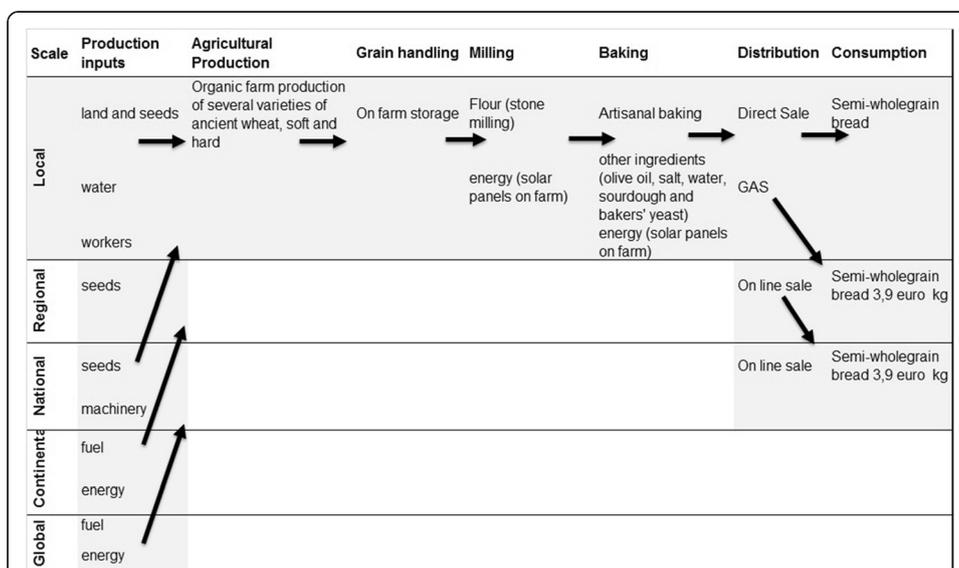
soft wheat for internal milling (30 %) and buys flour directly from other milling companies (70 %). Soft wheat supplies are based on production contracts with farmers according to specific quality specifications (or specific varieties that have the desired characteristics). The price is set on the basis of the commodity board of exchange or bargained at the beginning of the season: it may vary according to the amount purchased, and a premium price is granted when the farmers comply with Barilla's specification on wheat growing and storage and/or the wheat displays some specific quality characteristics. The requirements are strict because the industrial baking process cannot be adjusted "manually" (as the handcraft baker would do). Hence, there is the need for highly standardized raw material suitable for specific dough rising times and strength of flour. For flour, Barilla refers to three main millers with whom it makes contracts from 3 to 6 months. In this case it is not possible to know the exact origin of the grain. The main suppliers of flour are Italian, because flour is highly perishable during transportation. The production process occurs in two plants based in the North and South of Italy (i.e. Cremona and Melfi, respectively). Secondary processes include mixing of raw ingredients (flour, water, salt and yeast) to form a dough; bulk fermentation, division of dough into individual loaf-sized pieces, molding, proofing; baking of pieces in gas oven; cooling and packaging; production of packaging material; delivery of products to distribution platforms. Distribution channels of packaged soft bread entail large scale distribution for most part (75 %) then there are individual traders and retailers, all over Italy. The price list is national, there are discounts and promotions depending on the local market. Production processes allow a long shelf life (over 45 days) without the use of preservatives: at the end of the process the loaves are kept in sterile rooms, without any contamination and with addition of a splash of ethanol (a mild antibacterial). The longer shelf life of the product allows very low levels of waste at the

distribution and consumption levels. Differently from what happens to industrial bread production in other countries, this long shelf-life is due to the peculiarity of the Italian bread market: indeed, the Italian consumers normally use industrial bread in the absence of freshly baked bread.

**Mapping the local chain case study**

The local bread supply chain takes place on one single farm, located in the province of Pisa (rural area in central east part of Tuscany) from cultivation of grains to milling, baking and final sale of bread loaves (among other bakery products). Figure 2, the different steps on a scale, from local to global.

