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Farm costs and food miles: An assessment of the full cost of the UK weekly food basket

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Abstract

Changes in both farm production and food transport have resulted in the imposition of new levels of environmental costs. This study analyses the full costs of foods in the average weekly UK food basket by calculating the costs arising at different stages from farms to consumers' plates. Of the 12 commodities assessed, livestock produce contributes the most costs per kg. The external cost of UK agriculture up to the farm gate is estimated to be £1.51 bn yr^{-1}; it is calculated that a switch to organic production could lead to avoided costs of £1.13 bn yr^{-1}. Agricultural and food produce accounts for 28% of goods transported on UK roads, currently imposing estimated external costs of £2.35 bn yr^{-1}. The contribution made by sea and air transport is currently trivial owing to low volumes. However, road transport to carry food from the shop to home is estimated to impose a further £1.28 bn yr^{-1} to total external costs. Subsidies not targeted at environmental improvements cost consumers £2.88 bn yr^{-1}. Thus the real cost of the per capita UK food basket (£24.79) is calculated to be £2.91 more per person wk^{-1} (11.8%) if externalities and subsidies are included, with farm externalities (81 p), domestic road transport (76 p), government subsidies (93 p) and shopping transport (41 p) contributing the most. We assess a variety of scenarios for adoption of organic farming, localised food systems and sustainable transport to indicate the substantial potential to reduce environmental costs in the UK food system.

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Evaluating farm and food systems in industrialised countries

Recent years have seen growing concern about the sustainability of agricultural and food systems and the unintended side-effects that can be imposed on the environment and human health (Conway and Pretty, 1991; Pretty, 1995, 2002; NRC, 2000; Uphoff, 2002; Lang and Heasman, 2004). There are many perspectives on what constitutes sustainability and how it can be applied equally across agricultural contexts (Naess, 1992; Dobson, 1999; Pretty et al., 2003a). As a result, a variety of analytical approaches have been developed, including energy accounting (Leach, 1976; Cormack and Metcalfe, 2000; Carlsson-Kanyama et al., 2003), economic valuation of non-marketed goods and services (Pearce and Turner, 1990; Daily, 1997; Costanza et al., 1997; Pretty et al., 2000, 2001), ecological footprints (Rees, 2003), carbon accounting (Smith and Smith, 2000; Lal et al., 2004), and the use of indicators for sustainability (Lewis et al., 1997; Bailey et al., 1999; OECD, 1998; MAFF, 2000; Caporali et al., 2003).

Most of these approaches have focused on environmental impacts up to the farm gate, and have not assessed the additional environmental effects of transporting foodstuffs via processing to retail outlets and then to the point of consumption. Evidence is mounting that these farm to plate transport costs, or 'food miles' (Raven and Lang, 1995; Subak, 1999; Jones, 2001; Pirog et al., 2001; Garnett, 2003; Stephens et al., 2003), could be substantial. In addition, there is growing interest in local and regionalised food supply systems and the potential social and environmental benefits they could bring (Marsden et al., 2000; Cowell and Parkinson, 2003; Morris and Buller, 2003; Sage, 2003; Winter, 2003).

In this study, we assess the full cost of the UK weekly food basket by analysing the environmental costs to the farm gate for each major food commodity, and the additional environmental costs of transporting foods to retail outlets, and then to consumers' homes, and the cost of disposal of wastes. We then develop various production and transport scenarios to assess the best cost-avoidance options, and indicate where policy priorities should lie in the light of the findings.

The externalities arising from farm and food systems point to some important policy priorities for industrialised countries in Europe, North America and the OECD, where there are many similarities in both farm technologies and distribution systems for food. Important drivers that may differ from country to country include the quality and types of food eaten (as costs vary greatly according to commodity), the amount of farm inputs used that result in external costs, the average distance travelled by food from farm to plate, and the proportion of foods imported that impose externalities in other countries, thereby effectively exporting costs (Lang and Heasman, 2004). Some of these costs could be avoided with the adoption of more sustainable farming and food distribution systems.

The external benefits of agricultural systems include a wide range of unpriced goods and services, such as recreation and amenity value of landscapes, water holding capacity, carbon sequestration, wildlife and biodiversity, and contributions to rural economies and communities (Bollman and Bryden, 1997; Pretty et al., 2002; Pretty, 2002, 2004; Renwick et al., 2002; Dobbs, 2004). We do not address here the contributions that agricultural and land use systems make to positive externalities, and so do not seek to make any cost-benefit comparisons. There is a danger that this will appear to bias our analysis against modern agriculture. These positive side-effects are known to be substantial: for example, some 550 million day-visits are made to the countryside each year by urban people who derive value and pleasure from the farmed landscape. However, no study has yet put an aggregate value on the positive externalities. In this study, we therefore do not make any judgement about the comparative differences in contribution that conventional and organic farms make to positive externalities.

