Food Policy 34 (2009) 150–155

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Local food, food miles and carbon emissions: A comparison of farm shop and mass distribution approaches

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ARTICLE INFO

Article history:
Received 23 November 2007
Received in revised form 16 September 2008
Accepted 1 November 2008

Keywords:
Food miles
Carbon emissions
Food distribution
Sustainable food system

ABSTRACT

This paper provides a critical commentary on the conception of food miles followed by an empirical application of food miles to two contrasting food distribution systems based on carbon emissions accounting within these systems. The comparison is between the carbon emissions resultant from operating a large-scale vegetable box system and those from a supply system where the customer travels to a local farm shop. The study is based on fuel and energy use data collected from one of the UK's largest suppliers of organic produce. The findings suggest that if a customer drives a round-trip distance of more than 6.7 km in order to purchase their organic vegetables, their carbon emissions are likely to be greater than the emissions from the system of cold storage, packing, transport to a regional hub and final transport to customer's doorstep used by large-scale vegetable box suppliers. Consequently some of the ideas behind localism in the food sector may need to be revisited.

Introduction

Various tools have been brought to bear to analyse the problems of sustainable agriculture, the chosen method often primarily depending on the way sustainability is viewed and the background of the investigator (Leach, 1976; Cormack and Metcalfe, 2000; Carlsson-Kanyama et al., 2003; Costanza et al., 1997; Pretty et al., 2002; Rees, 2003; Lewis et al., 1997; Bailey et al., 1999). As the environmental impacts of global agro-food systems have been exposed (Conway and Pretty, 1991; Uphoff, 2002), the concepts of 'local food' and 'food miles' have become powerful polemical tools in policy discourses built around sustainable agriculture and alternative food systems (Lang and Heasman, 2004). Both are appealing in their apparent simplicity of application and have demonstrated the fluidity to be used in different contexts as the alternative food debate has progressed and changed. There has been a tendency to assume that local food is a solution to the problem of food miles. Local food both pre-dates food miles as a concept and, as a consequence, to some extent, helps to configure the conceptualisation of food miles. Originally the environmental impact of food miles was broadly conceptualised (SAFE Alliance, 1994; Raven and Lang, 1995; Subak, 1999). The reduction of food miles was seen as an aspect of making more explicit the links between particular foods and particular natures, a re-territorialisation or re-spatialisation of food production which begins to reverse the aspatialities which are, or were, an intrinsic part of a globalised food order (Winter, 2005). This was based on a growing realization that the properties of food are 'natural' and that heterogeneity of edaphic conditions gives rise to varied natures represented in varied foods. To reduce food miles implies the need for food systems grounded in local ecologies and responsive to consumer demands for quality food (Murdoch et al., 2000), hence the growing literature on the benefits of a more localised food supply system (Winter, 2003; Sage, 2003; Morris and Buller, 2003; Cowell and Parkinson, 2003).

However more recently, food miles have been linked much more explicitly to carbon accounting (Jones, 2001; Pirog et al., 2001; Smith and Smith, 2000; Lal et al., 2004) and the climate change debate. In some ways this has served to radically shift the food miles argument away from sustainable agriculture production systems *per se* to food distribution and retailing and, in particular, the use of carbon in transport. In their influential report to Defra on the validity of the concept, AEA Technology (2005) largely focus on CO_2 emissions as the key indicator of sustainability, and operates with a correspondingly narrow conception of environmental sustainability. For example, AEA provides a series of case studies on food miles which focus on energy and carbon emissions, for example comparing tomatoes grown in the UK to those imported from Spain, and not a wider conceptualisation of sustainability. Defra's (2006) Food Industry Sustainability Strategy takes a somewhat broader approach but still gives considerable salience to the role of transport in carbon emissions. Alongside the concern at the narrowing of the sustainability agenda brought about the by

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doi:10.1016/j.foodpol.2008.11.001

the focus on food miles is an equally important concern at the crude nature of the calculations used to assess carbon emissions in most studies hitherto. AEA's tomato case study is illustrative. Basically it amounts to a balancing out of the energy used in production (less in Spain because of the climate than in Britain) against the extra energy used in the transport to Britain. Such a simplistic approach masks the very real differences between contrasting production and distribution systems.