Floriddia family farm extends for more than 300 hectares, and employs 12 full time workers. Originally founded by their father, today the farm is led by Rosario and Giovanni, the two sons. The farm turned to organic agriculture in 1987, then started to experiment with the cultivation of ancient varieties of wheat and gradually decided to invest on farm milling and baking facilities. Thanks to the collaboration with the Rural Seed Network and the local association for organic farming, Floriddia experienced that the old varieties in rotation with legumes can achieve excellent results in terms of yields and decided to devote all its land to it. Technologically advanced milling and baking facilities have represented a major investment, partially funded by EU rural development scheme. Milling and baking activities are keen on preserving the nutritional value of wheat, allowing processing of low gluten, wholegrain flours and sourdough for fermentation. Customers are varied: from individual private companies mainly operating in the catering industry (restaurants, pizzerias, gastropubs, shops) and solidarity purchasing groups (i.e. gruppi di acquisto solidale, GAS) who regularly purchase through the website. The e-commerce service is available to any customers throughout the country but it is also possible to buy the products directly on farm.



**Fig. 2** Wheat to bread supply chain: WFSC framework for the local case. Source: authors' elaboration on Food supply chain framework. It is a representation of the main steps of the supply chain analysed on a gradient from local to global

**Discussion: the comparative assessment matrix**

Table 2 indicates the attributes (in alphabetical order) in the first column, then the emerging themes from the academic literature (second and third columns). The analysis of available literature allows to pinpoint some critical issues: these provide a focus for the assessment of the chains selected against the broad meaning of each attribute. The next columns indicate, respectively, a synthetic evaluation on the differences of performance between the two chains (high, medium or low) and a preliminary hypothesis on which chain displays the best performance, based on collected evidence and the assessment by the experts.

To be noted that some attributes find more room within the literature on wheat to bread chain than others do, which gives an indication on the relevance of each attribute in relation to this chain. This is also because attributes are closely connected to each other, and overlap to some extent, as for example “information”, “communication” and “traceability”, in relation to the “identity preservation” of wheat. There are connections among attributes that upraise relevant research issues, too. For example, “affordability” of bread, is framed in relation to “consumer behaviour” and “nutritional value and healthiness”. “Efficiency” is debated in relation to environmental impacts, beyond mere economic terms, and so on. Some other attributes, such as “food security”, represent wider “umbrella” concepts (or frames, see also Mooney and Scott, 2009) that cover a wide range of other (sub) attributes, such as “technological innovation”, “safety” or “waste”, as well as “nutrition” and “biodiversity”.

Moving to the sustainability performance of the two chains, based on available evidence and expert evaluation, overall local and global chains perform more or less well with respect to different sets of attributes. The two chains show an expected “complementary” sustainability performance. In other words, the local chain shows a better performance on spheres where the global is more constrained, and vice versa. The global chain shows a good performance in relation to all attributes that are positively correlated to scale. Moreover, the global chain has an advantage in terms of environmental impact (resource use and pollution, see Barilla 2012) and constraints in terms of food safety. It also relies on pervasive marketing communication strategies and continuous innovation investments, to safeguard its market performance. Furthermore, it shows good affordability for the consumer in terms of low price per kilo and accessibility of the product, marketed mainly through mass distribution. Less clear is whether such price affordability is combined with high nutritional value. Moreover, biodiversity and genetic improvement of wheat cultivars represent controversial matters and further investigations and reliable indicators should be defined in this sense.

The local chain case study is expected to perform better on other aspects of sustainability. For example, biodiversity is emphasized as a management strategy and the farmer explicitly refers to biodiversity protection when describing the farming system, seeds’ selection, and bread wheat processing. In addition, farmer’s added value received for wheat and bread is expected to be higher than in the other chains. The local bread is a niche product, with peculiar features and the farmer asserts that the price is fixed on the basis of production costs, which allows him to be economically sustainable. This however does not imply economic efficiency, as the farmer states that he activates the milling plant in relation to market demand for flour and bread, but quite below the production potential. In terms of information and communication, at the local level a