Environmental costs to the farm gate

The environmental costs of farming have been recently assessed for the UK (Pretty et al., 2001, 2000; Hartridge and Pearce, 2001; EA, 2002), Germany (Waibel et al., 1999), and the USA (Pimentel et al., 1995; Subak, 1999; Tegtmeier and Duffy, 2004). For this study, earlier data on UK farm externalities (Pretty et al., 2001, 2000; Hartridge and Pearce, 2001; EA, 2002) were reassessed by incorporating new data on eutrophication, greenhouse gas costs, energy embodied in inputs, and BSE (Renwick et al., 2002; Pretty et al., 2003b; Defra, 2004). The methods used in these studies are largely cost-based rather than demand-based, and involve use of replacement costs (e.g. hedgerows, wetlands), substitute goods (e.g. bottled water), loss of earnings (e.g. due to ill-health), and clean-up costs (e.g. removal of pesticides and nitrate from drinking water). Demand-based methods using willingness to pay (or be compensated) have tended to be used in studies to put a value on landscapes (Hanley et al., 1998).

One problem with all such studies is the difficulty of baselines and absolute costs. For example, if there were no livestock, then methane costs would be very much reduced. But if there were no agriculture, then there would still be an amenity value arising from the landscape. Thus these costs of agriculture are relative to an artificial baseline of zero. For our purposes here, the comparison between different agricultural systems (conventional and organic) provides an escape from this artificiality.

The UK studies indicate that total agricultural environmental and health costs are some £1514 M for the year 2000 (35% lower than originally calculated in Pretty et al., 2000). Some costs remain impossible to assess, such as antibiotic resistance arising from prophylactic use in livestock systems, and the chronic health effects of pesticides, and these are not included.

In Table 1, we compare the external costs of the current agricultural system with those that would arise were the whole of the UK farmed with organic production systems. The choice of this scenario is not because organic is the only form of agricultural system that is more sustainable than current practices, but because it has a well-defined system of standards (EC, 1991; FAO/WHO, 2001; IFOAM, 2000). Organic agriculture is a defined and certified system of agricultural production that seeks to promote and enhance ecosystem health whilst minimising adverse effects on natural resources. It is seen not just as a modification of existing conventional practices, but

Table 1
The negative externalities of UK agriculture (year 2000)

Source of adverse effects	Actual costs from current agriculture (£ M yr^{-1})	Scenario: 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
Off-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 micro-organisms and BSE	432.6	50.4
Totals	£1514.4	£384.9

Sources. Adapted from Pretty et al. (2000), Hartridge and Pearce (2001) and EA (2002).

as a restructuring of whole farm systems (Lampkin and Padel, 1994; FiBL, 2000; Sciallaba and Hattam, 2002; Caporali et al., 2003; Reganold, 2004). In 2003, there were 4104 organic farms in the UK covering some 741,000 ha (Defra, 2003). We used standard organic protocols to estimate the contribution that would be made to total costs by each of the ten sectors listed in Table 1. Pesticide costs arising from drinking water contamination and adverse effects on human health are assumed to fall to zero under an organic farming regime, as are any costs associated with BSE. Most of the other sectors would see declines in costs compared with conventional farming, but not to zero. Our assumptions on these are as follows:

(i) for drinking water, nitrate costs are assumed to fall by 20%, phosphate and soil losses by 75%, zoonoses by 20%, eutrophication by 75%, with monitoring costs remaining the same;
(ii) for gaseous emissions, methane costs from livestock are assumed to fall by 5%, ammonia by 25%, nitrous oxide by 80%, carbon dioxide from fuel use remains the same, and indirect emissions through reduced use of fertilizers and pesticides by 88%;
(iii) for soil costs, off-site damage is assumed to fall by 20%, and carbon dioxide losses in organic matter by 75%;
(iv) for biodiversity and landscape losses, costs are assumed to fall by 75% for wildlife, and by 90% for hedgerows losses, though remain the same for bee colonies;
(v) for micro-organisms and disease-agents, costs are assumed to fall by 75%.

We estimated that a complete switch to organic agriculture could lead to cost-avoidance (i.e. benefits compared with current agricultural systems) of £1129 M yr^{-1}.

These aggregate costs were used to calculate the costs for each of the twelve major arable, horticulture and livestock food commodities produced in the UK (cereals, potatoes, oil seed rape, sugar beet, fruit, vegetables, beef/veal, pork, poultry, mutton/lamb, milk and eggs). We assessed 19 categories of environmental costs for each of these 12 commodities, and calculated the relative contribution of each commodity to each cost category. In some cases, there is only one source for a problem (e.g. BSE from cattle); in others, there are multiple sources (e.g. nitrate from crops and livestock systems). We used various Defra datasets on area devoted to each commodity, on animal numbers, on input-use and on emissions to calculate these proportional contributions from each commodity (mean values taken for 1999–2001). In the UK, there are 4.89 M ha of arable, and 6.67 M ha of grassland (not including rough and hill grazing).