Consequently in this paper we study the carbon emissions from the use of fossil fuels during the storage–distribution–retail chain for the case of organic vegetables. In particular, we make a comparison of the relative emissions from a system based on large-scale growing, bulk cold storage, mass distribution to regional hubs, then home delivery, with the much simpler case of a hypothetical small local farm shop. This allows us to discover where in the large-scale system most emissions occur, thereby indicating for future work the likely areas of policy and management that might reduce these emissions through energy efficiency and changes in working practices, and to compare the emissions arising from the food miles generated by both approaches. Given the interest in food miles, organic production, localism and carbon emissions from energy use, the comparison is highly topical (Seyfang, 2006; Ilbery and Maye, 2005; Weatherell et al., 2003; Hinrichs, 2003; Rigby and Caceres, 2001; Morgan and Murdoch, 2000; Tait and Morris, 2000). Prior to presenting the evidence of our own case study on carbon emissions we examine some of the background and contextual literature on transport and shopping. In the conclusions we seek to place our findings in the wider context of food studies.

The question of sustainability in food production and distribution is obviously far wider that that of emissions from fossil fuel use, and includes questions of water pollution, rural economics, landscape amenity and a host of others (Pretty et al., 2005; Bollman and Bryden, 1997). However, by restricting the analysis it is easier to address in a quantitative manner one of the questions of most interest to the public, and one in which, through their purchasing decisions, they have the ability to effect change. In addition, the general production methods of the two systems as currently practised in the UK are relatively similar. It is only with regard to storage and distribution that major differences are evident, and here emissions from fossil-fuel use and the potential these have for contributing to climate change dominate the debate. However, as Table 1 shows, the external costs of agriculture are not minor, and because they are lower for organic production the storage–distribution–retail chain not addressed by Table 1 will be of greater relative importance for the organic sector.

Traffic, shopping and home delivery studies

Over the last decade there has been a rapid growth in home delivery for grocery and other items; however, travel for food and household items still represents 40% of all shopping trips by car, and 5% of all car use (Cairns, 2005) (see Table 2), equating to over 16 billion vehicle km per annum. There is therefore pressure to reduce the possible congestion to which this gives rise and reduce the resultant carbon emissions. This then begs the question of whether a further growth in home delivery is likely to reduce congestion/emissions or exacerbate them.

Table 2
National Travel Survey data about personal travel for shopping in the UK, 1998–2000 (Cairns, 2005).

Shopping trips primarily for:	Food	Non-food
Average trip distance (km)	4.8	9.0
Average number of trips per person per year	122	96
Average car/van driver travel generated per person per year (km)	290	400
Per cent of all car/van driver-km travelled per person per year	5.1	7.0

Source: Data from the National Travel Survey – an annual survey of approximately 9400 households designed to be representative of the UK, with results aggregated into 3-year bands for improved data reliability (DTLR, 2001 as reported in Cairns, 2005).

There has been a large amount of research on the environmental impacts of home delivery (Handy and Yantis, 1997; Romm et al., 1999; Transport en Logistiek, 2000; NERA, 2000; Browne et al., 2001; Hopkinson and James, 2001; Weijers, 2001; Mokhtarian and Salomon, 2002), and Cairns, 2005 has produced an excellent review of this and other research. Home shopping itself can be seen as one of many "soft" policies to reduce traffic growth alongside initiatives such as school travel plans, car sharing and teleworking.

In the UK, groceries account for 46% of total retail spending and the market is dominated by a few major chains (Tesco, Sainsbury, Asda and Morrisons) with 68% of customers describing these as the source of their "main grocery shopping" (Mintel, 2003). A similar position is reported in other developed countries. It is known that grocery shopping is a frequent activity, with over half of households undergoing a major food shop once a week and 60% of these are dedicated journeys not linked to other activities such as travel to work (Mintel, 2003; Cairns, 1995; Cairns, 2005).

There have been three main studies of the impact of grocery home deliveries on traffic using computer simulations (Cairns, 1996; Palmer, 2001; Punakivi et al., 2001; Punakivi and Holmstrom, 2001; Punakivi and Saranen, 2001; Punakivi and Tanskanen, 2002). These have used computer software to model the routes taken by householders to shops and of home delivery vehicles, and then compare the total length driven, given various assumptions. The results from these studies indicate that home delivery may well result in lower carbon emissions.