**Table 2** Sustainability attributes for the wheat to bread chain and assessment on difference and performance

Attribute	Literature analysis	Expert judgment		
	Critical aspect	Academic literature on bread chains	Differences <sup>a</sup>	Supply chain with best (expected) performance
Affordability	Access to nutritious and healthy bread for low income families, or across cities and city areas or in developing countries	Smith et al. 2013; Flynn et al. 2012; Olaoye et al. 2011; Mason et al. 2011; Lopez-Class and Hosler, 2010; Caraher et al. 2010; Duvenage and Schönfeldt, 2007	+++	Global bread is widely available and affordable in supermarkets, very often at promotion prices
Biodiversity	Decrease in soft wheat genetic diversity Evolution of bread wheat varieties in organic farming, Ancient varieties of wheat and sourdough fermentation.	Bonnin et al. 2014; Coda et al. 2014; Bonneuil et al. 2012; Dawson et al. 2012; Gallo et al. 2009; Falco et al. 2008	+++	The local organic farmer cultivates several ancient landraces and populations, while the global chain cannot use them due to supply shortage and instability, and technical characteristics
Connection	Role of social relationships in organic cereal networks. Embeddedness in conventional and alternative bread supply chains Identity preserved sourcing relationships between farmers and bakeries for quality	Milestad et al., 2010; Magnan, 2011; Penker, 2006	+	Both local and regional chains are highly integrated. The local chain produces the main ingredient while the global chain strictly monitors suppliers
Consumer behavior	Consumption in relation to health and nutritional information. Consumer behavior by vulnerable societal groups (pregnant women, children, poor)	Hellyer et al. 2012; Barre et al., 2011; Freedman and Bartoli, 2013	+++	Local and global breads have very different consumption uses.
Economic and ecological efficiency	Genetic progress in wheat yield in relation to nitrogen use. Improvements in baking ovens for better energy efficiency	Khatir et al. 2013; Tsegaye, 2012; Ortiz-Monasterio et al. 1997	+++	Global chain's scale of production allows economies of scale, also from an environmental point of view.
Farmers income and value added received	Role of farmers' cooperatives for aggregation, increased yields, adaptation to scarcity and impact of subsidy policies, price transmission along the chain.	Rumánková, 2014; Cacchiarelli et al. 2013; Bardsley and Bardsley, 2014; Jat et al. 2014; Schenk et al. 2014; Pan et al. 2014; Li and Rui, 2013; Kimura et al. 2010	++	Local chain fixes price in relation to production costs, global chain refers to global market prices
Food security	Increased wheat productivity, conservation of adaptable local landraces, political instability, impact of biofuel on food availability, sustainability.	He et al. 2013; Özbek 2014; Mujeeb-Kazi et al. 2013; Ahmed et al. 2012; Sternberg 2012; Azapagic et al. 2010; Pimentel et al. 2009;	+	Food security is a transversal issue. The three chains can be interpreted according to different "food security frames" (Mooney and Scott, 2009)

**Table 2** Sustainability attributes for the wheat to bread chain and assessment on difference and performance (*Continued*)