The basis for the allocations of each of the categories of negative externalities to the 12 crop and livestock commodities were as follows (see Pretty et al., 2000, 2001 for full details and references for each category):

1. Of all pesticide costs, 80% were allocated in proportion to area of each arable crop, and the remaining 20% evenly spread across all livestock categories.
2. Nitrate costs were allocated in proportion to area of each crop commodity and grassland for livestock.
3. Phosphate and soil erosion costs were allocated mainly to arable crops (91%), with an allocation to pigs for leaching (9%).
4. One third of *Cryptosporidium* costs were allocated to each of milk, beef and sheep, as the pathogen does not occur in pigs or poultry.
5. Eutrophication costs were allocated in proportion to area of crops and grassland.
6. Monitoring costs were allocated in proportion to area of all crops and grass.
7. Some 89% of agricultural methane emissions arise from enteric animals (75% from cattle, 25% from sheep), while the remaining 11% arises from manures of all animals (costs are equally allocated); and thus milk is calculated to contribute 35% to methane costs, beef/veal 35%, mutton/lamb 25%, and pork and poultry 2.5% each.
8. Ammonia costs arising from livestock wastes were allocated 20% each to milk, beef, pork, poultry and sheep.
9. Nitrous oxide costs were allocated in proportion to area of crops and grassland.
10. Carbon emitted from fossil fuel use (mostly for vehicles) was in proportion to area of crops and grassland, with costs adjusted up (double their proportional contribution) for pigs, poultry and eggs (owing to energy used in housing), and down by half for sheep (which are mostly outdoors).
11. Indirect energy costs arising from the manufacture of pesticides and fertilizers were allocated in proportion to the areas of crops and grassland.
12. Offsite soil erosion costs were allocated in proportion to the areas of crops and grass.

13. Organic matter carbon losses were allocated in proportion to just arable area (it is assumed that losses from grassland are negligible).
14. Biodiversity and wildlife costs were allocated in proportion to the area of crops and grassland.
15. Costs arising from losses of landscape features were allocated in proportion to area, with greater losses of hedgerows assumed to occur in arable rather than under beef/sheep.
16. Bee colony losses were proportional to just arable area.
17. The costs arising from acute pesticide adverse effects were allocated to 50% for sheep dips, 40% for cereals, and the remainder spread amongst remaining crops.
18. Some 75% of the costs to consumers from outbreaks are assumed to arise after the farm gate, and of the remaining quarter pathogenic outbreaks in food, some 90% are from livestock produce, and 5% each from fruit and vegetables.
19. BSE and new variant CJD costs were allocated to cattle alone.

The total costs arising from the cultivation and raising of each of the 12 commodities are shown in Table 2, together with the unit costs per kg, litre or dozen eggs using average UK production data for 1998–2001 (Table 2). The same series of calculations are shown for an organic production scenario. On a per kg basis, livestock produce imposes the greatest costs: beef/veal 64.8 p kg^{-1}, mutton/lamb 43.6 p kg^{-1}, pork 12.8 p kg^{-1}, poultry 5.68 p kg^{-1}. Oil seed rape imposes the highest costs for arable and horticultural produce (3.45 p kg^{-1}), followed by cereals (1.72 p kg^{-1}), fruit (1.44 p kg^{-1}), vegetables (0.61 p kg^{-1}), potatoes (0.42 p kg^{-1}) and sugar beet (0.22 p kg^{-1}). Some of these external costs are a significant proportion of the price received

Table 2
External costs to the farm gate for 12 food commodities grown and raised in the UK

Produce	External costs from conventional agriculture		Scenario: as if whole of UK was organic		Proportional change in external costs from conventional to organic (%)
	Total external cost (£ M yr^{-1})	Unit external costs (p kg^{-1})	Total external cost (£ M yr^{-1})	Unit external cost (p kg^{-1})	
Cereals	377.5	1.72	71.1	0.32	−18.6
Potato	28.2	0.42	3.5	0.05	−11.9
Oil seed rape	49.9	3.54	9.7	0.69	−19.5
Sugar beet	20.6	0.22	3.7	0.04	−18.2
Fruit	4.6	1.44	0.8	0.25	−17.4
Vegetables	17.6	0.61	3.0	0.10	−16.4
Beef/veal	441.9	64.79	82.5	12.09	−18.7
Pork	127.3	12.81	37.6	3.79	−29.6
Poultry	87.5	5.68	29.4	1.91	−33.6
Mutton/lamb	157.8	43.57	59	16.3	−37.6
		(p litre^{-1})		(p litre^{-1})	
Milk	171.2	1.22	73.3	0.52	−42.6
		(p dozen eggs^{-1})		(p dozen eggs^{-1})	
Eggs	30.3	3.96	11.3	1.44	−36.4

for commodities. For example, the 1.72 p kg^{-1} external cost for cereals represents a value of 17.7% of the average UK price of wheat in the first half of 2004; the 3.96 p dozen $eggs^{-1}$ is 6.3% of average 2003–04 UK price; and the 0.42 p kg^{-1} external cost for potatoes is 3.0% of the average 2003–2004 UK price (Defra, 2004).

With these unit costs for food commodities, it is now possible to reassess the full costs of each of the components of the weekly UK food basket.

The weekly food basket

The National Food Survey (NFS) and the Food Expenditure Survey (FES) (combined in 2003 as the Expenditure Food Survey) record data on weekly consumption and expenditure for each item of food in the average domestic food basket (Defra, 2002a,b). On average, each person in the UK consumes in the home 10.02 kg of food wk^{-1}, and this costs £17.26 wk^{-1} (average for 1999–2000). In addition, individuals spend £7.53 wk^{-1} on eating out (an average of three times per week), bringing the total weekly expenditure to £24.79 (eating out is 30% of food expenditure) for 11.68 kg of food (see Table 3).

