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DISTANCE MATTERS – THE ENVIRONMENTAL IMPACT OF REGIONAL AND NATIONAL SUPPLY CHAINS OF CANNED TOMATOES

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Distance matters – The environmental impact of regional and national supply chains of canned tomatoes

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Abstract

The environmental impact of food transportation depends on the trade-off between (increased) distances and the efficiency of modern logistics procedures. The relevant literature points out that such a trade-off is place and product specific, thus supporting the broadening of "food miles" research to new territories and product categories.

Here we analyze the environmental impact – in terms of global warming, local pollution and traffic congestion – of two different canned tomatoes brands produced in Italy and consumed in Sassari (Sardinia, Italy). The supply chain of the first brand extends over the whole continental Italian territory, while the second one is mainly located in Sardinia. Different distribution patterns (modern vs. independent retail) and shopping modalities (foot vs. car) are also considered.

The case study shows that the national supply chain contributes to global warming much more than the regional one, and therefore supports the view that shorter supply chains can be more sustainable than efficient logistics. The case study also confirms the very high impact of shopping by car, both in terms of global warming and local pollution.

Keywords: food miles; transportation; logistics; environmental impact; Italy; canned tomatoes.

Jel Classification: L99, Q51, Q56, R99

1. Introduction[1]

Globalization has brought to an exponential increase of food transportation. A first cause of such a growth is the evolution of consumption practices, characterised by increasing demands for highly processed and packed products, and for exotic or out of season products. Another reason is the evolution of supply patterns, with the advent of global firms and modern retailers. These agents have influenced the whole agribusiness upstream and downstream: the consolidation of partnership between few big operators has caused the marginalization of small local operators and the preference for distant suppliers, while the concentration of production and distribution infrastructures in few "hubs" has increased the distance between production areas and final markets (Böge, 1995). Moreover, as another outcome of the spread of modern retail, the use of private car for shopping has increased.

Since the mid-1990's several studies have extended the research on the environmental impact of agribusiness to the specific issue of "food miles", i.e. the distance covered by food products (Safe Alliance, 1994). Most "food miles" studies focuses mainly on global warming, while some others consider local atmospheric and acoustic pollution, or the impact related to road safety and infrastructures and vehicles building (AEA Technology, 2005; Pretty et al., 2005). Short supply chains have also been investigated in relation to the benefits they can bring with regard to non-environmental impacts, such as economic, social, cultural, sanitary ones (Sonnino and Mardsen, 2006; Winter, 2003).

While the initial theoretical debate on food supply chains re-localization enjoyed wide support (Coley et al. 2008) – also because of extra-environmental issues – the ensuing quantitative research, although confirming the relevant impact of food transportation on global warming (e.g. Garnett, 2003, reports an impact of food transportation for the UK equal to 3.5% of the total national greenhouse gases emissions), points

[1] In the paper the following abbreviations are used: Distribution Center: DC; Cash and Carry: C&C; Roll on-Roll off (vessel): RO-RO; Heavy Goods Vehicle: HGV; Light Commercial Vehicle: LCV; vehicle-kilometer (unit of measurement representing the movement of a road motor vehicle over one kilometer): v-km.

out that there is no direct connection between short supply chains and sustainability. In fact, because of trade-offs involved in supply chains organization, longer supply chains can result, in some contexts, less polluting than shorter ones. A first trade-off discussed in literature (Jones, 2001) opposes the impact of transport to the one of production. The choice of closer suppliers can involve the use of inputs that are more polluting in the production phases. The second significant trade-off involves the efficiency of logistics (AEA Technology, 2005). First, modal choice must be considered. In fact long distance supply chains can have a minor impact than shorter ones, if the last ones are based on vehicles with high impacts per ton-km. Typically, alternative short supply chains that provide niche markets use small vehicle with low efficiency and therefore loose part of their advantage on distances. Secondly, the load factor must be considered. The higher the load factor, the lower the environmental impact per unit of good transported. The actual strategy of stock minimization can be associated to low load factors, except if the carrier can organize multi-pick and multi-drop trips, return journeys, etc. Big manufacturers and modern distribution succeed in conciliating just-in-time and high load factors thanks to their scale economies and an organization centered on few regional range DCs, where goods are grouped and then sorted. This higher logistic efficiency per ton-km is usually the corollary of a transport intensive system, though.

Probably the more relevant result of all these studies is the place-specific and market-specific nature of environmental impacts of food supply chains. This is why the analysis of new contexts and products is needed. Here we consider the case of canned tomatoes consumed in Sassari (Sardinia, Italy).

The Italian market has been seldom analyzed. Compared to the rest of Western Europe, Italy features a lower penetration of modern distribution and superstores, and a non-negligible market share of independent retailers, especially for some products. Moreover, Italy is characterized by low efficiency and integration in the logistic sector, and by rather limited supply chains. The Italian canned tomatoes industry has been chosen as a case study, not only because this is an emblematic product of the Italian diet, but also because of the significance of productive tradition in shaping locational patterns. Moreover, the choice of a case study related to an island can help to pinpoint some tendencies, such as geographical and industrial constraints that influence supply chains patterns. Finally, while food miles research has until now been almost oriented toward fresh products, the analysis of canned tomatoes

– i.e. a processed food – can enlighten other issues, such as the role of production clusterization or the specific impact of packaging transportation.

The case study analyses eight scenarios that differ by place of production, distribution channel and shopping transport mode. We quantify their environmental global impact – through the CO_2 indicator – their contribution to local atmospheric pollution – through the PM_{10} indicator – and their involvement in traffic congestion – through the number of km driven in urban areas during peak hours. The following paragraph presents the case study, through the description of system boundaries, scenarios characteristics, impacts analyzed and main features of the assessment methodology. The results of the assessment are given in paragraph 3 and discussed in paragraph 4. Paragraph 5 draws some conclusions.

2. Case study

2.1 System boundaries and scenarios

Tomatoes products are one of the main Italian agribusiness. With 15% of the world market share, Italy is the first producer of processed tomatoes. Production is mainly concentrated in Apulia, in the South of Italy, but there are also big culture concentrations in the North of the country. With regard to the processing industry, the region of Naples (South) is its historical pole, even though this industry has also developed in the region of Bologna (North) in the last decade. As well as having high volumes of export, the processing industry covers the entire national market, with a product penetration reaching 98.5% and an average canned vegetable consumption of 24 kg per family per year (Ismea, 2007). Canned vegetables are mostly sold through modern distribution (Ismea, 2007), that has 95.4% of market share, while independent retail cover 3.7% of sales (if all consumer goods are considered, modern distribution has a share of 77% and independent retail a share of 14.8%).