In a study by Cairns (1996), it was concluded that:

- Even with a small number of customers and vans that can only carry a few loads of shopping, there are likely to be reductions in motorized travel of 70% or more per shopping load if customers

Table 1
The negative externalities of UK agriculture (year 2000). For comparison the UK's GDP in 2005 was around £1.2T (adapted from Pretty et al., 2005).

Source of adverse effects	Actual costs from current agriculture (£ M yr^{-1})	Costs as if whole of UK was organic (£ M yr^{-1})
Pesticides in water	143.2	0
Nitrate, phosphate, soil and cryptosporidium in water	112.1	53.7
Eutrophication of surface water	79.1	19.8
Monitoring of water systems and advice	13.1	13.1
Methane, nitrous oxide, ammonia emissions to atmosphere	421.1	172.7
Direct and indirect carbon dioxide emissions to atmosphere	102.7	32.0
OV-site soils erosion and organic matter losses from soils	59.0	24.0
Losses of biodiversity and landscape values	150.3	19.3
Adverse effects to human health from pesticides	1.2	0
Adverse effects to human health from microorganisms and BSE	432.6	50.4
Total	£1514.4	£384.9

no longer drive to the shops but have their shopping delivered instead from the same store by a fleet of delivery vans.
- As more customers shop from home, travel savings per shopping load are likely to increase as it is possible to schedule deliveries more efficiently.
- Effect on overall travel for food shopping will be determined largely by the level of take-up of home shopping services.

However, Cairn's study assumed that the origin of the groceries, whether home delivered or picked up by the consumer, was the same: the nearest supermarket (this is not the assumption used in the work of Palmer, 2001 or Punakivi et al., 2001; Punakivi and Holmstrom, 2001; Punakivi and Saranen, 2001; Punakivi and Tanskanen, 2002. In our case we have additional transport from the source of production and from the hub. We are also interested in other issues apart from traffic, namely emissions from vehicles, and energy use in chilled storage. Another difference is that Cairns assumed a maximum of 20 customers were served by one journey of the delivery van (Punakivi et al. assumed a maximum of 60). In our case the mean capacity of the vans is 80 customers.

Punakivi concluded that travel savings per shopping load could be substantial (50–70%) if a switch to home delivery is made, and that greenhouse gas emissions (from transport) could be reduced by between 17.7% and 87.2%.

There have also been a series of smaller pieces of work. Farahmand's and Young's (1998) study of a single 2500 m^3 food store, showed that a 10% replacement of the assumed 450 shopping trips during the peak pm hours by home delivery (using five vans with nine loads each) would lead to 320 car-km being replaced by 43 van-km, a reduction of 87%. In a study of an expanding suburb of Stockholm, Persson and Bratt (2001) found that the percentage reduction in total grocery traffic (compared to 0% home delivery) might be between 20% and 24% if half the community engaged in home grocery shopping for their main shop.

Other studies of note are Murto (1996), Orremo et al. (1999) and Freire (1999). All reported that overall traffic levels would fall if home delivery became common.

A case study of carbon emissions

The work reported here is somewhat different to that covered in the above studies. Apart from the need mentioned above to include other sources of emissions, no data are available on what fraction of trips to a local farm shop are solely for the purchase of groceries, i.e. are not chained. It would therefore seem unfair to assume that the likely reduction in vehicle movements from home shopping is on a one for one basis. For small farm shops there is also little data on the size of their catchment areas, so estimating greenhouse gas emissions from such trips is difficult. For these reasons, it was decided to use a comparative metric and to estimate the maximum distance, M_d, a person could travel such that their emissions are likely to be less than those emanating from the cycle of chilling, mass-transport, chilling and home delivery for the large-scale organic box system. As was stated above, any emissions from the operation of the farm shop have not been included; M_d is therefore likely to be an overestimate.