These data are obviously aggregate commodity costs for the whole of the UK and its food system. There will, however, be geographic and income-group variations according to choice of food consumed and expenditure. The average weekly food basket in Scotland is 4.4% less than the UK average, 6.8% less in Wales, 1.2% less in Northern Ireland, and 0.8% more in England. The most expensive two regions of England are London at £19.53 (+10.7%) and the South East at £20.35 (15.4%), and the least expensive are Yorkshire and Humberside at £16.08 (−9.1%) and the North East at £16.13 (−8.6%). Households earning >£725 gross wk^{-1} spend £22.03 (+24.9%), while those earning £180–375 spend 10.6% less, and those on <£180 spend 20.3% less (Defra, 2002a,b).

In order to relate external commodity costs (in pence kg^{-1}, p l^{-1} and p dozen $eggs^{-1}$ produced) to the environmental costs arising from the food choices made by consumers, several adjustments were made to account for losses in the supply chain and distortions arising from imbalances in imports and exports. A loss factor for each food product was calculated, as some produce is fed to animals (e.g. 73% of all cereals are fed to livestock: 1.49 Mt to cattle, 0.45 Mt to pigs, 0.13 Mt to poultry, 0.097 Mt to sheep, for a total of 2.16 Mt in 1999–2000), some is lost as waste, some is converted into secondary products or prepared meals (e.g. wheat to flour to bread, barley to beer), and some is disposed to landfill. Using the two national food surveys, weekly consumption data for the UK population of 59.64 M people were compared with national domestic agricultural production data to calculate a loss factor for each commodity.

In addition, further adjustments for imports and exports of foods have been made. Some of the farm externalities incurred in the UK are for food produced in the UK that is then exported, and some of the food consumed is from imported produce where farm externalities are incurred in overseas agricultural systems. Here we make an adjustment to account for externalities only incurred in the UK

Table 3
Components of UK weekly food basket and expenditure per person, plus price of each component including externalities to farm gate

Components of food basket	Consumption (home + eating out) g person^{-1} wk^{-1}	Expenditure (p person^{-1} wk^{-1})	Price including externalities from current agriculture (p person^{-1} wk^{-1})	Price including externalities if all organic agriculture (p person^{-1} wk^{-1})[a]
Liquid milk	751	37.6	39.4	38.4
Other milk and cream	1401	103.7	107.2	105.2
Cheese	135	72.4	91.3	75.9
Fats/oils	196	37.9	39.3	38.2
Eggs (no.)	1.72	17.3	18.4	17.7
Beef/veal	142	72.9	93.0	76.7
Lamb/mutton	68	33.1	39.5	35.5
Pork	83	32.2	33.1	32.5
Poultry	262	91.3	94.6	92.4
Bacon/other meat	487	222.5	227.7	224.1
Fish	166	97.3	97.3[b]	97.3[b]
Fresh potatoes	797	39.5	40.7	39.7
Fresh green vegetables	273	40.2	40.4	40.3
Other green vegetables	526	69.8	70.1	69.9
Processed vegetables	578	107.3	107.7	107.4
Fresh fruit	738	96.0	96.9	96.1
Other fruit and fruit products	373	42.7	43.2	42.8
Sugar and preserves	139	14.3	14.4	14.3
Bread	804	83.9	87.8	84.6
Cakes and biscuits	285	84.2	85.5	84.4
Other cereals and cereal products	544	140.4	143.1	140.9
Beverages (tea, coffee)	405	401.9	401.9[c]	401.9[c]
Other foods	387	77.1	79.0	77.4
Ice cream & products	139	25.6	26.0	25.8
Soft drinks (ml)	1129	74.2	74.9	74.4
Alcoholic drinks (ml)	806	322.6	326.5	323.3
Confectionary	72	41.5	41.6	41.5
Total[d]	11.68 kg	£24.79	£25.60	£24.98
Increase in price over actual paid			3.27%	+0.77%

[a] Organic scenario does not include price premiums
[b] Fish: no data on externalities costs from capture fisheries or aquaculture.
[c] No costs allocated for tea/coffee as grown overseas.
[d] Totals may not sum due to rounding.

to reflect environmental costs imposed by the current agricultural and food system and its mixture of exports and imports. It is important to note, however, that individual countries could reduce the negative environmental impacts of their agricultural systems by ceasing domestic production and switching to importing food. This would not lead to net environmental benefits at the global scale if this simply displaced externalities. Alternatively, if the overseas production systems were more environmentally-beneficial in comparison with domestic ones, then there may be a net environmental benefit (after transport costs were also accounted for). Here we simply take account of the current export–import patterns to reflect where domestic costs are imposed.

Using Defra data (mean 1999–2000) on imports and exports of the 12 commodities, ratios for domestic produce as a proportion of total consumption were calculated for each commodity. Only two have a ratio of <1, indicating that they are net exported (cereals 0.91, oil seed rape 0.82), the remainder varying from 1.04 for sheep products (where imports and exports are almost balanced) to 9.62 for fruit (where imports greatly exceed exports). Total annual food commodity movements are 19.6 Mt, comprising 12.2 Mt yr^{-1} for imports and 7.4 Mt yr^{-1} for exports, of which swapped commodities (with technically the same produce both imported and exported) amount to 5.23 Mt yr^{-1}. For example, 0.48 Mt of pork is imported each year, while 0.21 Mt is exported; 0.41 Mt of milk is imported and 0.43 Mt exported; and 0.13 M sheep are exported while 0.12 M are imported. Not all this produce is entirely substitutable, as imports and exports may be of different meat cuts or different types of animal. However, it is likely that commodity transport movements could be reduced.