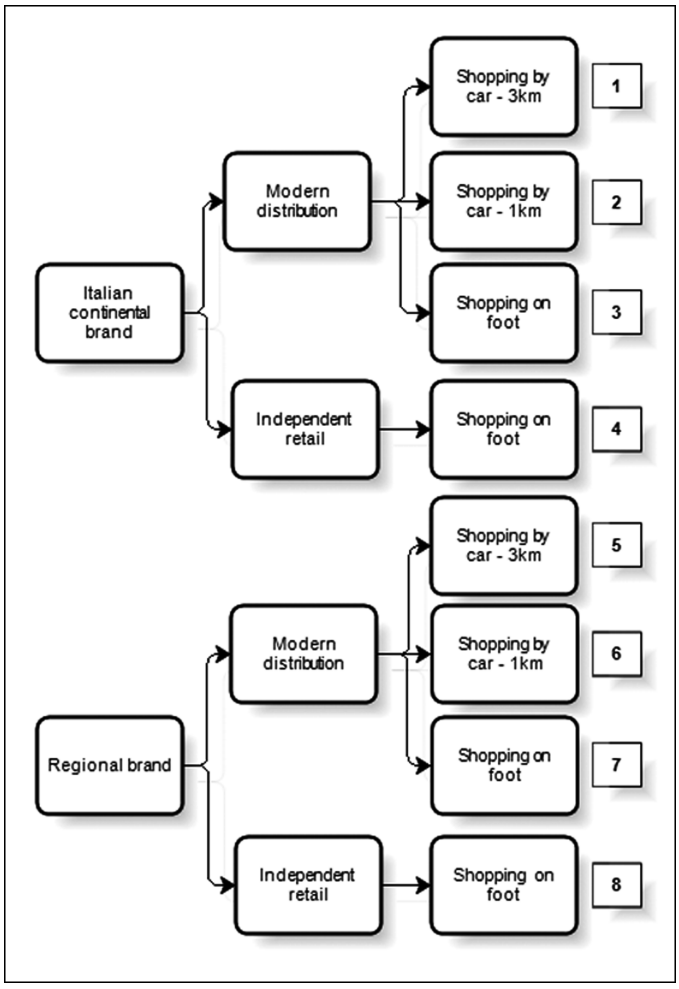
The research presented here compares eight scenarios of canned tomatoes supply chains. The scenarios differ:

- for production location, with a Sardinian regional brand and an Italian continental brand;
- for distribution channel, with modern distribution and independent retail;
- for shopping transport mode, where only shopping on foot has been considered for independent retail (because it's the

most representative way of shopping for this kind of stores) while both shopping on foot and by car have been considered for modern distribution.

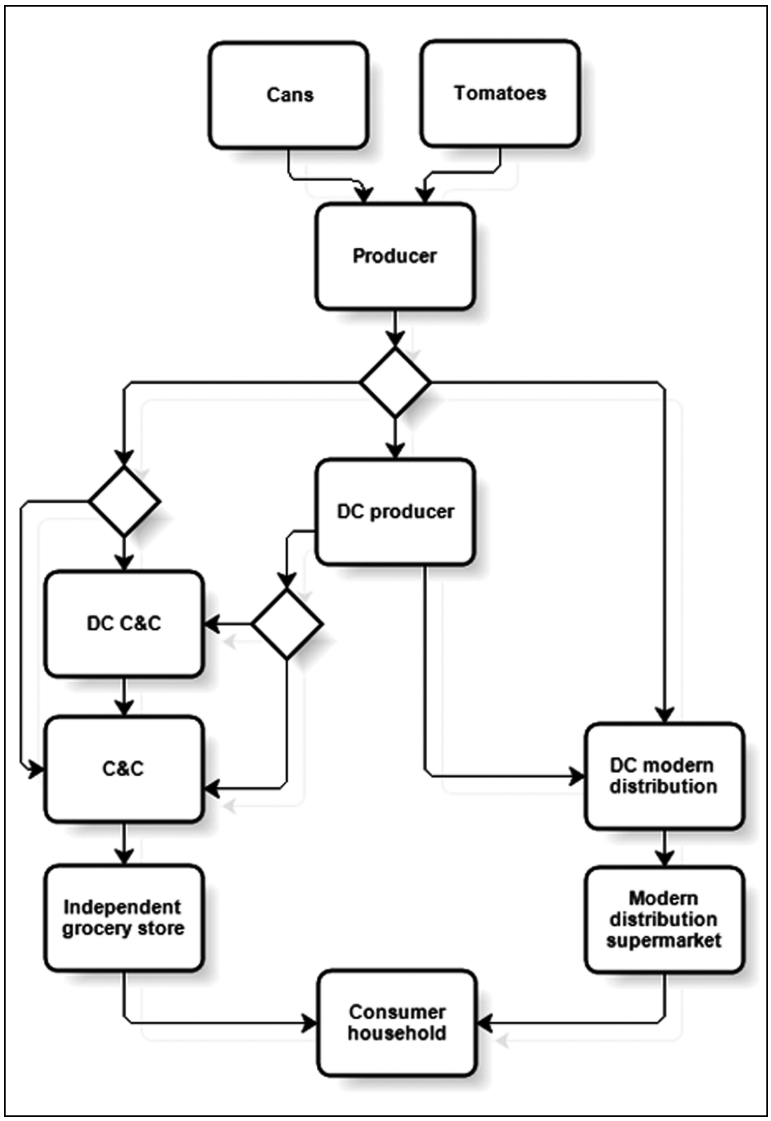
The city of Sassari, in the North of Sardinia, has been chosen as final market.

Fig. 1: Canned peeled tomatoes scenarios



The number of transport stages differs from scenario to scenario as the continental brand and some C&Cs linked to independent retailers organize their distribution through the centralization of loads in DCs.

Fig. 2: Supply chain boundaries



As represented in figure 2, the transport of some inputs has been excluded. Because of their low weight, salt and citric acid (that enter in the canned tomatoes recipe) have been excluded as well as label and secondary and tertiary packaging. The transport related to the input used in tomatoes and cans production and disposal of waste have also been excluded. With regard to tomatoes production, while pesticides and fertilizers give a high contribution to the energy consumption of the production stage, their low weight make their impact on transport marginal. The transport of cans inputs has a higher impact but has been excluded because, beside the difficulty of its assessment, scenarios show a low level of differentiation in these stages. Anyway, it must be said that the iron (and sometimes steel) used for cans production is the only important input that is imported (by sea, from other continents). At last, always because of low variability between scenarios and low share on total impact, the transport associated to vehicles and infrastructure production and fuel providing has been excluded.