Governance/even distribution of power	Governance responses to socio ecological risk Increased transparency in the chain.	Bardsley and Bardsley, 2014; Barling et al. 2009	++	Decision power is concentrated in both chains. The local chain is highly transparent, oriented to managing socio-ecological risks. The global chain is much more articulated: it aims at transparency in various ways, and addresses socio-ecological risks by working with wheat suppliers (currently more on durum wheat than on soft wheat).
Information and communication	Effects of information on consumer preference (e.g. functional ingredients). Consumer perception of bread quality, organic vs conventional bread.	Hellyer et al. 2012; Gellynck et al. 2009; Annett et al. 2008; Kihlberg et al. 2005;	+	Information and communication activity is very intense in the global chain, also on sustainability matters. Local chain relies on trust and conveys information directly.
Nutrition	Impacts of ingredients, baking methods, and types of bread on health (salt reduction, wholegrain, variety of grains, fiber). Potential of sourdough fermentation and baking techniques to improve nutritional properties of bread.  Fortification of staple foods.  Consumer attitude towards gluten free products  Value of label design and nutritional labeling format on consumer attention.	Antúnez et al. 2013; Talei et al., 2013; Békés, 2012; Belz et al. 2012; Jones, 2011; Dewettinck et al. 2008; Katina et al. 2005; Yusufali et al., 2012; Ozola and Straumite, 2012	++	Nutritional value is core in communication strategies of the local chain. The characteristics of raw materials is the most relevant aspect. Also the global chain's strategy focuses on nutritional value. Here the focus is more on recipe adaptation.
Profitability for farmers, processors and retailers/ Competitiveness	Selection decisions on healthier foods by retailers in terms of profitability  Competition enforcement in the wheat to bread sector to guarantee lower prices for consumers. Concentration in the milling and baking sectors as barriers to market entry	Ayala et al. 2012; Bonakele and Mncube, 2012; Tsegaye, 2012; Gracia et al. 2010; El-Lattief, 2011; Louw et al., 2013	Not available	Not enough data to give a reasonable judgement
Resilience and local development	Innovative governance responses to socio-ecological risk and roles of cooperatives; Benefits for production, resilience and conservation of biodiversity	Bardsley and Bardsley 2014; Enjalbert et al. 2011	++	Local chain has turned to ancient wheat varieties, organic agriculture and alternative food networks to differentiate and limit dependence from policy support. The global chain searches for integration with wheat suppliers to improve resilience and address socio-ecological risks.

**Table 2** Sustainability attributes for the wheat to bread chain and assessment on difference and performance (*Continued*)

Resource use and pollution	Environmental impacts of bread production at different scales (industrial, artisanal, home), of different baking methods and other parameters: country of origin of wheat, production method, type of flour, type of packaging (plastic and paper bags), bread losses and waste	Andersson, 2000; Andersson and Ohlsson 1999; Espinoza-Orias et al., 2011; Jury et al. 2011; Meisterling et al. 2009; Williams et al. 2010; Moudry et al. 2013; Yadav and Marshall, 2011; Williams and Wikström 2011; Koskela et al., 2014; Ruini et al. 2013	++	LCA studies available for the global bread show that resource use and pollution are lowest for this chain. The comparison based on emissions and energy use per kg. tend to advantage larger scale productions.
Responsibility	Corporate social responsibility of processors and retailers. Subsidies and social/political stability	Magnan, 2011; Forsman-Hugg et al. 2013; Salevurakis and Abdel-Haleim 2008	++	Global chain provides a corporate social responsibility report annually. The local chain is also third party monitored for being organic, and "socially"-monitored by direct relationships.
Safety	Food safety challenges of traditional foods and role of good manufacturing practices  Effects of sourdough fermentation on mycotoxins. Dissipation of pesticides during bread making	Lücke and Zangerl, 2014; Vidal et al., 2014; Cauvain, 2012; Sharma et al. 2005	+	Safety must be guaranteed in all chains considered, with differing constraints depending on context.
Technological innovation	Genetic improvement of wheat cultivars, yield improvement; innovations in machinery for milling and bread processing; standardization of sourdough technology; innovation related to health, pleasure, and convenience	Martínez-Monzó et al. 2013; Campbell et al. 2012; Skudra and Linina, 2011; Moroni et al. 2010; Sener et al. 2009; Clarke and Arendt, 2005; Rolfo et al. 1993.	++	Global chains has resources that allow continuous innovation. Local chain is very advanced related to its context and resources available (i.e. milling plant)
Territoriality	Locally adapted bread varieties and ancient grains. Willingness to pay for locality and organic.	Naspetti and Bodini, 2008; Pasqualone, 2013a	+++	Local bread reflects a strong link to territory and traditions.
Traceability	Ethical aspects of traceability and communication to the consumer  Shift towards higher quality and identity preserved wheat (varietal traceability)	Barling et al., 2009; Magnan, 2011; Pasqualone 2013b,c	+++	Local chain is de facto traceable, accessible and transparent. The global chain aims at increasing transparency and direct contact to consumer.