After adjustments for losses in the food chain and for imports–exports, costs for p kg^{-1} consumed rather than p kg^{-1} produced were calculated. These were applied to each item of food consumed in the weekly food basket, giving a total of 81.2 p wk^{-1}, or an additional 3.27% on the price of the weekly food basket, raising the real cost including environmental externalities to the farm gate to £25.60 (Table 3). In the food basket, no externalities for fish consumption were calculated, as there were no appropriate data, and none were added for overseas produce (e.g. coffee, tea) where farm externalities have not occurred in the UK. However, if this 81.2 p were multiplied by the total UK population, then it would wrongly imply costs greater than the £1514 M yr^{-1} calculated for farm externalities. This is because imports to the UK are greater than exports, and so externalities arising from total consumption are greater than from production alone.

The costs for a wholly organic food basket scenario were also calculated (Table 3). We assume that this organic food basket has the same constituents as the average UK food basket, and that prices do not affect these proportions. These costs amount to an additional 19.45p in environmental costs to the farm gate, or equivalent to an extra 0.79% on the price paid for the food basket. But consumers already pay a premium on organic food at most retail outlets, so their food basket already costs more than conventional food. Retail price data on each food product (Hamm et al., 2002; Ross, 2002) were used to calculate the cost of an identical but organically-sourced food basket. Two sources were compared: (i) supermarkets, where the average premium is 53%; and (ii) local box schemes and farm shops, where the average premium is 31%. The weekly food basket would cost £39.37 if bought at a supermarket (59% more than conventional), and £33.39 if bought via the local scheme (35% more than conventional).

Price premiums could be justified on the grounds that they cover the additional costs incurred by organic farmers in avoiding damage to the environment (though in practice higher prices arise because of the demand for organic products relative to supply). But the difference between farm externalities for the organic compared with conventional food basket (81.2 less 19.45 $p = 61.75$ p) is very much smaller than the premium charged to consumers (£14.58 at supermarket; £8.59 at local scheme). One explanation is that retailers, manufacturers and/or farmers are charging more as they believe some consumers will pay more. The difference can only be partially explained as representing the value of on-farm natural capital being built by farmers through improvements to soils, biodiversity, and landscape.

Transport to retail outlets

Vehicle transport imposes various environmental, social and health costs, and these have been calculated for the UK in pence per vehicle km (p vkm^{-1}) for various types of vehicle and the cost categories of congestion, harm to health (noise, asthma), climate change (from greenhouse gases) and infrastructure damage (Nash and Salmon, 1999; Dodgson et al., 2002). These costs are shown in Table 4.

National statistics record three measures for freight transport: bn t-km travelled, Mt of goods lifted and vkm travelled, and all measures have increased in recent years (DLTR, 2002; EEA, 2003). Between 1980–1982 and 2000, bn t-km for all goods rose by 65% to 149.3; Mt lifted by 23% to 1580; and vkm by 41% to 22.2 billion. Agri-food products (food, drink, tobacco, fertilizer) now account for 28.1%, 28.1% and 28.8% of these totals respectively (up from an average of 25.1% in 1980–1982). This is despite the fact that retail logistics are now claimed to be the most efficient in the world, with more centralised distribution centres, just-in-time stock management, factory gate pricing, information technology innovation, increased backhauling and more home deliveries (IED, 2003; Garnett, 2003).

Adjusting for the proportion of freight transported in different size vehicles (16% for 3.5–17 t; 39% for 17–33 t; 43% for >33 t) (DLTR, 2002), the total externalities of movement to retail outlets of agricultural produce is calculated to be £2348 M yr^{-1}. This is equivalent to £39 $person^{-1}$ yr^{-1}, or 75.7p wk^{-1}. With farm externalities, this now increases the real cost of the weekly food basket to £26.37 (a 6.4% increase).

National transport statistics already include a factor for empty running, more than a quarter (26.4%) of all vehicles on the roads are recorded as running empty (DLTR, 2002). In addition, only 59% of space is filled (the lading factor). Thus one tonne moved 1 km effectively travels 1.69 (i.e. 1/0.59) $\times$ 1.264 = 2.14 km, or each aver-

Table 4
Environmental and health costs (in pence) per vehicle kilometre for various modes of transport

Vehicle type	Costs (p per vehicle km)
Car	11.95
Light commercial	13.71
Heavy goods vehicle (rigid)	31.57
Heavy goods vehicle (articulated)	42.92

Sources. Nash and Salmon (1999) and Dodgson et al. (2002).

age km travelled carries only 46.7% of total possible load. Thus, as 26.4% of vkm are empty, some £619 M yr^{-1} of food mile costs could be avoided if vehicles were run to full capacity.