The main characteristics of the supply chains analyzed are described below, while exact distances and load factors are reported in table 1. The stages or groups of stages analyzed present some recurrent characteristics. Except for final distribution, outward journeys are almost always fully loaded. With regard to the transport of inputs, return journeys have no backward load, except, for the regional brand, in the segment between the plant of cans and that of canned tomatoes (40% of return loads). In the final product transport HGV with a capacity equal or higher to 28 ton are used, except in the stage between the regional brand canned tomatoes plant and the modern distribution DC. When final product transportation stages have backward load, transporters have to accomplish a detour in order to collect the cargo. Deviations are generally quite long in Sardinia (up to 200 km) and shorter in the continental part of Italy (50 km on average).

2.2 Regional supply chain

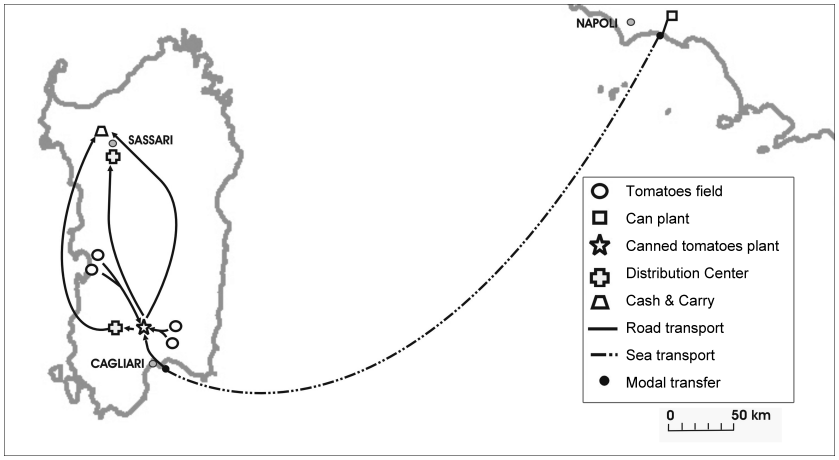
The regional canned tomatoes are produced in a medium-small firm that is marginal on the national market but is leader at regional level, with 40% of market share. The firm and the plant are located in the South of Sardinia, nearly 30 km from Cagliari.

The tomatoes arrive from the neighborhoods of the plant and from Oristano, at 50 km. Because of the absence of productive facilities in

Sardinia, cans come from the Naples region. As in the continental brand supply chain, in order to reach Sardinia, the lorries are embarked on RO-RO cargo vessels. Cans have a very low weight/volume ratio and therefore, even if the 28 ton capacity lorries travel fully loaded, the cargo is about 5 ton only.

From the canned tomatoes plant, the final product is sent to the modern distribution DC and C&Cs that are located near Sassari. For two of the C&Cs analyzed, the cargo is directly delivered while for the other two, the cargo is firstly send to a DC located near the plant. From there, another transporter takes the product to the C&Cs located in Sassari. In the case of modern distribution scenarios, it is the modern distribution firm itself that runs the transport from the plant to its DC, exploiting the return journeys of its delivery to Cagliari supermarkets (with 16.2 and 16.6 ton tonnage lorries).

Fig. 3: Regional brand routes



2.3 National supply chain

The continental brand analyzed, with 25% of tomato products market share, is leader at national level. Its production and distribution is spread over the whole peninsula, its barycentre being in the North while the specific "canned peeled tomatoes" (vs. other tomato products) is detached in the South. 80% of continental brand canned tomatoes is produced in a plant located in Apulia (130 km from Bari), while the remaining 20% is purchased from third firms, located in the Naples region.

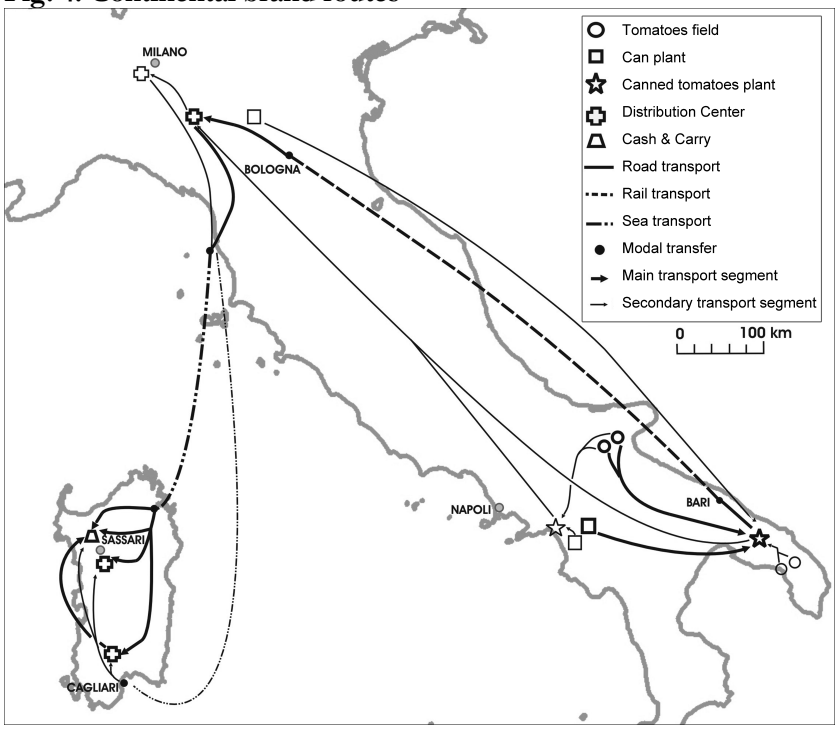
With regards to its own production, tomatoes arrive mainly from Foggia, in the North of Apulia, while a small part is sourced in the neighborhoods of the plant. Most part of cans arrive from the Naples region, while a small part arrive from the region of Bologna. Here too there's a very low load factor.

For the 20% of canned tomatoes produced by third firms, the analysis concentrated on one firm located in the Naples district. Here too, the tomatoes arrive from Foggia, while the firm controls a can plant in the neighborhoods of its processing plant.

With regards to final product distribution, the cargo is first send to a DC in the Bologna region and then dispatched to Sardinia. Peculiarly, the continental firm uses intermodal transport, which is not common for agribusiness products. 70% of canned tomatoes from the main plant travels from Bari to Bologna by rail, while the distance from the plant to the rail station and from the rail stations to the DC are covered by road. The remaining product, as well as the canned tomatoes coming from the Naples supplier travel to the DC by road. A part for one of the C&Cs, Sardinian clients are supplied through round deliveries that, after the arrival in Sardinia (the lorries embark in Leghorn and generally disembark in Olbia in the North or, sometimes, in Cagliari), cross the whole island and supply several destinations. For the two C&Cs linked to DCs, a transport stage from the DCs to Sassari must be added to the round delivery. One of the C&Cs is served through a different route in which the cargo is first sent to a DC in Milan and then to Sardinia (through the Leghorn-Olbia maritime route).