From M_d we can infer the maximum distance customers should consider travelling by car to a farm shop, rather than considering home delivery from a major supplier. In the case of chained journeys, M_d represents the additional distance a customer should consider travelling out of their way. As will be explained below, M_d is calculated assuming average UK car fuel efficiencies and emission factors.

Our large-scale system consists of short-term mass cold storage, mass road transport to a regional hub, short-term mass cold storage once more and home delivery via dedicated light duty vehicles (Fig. 1). The comparison system consists of short-term storage at ambient temperature and purchase on site by the customer (Fig. 2). In both cases most goods are assumed to have been produced on-farm and for goods that are not, for example bananas, both are assumed to have similar resultant carbon emissions, i.e. they are sourced and transported in a similar way.

Annual energy consumption data (for 2006) were obtained from one of the UK's largest mass distribution based growers and suppliers of organic vegetables (Riverford) for all the sources shown in

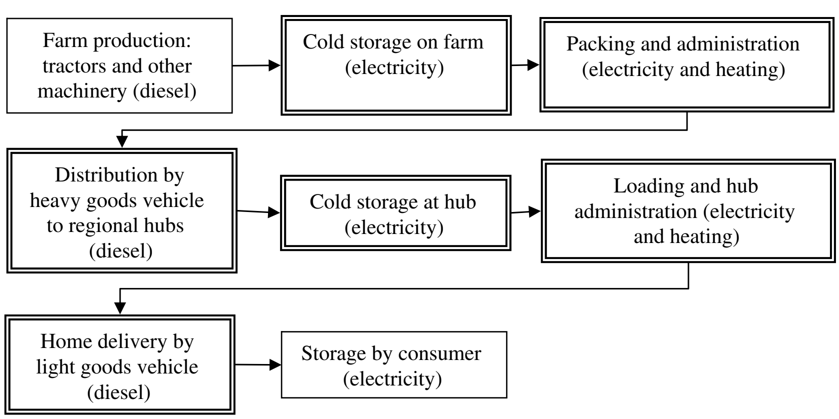

Fig. 1. Main sources of fossil fuel related carbon emissions and flow of product for the large-scale system. Only those with double borders are considered and used to form M_d.

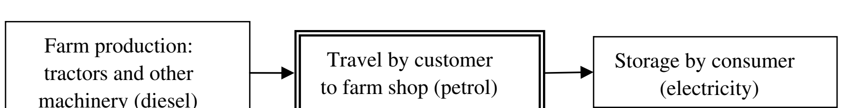

Fig. 2. Main sources of fossil fuel related carbon emissions and flow of product for the small-scale system. Only those with double borders are considered and used to form M_d.

Fig. 1. The cold storage, box packing and office premises are based at one location in the South-west of the UK with the majority of produce grown on surrounding land or nearby. Approximately 15% (by weight) of produce comes from other UK producers and 15% from overseas with a strict 'no air freight policy'. Once packed, boxes are transported by HGV to refrigerated 'hubs'; locations are accessed by one to six franchisees who then collect and distribute the boxes from the hub to customers in the local area. Over 32,000 boxes are shipped per week to 51 franchisees operating in the south of England each making five or six different delivery rounds in a week. Information was calculated around the business metric of energy use 'per box' or delivery, rather than 'per kg of produce'. Electricity, gas and heating oil use data were derived from billing information for the farm site (including packing, cold storage and administrative operations). Energy use in distribution was based on surveying the HGV carriers, intermediate cold store bills and final distribution LGV drivers. The HGV carriers reported an average per-box round trip of 0.25 miles (0.40 km), or 1300 boxes per lorry, and a recorded fuel efficiency of 9.9 mpg (3.5 km/l); this was converted into CO_2 emissions using standard factors (Carbon Trust, 2006). This figure could be more accurately assessed in future work by more in-depth surveying. Electricity bills for nine of the eighteen regional hubs were assessed to provide a figure showing the average use of electricity per box across all hubs. Information for the final distribution stage was gathered by surveying 24 of the 51 franchisees each of whom operate between one and seven vans (carrying around 80 boxes per van); the survey collected average distance travelled, fuel used and number of box deliveries per week. Fuel type was also gathered and showed vans to be predominantly run on diesel with a couple using petrol or LPG. Average energy input and CO_2 emissions per box were calculated based on standard factors for the appropriate fuel types (Carbon Trust, 2006).