Domestic data do not include air, ship and truck transport from overseas sources. However, climate change contributed by this overseas transport does affect UK consumers, and so data for carbon emissions from fossil-fuel consumption (C $t\text{-}km^{-1}$) (Gover, 1994; DLTR, 2002) and their marginal damage costs (Hartridge and Pearce, 2001) (£29.8 tC^{-1}, 2.98 p per kg of carbon as C) were used to calculate additional climate change costs per t-km. A factor for congestion, health or infrastructure for overseas transport is not included, as they do not directly affect consumers in the UK.

The produce imported by sea to the UK amounts to 388 Mt yr^{-1}, of which food, drink and agricultural inputs are 18.6 Mt. The costs per t-km for sea transport are 0.0082 p $t\text{-}km^{-1}$ (for 2.74 g C $t\text{-}km^{-1}$). Assuming a conservative average of 10,000 km per trip (by ship, New Zealand is 23,000 km distant, Australia 21,500 km, California 16,300 km, Netherlands 100 km, and Denmark 1200 km), then these 186 bn t-km incur costs of £15.25 M yr^{-1}. These costs are very small (0.65% transport of foods on domestic roads in the UK to retail outlets).

There are, however, concerns that air miles may be making a significant contribution to environmental costs. In 1998, there were 100 bn t-km of goods transported by air in 1998 worldwide (IPCC, 1999; Defra, 2001; DETR, 2000; DOT, 1991). UK airfreight (imports + exports) was 2 Mt for 1998, of which imports of fruit and vegetables were only 0.114 Mt yr^{-1}. For air trips, an average distance travelled of 8500 km was assumed (South Africa is 9600 km distant; New Zealand 18,800 km; Chile 11,700 km; Mexico 8900 km; Zambia 7900 km; Argentina 11,100 km; California 8800 km). With costs per t-km of 0.46 p $t\text{-}km^{-1}$(156 g C $t\text{-}km^{-1}$), then this gives a total of 0.97 bn t-km and an external cost of £4.46 M yr^{-1}. If all air freight travels in dedicated freight planes, then the full costs are incurred (every extra kg consumed requires extra space). But some air freight is carried in the belly of passenger planes, so does not technically incur the full marginal cost – just the extra fuel required to haul the additional freight. Globally, 50% of air-freight is in the belly of passenger planes (Garnett, 2003), and so the external costs of air imports of fruit and vegetables is only £2.23 M yr^{-1}. Once again, this is trivial compared with the environmental costs of domestic transport (0.09% of domestic road costs). However, it is important to note that if all of the weekly food basket were transported by air, then the additional environmental costs would become severe. It is only because of the low volume at present that these costs remain relatively low.

Transport of food to home and to landfill

Once the food is at the retail outlet, consumers still have to transport it home for consumption. National statistics on shopping trips and the environmental costs of transport for cars, buses, walking and cycling were used to calculate the cost for shopping for food (Dodgson et al., 2002; Defra, 2002d). Each person in the UK made 221 shopping trips per year in 2000 (up from 210 in 1985–1986), with an average length of 6.4 km (up from 4.6 km), resulting in a total travel of 1414 km yr^{-1} (up from 978 km yr^{-1} in 1985–1986). Of these shopping trips, 58% were made by car, 30% by walking, 8% by bus and 3% cycle. The 221 trips are equivalent to 4.25 per person wk^{-1}.

Assuming that only half of trips are solely for food, and that food shopping is per household rather than per person (the food basket is per person, and on average there are 2.32 persons per household), then 110.5 trips are made per household per year for food. As the average distance is 6.4 km, these trips cover 706 km yr^{-1} for food, or 13.6 km per week. Of these, 7.89 km are by car (at cost of 11.95 p vkm^{-1}), 1.09 are by bus (at 33.57 p vkm^{-1}, but with 30 people per bus), and 4.49 km are by walking and cycling (at zero cost). This gives a total cost for transport to home of 95.43 p $household^{-1}$ wk^{-1}, 41.1 p $person^{-1}$ wk^{-1}, and an aggregate of £1275.7 M yr^{-1}.

Each person produces 74 kg of domestic organic waste per year (Defra, 2002d; Strategy Unit, 2002). Each household throws away 3.29 kg wk^{-1}, plus an additional 4.06 kg wk^{-1} of food packaging, resulting in a total disposal of 9.8 Mt yr^{-1}. As each garbage truck carries some 10 t when compressed, and travels 23 km from depot to pickup to landfill site (DLTR, 2001), then these loads at an environmental costs of 31.57 p vkm^{-1} incur aggregate costs of £7.12 M yr^{-1} or just 0.002 p $person^{-1}$ wk^{-1}.

The issue of subsidies

Subsidies can be seen to be part of the full cost of food, as they are payments from taxpayers to farmers. They are not externalities, but can exacerbate them by increasing output beyond that which would be dictated by market conditions. Public subsidies can be progressive, as the wealthy pay more tax than the poor, and the benefits of the subsidies are equally spread amongst food consumers (though some food production systems have not to date received public support, e.g. pigs, vegetables). Subsidies only have their full effect if they encourage the production of public goods (or positive externalities) that are available to consumers. But until 2004, formal subsidies have mostly supported agricultural production systems that give rise to adverse environmental effects, and so must logically be seen as perverse. Annual support for organic farming amounted to £6–18 million per year for 1999–2000 and 2000–2001.