Figure 4 reports a schematization of continental brand transport stages. When a stage is characterized by different routes or suppliers, the most important one is represented with a thicker line.

Fig. 4: Continental brand routes



2.4 Final distribution and shopping

Once arrived in the C&Cs and modern distribution DCs, the products of the two brands follow the same channels. Therefore, scenarios only differ for the kind of distribution, whether modern distribution supermarkets or independent grocery stores. In both cases, the analysis is referred, through an average value, to all the stores located in Sassari city centre.

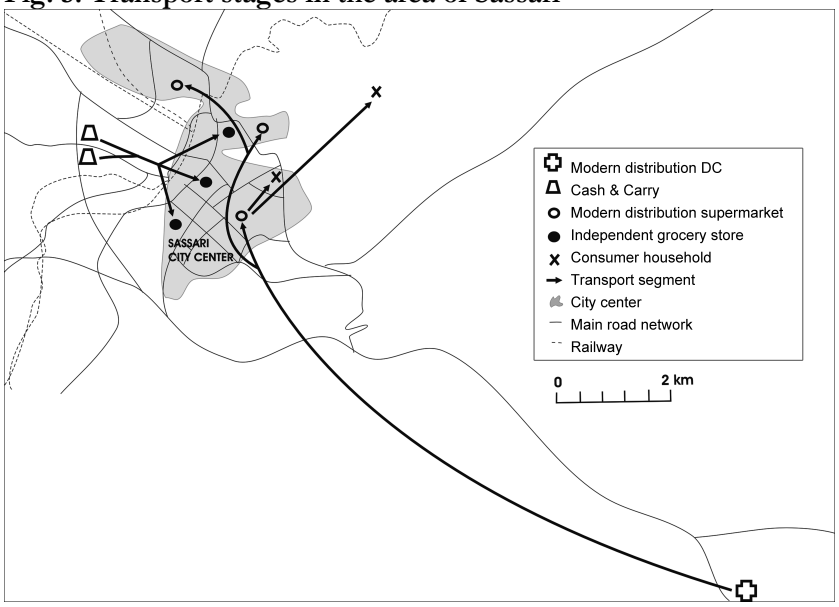
The modern distribution group organizes the distribution on the whole region around one DC, located 15 km south from Sassari. The deliveries and round deliveries to Sassari are done with 7.7-17 ton tonnage lorries that are loaded at 90% on average. There are no backward cargos and the deliveries are always done in the morning, during or at margin of peak-hours.

For their purchases, most independent retailers refers to C&Cs. All C&Cs are located in an industrial area at 8 km from Sassari. Retailers make their purchases by their own, usually turning to different C&Cs. They use LCV and, in this segment that has no outward load, the load of

the backward journey has an average weight of few quintals (1-6). Only some of the retailers make their purchases during the morning peak-hours.

The analysis of shopping impact has been done on different scenarios of modal choice and household location. For independent grocery stores it has been assumed that all the clients make their shopping on foot while for modern distribution supermarkets both shopping on foot and by car have been considered. Two household locations have been considered: the first one is in the city centre, 1 km from the supermarket, while the second one is located in the suburbs, 2 km from city centre and 3 km from the supermarket. The load factor assumed for each consumer is equal to 15.8 kg of net peeled tomatoes.

Fig. 5: Transport stages in the area of Sassari



2.5 Impacts and mains features of the assessment methodology

The effects of canned tomatoes transport on environment and traffic have been assessed through some quantitative indicators, that were chosen in order to best reflect the magnitude of the damage, according to pollutant and exposed population characteristics.

CO_2 has been chosen as global impact indicator as, with regard to the transport sector, this is the key factor of global warming. It has been assessed for all stages. With regards to global impacts, we also assessed

energy consumption, because of the unavailability of the CO_2 indicator in some of the studies we refer to for results comparison. Anyway, as energy consumption is, in our case study, tightly correlated to CO_2 emissions, the results for this indicator are not further discussed, except for comparison with other studies.

PM_{10} emissions have been assessed only in urban and suburban areas of Sassari (city centre and a strip of 5 km radius around it) because it is particularly harmful in densely populated areas.

The effects of supply chains on traffic congestion have been assessed only where additional vehicles can bring an important contribution to traffic slowing down, that is, during peak-hours in the Sassari urban centre.

The assessment methodology has been based on real-life data from face to face and phone interviews to operators of the supply chains analyzed. The interview results have been integrated with data from cartographic software and statistics.

Given the system boundary, for every stage and scenario, the impact assessment methodology has been developed as follow:

- assessment of the distance related to the transport stage, inclusive of empty backward journey or detour;
- assessment of the number of vehicles that are necessary for transporting one net ton of peeled tomatoes equivalent;
- definition, for pollution indicators, of the emissions factors per v-km, given the reference vehicle fleet;
- assessment of CO_2 and PM_{10} emissions and urban km driven during peak-hours related to the transport of one net ton of peeled tomatoes.

See the Appendix for more methodological details.

3. Results

3.1 Scenarios impacts

The quantification of the impacts associated with considered supply chains revealed large differences between scenarios and between segments. The lowest impact scenario – with 55,742 gr CO2/ton output, 0.64 gr PM_{10}/ton output, and 0.1 km in high traffic situation/ton output – is the one with consumption of regional brand canned tomatoes purchased by foot in a modern distribution supermarket. The worst scenario – with 199,945 gr CO2/ton output, 17.95 gr PM_{10}/ton output and 45.7 km in high traffic situation/ton output – is the one with consumption of continental brand canned tomatoes purchased by car in

a modern distribution supermarket located at 3 km from the client's domicile. The most significant differences between scenarios derived from product origin and shopping transport mode. Modern distribution is less polluting than independent retail but the difference is not so high, especially for global impacts.