**Table 2** Sustainability attributes for the wheat to bread chain and assessment on difference and performance (*Continued*)

Waste	<p>Identification of bread waste determinants</p> <p>Innovation to retard bread staling and role of packaging for preventing bread loss</p> <p>Bread waste valorization options (and environmental impacts)</p>	<p>Vandermeersch et al., 2014; Fadda et al. 2014; Freedman and Bartoli 2013; Espinoza-Orias et al. 2011; Williams and Wikström 2011; Mohammadi, 2007; Rosing and Nielsen, 2004; Andersson and Ohlsson 1999</p>	+	Both chains show low levels of waste for different reasons. Both breads have a long shelf life: local bread can be re-used in typical recipes, global bread has a 40 days shelf life
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<sup>a</sup>The column "Differences" expresses high (+++), medium (++), low (+) differences between local and global bread chains

much less costly communication strategy occurs, based on the “word of mouth” and direct social relationships. The role of trust between consumers and producer plays here a crucial role, and it is strongly related to the territorial identity of products and processes. The nutritional value of the local bread is object of particularly intense information transfers, also supported by the collaborations of supply chains with researchers – also in the medical fields – although there isn’t any formal nutritional claim on the products.

## Conclusions

This paper delivers a literature review around the sustainability of wheat-to-bread chains, proposes a set of sustainability assessment criteria, and identifies major critical aspects of two Italian case studies, thus resulting in a case study-based qualitative assessment. Our analysis pinpoints chains attributes that help discriminate local and global food systems for their overall sustainability. Among the investigated food attributes, nutritional quality and waste deserve further investigation. Nutritional quality is key in human health and associated to most production chain phases, as well as with consumption patterns, consumer sensitivity to health issues and retail price. The attribute “waste” has a marginal importance for the sustainability of the investigated case studies, thus contrasting with the intuitive relevance of food waste and the high importance within the academic literature and the policy discourse. The outcome of our research supports previous studies (e.g. Barling et al., 2009; Lusk and Briggeman, 2009) by highlighting that ethical attributes, such e.g. environmental impact and traceability, can significantly affect consumer purchasing behaviour. A major limitation of this work is the inevitably partial literature review: we cannot claim to have included all relevant academic studies. Despite having aimed at transparency and objectivity, the present assessment resulted from Authors’ judgment. In addition, our results are based on two Italian case studies, which makes generalization hardly viable. Those two case studies were identified as examples of a local and a global food system, thus not being representative for neither the huge internal variability of both local and global supply-chains, nor of food systems with intermediate characteristics. These intermediate food systems also deserve sustainability assessments. Further research comparing food chains with different geographical scope over multiple dimensions of sustainability would help the validity of our study. The methodological framework that we deliver can help identify issues to deal with and critical gaps, thus representing a starting point for further empirical research. Particularly, attributes could be evaluated using weighting factors; supply chain stakeholders could be involved via participatory methods, such e.g. participatory checklists. In addition, using measurable indicators to approximate the impact of subsets of attributes on food chain sustainability will help research objectivity and comparability.

## Endnotes

<sup>1</sup>It is worth emphasizing that the comparison is focused on supply chains and not on the final products of the two selected cases, which are extremely diverse, both in terms of intrinsic quality and price.

<sup>2</sup>We have dropped animal welfare and fair trade and joined closely related attributes. In particular: resource use and pollution; resilience and local development; connection and labour relations.

<sup>3</sup>World Food System Center, ETH, Zurich. <http://www.worldfoodsystem.ethz.ch/research/CRP.html> accessed on 3/2/2015.

#### Abbreviation

AFN: Alternative Food Networks; NGO: Non-governative organization; PDO: Protected Designation of Origin; PGI: Protected Geographical Indication; WFSC: World Food System Center.

#### Competing interests

The authors declare that they have no competing interests.

#### Authors' contributions

FG carried out the systematic review, interviews and data collection and wrote the Methods and the Discussion sections. OG wrote the background section. FB wrote "The bread sector in Italy" section, AM wrote "Mapping the global chain case study" section and SG wrote "Mapping the local chain case study" section. LC contributed to the conclusions, together with all other authors. GB conceived, designed and coordinated the study. All authors critically revised and approved the manuscript.

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