The average annual UK government subsidy for all agriculture in 1999–2000 and 2000–2001 was £3.102 billion (Defra, 2002c). We did not use data for 2001–2002 as this included an additional £2 bn for foot and mouth disease, giving a total of £5.26 bn. For each person in the UK, the £3102 M represents an additional cost of £52 yr^{-1}, or £1 per week. However, some £219 million of this total was used for rural development and agri-environment schemes intended to create positive externalities (Defra, 2002c). Assuming that these are successful, we removed them from total costs to leave total subsidies of £2883 M yr^{-1}, which is equivalent to 93 p $person^{-1}$ wk^{-1}.

The full costs and scenarios for cost-avoidance

Table 5 contains a summary of our estimates of the full costs paid by UK consumers for their food basket. The weekly food basket rises in cost from the £24.79 paid by consumers by £2.91 per person wk^{-1} (11.8%), with farm externalities (81.2 p), domestic road transport (75.7 p), government subsidies (93 p) and shopping transport (41.1 p) contributing the most. Sea and air transport and transport to landfill are very small contributors to overall cost. This amounts to additional costs of £8045 million yr^{-1} to the whole food system.

This could be an underestimate of the full costs, as many environmental side-effects in the food chain have not been assessed here. These include energy consumed by processors, manufacturers and wholesalers for light, heat, refrigeration and transport, disposal of food packaging, foods consumed by domestic pets, methane emissions from landfill and sewage waste, and the energy required for domestic cooking. In addition, we have not assessed the health consequences of the dietary choices made for the weekly food basket (Kenkel and Manning, 1999; Ferro Luzzi and James, 2000; Rayner, 2001; Wanless, 2004). Such diet-related ill-health is costly, but clearly not a direct consequence of types of agricultural systems.

Another source of error arises from recent changes in farm practices, with many farms adopting environmentally-sensitive practices in recent years, and so our estimates of environmental costs may be too high. At the same time, transport distance to retail outlets and by shopping is increasing, and so these costs may be

Table 5
Summary of components of full costs of the UK food basket (average for 1999–2001)

	Annual costs (£ M yr^{-1})	Costs per person (p $person^{-1}wk^{-1}$)	Proportion of total externalities (%)
Agricultural externalities	1514	81.2[a]	18.8
Domestic road transport (from farm to shop)	2348	75.7	29.2
Sea, internal water and air transport for imports	17	0.005	<0.01
Shopping (from shop to home)	1276	41.1	15.8
Waste disposed to landfill	7	0.002	<0.01
Total externalities	5162	198	
Government subsidies	2883	93	
Price paid for food basket (including eating out)	89,500	2479	
Full cost of food basket (total externalities and subsidies)	8045	291	–
Full cost (including externalities and subsidies)	97,545	2770	–

[a] The agricultural costs per person are not simply annual costs divided by population, as account has been taken of imports and exports to and from the UK.

Table 6
Avoided costs under different scenarios for adoption of organic farming, localised food systems and more sustainable transport options

Scenarios	Current external costs (£ M yr^{-1})	Revised total external costs under each scenario (£ M yr^{-1})	Revised per capita external costs under each scenario (p $person^{-1}$ wk^{-1})	Avoided costs with new farm and/or transport strategies (£ M yr^{-1})
A. Farm externalities				
A1. All farms organic (from Table 1)	1514	385	19.5	1129
B. Transport to retail outlet				
B1. Local food system (all less than 20km)[1]	2348	229	7.4	2119
B2. National with maximised rail[2]	2348	842	27.2	1506
B3. All continental Europe[3]	2348	3374	108.8	(1026)[10]
B4. All global ship[4]	2348	2712	87.4	(364)[10]
B5. All global air[5]	2348	19,708	636.1	(17,360)[10]
C. Transport to home				
C1. Shopping all by cycle/walk[6]	1276	0	0	1276
C2. Car shopping replaced by bus[7]	1276	126	4.1	1150
C3. Car and bus replaced by home delivery[8]	1276	549	17.7	727
D. Waste				
D1. All organic material composted[9]	7	0	0	7

[1] All of food basket sourced from within 20 km of retail outlet.
[2] 80% of food travels by rail (with zero congestion costs) and 20% by road, and that costs are 56 g C t-km^{-1} by road (large truck) and 11.1 g C t-km^{-1} by rail.
[3] All food sourced within continental Europe, travelling an average of 1500 km, then 444 Mt (at 25 t carried per vehicle) would require 17.76 M vehicles to travel 26,640 M km yr^{-1}; and using an external cost of 1.8 p t-km^{-1} (just climate change costs are included, as congestion, health and infrastructure damage occurs elsewhere in Europe), and multiplying by the ratio of 2.14 (for empty running and lading factor).
[4] All food imported by sea, and that 10,000 km travelled, then 4440 billion t-km would be carried at 0.0082 p t-km^{-1}.
[5] All food imported by air, and that 8500 km travelled, then 3774 billion t-km would be carried at 0.46 p t-km^{-1}.
[6] Cycling and walking incur no transport externalities (we do not count the health benefits of exercise here).
[7] All current car transport replaced by bus (and 33% still by walking and cycling.
[8] All car and bus transport replaced by home delivery, and assuming a 60 km round trip once per week to 20 households, and costs for LDVs at 13.71 p v-km^{-1}.
[9] All organic food waste is composted at the home.
[10] (brackets) indicates an increase in costs.

underestimates. A further source of uncertainty arises from the comparison of organic and conventional systems, as we have relied on assumptions that certain practices would guarantee certain environmental outcomes. This may not prove to be true, for example, if organic farming were to be much more widespread than at present.