Tab. 1: Distances, loads and impacts associated to the different stages

	Ton product/ ton net output	Road outward distance	Sea outward distance	Rail outward distance	Total outward distance	Average load	CO2/ton net output Road	CO2/ton net output Sea	CO2/ton net output Rail	CO2/ton net output Total	PM10/ton net output Total	Urban distance peak hours/ton net output
	(ton)	(km)	(km)	(km)	(km)	(ton)	(gr)	(gr)	(gr)	(gr)	(gr)	(km)
REGIONAL SUPPLY CHAIN												
Tomatoes fields – Canned tomatoes plant	1,20	42	0	0	42	9,36	5.571	0	0	5.571	0	0
Cans plant – Canned tomatoes plant	0,13	45	522	0	567	3,32	1.844	39.710	0	41.554	0	0
Canned tomatoes plant – Moder distribution DC	1,13	175	0	0	175	12,33	11.449	0	0	11.449	0	0
Canned tomatoes plant – C&Cs	1,13	211	0	0	211	21,60	11.054	0	0	11.054	0,29	0
CONTINENTAL SUPPLY CHAIN												
Tomatoes fields – Canned tomatoes plant	1,20	203	0	0	203	13,04	17.040	0	0	17.040	0	0
Cans plant – Canned tomatoes plant	0,13	437	0	0	437	3,00	19.154	0	0	19.154	0	0
Canned tomatoes plant – Modern distribution DC	1,13	1157	370	356	1883	23.80[a]	55.983	28.916	8.434	93.332	0,21	0
Canned Tomatoes plant – Producer DC	*1,13*	*541*	*0*	*356*	*898*	*19.44[a]*	*28.924*	*0*	*8.434*	*37.357*	*0*	*0*
Producer DC – Modern Distribution DC	*1,13*	*615*	*370*	*0*	*985*	*26,20*	*27.059*	*28.916*	*0*	*55.975*	*0,21*	*0*
Canned tomatoes plant – C&Cs	1,13	1279	364	356	1999	22.60[a]	64.482	30.665	8.434	103.580	0,45	0
Canned Tomatoes plant – Producer DC	*1,13*	*541*	*0*	*356*	*898*	*19.44[a]*	*28.924*	*0*	*8.434*	*37.357*	*0*	*0*
Producer DC – C&Cs	*1,13*	*738*	*364*	*0*	*1102*	*24,20*	*35.558*	*30.665*	*0*	*66.223*	*0,45*	*0*
FINAL DISTRIBUTION												
Modern distribution DC - Supermarkets	1,13	19	0	0	19	4,80	2.560	0	0	2.560	0,64	0,1
C&Cs – Independent grocery stores	1,13	4	0	0	4	0,30	5.598	0	0	5.598	3,49	0,7
SHOPPING												
Supermarket – Central household	1,13	1	0	0	1	0,01	33.668	0	0	33.668	8,01	45,6
Supermarket – Suburbs household	1,13	3	0	0	3	0,01	67.859	0	0	67.859	17,1	45,6

[a] rail segment is not considered

Fig. 6: Scenarios comparison: CO_2 emissions per stage

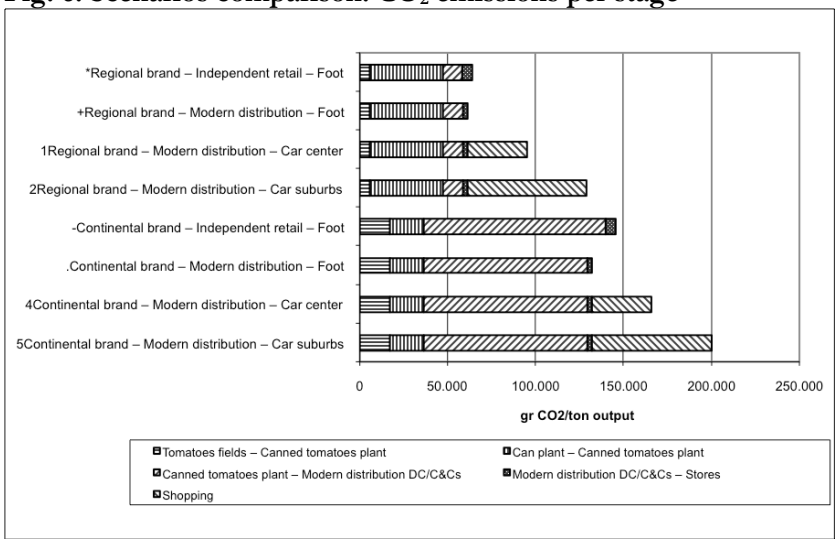


Fig. 7: Scenarios comparison: PM_{10} emissions per stage

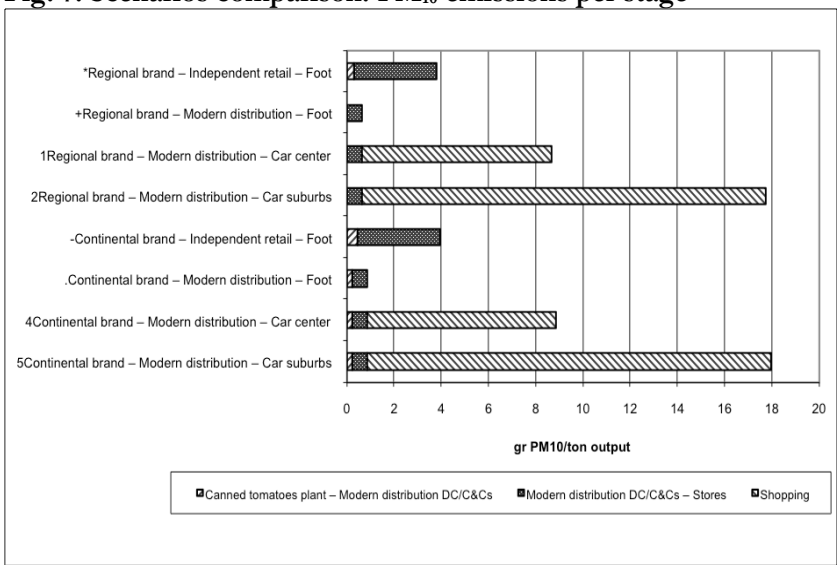
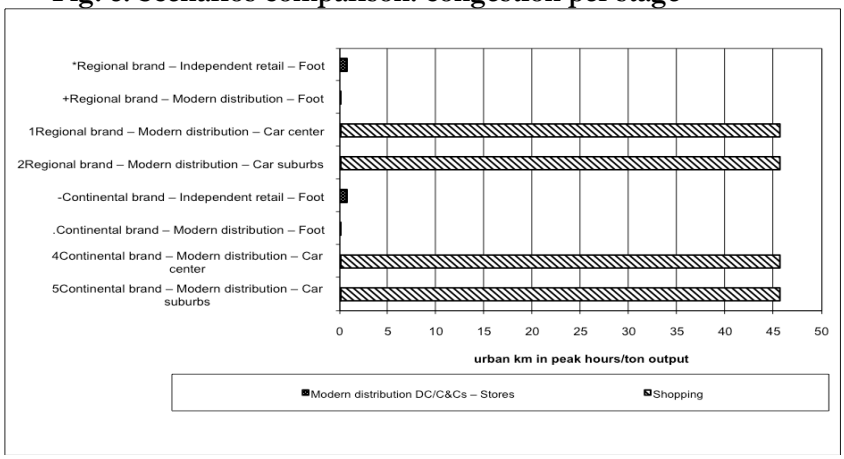


Fig. 8: Scenarios comparison: congestion per stage



3.2 Differences between regional and continental brands

With reference to global impacts, the continental brand is systematically worse than the regional one, regardless of distribution channels and shopping transport mode. As for CO_2 emissions, if we only consider the segments where the two brands differ, the ratio between continental and regional brand is 2.43 in the modern distribution scenario and 2.65 in the independent retail one.