The hypothetical small-scale system has no emissions connected to cold storage, regional hubs, HGVs or LGVs; carbon-wise it is therefore at a natural advantage. Furthermore, here we assume there are no meaningful emissions resulting from the operation of the farm shop or its administration. This is, as with the total lack of any cold storage, highly optimistic. As we consider any emissions from production on the farm, or eventual storage by the customer equal in both cases, the only source to be considered for the small-scale approach is that from the customer's journey to and from the farm shop.

The following assumptions were made:

1. Emissions were measured solely in terms of CO_2. However, as soil and animal emissions have been ignored, the contributions from other greenhouse gases are expected to be low.
2. The following standard emission factors were used for the conversion from fuel volume to $kgCO_2$. Energy content of diesel = 10.7 kWh/L, carbon emission factor for diesel = 0.25 (0.24 petrol) $kgCO_2$/kWh, electricity 0.43, natural gas 0.19 (for LPG used in some vans emissions is 0.21 $kgCO_2$/kWh) (Carbon Trust, 2006).
3. Calculation of energy use per box was based on electricity & heating fuel use and total box sales for 2006.
4. Use of diesel/LPG in lift trucks at farm and hubs has not been accounted for: this is expected to be minimal however.
5. M_d was calculated for a round trip in a petrol car that has carbon emissions equivalent to the current UK average of 0.210 kgCO2 per km (i.e. 10.97 km/l, or 31 miles per gallon) (Dept. for Transport, 2006).
6. The quantity of produce purchased by a box scheme customer or a farm shop customer is the same.

M_d is given by:

$$M_d = \frac{E}{e} \quad (1)$$

where e is the average emission factor ($kgCO_2$ per km) for a UK car and E is the total resultant emission of carbon dioxide per box for the large-scale system:

$$E = \sum_i E_i \quad (2)$$

with i running over all the sources considered (i.e. cooling, packing, administration, HGV, hub administration, hub cooling, LGV).

Table 3 shows the values found for E_i. The transportation of the product accounts for around 70% of the carbon emissions, and chilling at both the production/packing centre and the hubs account for about 30%. The single most important source is the LGVs used for final delivery; this indicates that efforts to reduce the environmental impacts of home delivery might best be focused towards this source in the first instance.

Using the results given in Table 3, and Eq. (1), M_d is found to be 6.7 km (4.2 miles), or 6.54 km (4.06 miles) if calculated in non-primary energy units, rather than carbon. This is a surprising result and arises from the inherent efficiencies of the mass distribution system outweighing other emissions.

The sum of associated CO_2 emissions for the large scale delivery system is 1394 g per delivery. A comparison with the perhaps more conventional route of individual customers driving to the theoretical farm shop can now be made. Department for transport statistics [TSGB 2007:Energy and the Environment Data tables, http://www.dft.gov.uk/pgr/statistics/datatablespublications/energyenvironment/tsgbchapter3energynvi1863.pdf>] provide the average CO_2 emission factor for cars on the road in the UK as 207 gCO_2/km for petrol cars (equivalent to 31 mpg fuel consumption), and 188 gCO_2/km, 36 mpg in a diesel. Under the Government's labelling system this classes the average vehicle as an 'F' on a scale of A–G in terms of CO_2 emissions.

The headline figures used above relate to petrol vehicles due to the disproportionate use of petrol fuelled vehicles in relation to diesel.

Using Eq (1), M_d can now be found for the average petrol and diesel vehicles.

$$\text{Petrol}: M_d = 1394\ gCO_2/207\ g/km \quad M_d = 6.7\ km\ \text{or}\ 4.2\ \text{miles}$$

$$\text{Diesel}: M_d = 1394\ gCO_2/188\ g/km \quad M_d = 7.4\ km\ \text{or}\ 4.6\ \text{miles}$$

A similar calculation can be made in non-primary energy units by taking the calorific value of the vehicle fuel and making a comparison with the sum calorific value of the energy embedded in the distribution measured here (diesel, electricity, heating fuel) as shown in Table 4.