An important policy question centres on what might be done to avoid some of these costs through adoption of more sustainable methods of food production, localised food systems, and more sustainable methods transport, such as substituting bus for car, ship for air, rail for road, and reducing empty running and unfilled vehicles.

We calculated the benefits of various scenarios for changes in farm practice, transport to retail outlets, transport to home and for waste disposal (Table 6). If the food basket were all organic and subsidies all used for agri-environmental purposes (as can eventually be expected following the reform of the Common Agricultural Policy), and that food were locally-sourced or predominantly transported by rail, and then transported home by walking/cycling, bus or home delivery, then external costs would fall from 11.8% of the food basket to 1.1–1.8%, saving each person in the UK £2.41–2.65 wk^{-1}. The saving would be less if the food basket was all conventional (Table 7). If all food were sourced within 20 km of homes or other places of consumption, then we estimate that £2119 M of environmental costs would be avoided.

But if an entirely organic food basket was sourced from continental Europe and transported by current transport modes, then the avoided costs to the farm gate would be offset by the transport costs (though any farm costs would be incurred outside the UK). Furthermore, produce entirely globally-sourced by air would increase

Table 7
Comparison of various transport scenarios for conventional and organic food baskets

	Total cost of individual food basket (price + externalities) (£ wk^{-1})	% increase in total cost over price paid	Saving per person over current full costs (£ wk^{-1})
Total current food basket costs (price + externalities arising from conventional agriculture, national and car transport, waste to landfill, and subsidies)[a]	£27.71	11.8	–
Current food basket with different transport scenarios			
+ local food + walk/cycle	£26.60	7.3	£1.11
+ local food + home delivery	£26.78	8.0	£0.93
+ local food + bus	£26.65	7.5	£1.06
+ national road + car	£27.70	11.7	£0.01
+ national rail + bus	£26.84	8.3	£0.87
+ continental Europe + car	£28.03	13.1	(£0.32)
+ global air + car	£33.30	34.3	(£6.59)
All organic food basket with different transport scenarios			
+ local food + walk/cycle	£25.06	1.1	£2.65
+ local food + home delivery	£25.24	1.8	£2.47
+ local food + bus	£25.10	1.3	£2.61
+ national road + car	£26.15	5.5	£1.56
+ national rail + bus	£25.30	1.2	£2.41
+ continental Europe + car	£26.48	6.8	£1.23
+ global air + car	£31.76	28.1	(£4.05)

[a] From Tables 4 and 5.

the price to each person by an additional £4.05 wk^{-1} if is was organic and £6.59 wk^{-1} if conventional (Table 6). Some £1276 M of costs would be avoided if all food shopping were by cycle or walking; £1150 M avoided if cars were replaced with public transport; and £727 M avoided if car and bus were replaced by home delivery schemes.

These scenarios, though unlikely to arise entirely, do indicate the scale and relative contributions to the weekly food basket of various components of the food chain. The data suggest that degrees of local-ness might be more significant than previously considered. They also indicate that consumers' decisions on specific choices of food (here organic vs. conventional) and transport can have an important affect on farm systems and the environment, and will be an important consideration in future policy reform. The data further indicate the value of domestic garden and allotment produce, as such food production incurs low to zero farm externalities, and effectively zero transport externalities (allotments currently produce 0.22 Mt yr^{-1} of fruit and vegetables, compared with 3.17 Mt produced on farms).

Concluding comments

We have calculated the environmental costs of the UK food basket, and found that farm externalities, domestic road transport to retail outlets, domestic shopping transport and subsidies are the main contributors to the estimated hidden costs of £2.91 per person per week (11.8% more than the price paid). It is clear that actions to reduce farm and food mile externalities, and shift consumers' decisions on specific shopping preferences and transport choices would have a substantial impact on environmental outcomes. The potential for food and transport businesses and governments to reduce these externalities would appear to be considerable. The key policy questions now centre on how best to do this using a variety of taxation, incentive, and regulatory mechanisms. It will be important to ensure that agriculture and food policy reforms continue to result in the production of safe and nutritious food whilst also maximising the production of positive externalities.

The most likely scenario for the immediate future is 'business as usual' with some incremental change. It could be, however, that external shocks institute more radical change. Such potential shocks range from another energy or oil crisis to the realisation of the seriousness of climate change or of the immense costs of current systems such as we outline here.

However, localisation of food systems, such as we point to here, would require changes in the behaviour of actors and businesses across the whole supply chain, with localised geographic areas needing different patterns of land use to supply local markets and consumers. Some of these changes may lead to trade-offs and losses in overall system sustainability, or possibly losses in jobs in the freight or input supply industries. In addition, proximity alone may not be a good measure of sustainability, as a long journey on water has a lower impact than a shorter one by road. At the same time, though, globalising trends in food systems are likely to continue, making localisation harder and less likely to occur, despite the net economic benefits.

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