In the transport of inputs, the continental brand is altogether the most efficient (the continental/regional brand ratio is equal to 0.87). This is due to the high impact of can transport for the regional brand (ratio 0.46) that has to import them from the continent. Because of smaller distances, the regional brand is more efficient for the transport of tomatoes (ratio 3.06).

So, the high impact of the continental brand is primarily due to the segment between the plant and modern distribution DC/C&Cs where the ratio between continental and regional brand amounted to 8.15 for scenarios with modern distribution and 9.37 for the independent retail one. This is primarily due to the national scale organization of the supply chain, with goods crossing the whole country to reach the DC, but also to distribution procedures, probably typical for the distribution of continental products in Sardinia, which contemplate long round deliveries on the island. Finally, the sea transport leg is high-impact and eliminates the continental brand advantage in the transport of inputs.

With regard to PM_{10}, the differences between the two brands are minimal. They are due to the fact that the continental brand round deliveries pass near the city of Sassari.

3.3 Differences between distribution channels

Under the same shopping conditions, the independent retail channel is systematically worse than modern distribution, both for global impact and local pollution – except in the stage between regional canned tomatoes plant and modern distribution DC/C&Cs.

With reference to global impact, independent retail is slightly less efficient than modern distribution with a ratio of 1.2 for the continental brand scenario and 1.1 for the regional brand one. In the case of the continental brand, which has a very tortuous pattern of distribution in Sardinia, the difference between the distribution channels derives primarily from the stage between the canned tomatoes plants and modern distribution DC/C&Cs. For the regional brand, instead, it is the final distribution to the shops that is important in the comparison between distribution channels. Compared to modern distribution, independent retailers have a high impact per km as they go (empty) with LCV at the C&Cs and buy few tons of goods. In the final distribution to the shops, the ratio is 2.2.

While differences between distribution channels in terms of global impacts are limited, if compared to the overall impact of the scenarios, these differences are more relevant in terms of local pollution. Apart from shopping, the main contribution to local pollution is given by final distribution from modern distribution DC and C&Cs to stores, where, of course, independent retail is much less efficient than modern distribution (ratio 5.4).

Finally, independent retail shows more kilometers driven during peak-hours than modern distribution, because of the lower load factor. Anyway, the contribution of final distribution to traffic congestion is insignificant.

3.4 Differences between shopping transport modes

Shopping by car is one of the largest contributor to the overall impact of canned tomatoes supply chains. With regards to CO_2 emissions, shopping by car weighs between 20% and 53% of the overall impact (for the regional brand supply chain, the 3 km trip by car for shopping produce more CO_2 than the sum of all the other stages). Furthermore, shopping contributes between 90% and 96% of the local pollution

overall impact, while it is practically the only factor responsible for traffic congestion.

So, the superiority of shopping on foot appears as one of the major evidences of our analysis. The previous paragraph revealed the advantage of modern distribution for the final distribution stage. Now, it should be noted (as we have done with the choice of scenarios analysed) that shopping on foot is much more common for independent retailers than for supermarkets. For CO_2 and congestion, the advantages of shopping on foot are clearly higher than the difference between modern distribution and independent retail in the final distribution. For those two impacts, the independent retail channel therefore appears to be an attractive option. Even with regard to emissions of PM_{10}, shopping weighs more than the final distribution stage. But the difference between distribution channels is here of some importance and the scenario with shopping on foot in modern distribution supermarkets appears to be really superior. Indeed, if both the final distribution and shopping are considered, the independent/modern distribution ratios with regard to PM_{10} for shopping in modern distribution supermarket on foot, by car with a 1 km outward trip and by car with a 3 km outward trip are 5.5, 0.4, 0.2, respectively.

4. Discussion

4.1 Comparison with other studies

The definition of boundaries and other assumptions make it very difficult to compare studies from different backgrounds. Some studies in the literature may anyway provide useful elements for comparison.

First, the results of our study can be compared with studies related to canned tomatoes production stages. In fact, considering the overall supply chain impact, differences between transport scenarios and the possibility of reducing the impact of transport or transport stages may result more or less critical.

From the literature we find information on energy consumption of tomato production and processing (therefore can production and waste disposal processes are not considered, as well as the transport of inputs and the energy incorporated in the equipment). With reference to tomato production, Miyao et al. (1997) report a value of 0.78 GJ/ton (that is, considering the input/output ratio, 0.94 GJ/ton canned tomatoes). The data refers to California and open field conventional agriculture. It should be noted that, in addition to other possible differences (type of fuel, more or less intensive methods), the tomatoes used by the two

Italian brands we tested are produced by methods of integrated farming that generally makes minor use of fertilizers and pesticides. With reference to the processing stage, Carlsson-Kanyama and Faist (2000) offer a range of values (3 observations) of 2.1-3.8 GJ/ton canned tomatoes.

In our case study, the impact of transport amounted to 0.76 GJ/ton output for the less energy intensive scenario and 2.81 GJ/ton output for the most energy intensive one. According to the values indicated above, with regard to the less energy intensive scenario, the impact of the overall supply chain would therefore be of 3.8-5.5 GJ/ton output, with a contribution of transport stages equal to 14-20%. In the scenario with the highest energy consumption, the whole supply chain impact would be equal to 5.85-7.55 GJ/ton output, with a contribution of transport that would amount to 37-48%. It appears that transport is never marginal and can be really crucial in cases of low energy efficiency of transportation.