The sum energy expended throughout the distribution chain is 5.7 kWh per delivery, which equates to 0.6 L of petrol or 0.5 L of diesel. Taking the average fuel consumption figures mentioned above we can then calculate M_d as 6.5 km/4.0 miles and 7.4 km/4.6 miles for petrol and diesel respectively. Thus for a consumer, the mass distribution system would be a more carbon and energy efficient way of obtaining vegetables if an extra trip of more than 7.4 km would have to be made to a farm shop.

Table 3
Carbon emissions from the large-scale box system.

Source, i	E_i, $kgCO_2$/box	% of total system emission
Packing, cold storage and administration at farm	0.30	21.4
HGV transport	0.36	25.7
Intermediate cold storage and administration at hub	0.04	2.8
Final LGV distribution	0.70	50.0

Table 4
Sources of Embedded Energy in Box System.

Category	Energy per box (kWh)
Packing, refrigeration and admin at farm	0.64
HGV transport	2.14
Intermediate refrigeration	0.08
Final distribution (LGV)	2.87
Total	5.72

Conclusion

A comparison has been made between the carbon emissions resultant from operating a large-scale vegetable box system and those from a supply system where the customer travels to a local farm shop. Growing and sourcing of produce have not been considered in the comparison, as both typically operate in a similar way in regard to this in the UK. The study was based on fuel and energy use data collected from one of the UK's largest suppliers of organic produce.

The results are consistent with those from theoretical computer-based simulations of the impact of home delivery. For the large-scale system, we see that the bulk of the emissions arise not from chilling or mass transportation using HGVs but the final delivery phase using LGVs.

Whilst it is obvious that the box system results in many more food km (on average 360 km per box in this study) than purchasing from a local farm shop, this is shared between a large number of boxes. The need to consider this point when making use of the concept of food miles was one of the main conclusions of the AEA report (AEA Technology 2005). Our work shows that the concept of food miles, as typically used, is of little value per se and that it is the carbon emission *per unit of produce* over the transport chain that really matters. The concept of food miles has undoubtedly served an important ideological and political role in highlighting the importance of carbon footprints in the food system. To that extent it has been a useful device in the wider sustainability debate. But it is now time for businesses and consumers to adopt a more broadly conceptualised carbon accounting life cycle assessment. Riverford Organics, as one of the most well known suppliers of organic produce, is playing a leading role in developing an appropriate methodology for this.

We have found that if a customer drives a round-trip distance of more than 7.4 km in order to purchase their organic vegetables, their carbon emissions are likely to be greater than the emissions from the system of cold storage, packing, transport to a regional hub and final transport to customer's doorstep used by large-scale vegetable box suppliers. This suggests that with regard to such emissions, some of the ideas behind localism in the food sector may need to be revisited. But such a conclusion needs to be seen in the broader context of sustainability, as indicated in the introduction to our paper.

Sonnino and Marsden (2006) have argued that it is mistake to see 'alternative' and 'conventional' food networks as separate spheres. Instead there are a range of competing agri-food geographies built upon "different sets of quality and commercial conventions and different degrees of horizontal and vertical embeddedness" (Sonnino and Marsden, 2006, 196). The food consumer is not confronted simply with a choice between 'local-good' and 'global-bad'. As our data in this paper, shows purchasing the most geographically local produce per se does not necessarily mean the lowest carbon impact. Many factors are involved. Nor is carbon the only way to evaluate the impact of purchasing decisions. We might also need to factor in the implications for biodiversity and landscape, for local employment, for fair trade and for international social justice. The claims for the heuristic value of the concepts of food miles and of local food systems need to be seen in the context of careful evidence-based case studies of the type given in this paper. At the same time we cannot expect consumers to take into account life cycle analysis of every product they buy, nor indeed that public or private sector bodies can afford to conduct such exercises for every product or retailing systems. What is needed is a sophisticated public debate on food systems in which catch phrases, such as 'food miles', which were useful to initially capture media attention, now give way to more nuanced approaches based on strategic case studies of specific retail systems and/or key commodity sectors.

Acknowledgements

The research on which this paper is based was undertaken as part of a KTP research project. We acknowledge both Riverford Organics and the UK Department for Business, Enterprise and Regulatory Reform for their sponsorship of this research.

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