With reference to other studies on food miles, a study by Rizet and Keïta (2005) on yoghurt transport in France seems a good candidate for comparison for the shopping stage. The authors assume that the average purchase in supermarkets is 15 kg. They also assume an average distance between home and supermarket of 4.5 km (urban driving) and consider that only 50% of consumers shop by car. They assess a shopping impact of about 100,000 geqCO_2/ton. Apart from the difference in methodology that takes into account the actual modal split of purchases (while we opted for various scenarios), the assumptions of the authors, based on the literature, are consistent with ours. When the results get adjusted to the assumptions of our own study, the assessment proposed by Rizet and Keïta is about 25% higher than our. It seems that the difference should be attributed to the choice of emissions and consumption factors. Rizet and Keïta confirm the high weight of shopping on total transport impact. Shopping impact turns out to be slightly lower than the one related to the entire logistic chain component (about 110,000 geqCO_2/ton) that includes, in their study, both phases of transport upstream and downstream from the plant (from inputs to points of sale) and energy consumed in logistic platforms. It must also be noted that the supply chain of yoghurt they analysed has greater energy consumption because of the refrigeration of the product.

4.2 New knowledge and key issues

The research confirms some trends identified by other studies but at the same time emphasizes the place-specific nature of the results, that

appear to be strongly influenced by specific elements of the supply chains examined, and by the Italian context.

Our study confirms the results obtained by other researchers concerning the huge weight of shopping by car. Congestion and local pollution are almost exclusively related to shopping and, with respect to global impacts, shopping by car generates a share of CO_2 emissions that varies, depending on the scenario (with shopping by car), from 20% to 53%. Even if an evolution in the organization of logistic chains can bring to environmental benefits, a modal shift for purchases remains a priority objective for reducing the impact of our food consumption.

With regards to the weight of the other stages, the final distribution has obviously a high impact per v-km because of the use of small and medium tonnage vehicles. The weight of the other stages, upstream and downstream of the canned tomatoes plant, differs for the two brands. Anyway, while this phenomenon has been seldom studied in food miles research, the high impact of transporting primary packaging must be underlined. Solid packaging has a low weight/volume ratio and therefore the lorries carrying it have a low load factor. In spite of its low input/output ratio, primary packaging contributes highly to the impact of the upstream part of the supply chain and it suggests that the transport of processed food (with solid packaging) can be much more polluting than the one of unprocessed food (conservation necessity still remaining).

Our study supports the view that, in terms of global impacts, local supply chains are a better option. The superiority of the regional industry is partly due to the specificities of the product and the final market examined. First, the geographical demarcation of Sardinia greatly influences the organization of supply chains. In the case of the regional brand, this implies both disadvantages and advantages. With regard to disadvantages, the regional brand has to import from the mainland the inputs that are not available locally (in our case the cans) with a high impact due to distances and maritime transport. On the benefits side, there is a strong convenience in having the productive inputs located on the island, while on mainland the distance factor is weaker and this may lead, because of other decision variables, to prefer more distant inputs. Moreover, the geographical identity probably steers consumers toward regional products.

With reference to the continental brand, maritime transport (both brands have a sea leg with a similar impact) and the low concentration of urban centers in Sardinia, that requires long round deliveries, contribute

greatly to the impact. We estimated that the global impact of the stage that goes from canned tomatoes plants to modern distribution DC/C&C could be, for destinations in northern Italy, almost 50% lower than for the Sardinian market.

A second reason supporting the superiority of the regional brand is the particular inefficiency of the continental brand service to the Sardinian market. The continental brand has a DC in southern Italy that is used for canned tomatoes distribution in the south of the peninsula. At low organization costs, the continental brand could rely on that DC for its distribution in Sardinia and reduce its impact this way. We estimated that such a scenario could reduce by about 50% the impact of the segment that goes from canned tomatoes plants to modern distribution DC/C&C.

The superiority of regional supply chains is a controversial topic in food miles literature. However, according to the quantitative assessment, the specificities of the supply chains analyzed seem not sufficient to explain the superiority of the regional scenarios, so that, when comparing local and national industry, our research is definitely in favor of local supply chains. In non-island geographical areas, it may anyway be more difficult to organize efficient regional supply chains.

The results of our survey are particularly interesting with regard to the issue of logistics efficiency. While the literature emphasizes that longer supply chains may be better if they present economies of scale and inventory centralisation strategies (Garnett, 2003), the transit to a DC appears in our study as a factor that increases the impact. Apart for final distribution, we have similar results in terms of vehicle size and load factors irrespective of the size of the company and the strategy of centralization. It should however be specified that Italy is known for its low logistic efficiency and it is possible that, in other countries, the inventory centralization is managed in a better way.

The reflection on the impact of centralization should also be applied to final distribution. If in our case study modern distribution is more efficient than independent retail in terms of global impact, it should be noted that this is due to the choice of the final market analyzed. In fact, the city of Sassari is located near the only regional DC of the modern distribution company. If we had chosen another final market, the distance between the DC and the final market would have been greater. In contrast, for independent retailers, at least in medium and large cities, there are always C&Cs in the neighborhood and therefore, the global impact is less dependent on the final market location. It must however

be noted that C&Cs are used only for part of the independent channel and that short supply chains that offer organic products, homemade products, etc. often use other distribution channels that are less efficient.

In addition to distances and logistic efficiency, shipping is a third element that highly contributes to our case study global impact. While literature emphasizes the low impact of this mode of transportation, this is true only for certain types of vessels. In the case of RO-RO cargo vessels, the impact is much higher. According to our assessment, the impact per v-km in the sea leg is about twice the one of HGV.

5. Conclusions

Our investigation has shown the great variability of the impact associated with the transport of canned tomatoes, depending on the product's origin and modal choice of shopping. Shopping by car appeared, in accordance with the results of earlier research, to be responsible for the impact associated with the transport of food goods in a major way.

While the importance of supply chains re-localization is a controversial issue, in this case study the regional supply chain appears to be far less polluting than the national one. Therefore, with regards to the trade-off between a reduction in distance and the logistic efficiency gain that results from the centralization of loads, our case study supports the view that short supply chains can be much more efficient than an organization based on large scattered patterns and grouping on DCs.

With reference to the global impact, there are no significant differences between modern distribution and independent retail. Now, aside from the crucial question of willingness to shop on foot in different categories of stores, independent retail presents more critical values with reference to local air pollution.

With regards to the segments upstream from the canned tomatoes plant, the transport of packaging appeared very polluting. While preserving the trade-off between transport and the impact linked to product perishability, the purchase of processed and packed products increases the impact of food consumption with respect to transport, as well as production.

The very clear results of the survey corroborate our conclusions both with regards to methodology uncertainties and specificities of supply chains examined. However, it clearly emerges from the study that the magnitude of impacts and the comparison between alternative supply chains are highly influenced by geographical and productive specificities

of the contexts analyzed. All in all, the Italian canned tomatoes market appears less polluting than those of other countries with regard to transport, because it remains within the national borders (TRT, 2006), while the clusterization of the industry in few national poles reduce the possibility and propensity to organize supply chains exclusively based on local inputs.

Appendix: assessment methodology

Data sources

In order to better reflect the case studies characteristics, we have referred as much as possible to primary data coming from interviews. Because of incompleteness of data characterization given by interviewees, for some segments, we have integrated primary data with statistics. Therefore the methodology presents differences between stages with regard to data sources. If a uniform model based on average data can be preferable for the purpose of reproducing the analysis, this case-by-case methodology allow to use all available detailed information.

We have used the following main data sources:

- Interviews to: representatives of the two canned tomatoes brands and the modern distribution group, four independent retailers that have been assumed as sample for this distribution channel, transporters;
- statistics on emissions factors (DB by APAT based on CORINAIR methodology and 2005 Italian vehicle fleet) and vehicle fleet (DB by ACI Italian Automobile Club, "Autoritratto" 2007);
- cartographic software (google maps) for distance measurement.

Computation of impacts

Impacts, measured as emissions and km driven during peak hours per net ton of peeled tomatoes, have been computed for every stage, while the impacts per scenario have been obtained by summing the stages that compose them. For stages that present heterogeneity, the total impacts have been computed as follows:

- *multi driving style stages*: assessment of segments corresponding to each driving style and sum;
- *multi operator stages* (change in vehicle and cargo characteristics after reloading): assessment of segments corresponding to each operator and sum;

- *multi segment stages* (multiple locations of inputs and suppliers, multiple routes): assessment of each segment and weighted average, according to product weight.

Distance assessment

The distances assumed for the assessment are inclusive of empty backward journey or detours done in order to collect a return cargo. We use the shorter route proposed by the cartographic software as reference. For the calculation of distances the following assumptions have been made:

- *stages without return cargo in urban area*: exact round trip distance;
- *stages without return cargo in extra-urban area*: distance equal to twice the outward route;
- *stages with return cargo*: outward route plus half of the detour done in order to collect a return cargo.

Assessment of the number of vehicles needed for transport

The computation of the number of vehicles necessary to transport the quantity of input that is used for the production/distribution of one net ton of peeled tomatoes has been done as follow:

- assessment of the input-output ratios (1.3 for tomatoes, 0.13 for cans, 1.2 for the finished product);
- assessment of the number of transport package units carried by each vehicle;
- assessment of the weight of a loaded transport unit, under the hypothesis that it is exclusively loaded with canned tomatoes or their inputs;

For every stage, the number of vehicles necessary to transport the equivalent of one net ton of peeled tomatoes is equal to 1/ (vehicle load * input-output ratio).

For the shopping stage, the load factor has been assessed on the basis of the national average value of supermarket purchases and a sample of receipts that gave the price/weight ratio.

Assessment of emissions factors

For road transport, we used emissions factors per v-km, differentiated by fuel, tonnage, technology and driving style.

- driving style (urban, rural, highway) has been assessed on the basis of cartographic software indications and, for urban driving style, building density (assessed on satellite images);
- total emissions factors have been used (vs. hot emissions);

- when interviewees have not been able to specify vehicle technology, we referred to the average value of the transporter origin district fleet;
- for the shopping by car stage we used the average value of the Sassari district fleet.

For sea legs, emissions factors have been assessed from an interview to a representative of a RO-RO cargo ship firm who gave the fuel consumption values (equivalences emissions/ liter of fuel from Lombard, Molocchi, 2001). Here, emissions factors per v-km (that is lorry-km) are independent of lorries characteristics and total ship emissions must be divided by the number of lorries embarked. The emissions per sea segment are made up of two components:

- a variable emissions factor, that depends on the leg length;
- a fixed emissions factor, related to embark and disembark operations.

For the rail segment, instead of v-km, reference was made to Italian average electricity consumption per ton-km (data by ENEA, Italian Body for New Technologies, Energy, Environment), that take into account the percentage of empty backward journeys. The CO_2 emissions factors have been assessed on the basis of the electricity mix used in Italy (from "the green house gas protocol initiative" website and Lombard, Molocchi, 1998).

Assessment of the transport impacts per net ton of peeled tomatoes

For each segment, impacts have been computed as follow:

- *pollution indicators*: distance * n. vehicle/ ton of net peeled tomatoes *emission factor/v-km;
- *congestion*: km driven in urban area during peak hours * n. vehicle/ ton of net peeled tomatoes. For the assessment, the hourly distribution of purchases has been measured: 6% of supermarkets receipts are emitted during the morning peak-hours and 30% during the afternoon peak-hours.

Uncertainties

The methodology presents some uncertainties related to the assumptions made and the choice of secondary data. Results are very sensitive to these elements; however, having had very clear results with regards to scenarios and stages comparison, uncertainties did not question the main conclusions of the analysis. Yet, uncertainties and the subjectivity of some methodological choices hamper the possibility to compare the result with other studies.

For the assessment of distances, the following allocation choices must be quoted:

- the choice of allocating to our supply chains half of the detour distance for return load recovery is subjective, another allocation criteria could have been chosen;
- in case of round deliveries a distance equal to the entire round delivery as been accounted for all the destinations concerned, with a possible overestimation of the impact associated to the locations nearest from the origin;
- when the respondent was not able to provide the exact value, the length of the deviation has been assessed as a percentage of the journey, according to transporter indications or interviews sample. While the willingness to take a detour depends on the length of the journey, this method, preferred to a fixed distance, can lead to overestimate or underestimate the detour.

With regards to secondary data the following assumption can brought to uncertainties:

- to complete missing data from interviews we had to match the vehicle fleet DB, split by classes of tonnage, with the one on emissions factors, split by total weight classes. It has then been necessary to subdivide the tonnage classes and report them to the total weight classes (equivalences from Unione petrolifera, 2007) in order to assess the average emissions factors and this operation can have had distortive effects;
- for the shopping by car stage, because of the low load factor, the data used for the assessment of the average weight of purchases can highly influence the value of the impacts associated to the stage;
- in order to assess the emissions factors for the sea legs, we assume that all the lorries where carried on RO-RO cargo ships while it is probable that part of the lorries travels on mixed RO-RO vessels (cargo and passengers), with different emissions factors.

At last, the following choices related to system boundary must be stressed:

- local pollution has only been considered in Sassari and thus it is undervalued when the supply chains pass close to other urban areas. Because of the lower number of reloadings, the assessment of local pollution outside Sassari would probably benefit the regional brand;

- in defining the inputs that could be excluded from the analysis we considered their marginal weight or similarities between scenarios with reference to the transport of these inputs. However, given that some excluded inputs have a significant impact, such as the transport of steel necessary for can production, the meaningfulness of the comparison between the impact of the transport stages and other stages of the supply chain may be distorted.

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